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Effects of coffee husk and nitrogen levels on yield and yield attributes of maize (*Zea mays* L.) at Dilla, South Ethiopia

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ABSTRACT

Soil fertility decline is a major constraint to agricultural production and productivity. A field experiment was conducted during the rainy season of 2012-13 at Dilla University, College of Agriculture farm to study the effects of coffee husk and nitrogen levels on yield and yield attributes of maize. Factorial combinations of four rates of coffee husk (0, 0.4, 0.8 and 1.20 t ha^{-1}) and four levels of nitrogen (0, 16, 32 and 64 kg ha^{-1}) were laid out in randomized complete block design with three replications. Before incorporation of the husk, a composite soil sample was taken from the experimental plots (0-30 cm depth) to observe some selected soil physico-chemical properties. The results of the soil sample test showed that the soil of the experimental site was sandy clay loam in texture; neutral in reaction (pH = 6); very low in organic matter content(0.83%); low to medium in its total nitrogen (0.14%); low in available phosphorous (8 mg kg^{-1}) and slightly alkaline EC (4.5). Plant height, number of rows per ear, and 100 kernels weight were not significantly ($P>0.05$) affected by the coffee husk and N. However, significant effects ($P< 0.05$) were observed on days to tasseling, physiological maturity, harvest index, and grain and stover yield. The maximum grain yield (118 q ha^{-1}) was obtained from the application of 32 kg N ha^{-1} and maximum plant height (2.55m) was attained at 0.8t/ha husk. On the other hand, the highest values of stover yield (493 q ha^{-1}) was obtained at 64kg N ha^{-1} and harvest index (27%) were obtained on application of 32kg N ha^{-1}. Generally, the inorganic nutrient source applied alone and in combination with organic source has improved most of the yield related traits and yield of maize.

Key words : Coffee husk, maize, nitrogen, yield

INTRODUCTION

Maize (*Zea mays* L.) is an important grain crop of the world and it ranks 3rd after wheat and rice in area basis and total production (CSA, 2008). It is used in many ways different from other cereals. It is used as a human food, feed for livestock and industrial purposes. Millions of people depend on maize for their daily food in sub-Saharan Africa. In Ethiopia, maize is the major and staple food and one of the main sources of calorie in the major maize producing regions (Million and Getahun, 2001; Tolessa *et al*. 2001). In Ethiopia, maize is cultivated in about 1.75 million hectares (ha), which accounts for 20% of the 8.5 million ha (79.98%) of land allocated for all cereals. It ranks second after teff (*Eragrotis tef*) in area coverage, first in total national production and yield per ha (CSA, 2008). Considering its importance in terms of wide adaptation, total production and productivity, maize has been selected as one of the high priority crop to feed the increasing population of Ethiopia. Despite its importance the yield and productivity of maize in the country in general and in southern-region in particular is low as compared to its potential. Among the major constraints on decreased production of maize are poor soil fertility, limited supply of production inputs like fertilizer and improved seed (Hailu, 1979). Soil fertility decline is one of the major constraints for food production and insecurity in the region. Farmers found it expensive to replenish soil fertility due to increased price of inorganic fertilizers. Other contributing factors for low soil fertility and low grain yield include complete removal of crop residue, soil erosion, insufficient use of fertilizer, deforestation continuous cultivation without maintaining soil fertility and population pressure farmers cannot afford to buy chemical fertilizers (Tenaw, 2000).

Ethiopia produced 215,000 tons per year of clean coffee for export and domestic use (FAO, 2004). This yield is associated with an estimated 242,000 tons of byproducts that are being wasted annually. The southern region of Ethiopia has favorable weather condition for coffee plantation (Tsige, 1996). More than 242,000 tons of coffee byproduct (residue) is produced yearly in the southern region alone. Currently, for lack of better means of disposal, coffee pulp from wet processing is simply dumped in to river, which is also the water source for domestic use by the population in close proximity to the processing site. The coffee husk from dry processing in contrasts is burnt (Tsige, 1996) all this results in environmental pollution. But coffee residue could be a good source of plant nutrients and its efficient use could enhance improvement in soil organic matter, grain yield and water-use efficiency (Hailu, 1979).

In the absence of application of inorganic fertilizers, use of locally available organic materials alone may frequently be inadequate, both in quantity or diversity, to supply the nutrient demands. Inorganic fertilizer coupled with effective management of organic matter is critical for the intensification of traditional farming systems to meet the immediate demand for high food production (Tenaw, 2000).

In the southern region 44 to 47% of the farmers use low level of fertilizer (Getahun and Tenaw 1990); thus inadequate use of inorganic and/ or organic fertilizer leads to depletion of soil nutrients in particular with exhaustive crops like maize.

Coffee byproduct (pulp or husk) as an organic fertilizer can be an alternative for the resource poor farmers however, the nutrients in the husk may be poor for plant growth because of low nutrient availability, thus large quantities of husk are required, which becomes too bulky to transport to point of application. At the same time the use of chemical fertilizer alone is costly. This calls for combined application of organic (coffee husk) and chemical fertilizer to make the production process more suitable.

Thus, coffee-growing farmers in the region and other parts of Ethiopia can sustain production and productivity by using coffee residue together with N fertilizer and by doing so reduce environmental hazard. Thus low soil fertility and costliness of chemical fertilizer call for combined use of organic (coffee residue) and inorganic fertilizer. Therefore, this study was conducted to investigate the effects of coffee husk and N fertilizer on growth and yield of maize.

MATERIALS AND METHODS

The research was conducted under rain-fed conditions during the long rainy season of 2012-13 in the cropping season at Dilla University College of Agriculture farm, Gedeozone, southern nations nationalities and Peoples' Regional State (SNNPRS). Dilla is located at 365 km far from Addis Ababa which is capital of Ethiopia and lies between 6°14'N latitude and 38°31'E longitude and has an altitude of 1600 meter above sea level. The region has sub-humid climate with bimodal rainfall and receives an average annual rainfall of approximately 1000 mm and mean annual temperature of 18°C. Soil type is sandy clay loam in texture, neutral in reaction (pH = 6); very low in organic matter content(0.83%); low to medium in its total nitrogen (0.14%); low in available phosphorous (8 mg/kg) and slightly alkaline EC (4.5).

Maize variety (BH-540) was used for the study. It is a late maturing variety (about 140-150 days to maturity) released in 1995 by the Bako Agricultural Research Center, Ethiopia. The variety performs well in altitude range of 1000-1200 MSL and rainfall ranging from 1000-1200 mm. It has been reported to produce 8-10 and 5.0-6.5 t ha^{-1} grain yields under on-station and on-farm experiments, respectively. The variety is vigorous, high yielding, highly responsive to inputs, moderately tolerant to diseases like Gray Leaf Spot (GLS), Turcicum Leaf Blight (TLB) and Common Leaf Rust as well as lodging with a plant height of 230-260 cm (Mosisa *et al.* 2001).

The experimental field was prepared following the conventional farmers' tillage practice. This experiment consisted of a combination of four rates of coffee residue (0, 0.4, 0.8 and 1.2 t ha^{-1}) with four rates of nitrogen fertilizer (0, 20, 40 and 60 kg N ha^{-1}) a total of 16 treatments was arranged in factorial randomized complete block design with three replication. Plot size for all treatments was 3m width x 3m length. Each experimental unit had a plot size of 3 m × 4.5 m (13.5 m^2). Spacing of 75 cm between rows and 25cm between plants was used. Two seeds per hill were sown to ensure emergence and good stand of the crop. However, to obtain the required plant density the seedlings were thinned to one plant per hill 4 weeks after emergence. The blocks were separated by a 1 m wide-open space (pathways) whereas the plots within a block were 0.75 m apart from each other. Different levels of N as per treatments in which it was splitted into two equal parts (half at sowing and the other half before tasseling) were applied as urea and full basal dose of triple super phosphate (TSP) granule fertilizer was applied at sowing to all the plots uniformly. All other agronomic practices were uniform for all the experimental units.

Five soil samples were randomly taken from the surface layer of 0-30 cm depth at different spots of the experimental field before planting. The samples were thoroughly mixed to make one composite sample representing the experimental field. The soil samples were air dried and passed through a 2 mm mesh sieve for chemical analysis. Accordingly, soil pH was determined potentiometrically in 1:2.5 soil-water ratio mixtures using a glass electrode attached to a digital pH-meter as described by Carter (1993). Soil organic carbon content was estimated using the wet oxidation method of Walkley and Black (1934) in which the carbon was oxidized with potassium dichromate ($K_2Cr_2O_5$) in sulfuric acid solution. Finally, the OM content of the soil was calculated by multiplying the percent organic carbon by 1.724. Total N content of the soil was determined using the Micro Kjeldahl method by oxidizing the OM through sulfuric acid digestion and distillation and converting the N into NH_4^+ as ammonium sulfate as described by Dewis and Freitas (1970). To determine available soil P, calorimetric measurements were taken after extraction of soil samples by the Olsen sodium bicarbonate ($NaHCO_3$) method at pH 8.5 following the procedures outlined by Olsen *et al*., (1954). Soil cat^+ ion exchange capacity (CEC) was determined by ammonium acetate ($NH_4C_2H_3O_2$) method after leaching the $NH_4C_2H_3O_2$ extracted soil samples with 10% sodium chloride (NaCl) solution (Chapman, 1965). Then it was determined from ammonium acetate saturated samples through distillation and measuring the ammonium using the modified Kjeldahl procedures as described by Chapman (1965).

Data collected on crop phonological events like days to 50% tasseling, days to 50% silking, days to 50% physiological maturity; data collected on growth parameters like plant height (cm) and ear height was measured at maturity from five randomly taken plants at maturity; data on yield and yield related traits like number of grains/ear, thousand kernels weight (g), stover yield (kg ha^{-1}), grain yield (kg ha^{-1}),harvest index (%) and subjected to analysis of variance using SAS version 9.2 statistical software (SAS,2008) followed by mean separation of treatments using least significant difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSION

Physical and chemical properties of the experimental soil before sowing

The results of the soil sample analysis (Table1) revealed that the textural class of the surface soil is sandy clay loam with particle size distribution of 46% sand, 26% silt and 28% clay. The pH of the experimental soil was 6 with neutral range and EC 4.75 which was moderately saline.

Total N content of the surface soil sample of the study site is normally rated as low to medium (0.14%) based on the classification of Landon (1991). As the area receives high rainfall, N leaching problem could be a reason for the decline of total nitrogen in the site. This low to medium total N content indicates that the soil of the study site is in fact deficient in N to support proper growth and development of crops justifying that it needs to be fertilized with external sources of N. The available P of the experimental soil was 8 mg/kg. With regard to the levels of Olsen extractable P in the soil, the available P content of the soil is rated as low based on the ratings of Landon (1991).

Crop phenology

The analysis of variance revealed a non-significant difference (P> 0.05) on days to 50% emergence but application of coffee husk and nitrogen had a significant effect on days to 50% tasselling and days to 50% physiological maturity due to the applied N and coffee husk as well as their interaction effects (Table 2). Days to tasselling and maturity of maize were significantly earlier in plots applied with fertilizer compared with the unfertilized plots (control). This might be due to better soil fertility which led to increased concentration and uptake of nutrients from plots applied with fertilizer. In line with this agree with the works of Orkaido (2004), Regassa (2005) who found enhanced early maturity of sorghum and rice with increased levels of N fertilization and it was also significantly affected by the application of N. Besides, Regassa (2005) reported that the phenology of sorghum was greatly affected by N application where days to 50% flowering and physiological maturity of the unfertilized crops increased by 99 to 133%. This result disagrees with the findings of Cassman *et al*. (2003) and Orkaido (2004) who reported that days to tasseling were significantly affected by the successive additions of N, and with increasing rates of N fertilizer, the crop took a shorter period to tassel than the treatments receiving either no or lower rates of N.

Crop growth parameters

Plant height

The analysis of variance showed plant height of maize was significantly affected by the application of coffee husk(Table 2), which might be due to improvement in some physical (soil moisture) and chemical properties of soil treated with coffee husk so there is better plant growth However application of N has not shown any significant effect on plant height. Tenaw *et al*., (2006) also reported a significant effect of N and P fertilizer on maize plant height in maize-bean intercropping.

Number of rows and ear height

Application of coffee husk and Nitrogen did not have significant effect on ear height and number of rows per ear of maize (Table 3). Application of fertilizer increased ear height by 3.2% over the control. Decrease in ear height and number of rows per ear from unfertilized plots was due to low soil fertility. In contrast to this Firehiwot (2008) reported that application of fertilizer increased

Table 1. Physical and chemical properties of the experimental soil before sowing

pH (H20)	EC	Total Nitrogen (%)	Available Phosphorus (mg kg^{-1})	Organic matter (%)	Textural class
6	4.75	0.14	8	0.83	Sandy clay loam

Table 2. Effect of coffee husk and N on crop phenology and plant height of maize

Treatments	Days to			Plant height (m)
	Emergence	Tasselling	Maturity	
Coffee husk (t ha^{-1})				
0	7	72.42a	115.17c	2.45b
0.4	7	71.92b	115.50c	2.45b
0.8	7	71.33c	117.17b	2.55a
1.2	7	70d	117.75a	2.47ab
LSD	NS	0.45	0.47	0.09
CV (%)	0.5	0.56	0.49	4.52
Nitrogen (kg ha^{-1})				
0	7	73a	116.00b	2.46
16	7	71b	116.17b	2.48
32	7	71b	112.67a	2.49
64	7	72a	110.75a	2.49
LSD	NS	0.45	0.47	NS
CV (%)	0.5	0.56	0.49	0.49

Table 3. Effect of coffee husk and N on yield and yield components of maize

Treatments	Ear height (m)	Number of rows ear^{-1}	Hundred grain weight (g)	Stover Yield (q ha^{-1})	Grain yield (q ha^{-1})	Harvest Index (%)
Coffee husk (t ha^{-1})						
0	1.54	12.83	42.00	434.67b	114.58a	25.58a
0.4	1.55	13.00	43.83	492.58a	105.92b	21.67b
0.8	1.51	12.75	43.75	486.25a	117.67a	25.42a
1.2	1.56	12.92	46.00	405.33b	109.08b	26.92a
LSD	NS	NS	NS	47.94	4.48	2.84
CV (%)	8.66	5.44	13.18	12.65	4.80	13.41
Nitrogen (kg ha^{-1})						
0	1.50	12.75	42.42	407.67c	103.5c	25.67a
16	1.57	12.67	43.92	440.33bc	112.92b	26.17a
32	1.53	12.92	44.83	477.17ab	118.92a	27.08a
64	1.55	13.17	44.42	493.67a	111.92b	22.67b
LSD	NS	NS	NS	47.94	4.48	2.84
CV (%)	8.66	5.44	13.18	12.65	4.80	13.41

number of rows per ear and height by 19.6 and 15.7% over the control, respectively.

Yield and yield attributes

Seed weight

Analysis of variance indicated that coffee husk and nitrogen has no significant effect on hundred seed weight (Table 2). This agrees with the finding of Tenaw (2000) who reported no significant effect of N fertilizer on thousand kernel weight of maize. The result of this study disagrees with Sergio and Andrade (1995) reported a significant effect of N fertilizer on kernel weight of maize while low N reduced kernel weight between 9 and 25% relative to the unfertilized maize. Gautam and Kaushik (1982) also reported that application of N fertilizer increased thousand kernel weight of finger millet.

Stover yield

Analysis of variance indicated that stover yield of maize was significantly affected by application of husk and nitrogen (Table 3). Highest stover yield of 492.58 q ha^{-1} was obtained in treatments which apply 0.4 t ha^{-1} coffee husk than others also application of 64 kg ha^{-1} N increased stover yield by 17.4% over the control treatments. This increase might build-up soil nutrient and improved soil physical and chemical properties from application of coffee husk and N fertilizer. Maize stover yield showed consistent increment due to the application of N and coffee husk except when husk increased to 1.20 t ha^{-1}. stover yield increased consistently as N rate increased. There was a general reduction in stover yields at low levels of N and husk and a general increase at high levels of N (Table 3). The most probable explanation for this event is organic soil fertility amendments usually improve structure and water holding capacity of soils which in turn promotes the vegetative growth of a plant together with N. Similar results was reported by Cassman *et al*. (2003) and Gupta (2004) in which the average maize stover yield for the N and GM treatments ranged with a yield increment of 25 to 75 per cent and 6 to 68 per cent over the control treatments, respectively.

Grain yield

Analysis of variance showed that coffee husk and N application significantly increased grain yield of maize. Highest grain yield of 117.67qha^{-1} was obtained in treatments which apply 0.8t ha^{-1} coffee husk and in treatments which apply 32 kg ha^{-1} N. application of N and coffee husk above and below 32kg ha^{-1}N and 0.8 t ha^{-1} decrease yield of maize (Table 3). The increase in grain yield might be due to increased concentration and uptake of nutrients in the above ground dry matter yield of maize (Tenaw *et al*. 2006). The low yield in unfertilized plots might be attributed to reduced leaf area development resulting in lesser radiation interception and consequently low efficiency in the conversion of solar radiation (Speding *et al*., 1981). Lucas (1986) also reported reduced crop yield where N fertilizer was not applied. Increased application of N fertilizer, on the other hand, was accompanied by increased grain yield as reported by other researcher (Tenaw, 2000).The results of the present study were in agreement with the findings of the field studies conducted by Cassman *et al*., (2003) and Ademiluyi and Solomon (2007) using maize as a test crop who reported maize grain yield due to N and GM levels in yield increment of 18 to 89% and 24 to 84% over the control treatments, respectively. Similar result was reported by different researcher who reported that coffee residue without fertilizer increased grain yield (91%) as compared to the control. Addition of coffee residue and/or N fertilizer accounted for 31% of the total variations in grain. N fertilizer alone increased grain yield by 149% relative to the control.

Harvest index

Harvest index (partitioning efficiency of dry matter in to grain) was significantly affected by application of coffee husk and N fertilizer (Table 3). Harvest index of maize increased when treated with N fertilizer and coffee husk application up to 32 kgha^{-1} N and 1.2 t ha^{-1} coffee husk as compared to controlled treatment. This result agrees with the finding of different researcher who reported that Tenaw (2000) who reported that harvest index increased as the rate of N fertilizer application increased up to 92 kg ha^{-1}N. Moreover, Ludlow and Muchow (1988) stated that a higher transfer of assimilates to the grain would maximize the harvest index and reduce the proportion of dry matter produced early in the growth that may be left as a stover.

CONCLUSION

Integrated nutrient management for crop production requires that quantitative information on all nutrient sources be made available. In the case of local sources, there is still a need to at least organize existing knowledge for local implementation. Moreover, the current awareness is towards organic fertilizers due to the high inputs and transport costs of agrochemicals which made the use of inorganic fertilizers on food crops uneconomical for most small farmers and its negative consequence on the environment. On the otherhand, inadequate uses of fertilizers result in lower yield. Hence, uses of low rates of inorganic fertilizers with the integration of farm generated resources such as crop residues and legumes that can be incorporated as a green manure or growing trees and shrubs that will provide easily decomposable green materials for composting and mulching are among the most important concerns to maximize crop yields. In view of this, afield experiment was conducted to study the effects of coffee husk at rates (0, 0.4, 0.8 and 1.2 t ha^{-1}) and N levels (0, 16, 32 and 64 kg ha^{-1}) on yield related traits and yield of maize at Dilla university, using RCBD with factorial arrangement in 3 replications.

The results of the soil sample test showed that the soil of the experimental site was sandy clay loam in texture; neutral in reaction (pH = 6); very low in OM content (0.83%); low to medium in its total N (0.14%); low in available P (8 mg kg^{-1}) and slightly alkaline EC (4.5). Plant height, number of rows per ear, and 100 kernels weight were not significantly ($P>0.05$) affected by the coffee husk and N. However, significant effects ($P< 0.05$) were observed on days to tasseling, physiological maturity, grain as well as stover yield and harvest index. Increased application of N and coffee husk resulted in increment of plant height, grain and stover yields, hundred kernels weight and harvest index. The least record in all parameters was from the control treatment except for on days to tasseling, physiological maturity. In addition, the mean grain yields, stover yields, hundred kernels weight and harvest index exhibited an increase with increasing rates of N fertilizer. Increased application of N and other organic inputs including coffee husk, a complete agronomic package including proper field preparation and appropriate time of sowing are needed to reach optimum production level of the crop and for better and increased quantity of the yield and yield attributes. Moreover, increased application rates of husk and low rates of N fertilizers are better than the application of either N fertilizer or husk alone. In agreement with the result of the present study and various other studies have shown, organic nutrient sources particularly when integrated with mineral fertilizers can improve crop yield and land productivity. Since nutrient availability is a function of a number of factors and their interactions, fertilizer recommendations for crops in most cases should be based on soil tests for plant available nutrients. However, a major limitation is that, for the same sites plant species and management systems may differ from year to year due to different seasonal conditions. The general conclusive remark from the result of the current study, increased application rates of husk and low rates of N fertilizers are better than the application of either N fertilizer or husk alone. In agreement with the result of the present study and as various other studies have shown, organic nutrient sources particularly when integrated with mineral fertilizers can improve crop yields and land productivity. provided base line information for further research and development efforts in soil fertility management for sustainable utilization of the soil resources in the area. This experiment was conducted only in one location for one cropping season on one crop variety. Hence, studies involving different hybrid varieties, different N levels and coffee husk rates replicated in seasons over several locations should be conducted in order to recommend agronomically optimum and economically feasible rates of N and husk under the agro-climatic conditions of the area.

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