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# Effects of Organic and Inorganic Fertilizers on Yield and Yield Components of Maize at Wujiraba Watershed, Northwestern Highlands of Ethiopia

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## ABSTRACT

Maize (*Zea mays* L.) is one of the most important staple food crops in Ethiopia although its yield is low. Intensive cultivation causes plant nutrient depletion and yield decline. The objective of this experiment was, therefore, to investigate the effects of combined application of organic and inorganic fertilizers on yield and yield components and nutrient contents of maize. Field experiments were conducted on Nitisols (acidic soils) for two consecutive cropping seasons at Wujiraba watershed, northwestern highlands of Ethiopia. The experiments were laid down in RCBD as factorial combinations of three levels of N (0, 60 and 120 kg N $ha^{-1}$), compost (0, 5 and 10 tn compost $ha^{-1}$) and S (0, 15 and 30 kg S $ha^{-1}$) fertilizers which were replicated three times. In this experiment, significant ($p \leq 0.05$) differences were observed on maize grain yield, total above ground dry biomass, plant height, grain number per cob, cob weight, thousand seed weight, N and S concentration of leaves and grains by such fertilizers combinations. The highest mean grain yield, dry biomass, plant height, grain number per cob, cob weight, thousand seed weight, N concentration in leaf and grain (7.9, 22.4 t $ha^{-1}$, 2.52 m, 486, 0.44 g, 492 g, 3.25 and 1.4%) were observed in plots treated with fertilizer combinations of 120 kg N $ha^{-1}$, 10 t compost $ha^{-1}$ and 15 kg S $ha^{-1}$, respectively. From this study it is possible to infer that integrated application of organic and inorganic fertilizers increased crop yields. Hence, incorporation of compost with inorganic N and S fertilizers for maize enhanced grain yield by adding nutrients.

**Key words:** Integrated application, intensive cultivation, nitisols, nutrient depletion, yield decline

## INTRODUCTION

Although, Ethiopia has potentially rich land resources, agricultural productivity is low (Tena and Beyene, 2011) mainly due to soil erosion, acidity and nutrient depletion (Hurni *et al.*, 2010; Taffesse *et al.*, 2011). Crop yield tends to decrease when soil depleted in its nutrients (Chavez *et al.*, 2014). Stoorvogel *et al.* (1993) estimated that in the arable lands of Ethiopia annual net nutrient depletion exceeded 30 kg nitrogen (N) and 20 kg potassium (K) $ha^{-1}$.

Among cereals, maize is an important crop which ranks third after wheat and rice in the world (Rasheed *et al.*, 2004). Maize was originated in Mexico (Dowswell *et al.*, 1996) and introduced to Ethiopia in the late 16th and early 17th century by the Portuguese (Aboma *et al.*, 2001; Orkaido, 2004). Although, maize grows in different agro-ecological zones (Twumasi-Afriyie *et al*., 2001). It is cultivated mostly in warmer areas along the western and southwestern parts of Ethiopia (Negassa *et al*., 2007).

Maize is the primary staple food in Ethiopia (Abera *et al*., 2013) and critical to 8 million smallholder livelihoods (Rashid *et al*., 2010). According to CSA (2013), among cereals, maize is the first and second crop in terms of production and area coverage followed by and next to teff (*Eragrostis tef* Zucc.) by accounting 26.6% (6,158,317.6 t and 16.4% (2,730,272.9 ha), respectively with average yield of 3.1 t $ha^{-1}$. Maize is among the principal cereal crops grown in northwestern Ethiopia and ranks first in its productivity (Ermias *et al*., 2007).

Tropical smallholder farming systems including Ethiopia lack sustainability, mainly due to nutrient losses by soil erosion, lack of soil fertility restoring inputs and unbalanced nutrient mining (Ajayi *et al*., 2007; Hirpa *et al*., 2009). Achieving high maize yield requires adequate and balanced supply of plant nutrients (Barbieri *et al*., 2008) as declining soil fertility is a prominent constraint for maize production (Okoko and Makworo, 2012). Although Ethiopia is Africa's fourth biggest maize producer (ECEA., 2009), its yield is too low. However, in sub-humid agro-ecosystem of Western Ethiopia, the highest maize grain yield (11.0 t $ha^{-1}$) was recorded under the farmers' field for Sasokawa Global 2000 (Negassa *et al*., 2007). Surprisingly, Lee and Tollenaar (2007) and Johnson *et al*. (2006) reported that maize has even yield potential of 25 t $ha^{-1}$. However, low soil fertility and low levels of input use are some of the major crop production constraints in Ethiopia (Taffesse *et al*., 2011; Abreha *et al*., 2013) including maize crop.

Nitrogen is a determinant nutrient for plant growth (Hossain *et al*., 2007) and the most important nutrient limiting maize yield in various parts of the world (Miao *et al*., 2007). Maize is a heavy feeder of N (Onwueme and Sinha, 1991). For instance, it responded the highest yield by applying heavy N fertilizer in Achefer and Mecha Districts of Amhara National Regional State (ANRS) and Alemaya University, Ethiopia at 180 and 250 kg N $ha^{-1}$, respectively (Ermias *et al*., 2007). However, most agricultural soils are deficient in N for growing maize as it is lost by leaching, erosion, gaseous emissions or denitrification (Peoples *et al*., 1995). Accurate fertilizer N recommendations for maize production are important for maximizing productivity and minimizing the environmental impacts (Miao *et al*., 2007). Soils also become deficient in sulfur (S) nutrient and in Ethiopia, little attention is given to S fertilizer where its impact on crop performance is almost untouched (Kiros, 2007).

The proper rates of plant nutrients are determined by knowledge about the nutrient requirement of the crop and supplying power of the soil (Tilahun, 2007). However, farmers of Ethiopian highlands have applied chemical fertilizers Di-Ammonium Phosphate (DAP) and urea to increase crop yields at blanket irrespective of site-specific and crop-nutrient requirements (Attanandana and Yost, 2003). For instance, Ermias *et al*. (2007) noted that in northwestern Ethiopia, farmers apply 100/100 kg $ha^{-1}$ DAP/Urea for maize production. Nevertheless, farmers in Wujiraba watershed do not apply even such blanket recommendations of fertilizer rates. The use of inorganic fertilizers also becomes chronic problem due to its cost (Bohlool *et al*., 1992; Kotschi, 2013) and deterioration in soil physical, chemical and biological properties (Bibi *et al*., 2010) that urge sustainable options.

Compost is often viewed as a resilient way of improving soil fertility by improving soil physical properties and increasing soil Organic Carbon (OC), N, S and P nutrients (Saison *et al*., 2006). However, the use of farmyard manure (FYM) for domestic energy consumption and crop residue removal for animal feeding greatly affects soil fertility in the study area. Since subsistence farmers have very low financial resources to afford the prices of inorganic fertilizers and Organic Matter (OM) is slow in its nutrient release, it is necessary to seek for affordable and less risky nutrient management practices (Bohlool *et al*., 1992) that contain necessary ingredients for superior performance (Bibi *et al*., 2010). Many research findings have shown that neither inorganic nor organic fertilizers alone can result in sustainable productivity (Tadesse *et al*., 2013). These scenarios necessitate the use of integrated nutrient management in maize production since combined use of organic and inorganic fertilizers builds ecologically sound and economically viable farming systems (Rajeshwari, 2005; Negassa *et al*., 2007).

Although the watershed is sub-humid in its agro-ecology (Bationo *et al*., 2006) and conducive for maize production, maize yield is low mainly due to low soil fertility by torrential rainfall, continuous cropping, manure and crop residue removal. Farmers in the watershed do not adequately practice the preparation and application of compost integrated with inorganic fertilizers. Hence, increasing yield in maize production could be taken an important step and actual fertilizer recommendations should be made on the basis of experimental results for different nutrients (Fageria *et al*., 2011).

However, study on an integrated nutrient management in general and maize production has not been yet conducted in the study area. Due to lack of scientific research works, scientific recommendations for the combined application of organic and inorganic fertilizers are not available in the study area, Since inorganic fertilizers are scarce and costly while the cost of organic fertilizers is low and has long lasting effect, it is pertinent to study the effects of an integrated use of inorganic and organic fertilizers. Therefore, the objective of this study was to investigate the effects of integrated application of compost, N and S fertilizers on maize yield and yield components.

## MATERIALS AND METHODS

**Description of the study area:** The study was conducted at Wujiraba watershed, located in Chilga District of North Gondar Zone in the ANRS (Fig. 1). The watershed is situated at about

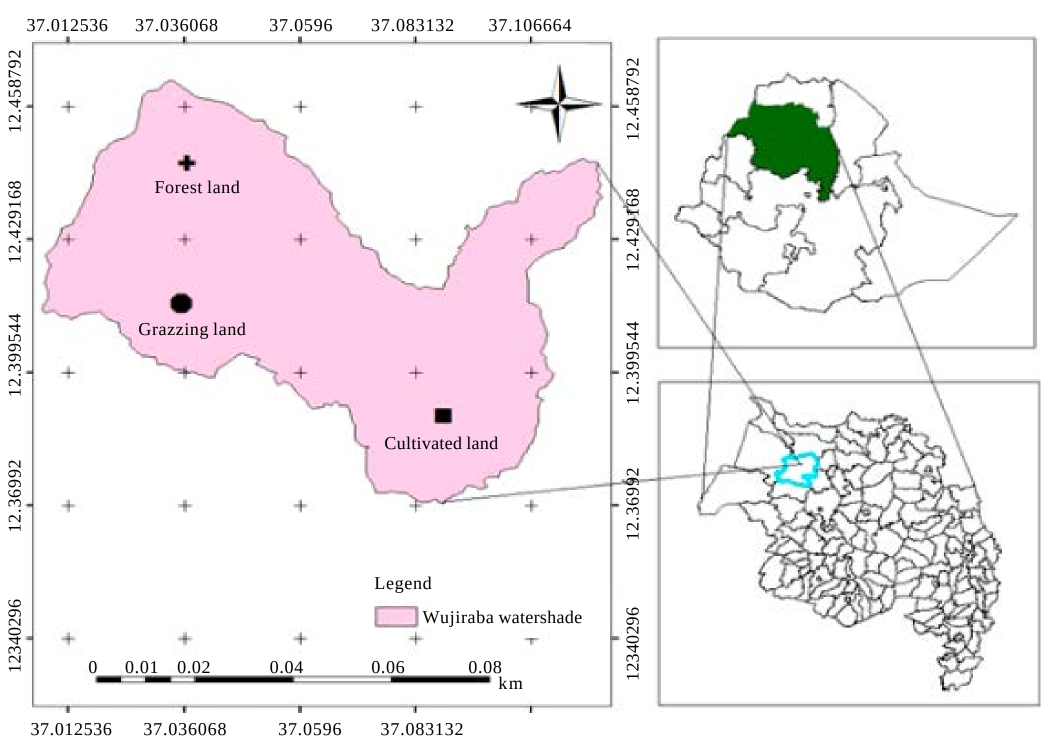


Fig. 1: Location map of the study area

60 km west of Gondar city and 760 km northwest of Addis Ababa (capital of Ethiopia). Geographically, the watershed lies at 12°32' 16"-12°35' 20" N latitudes and 37°03' 58"-37°06' 23" E longitudes with an area of 62.68 $km^2$ and elevations ranging from 1910 and 2267 m.a.s.l.

Geologically, the study area is covered with thick trap series volcanic rocks consisting mainly of weathered and jointed basalt and the soils were developed from the parent materials of volcanic origin, predominantly Tertiary basalt (Chorowicz *et al*., 1998). The watershed is characterized by unimodal rainfall pattern that occurs from May to October. The ten years (2003-2012) total average annual rainfall for the study area was 1237 mm while the annual mean minimum and maximum temperatures were 13.6 and 23.7°C, respectively. The natural vegetation of Wujiraba watershed is very low except some trees and grasses on reserved areas. The economic activities of the local community in the study area are primarily mixed farming system. The watershed is suitable for growing large variety of crops grown in rotation by rain fed system without fallowing due to high population pressure.

## Experimental procedures

**Treatments and experimental design:** The field experiment was conducted for two consecutive cropping seasons of 2012 and 2013 using rainfall. The field experiment was conducted on soil group Nitisols (FAO., 2006). The experiment was factorial combinations of three rates of compost (0, 5 and 10 t compost $ha^{-1}$), N (0, 60 and 120 kg N $ha^{-1}$) and S (0, 15 and 30 kg S $ha^{-1}$) fertilizers. Mineral P fertilizer as Triple Super Phosphate (TSP) was applied uniformly to all plots. Improved maize variety of Bako hybrid (BH-540) was used as a test crop.

**Compost preparation and analysis:** Compost was prepared from decomposable materials of clovers, home residues, weeds and grasses, leaves of trees, ashes, cow dung, sheep manure, poultry manure and top soil which was turned every month. The nutrient contents of compost such as OC, total N, nitrate ($NO_3^-$), ammonium ($NH_4^+$), available S and available P and pH value were tested in the laboratory after compost was matured. Organic carbon was analyzed by Walkley and Black method (Walkley and Black, 1934) while total N by micro-Kjedahl method (Jackson, 1958), available S by Turbidimetric method (Kowalenko, 1985), available P using Olsen method (Olsen *et al*., 1954) and pH was measured in suspension of 1:2.5 compost to potassium chloride (KCl) solution ratio (Chopra and Kanwar, 1976).

**Analysis of soil physicochemical properties:** Soil samples at plow depth (0-30 cm) were collected prior to maize planting. Soil samples were collected with augur in the experimental field in three blocks based on slope. Composite soil samples of 1 kg was collected from 13 spots in a block and thoroughly mixed. Soil samples were air dried and ground to pass through 2 mm sieve size except for total N and OC which were passed through 0.5 mm sieve. Soil samples were carried out at the Bahir Dar Soil Testing and Fertility Improvement Laboratory and Amhara Design and Supervision Works Agency Soil Laboratory Centers based on their standard procedures.

Soil texture was determined by the Bouyoucos hydrometer (Day, 1965). Bulk density $(\rho_b)$ was determined from undisturbed soil samples using core samplers (Rowell, 1997) while particle density $(\rho_s)$ was estimated by the psychnometer method (Baruah and Barthakur, 1997). Total porosity (f) was calculated from the values of $(\rho_b)$ and $(\rho_s)$ as:

$$f = \left(1 - \frac{(\rho_b)}{(\rho_s)}\right)100$$

Soil pH was measured in suspension of 1:2.5 soils to KCl solution ratio (Chopra and Kanwar, 1976). Total N was determined by micro-Kjedahl method (Jackson, 1958), available P by extraction with Bray II method (Bray and Kurtz, 1945) using 0.03 M $NH_4F$ and 0.10 M HCl solution, CEC and exchangeable calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) were extracted with 1 M $NH_4OAc$ at pH 7. Exchangeable Ca and Mg were analyzed using atomic absorption spectrophotometer, while Na and K by flame photometer (Chapman, 1965; Rowell, 1994). Soil Organic Carbon (OC) was determined by the chromate acid oxidation method (Walkley and Black, 1934) and available S by Turbidimetric method (Kowalenko, 1985).

**Field experiment:** The experimental field was plowed three times for each of the two cropping seasons. The space between blocks was 1.5 m and plots 1 m. The space between each row was 70 cm and planted seed was 30 cm. Plot size was 4.20 m by 3.90 m (16.38 $m^2$). The total area used for this project was 17.70 m by 143.40 m (2538.18 $m^2$). The net area of a plot was 2.80 m×3.30 m = 9.24 $m^2$.

**Plant tissue analysis:** The experiment was conducted in the Laboratory to evaluate nutrient concentrations of maize crop. Plant leaf was taken from 12 plant samples in the net area of a plot below the silk during silking stage while grains were taken in each plot after harvesting maize. Composite samples of leaf and grain were analyzed for total N and S concentrations using the above procedures.

**Agronomic data collections:** Agronomic data was collected in the field for each of the two growing seasons. The collected data include plant height, husked cob weight, number of grains per cob, grain yield, total above ground dry biomass and thousand seed weight plant height was measured from the soil surface to the tip by meter during maturity stage. Husked cob weight was measured by gram during harvesting and number of grains per cob was recorded simply by counting. Grain yield and total dry above ground biomass (t $ha^{-1}$) for each plot were recorded after harvesting and air drying the samples to constant weight. One thousand maize grains were also weighed.

**Statistical analysis:** The collected data was subjected to analysis of variance (ANOVA) in Randomized Complete Block Design (RCBD) replicated three times using statistical analysis systems (SAS) software (SAS., 2002). General linear model (GLM) was employed and treatment means were compared using Least Significant Differences (LSD) by Fisher's test at 0.05. Moreover, simple Pearson's correlation analysis was also done.

## RESULTS AND DISCUSSION

**Selected physicochemical properties of the experimental soils and compost:** The soil is clayey in texture, moderate in f, very low in pH, low in OC, total N, available P and S but high in CEC. The low contents of total N and OC could be attributed to the effect of intensive cultivation. Similarly, Saik *et al*. (1998) and Negassa and Gebrekidan (2003) revealed that cultivation of land results in the reduction of OC and total N. The low content of available P might be also due to its low pH (fixation) problem (Table 1).

Compost is a source of various nutrients which could be resilient in the soil that might be due to the effects of the nutrient rich raw materials that were used as a source for its preparation.

Table 1: Selected physicochemical properties of the experimental soils before planting maize

| Parameters | Mean values |
|---|---|
| **Texture (%)** | |
| Sand | 12.00 |
| Silt | 28.00 |
| Clay | 60.00 |
| **Texture class** | |
| $(\rho_b)$ (g $cm^{-3}$) | 1.20 |
| $(\rho_s)$ (g $cm^{-3}$) | 2.40 |
| f (%) | 47.80 |
| pH/KCl | 4.53 |
| OC (%) | 1.60 |
| Total N (%) | 0.15 |
| Available P (ppm) | 4.80 |
| Available S (ppm) | 2.90 |
| CEC (cmole+$kg^{-1}$) | 32.60 |
| Exchangeable Ca (cmole+$kg^{-1}$) | 9.60 |
| Exchangeable Mg (cmole+$kg^{-1}$) | 2.10 |
| Exchangeable K (cmole+$kg^{-1}$) | 0.60 |
| Exchangeable Na (cmole+$kg^{-1}$) | 0.20 |
| PBS (%) | 41.60 |

Compost was prepared from clovers, home residues, weeds and grasses, leaves of trees, ashes, cow dung, sheep manure, poultry manure and top soil. Compost acted as store house of nutrients which was rich in OC (18.5%), total N (0.83%), available P (650.7 ppm) and S (17.8 ppm), CEC (94.4 cmolc $kg^{-1}$, exchangeable Ca (47.1), Mg (26.7), K (2.5) and Na (0.4 cmolc $kg^{-1}$), respectively as well as $NH_4^+$ (332.1) and $NO_3^-$ (259.6 ppm) with C: N ratio of 22:1 which could be emanated by microbial activities during the decomposition of compost.

## Analysis of grain yield and yield components of maize

### Plant height, husked cob weight and grain number per cob

**Plant height:** Statistical analysis of data revealed that there was significant ($p \leq 0.01$) difference in plant height among the interaction effects of N, compost and S fertilizers (Table 2). The tallest mean plant height (2.52 m) was recorded in plots treated with 120 kg N $ha^{-1}$, 10 t compost $ha^{-1}$ and 15 kg S $ha^{-1}$ fertilizers while the shortest (1.26 m) was observed under the control which revealed an increase of about 100%.

This high increase in plant height with the increase in N and compost together with medium rate of S fertilizers might be due to their synergistic effects of increasing nutrient use efficiencies and special effects of compost which acted as the store house of different plant nutrients, reduce P fixation, improve CEC, aeration, root penetration, water storage capacity of the soil, etc., as well as being host of different microbes. These results were coincide with the findings of Adekayode and Ogunkoya (2010) who explained that there was very high significant difference in maize plant height in plots treated with high fertilizers compared with nil application. Plant height had significant ($p \leq 0.001$) and very strong positive correlations (r = 0.91, 0.94, 0.9 and 0.92) with grain yield, total above ground dry biomass, grain number per cob and husked cob weight, respectively (Table 3). Haseeb-ur-Rehman *et al.* (2010) revealed that plant height is an important yield component as the more green area, the more will be photosynthetic activity and share to grain

Table 2: Interaction effects of N, compost and S fertilizers on maize plant height, cob weight and grain number per cob of maize

| N and S rates (kg ha$^{-1}$) | | Plant height (m) at compost rate (t ha$^{-1}$) | | | Cob weight (g) at compost rate (t ha$^{-1}$) | | | Grain No. per cob at compost rate (t ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | S | 0 | 5 | 10 | 0 | 5 | 10 | 0 | 5 | 10 |
| 0 | 0 | 1.26$^{j}$ | 1.42$^{h}$ | 1.39$^{hi}$ | 0.07$^{g}$ | 0.1f$^{g}$ | 0.13$^{f}$ | 153$^{k}$ | 181$^{ij}$ | 183$^{ij}$ |
| | 15 | 1.38$^{hij}$ | 1.418$^{hi}$ | 1.45$^{h}$ | 0.10$^{fg}$ | 0.13$^{f}$ | 0.13$^{f}$ | 155$^{ij}$ | 193$^{i}$ | 163$^{ij}$ |
| | 30 | 1.41$^{hi}$ | 1.35$^{hij}$ | 1.29$^{ij}$ | 0.10$^{fg}$ | 0.09$^{fg}$ | 0.10$^{fg}$ | 147$^{j}$ | 166$^{ij}$ | 192$^{i}$ |
| 60 | 0 | 2.09$^{fg}$ | 2.06$^{fg}$ | 2.09$^{fg}$ | 0.252$^{cde}$ | 0.25$^{de}$ | 0.27$^{cd}$ | 335$^{fgh}$ | 331$^{fgh}$ | 351$^{d-h}$ |
| | 15 | 2.058$^{g}$ | 2.15$^{c-g}$ | 2.13$^{d-g}$ | 0.23$^{de}$ | 0.21$^{e}$ | 0.26$^{cd}$ | 317$^{h}$ | 337$^{e-h}$ | 329$^{gh}$ |
| | 30 | 2.17$^{c-g}$ | 2.1e$^{fg}$ | 2.08$^{fg}$ | 0.25$^{de}$ | 0.24$^{de}$ | 0.24$^{de}$ | 312$^{h}$ | 316$^{h}$ | 321$^{h}$ |
| 120 | 0 | 2.35$^{b}$ | 2.19$^{c-f}$ | 2.25$^{bcd}$ | 0.33$^{b}$ | 0.31$^{b}$ | 0.34$^{b}$ | 403$^{bc}$ | 382$^{bcd}$ | 421$^{b}$ |
| | 15 | 2.32$^{b}$ | 2.22$^{b-e}$ | 2.52$^{a}$ | 0.31$^{b}$ | 0.30$^{bc}$ | 0.44$^{a}$ | 380$^{b-e}$ | 370$^{c-g}$ | 486$^{a}$ |
| | 30 | 2.25$^{bcd}$ | 2.27$^{bc}$ | 2.23$^{bcd}$ | 0.33$^{b}$ | 0.33$^{b}$ | 0.32$^{b}$ | 404$^{bc}$ | 384$^{bcd}$ | 374$^{c-f}$ |
| $R^2$ | | | 0.95 | | | 0.91 | | | 0.92 | |
| CV (%) | | | 5.8 | | | 16.3 | | | 13.1 | |
| F-test | | | ** | | | ** | | | *** | |
| LSD | | | 0.12 | | | 0.04 | | | 43.4 | |

***,**Significant at p≤0.001 and p≤0.01 level, respectively. Means with the same letter are statistically non-significant at p≤0.05 according to Fisher's LSD

Table 3: Pearson's correlation matrix for maize crop yield and yield components, nitrogen and sulfur concentrations and uptakes

| Parameters | Height | Cob wt | GNC | Yield | Biomass | TS wt | Gr N | Leaf N | Gr S | LS |
|---|---|---|---|---|---|---|---|---|---|---|
| Height | 1.0 | | | | | | | | | |
| Cob wt | 0.92*** | 1.0 | | | | | | | | |
| GNC | 0.90*** | 0.97*** | 1.0 | | | | | | | |
| Yield | 0.91*** | 0.96*** | 0.95*** | 1.0 | | | | | | |
| Biomass | 0.94*** | 0.97*** | 0.95*** | 0.98*** | 1.0 | | | | | |
| TS wt | 0.7*** | 0.76*** | 0.79*** | 0.75*** | 0.77*** | 1.0 | | | | |
| Gr N | 0.79*** | 0.86*** | 0.85*** | 0.89*** | 0.88*** | 0.63*** | 1.0 | | | |
| Leaf N | 0.76*** | 0.86*** | 0.84*** | 0.87*** | 0.85*** | 0.63*** | 0.89*** | 1.0 | | |
| Gr S | 0.48*** | 0.51*** | 0.53*** | 0.51*** | 0.52*** | 0.42*** | 0.57*** | 0.56*** | 1.0 | |
| LS | 0.29** | 0.38*** | 0.37*** | 0.37*** | 0.37*** | 0.47*** | 0.42*** | 0.36** | 0.39*** | 1.0 |

***Significant at p≤0.001; **Significant at p≤0.01; *Significant at p≤0.05 levels; Cob wt: Cob weight; GNC: Grain No. per cob; TS wt: Thousand seed weight; Gr N: Grain N content; Gr S: Grain S content; LS: Leaf S

yield. Furthermore, Dilshad *et al.* (2010) notified that plant height is an important parameter of yield in maize as usually taller plant bears more cobs and offers more yield.

**Husked cob weight:** In this study, the interaction effects of N, compost and S fertilizers were significantly (p≤0.01) different in husked cob weight (Table 2). The highest mean cob weight (0.44 g) was recorded in plots treated with fertilizer interactions of 120 kg N ha$^{-1}$, 10 t compost ha$^{-1}$ and 15 kg S ha$^{-1}$ while the lowest (0.07 g) was indicated in the control with a difference of 0.37 g. This high difference in husked cob weigh with an increase in N and compost fertilizers accompanied with medium rate of S fertilizer might be again due to their synergistic effects and soil modifying powers of compost fertilizer. Significant (p≤0.001) and very strong positive associations (r = 0.96, 0.97 and 0.97) were also elucidated between husked cob weight and grain yield, above ground dry biomass and grain number per cob, respectively (Table 3).

Table 4: Interaction effects of N, compost and S fertilizers on grain yield, above ground biomass and thousand seed weight of maize

| N and S rates (kg ha$^{-1}$) | | Grain yield (t ha$^{-1}$) at compost rate (t ha$^{-1}$) | | | Above ground dry biomass (t ha$^{-1}$) at compost rate (t ha$^{-1}$) | | | Thousand seed weight (gm) at compost rate (t ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | S | 0 | 5 | 10 | 0 | 5 | 10 | 0 | 5 | 10 |
| 0 | 0 | $1.4^{f}$ | $2.3^{e}$ | $2.5^{e}$ | $5.3^{k}$ | $6.6^{ikj}$ | $7.1^{ij}$ | $240^{i}$ | $344^{h}$ | $337^{h}$ |
| | 15 | $2.1^{ef}$ | $2.5^{e}$ | $2.7^{e}$ | $6.2^{ijk}$ | $7.2^{ij}$ | $7.6^{i}$ | $323^{h}$ | $310^{h}$ | $344^{h}$ |
| | 30 | $2.5^{e}$ | $2.2^{e}$ | $2.3^{e}$ | $5.6^{jk}$ | $6.1^{ijk}$ | $6.8^{ijk}$ | $320^{h}$ | $332^{h}$ | $336^{h}$ |
| 60 | 0 | $4.9^{c}$ | $4.5^{cd}$ | $5.1^{c}$ | $12.3^{fg}$ | $11.8^{gh}$ | $13.9^{ef}$ | $401^{efg}$ | $410^{d-g}$ | $413^{c-g}$ |
| | 15 | $3.9^{d}$ | $4.5^{cd}$ | $5.0^{c}$ | $10.4^{h}$ | $11.7^{gh}$ | $13.1^{fg}$ | $398^{fg}$ | $430^{b-f}$ | $402^{efg}$ |
| | 30 | $4.6^{cd}$ | $4.5^{cd}$ | $4.4^{cd}$ | $12.0^{gh}$ | $12.7^{fg}$ | $12.0^{gh}$ | $383^{g}$ | $436^{b-e}$ | $398^{fg}$ |
| 120 | 0 | $6.3^{b}$ | $6.5^{b}$ | $7.6^{a}$ | $17.8^{b}$ | $15.9^{cd}$ | $17.0^{bc}$ | $432^{b-f}$ | $413^{c-g}$ | $460^{ab}$ |
| | 15 | $7.3^{a}$ | $6.1^{b}$ | $7.9^{a}$ | $17.4^{bc}$ | $15.0^{de}$ | $22.4^{a}$ | $431^{b-f}$ | $445^{bc}$ | $492^{a}$ |
| | 30 | $7.6^{a}$ | $6.6^{b}$ | $6.5^{b}$ | $16.6^{bcd}$ | $17.7^{bc}$ | $16.9^{bc}$ | $431^{b-f}$ | $437^{bcd}$ | $455^{b}$ |
| $R^2$ | | | 0.95 | | | 0.91 | | | 0.92 | |
| CV (%) | | | 5.8 | | | 16.3 | | | 13.1 | |
| F-test | | | ** | | | ** | | | *** | |
| LSD | | | 0.12 | | | 0.04 | | | 43.4 | |

***,**Significant at $p \le 0.001$ and $p \le 0.01$ level, respectively. Means with the same letter are statistically non-significant at $p \ge 0.05$ by Fisher's LSD, NS: Non-significant

**Grain number per cob:** The interaction effects of N, compost and S fertilizers had significant ($p \le 0.001$) effects on the grain number per cob (Table 2). The highest mean grain number per cob (486) was counted in plots treated with high doses of N and compost together with medium S fertilizers (120 kg N ha$^{-1}$, 10 t compost ha$^{-1}$ and 15 kg S ha$^{-1}$) where as the lowest (153) was recorded in the control which indicated an increase of about 217.6%. This high increase in grain number per cob with the increase of N and compost along with medium S fertilizer rate might be due to again the synergistic effects of these fertilizers that improved nutrient use efficiencies and normal development of the maize crop with increasing grain number per row, cob weight and cob length. There was also significant ($p \le 0.001$) and very strong positive correlations ($r = 0.95$) between grain number per cob and grain yield and total above ground dry biomass, respectively (Table 3). Rasheed *et al.* (2004) reported that maize crop fertilized at the rate of 150 and 20 kg N and S ha$^{-1}$ produced maximum grain number per cob. Grain numbers per cob have direct effect on grain yield of maize per unit area (Haseeb-ur-Rehman *et al.*, 2010).

**Grain yield, total above ground dry biomass and thousand seeds weight**

**Grain yield:** Interaction effects of N, compost and S fertilizers had shown significant ($p \le 0.01$) difference on grain yield (Table 4). The highest mean grain yield (7.9 t ha$^{-1}$) was recorded in plots treated with 120 kg N ha$^{-1}$, 10 t compost ha$^{-1}$ and 15 kg S ha$^{-1}$ fertilizers while lowest (1.4 t ha$^{-1}$) in the control with a difference of 6.5 t ha$^{-1}$. The maximum grain yield attained by the interaction of such high doses of N and compost fertilizers might be also due to the synergistic effects of N, compost and S fertilizers. These results were supported by the findings of N'Dayegamiye *et al.* (2010) who reported that application of compost with 120 kg N ha$^{-1}$ led to high maize yields.

Bayu *et al.* (2006) and Makinde and Ayoola (2010) stated that high and sustainable crop yields are only possible with integrated use of mineral fertilizers with OM. Rasheed *et al.* (2004) also found that the maximum grain yield of maize was obtained from plots fertilized with 150 kg N ha$^{-1}$ and 15 kg S ha$^{-1}$. Tadesse *et al.* (2013) also noted that applying FYM at 15 t ha$^{-1}$

with 120 kg N $ha^{-1}$ and 100 kg $P_2O_5$ $ha^{-1}$ responded the maximum grain yield which increased by 123.0% compared to the control. Similarly, Dilshad *et al.* (2010) reported that combined use of organic and inorganic fertilizers improved grain yield.

High doses of N and compost fertilizers increased grain yield as N is the main driving force to produce large yields of maize (Nivong *et al.*, 2007) and compost is responsible in improving soil physical, chemical and microbial conditions. Connor *et al.* (1993) reported that the use of higher rates of N fertilizer increased crop photosynthetic rate, increase crop growth and grain yield. Miao *et al.* (2007) and Onasanya *et al.* (2009) elucidated that application of high N fertilizer (120 kg N $ha^{-1}$) enhanced grain yield, number and weight of grains per cob and 1000 grain weight.

Lampkin (1992) indicated that use of compost over several seasons increased maize yields by 40-60% but 80-95% in combination with inorganic fertilizers. However, the best response of S fertilizer in this experiment was at 15 kg S $ha^{-1}$ combined with high doses of N and compost fertilizers. Weil and Mughogho (2000) reported that significant responses by maize to S fertilizer were shown generally in the range of 12-20% increase in grain yield in Kenya, Zimbabwe and Nigeria. Barker and Pilbeam (2007) also reported that the recommended S rates vary between 20 and 50 kg S $ha^{-1}$ for cereals. However, Rasheed *et al.* (2004) noted that the highest maize grain yield of 8.59 t $ha^{-1}$ was recorded at the rate of 150 kg N and 30 kg S $ha^{-1}$.

Grain yield had also significant ($p \le 0.001$) and very strong positive correlations (r = 0.98, 0.95 and 0.96) with total above ground dry biomass, grain number per cob and husked cob weight, respectively (Table 3). Pagano and Maddonni (2007) elucidated similar reports that the yield of maize is the product of grain number per cob and cob weight.

**Total above ground dry biomass:** Significant ($p \le 0.001$) difference was also observed on total above ground dry biomass by the combined effects of N, compost and S fertilizers (Table 4) where the highest (22.4 t) was recorded in plots treated with 120 kg N $ha^{-1}$, 10 t compost $ha^{-1}$ and 15 kg S $ha^{-1}$ while the lowest (5.3 t) in the control with a difference of 17.1 t $ha^{-1}$. This high difference in total above ground dry biomass might be also due to the synergistic effects of N, compost and S fertilizers as well as high doses of N and compost fertilizers which are well known for the vegetative growth of plants. Barker and Pilbeam (2007) reported that S and N fertilizers show strong interactions in their nutritional effects on crop vegetative growth due to their mutual occurrence in amino acids and proteins. Kibunja *et al.* (2010) reported that total dry matter of maize was higher in treatment combinations of inorganic and organic fertilizers than chemical fertilizers alone. High N fertilizer application could improve the growth and above ground biomass production of maize crop as maize is the heavy feeder of N. Fageria *et al.* (2011) stated that N deficiency delayed the vegetative and reproductive stages of phenological development and biomass production of maize.

**Thousand seeds weight:** Combined application of N, compost and S fertilizers significantly ($p \le 0.001$) affected thousand seed weight. The highest mean thousand seed weight (492 g) was again recorded in plots treated with 120 kg N $ha^{-1}$, 10 t compost $ha^{-1}$ and 15 kg S $ha^{-1}$ fertilizer rates while the lowest (240 g) was in the control with an increase of 105.0%. Such high increase in thousand seed weight might be also due to the synergistic effects of combined fertilizers for better growth and grain filling of maize crop. There was also significant ($p \le 0.001$) and strong positive correlations (r = 0.75, 0.77 and 0.79) between thousand seed weight and grain yield, total above ground dry biomass and grain number per cob, respectively (Table 3).

Table 5: Interaction effects of N, compost and S fertilizers on N and S nutrients concentration of maize leaf and grain

| N and S rates (kg ha$^{-1}$) | | Leaf N content (%) at compost rate (t ha$^{-1}$) | | | Grain N content (%) at compost rate (t ha$^{-1}$) | | | Leaf S content (%) at compost rate (t ha$^{-1}$) | | | Grain S content (%) at compost rate (t ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | S | 0 | 5 | 10 | 0 | 5 | 10 | 0 | 5 | 10 | 0 | 5 | 10 |
| 0 | 0 | $2.13^{i}$ | $2.35^{f-i}$ | $2.51^{c-g}$ | 0.61i | $0.72g^{hi}$ | $0.76^{e-h}$ | $0.186^{n}$ | $0.24^{ghi}$ | $0.29^{c}$ | $0.08^{i}$ | $0.09^{ghi}$ | $0.094^{ghi}$ |
| | 15 | $2.276^{hi}$ | $2.27^{hi}$ | $2.39^{e-h}$ | $0.69^{hi}$ | $0.69^{hi}$ | $0.76^{d-h}$ | $0.27^{def}$ | $0.20^{1m}$ | $0.26^{c-f}$ | $0.09g^{hi}$ | $0.10^{d-i}$ | $0.105^{d-h}$ |
| | 30 | $2.34^{ghi}$ | $2.48^{d-h}$ | $2.45^{e-h}$ | $0.74^{f-i}$ | $0.74^{f-i}$ | $0.76^{d-h}$ | $0.24^{hij}$ | $0.24^{i-l}$ | $0.27^{c-f}$ | $0.09^{hi}$ | $0.09^{f-i}$ | $0.092^{ghi}$ |
| 60 | 0 | $2.55^{c-g}$ | $2.62^{cde}$ | $2.68^{cd}$ | $0.90^{cde}$ | $0.84^{c-g}$ | $0.90^{cd}$ | $0.22^{lm}$ | $0.22^{klm}$ | $0.24^{ijk}$ | $0.09^{f-i}$ | $0.10^{1c-h}$ | $0.116^{a-f}$ |
| | 15 | $2.69^{cd}$ | $2.72^{c}$ | $2.57^{c-f}$ | $0.91^{c}$ | $0.88^{cde}$ | $0.95^{c}$ | $0.28^{cde}$ | $0.28^{cd}$ | $0.29^{c}$ | $0.10^{d-i}$ | $0.106^{c-h}$ | $0.122^{a-d}$ |
| | 30 | $2.59^{cde}$ | $2.68^{cd}$ | $2.72^{c}$ | $0.87^{c-f}$ | $0.89^{cde}$ | $0.94^{c}$ | $0.25g^{hi}$ | $0.24^{ijk}$ | $0.24^{fgh}$ | $0.11^{c-h}$ | $0.11^{b-f}$ | $0.10^{e-i}$ |
| 120 | 0 | $3.02^{ab}$ | $3.19^{cde}$ | $3.09^{cde}$ | $1.17^{b}$ | $1.25^{b}$ | $1.28^{cde}$ | $0.24^{ijk}$ | $0.23^{j-m}$ | $0.33^{b}$ | $0.09^{f-i}$ | $0.113^{b-f}$ | $0.12^{a-e}$ |
| | 15 | $3.03^{cde}$ | $2.97^{b}$ | $3.25^{a}$ | $1.18^{b}$ | $1.3^{cde}$ | $1.406^{a}$ | $0.23^{j-m}$ | $0.26^{efg}$ | $0.36^{a}$ | $0.09^{f-i}$ | $0.13^{cde}$ | $0.14^{a}$ |
| | 30 | $3.11^{cde}$ | $3.08^{cde}$ | $3.18^{cde}$ | $1.20^{b}$ | $1.17^{b}$ | $1.22^{b}$ | $0.28^{c-f}$ | $0.28^{cde}$ | $0.34^{b}$ | $0.10^{d-i}$ | $0.11^{c-h}$ | $0.13^{cde}$ |
| $R^2$ | | | 0.9 | | | 0.91 | | | 0.96 | | | 0.64 | |
| CV (%) | | | 5.1 | | | 9.1 | | | 4.1 | | | 12.3 | |
| F-test | | | *** | | | *** | | | *** | | | *** | |
| LSD | | | 0.22 | | | 0.14 | | | 0.01 | | | 0.02 | |

***,**Significant at $p\leq 0.001$ and $p\leq 0.01$ level, respectively. Means with the same letter are statistically non-significant at $p\leq 0.0$ according to Fisher's LSD

## Analysis of nitrogen and sulfur concentrations in maize crop

**Leaf and grain nitrogen concentration of maize:** The interaction effects of N, compost and S fertilizers had significant ($p\leq 0.001$) effect on N concentrations of maize leaves. The highest mean leaf N concentration (3.25%) was observed in leaves grown in plots treated with fertilizer rates of 120 kg N ha$^{-1}$, 10 t compost ha$^{-1}$ and 15 kg S ha$^{-1}$ while lowest (2.13%) was recorded in the control with an increase of 52.6% which might be due to high N availability in the soil as a result of the high N and compost fertilizers Leaf N concentration had significant ($p\leq 0.001$) and strong positive correlations (r = 0.89, 0.87 and 0.85) with grain N, grain yield and dry biomass, respectively (Table 3). Shinano *et al.* (1994) reported that N accumulation improves yield of field crops and another study stated that the higher the yields, the greater the withdrawal of nutrients.

The nitrogen concentration of maize grain was also significantly ($p\leq 0.001$) different by the interaction effects N, compost and S fertilizers (Table 5). The highest mean grain N (1.406%) was observed in plots treated with 120 kg N ha$^{-1}$, 10 t compost ha$^{-1}$ and 15 kg S ha$^{-1}$ while lowest (0.61%) in the control with an increase of 132.0% which might be also due to high N availability from the soil by high doses of N and compost fertilizers. There was also significant ($p\leq 0.001$) and strong positive correlations (r = 0.89, 0.88 and 0.86) between grain N content and grain yield, total above ground biomass and husked cob weight, respectively (Table 3). Fageria *et al.* (2011) stated that nutrient deficiencies cause concentrations to decrease in plant tissues. He also notified that at harvest, grain N concentration of maize ranges from 1.0-2.0%.

**Leaf and grain sulfur concentration of maize:** Significant ($p\leq 0.001$) difference was observed on leaf S concentrations among the treatments as a result of the interaction effects of N, compost and S fertilizers (Table 5). The highest mean leaf S (0.36%) concentration was recorded in plots treated with 120 kg N ha$^{-1}$, 10 t compost ha$^{-1}$ and 15 kg S ha$^{-1}$ while the lowest (0.19%) in the control with an increase of 89.5%. These high discrepancies in leaf S concentration might be due to the high compost for source of S nutrient and high N fertilizer rate that acted as synergistic effect with S fertilizer to facilitate the S uptake and utilization efficiencies of maize crop. Barker and Pilbeam (2007) reported that total S content in the vegetative parts of crops varies between 0.1 and 2%. There was also significant ($p \leq 0.001$) difference on grain S content of maize by the interaction effects of N, compost and S fertilizers where the highest (0.14%) was recorded in plots treated with 120 kg N $ha^{-1}$, 10 t compost $ha^{-1}$ and 15 kg S $ha^{-1}$ which showed an increase of 75% relative to the control (Table 5) which might be also due to high rate of compost application (acted as the source for S nutrient) and high N fertilizer with its high synergistic effect with S fertilizer.

## CONCLUSIONS

There was a great increase in yield and yield components, nutrient concentrations of maize crop with the integrated application of organic and inorganic fertilizers relative to the sole use of either of them or the control. The maximum grain yield and yield components of total biomass, grain number per cob, cob weight, plant height and thousand seed weight as well as tissue N and S concentrations of maize crop were recorded prominently in plots treated with 120 kg N $ha^{-1}$, 10 t compost $ha^{-1}$ and 15 kg S $ha^{-1}$. Since maize is a heavy feeder of N fertilizer, application of high dose of N fertilizer together with good nutrient sourced compost has paramount importance for improving its yield. Although available S content of the experimental soil is too low, high rate of S fertilizer (30 kg S $ha^{-1}$) didn't respond high yield and yield components of maize crop. Hence, application of S fertilizer beyond 15 kg $ha^{-1}$ is wastage. This experiment showed that productivity of maize is considerably higher when farmers use integrated soil fertility management options. Therefore, the use of integrated organic and inorganic fertilizers should be recommended for farmers because they were affordable options for increasing maize yields with improving soil fertility in the small-scale farming systems of the study area.

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