Evaluation of urea and ammonium sulfate on yield and yield components of sesame (Sesamum indicum L.) under high pH vertisol of Western Tigray, Northern Ethiopia

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Field experiment was conducted during 2012/13 and 2013/14 cropping season at Kafta Humera to evaluate sesame response to Urea and Ammonium sulfate. Treatments were: 0, 41 N from urea+20P, 20 N from Urea + 21 N from NH$_4$SO$_4$ [24 S] +20P and, 41 N from NH$_4$SO$_4$ [47 S] +20P were applied at five farmers’ field with two replications. The initial soil analysis revealed that strong alkaline, low organic matter and Nitrogen while very low in available phosphorus and sulfur, high CEC with clay texture. The agronomic parameters like 50% Flowering, days to 50% Maturity, plant height, Length of pod-bearing zone, Number of capsule per plant, Number of seeds per Capsule and grain yield were significantly (P < 0.05) affected by treatments. treatments received 20 N from Urea + 21 N from NH$_4$SO$_4$ [24 S] +20P followed by 41 N from urea +20P obtained additional grain yield (148.1% & 85%), number of capsules per plant (79.5% & 56.5%), plant height (60.7% & 31.7%), Branch number (62.7% & 28.7%) over the control, respectively. While the length of pod-bearing zone was significantly affected due to only 20 N from Urea + 21 N from NH$_4$SO$_4$ [24 S] +20P. This study implies that sulfur, Nitrogen and phosphorus in the area are deficient nutrients that limit Sesame crop production. Hence, a combined application of urea and ammonium...
sulfate as the sources for nitrogen and sulfur with phosphorus is best to enhance sesame crop production on Vertisols of Kafta Humera.

Subjects: Agriculture & Environmental Sciences; Soil Sciences; Soil Conservation Technology; Agronomy

Keywords: Ammonium sulfate; Kafta Humera; sesame; urea; vertisol

1. Introduction
Ethiopia is the Sixth largest sesame producer in the world (FAOSTAT, 2012) and third sesame exporter next to Nigeria and India (Ministry of Trade, 2013). In Ethiopia, Sesame ranks second from the oilseeds next to Noug (Guizotia abyssinica Cass.) (CSA, 2013) and it exported first (79%) from oil seeds and second (20%) from agricultural export next to coffee (Ministry of Trade, 2013). The productivity of sesame in the lowlands of western and northwestern Tigray is still lower than 5.25 quintal/ha in 2013 (Fiseha, Yemane, & Fetien, 2015) compared with the national average yield of about 7.57 quintals/ha in the same year (CSA, 2013) and by far lower than with the world average yields, especially compared with countries like Mozambique which reaches up to 15 quintals/ha (Buss, 2007).

Lack of desirable agronomic qualities, low soil fertility, uncomfortable pH status and lack of varieties which respond to inorganic fertilizers are the challenges for the decrease in productivity (Ayana, 2015). Declining soil fertility of Nitrogen, Potassium, Zinc and Boron especially low to very low level of soil sulfur was observed at Kafta Humera (EthioSIS, 2014). Only using Urea and DAP (Di Amine phosphate) fertilizers have not been seen to increase crop yield in the high pH soils of lowland areas. Though 50 kg urea (23 N) and 100 kg DAP (18 N and 20P) were recommended (Humera Agricultural Research Centre, 2012) for Kafta Humera; as the Urea fertilizer becomes less readily available due to volatilization, and soils of the area are demanded for additional nutrients like sulfur alternatives are being sought for Nitrogen and sulfur demanded areas. Ammonium sulfate (AS) is one of the alternate fertilizer products that can potentially provide the benefits of Urea (i.e. steady N supply, reduced ammonia volatilization) as well as sources for sulfur. However, there are few or no studies comparing and evaluating Ammonium sulfate and Urea for major cereal, and oil crops especially sesame crop in the country particularly in Kafta Humera. Hence, studies of this type are needed to allow Farmers to make informed about alternative N and S fertilizer use. Such major research effort was required to halt and reverse the situation and develop improved and alternate fertilizer options if long-term productivity is to be secured in this area.

1.1. Objective
To compare and evaluate Urea and Ammonium sulfate as Nitrogen and Sulfur sources and Response on yield and yield components of sesame grown at high pH Vertisols of Kafta Humera.

2. Materials and methods

2.1. Area description
The experiment was conducted during 2012/13 and 2013/14 cropping season in Kafta Humera District, Northern Ethiopia. It is located at about 1100 km North West of Addis Ababa the capital of Ethiopia, at 1,512,218.50 m to 1,597,861.12 m Northing and 213,444.75 m to 343,131.93 m Easting, with an elevation range of 527 to 1891 m above sea level and 6756 km² area coverage (Figure 1).

It is bounded by Eritrea in the North, Tahtay Adyabo and Welkayt Districts in the East, Tsegede District in the South, and republic of Sudan in the West. Vertisol is the dominant soil type of this area.
The mean annual rainfall of the area is about 576.4 mm (2007–2013) that usually starts at about the end of June and ends in early September (Fiseha et al., 2015) with maximum temperature ranges from 33°C to 42°C while the minimum temperature from 17.5°C to 22.2°C (Hailemariam, Gebeyehu, & Girmay, 2016).

2.2. Site selection, soil sampling and analysis

Field experiment was conducted across high pH Vertisols on five locations (farmers’ field) with homogenous soil type, sulfur and Nitrogen deficiencies. Prior to the experiment composite soil samples were taken by inserting auger up to a depth of 20 cm (root depth) from each field. All the subsample of a single composite sample were collected in a bucket and thoroughly mixed. Finally, about 1 kg of soil was taken using quartering method from the bulk composite soil sample to a polyethylene bag with the necessary label on it. This field soil samples were air-dried at a convenient room temperature to reduce soil mineralization (Ryan, Estefan, & Rashid, 2007) and milled. Except for soil organic carbon (OC) and soil total Nitrogen (TN) analysis which passed through 0.5 mm sieve; soil pass through 2 mm diameter mesh sieve and laboratory analysis were made for Texture, pH, available Phosphorus (av.P), and Cation Exchange Capacity (CEC) following their respective standard procedures at Mekelle Soil, Plant and Water Analytical Laboratory. The pH of the soil was determined by preparing soil water solution at the ratio of 1:2.5 as described by Schlichting, Blume, and Stahr (1995) and Ryan et al. (2007). Soil pH was then measured by inserting the electrodes of the pH meter into the soil suspension following its calibration. The organic carbon was measured by the modified Walkley-Black method (Estefan, Sommer, & Ryan, 2013) and Organic matter percentage was calculated as Organic carbon percentage multiplying by a factor of 1.724. Total nitrogen was determined by wet digestion followed by ammonium distillation and titration using Kjeldhal method (Estefan et al., 2013 & Soil Survey Staff, 2011).
Olsen’s method was used to determine available phosphorus (Olsen, Cole, & Watanabe, 1954). The Particle size of the area was also analyzed following Bouyoucos hydrometer method (Day, 1965). Cation Exchange Capacity (CEC) was determined by replacing exchangeable cations with sodium acetate (Chapman, 1965).

### 2.3. Experimental design and procedures

An experiment was conducted to reveal the response of sesame to urea and Ammonium sulfate (AS) as an alternative Nitrogen source and Sulfur source on yield and yield components of sesame crop grown at high pH Vertisols of Kafta Humera. Four treatments: (1) Control (0), (2) 41 N from urea + 20 P, (3) 20 N from Urea + 21 N from NH$_4$SO$_4$ [24 S] +20 P and, (4) 41 N from NH$_4$SO$_4$ [47 S] +20 P were used as treatments. The Design was Randomize Complete Block Design (RCBD) with two replications at five farmers’ field and Plot size of 4 m X 5 m (20 m$^2$). Spacing between plants and rows was 10 cm and 40 cm, respectively, with a seed rate of 2 kg/ha. A newly released improved variety of Sesamum indicum L. locally called Setit 1 (Figure 2) was used as a test crop and the seeds were planted at 5 cm depth. Ammonium Sulfate was used as the source of Nitrogen and Sulfur fertilizer with 21% and 24%, respectively. Except the control (with 0 kg ha$^{-1}$), 20 kg/ha phosphorus (P) was applied for each experimental plot. The nitrogen and phosphorus rate was used based on the Humera Agricultural Research Centre (2012) recommendation (41 N and 20 P). The rate for ammonium sulfate was also based on as it will give/contribute the 41 N (as the recommended Nitrogen from urea and DAP which was 41). The planting method was row planting and Urea was applied in split dose, that is, half at planting and half at 35 days after germination, while TSP (Triple Super Phosphate) and Ammonium sulfate were applied in full dose at planting time. All management practices such as Land preparation, plowing, weeding and other agronomic management were carried out.

### 2.4. Data collection, plant sampling and analysis

Days to 50% Emergence, Days to 50% flowering, Days to 50% maturity, Branch number, Plant height, Length of pod-bearing zone, Number of Capsule per plant, Number of seed per Capsule, and Grain Yield were collected. Plant height was determined by measuring the length of the plants from the ground level to the top at physiological maturity. At physiological maturity 10 representative’s plant samples were used for yield parameters (Branch number, Plant height, Length of pod-bearing zone, Number of Capsule per plant, and Number of seed per Capsule) data collection. plants were harvested from a net plot size of 10 rows = 20 m$^2$ and; air dried in an open dry environment and Grain yield was determined by weighing using sensitive balance. Grain yield per plot was determined after carefully separating the grain from the straw.

### 2.5. Data analysis

Two- year combined analysis of variance was subjecting to the statistical software program SAS, 2004, version 9.0 to carry out for yield and yield parameters of the crop to determine its response to the applied fertilizers. For statistically significant different parameters, the means were separated using the least significant difference (LSD). For profitability of sesame production using different fertilizer sources, marginal rate of return (MRR) was calculated as the change in net revenue (NR) divided by the change in total variable cost (TVC) of the successive net revenue and total variable cost levels (CIMMYT, 1988).

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Figure 2. Sesame crop at Kafta Humera.
3. Results and discussion

3.1. Preplanting soil analysis

Soil pH was classified as strong alkaline as per the pH rating category suggested by Yuste and Gostincar (1999). The total percentage of organic matter and Total Nitrogen were Low as prescribed by Tadesse, Haque, and Aduayi (1991) while very low in available phosphorus according to the availability index suggested by Cottenie (1980). This might be due to the nutrient mining from the soil by the agricultural crops especially sesame and sorghum crops and fertilizer usage was not experienced in the area for the last 60 to 70 years. According to FAO (2006) the soil result indicated that the area has high Cation Exchange capacity and classified as Clay texture (Table 1).

3.2. Sesame yield response to ammonium sulfate and urea

The two years combined analysis of variance showed that except days to 50% Emergence and 50% Flowering all yield and yield components (the days to 50% Maturity, plant height, Length of pod-bearing zone, Number of capsule per plant, Number of seeds per Capsule and grain yield were significantly (P < 0.05) affected by treatments (Table 2). Significantly higher sesame yield was recorded with Soils that received 20 N from Urea + 21 N from NH₄SO₄ [24 S] + 20 P (830.68kg/ha) followed by soils with Recommended NP (41 N from urea +20 P) (619.06kg/ha) over the control (334.89kg/ha).

Soils treated with 20 N from Urea + 21 N from NH₄SO₄ [24 S] +20 P and 41 Nitrogen and 20 phosphorus (recommended N&P) gave yield advantage by about 148% and 85% over the control, respectively, while the number of capsules per plant was improved by 79.5% and 56.5%. Simultaneously plant height was increased by 60.7% and 31.7%, Branch number by 62.7% and 28.7% over the control (without fertilizer) treatment. Though the length of pod-bearing zone of the treatments with 20 N from Urea + 21 N from NH₄SO₄ [24 S] + 20 P was longer than the control by about 63.4%, there was no significant difference among soils treated with the 41 Nitrogen and 20 phosphorus (recommended N&P) and the control. This increment of the Grain yield of sesame might be as a result of increasing of the other plant components (plant height, higher number of branches, and length of pod-bearing zone, capsule number and number of seed per capsule as a result of the sulfur in addition to the recommended Nitrogen and phosphorus in the area. This finding is in agreement with Gebre et al. (2006) and Hailemariam et al. (2016); they indicated that the probable increment of the Grain yield of sesame was influenced by Plant height, Number of capsule per plant and number of branches. Similar finding was discussed by Desai, Shah, and Kukadia (1981) who reported that capsule number had pronounced influence on grain yield for sesame.

Sesame with treatments of 20 N from Urea + 21 N from NH₄SO₄ [24 S] +20 P and 41 Nitrogen and 20 phosphorus also have matured earlier (80.4 days) and (83 days) than the control (85.0days) respectively.

This study also shows that, though there was no significant difference on Number of seeds per capsule, days to 50% emergence and days to 50% flowering, there was a Significant difference on many of the yield and yield components among the treatments of 20 N from

| Texture (%) | Clay | Silt | Sand | pH (1:2.5H₂O) | OM (%) | TN (%) | Av. P-Olsen (mg kg⁻¹) | CEC (cmol⁺ kg⁻¹) |
|-------------|------|------|------|---------------|--------|--------|----------------------|-----------------|
|             | 53   | 22   | 25   | 8.29–8.53     | 0.88–0.91| 0.062–0.049 | 2.97–3.073           | 23.9–25.8       |

Note: OM = Organic Matter; CEC = Cation Exchange Capacity; TN = Total Nitrogen and Av. P = Available Phosphorus
Table 2. One way analysis of variance for sesame yield attributes response to the application of Ammonium sulfate and Urea

| No  | Treatments                                         | D50%E | D50%F | D50%M | Br.N  | Pht(cm) | LpbZ(cm) | NC/P | NoS/C | G.Y(kg/ha) |
|-----|----------------------------------------------------|-------|-------|-------|-------|--------|----------|------|-------|------------|
| 1   | Control (0)                                        | 4.0   | 44.2  | 85.0  | 1.85  | 87.78  | 44.60    | 33.14| 52.04 | 334.89     |
| 2   | 41 N from urea + 20 P                              | 4.0   | 43.6  | 83.0  | 2.38  | 115.56 | 52.68    | 51.86| 61.30 | 619.00     |
| 3   | 20 N from Urea + 21 N from NH₄SO₄ [24-S] + 20 P    | 4.0   | 43.6  | 80.4  | 3.01  | 141.08 | 72.88    | 59.49| 61.74 | 830.68     |
| 4   | 41 N from NH₄SO₄ [47-S] + 20 P                      | 4.0   | 43.4  | 79.6  | 3.22  | 144.22 | 74.00    | 62.40| 61.86 | 866.18     |
| LSD(<0.05) |                                              | Ns    | Ns    | 1.91  | 0.46  | 21.96  | 15.51    | 6.90 | 3.10  | 159.29     |
| CV  |                                                   | -     | 5.07  | 1.74  | 13.04 | 13.41  | 18.95    | 9.95 | 3.92  | 17.93      |

Mean values across columns followed by the same letter(s) are not significantly different at P > 0.05

NB: AS-ammonium sulfate, D50%E-days to 50% emergence, D50%F-days to 50% flowering, D50%M-days to 50% maturity, Pht (cm)-plant height in centimeter, Br.N-branch number, LpbZ (cm)-length of pod-bearing zone in centimeter, NC/P-number of capsules per plant, G.Y (kg/ha)-grain yield in kilogram.
Urea + 21 N from NH$_4$SO$_4$ [24 S] + 20 P and treatments with 41 N from urea +20 P. Soils treated with 20 N from Urea + 21 N from NH$_4$SO$_4$ [24 S] +20 P gave yield advantage by about 34.2% over the 41 Nitrogen and 20 phosphorus (recommended N&P). The number of capsules per plant was improved by 14.7%. While Length of pod-bearing zone was increased by 38.3%, plant height was improved by 22.1% and Branch number by 26.5% over the treatment with 41 Nitrogen and 20 phosphorus.in addition, sesame with soils that received 20 N from Urea + 21 N from NH$_4$SO$_4$ [24 S] + 20 P was also matured earlier (80.4 days) than the soils with 41 N from urea +20 P (83 days). This indicates that sulfur is important in growing attributes of sesame in addition to the Nitrogen and phosphorus fertilizers and has effect on early maturing. A study conducted by Sharma and Gupta (2003) also revealed that sulfur is important to increase the production and productivity of sesame. Alberta (2004) and Hailemariam et al. (2016) also reported that sulfur deficiencies in cereals can cause a delay in maturity by about 3 to 10 days.

However, there is no significant difference among treatments with 41 N from NH$_4$SO$_4$ [47 S] a + 20 P and soils with 20 N from Urea + 21 N from NH$_4$SO$_4$ [24 S] +20 P in all yield and yield components. This shows that increasing sulfur amount beyond 24 kg on the study area may not important though the soil is deficient in sulfur. Hailemariam et al. (2016) discussed that adding of nutrients to soils with low nutrient gives high response up to the optimum level, but addition of nutrients after the optimum point is luxury and even it can be toxic to the crop then decreasing the yield. He also concluded that sulfur with 20 kg per hectare is economically recommended with flatbed at Kafta Humera. Similarly, Puste, Pramanik, Jana, Roy, and Devi (2015) found that grain yield response per kilogram of sulfur application for sesame is found to be a quadratic function and they also indicated that maximum response was recorded at the sulfur level of 20 kg ha$^{-1}$ and decreased with the increase in Sulfur level.

3.3. Partial budget analysis

The marginal rate of return at the application of (41 N from urea +20 P) and (20 N from Urea + 21 N from NH$_4$SO$_4$ [24-S] +20 P) kg ha$^{-1}$ is 7.76 and 754.71, respectively, which is greater than 1. As the ratio of MRR for these rates is greater than 1, investing extra money is economical (CIMMYT Economics Program, 1988). Thus, application of nitrogen and phosphorus fertilizers (41 N from urea +20 P) or nitrogen, phosphorus and sulfur fertilizers (20 N from Urea + 21 N from NH$_4$SO$_4$ [24-S] +20 P) kg ha$^{-1}$ is economically profitable. This indicates that smallholder farmers and investors can use application of 41 N from urea +20 P kg ha$^{-1}$ or 20 N from Urea + 21 N from NH$_4$SO$_4$ [24-S] +20 P kg ha$^{-1}$ based on their capacity on investing these fertilizers and their yield interest up to the level of 24 kg sulfur (20 N from Urea + 21 N from NH$_4$SO$_4$ [24-S] +20 P) optimum return (Table 3).

4. Conclusion and recommendation

Days to 50% Maturity, plant height, Length of pod-bearing zone, Number of capsule per plant, Number of seeds per Capsule and grain yield were significantly (P < 0.05) affected by treatments. Higher sesame yield was obtained with Soils that received 20 N from Urea + 21 N from NH4SO4 [24 S] + 20 P followed by soils with 41 N from urea +20 P. This is due to the Nitrogen and Sulfur nutrients from both urea and ammonium sulfate fertilizers; and as the study area was high pH soil, these fertilizers have acidifying effect on this alkalinity property in addition to their importance as nutrient especially the sulfur. However, there was no significant difference among treatments with 20 N from Urea + 21 N from NH4SO4 [24 S] +20P and treatments with 41 N from NH4SO4 [47 S] + 20 P on the sesame yield and yield components. This might be due to the demand for the sulfur level is not exceeds beyond 24 kg ha$^{-1}$ in Kafta Humera. Thus, application of the 20 N from Urea + 21 N from NH4SO4 [24 S] +20 P is recommended for optimum benefit, however smallholder farmers and investors can use either the 20 N from Urea + 21 N from NH4SO4 [24 S] +20 P or 41 N from urea +20 P in the study area as well as elsewhere areas with similar agroecologies. Other sources of sulfur fertilizers with their plant uptakes and efficiency should be studied.
| No | Fertilizer Levels (kg ha\(^{-1}\)) | Fertilizer Cost (Birr) | Tillage and labor cost (Birr) | Transport and labor cost (Birr) | Total variable cost (TVC) (Birr) | Grain yield (kg ha\(^{-1}\)) | Total revenue (TR) (Grain yield*25 Birr) | Net revenue (TR-TVC) | Marginal rate of return (MRR) (ratio) |
|----|----------------------------------|-----------------------|-------------------------------|-------------------------------|---------------------------------|-----------------------------|---------------------------------------|---------------------|--------------------------------------|
| 1  | Control (0)                      | 0.0                   | 1200                          | 0.0                           | 1200                            | 334.9                       | 8373                                  | 7173                | -                                    |
| 2  | 41 N from urea +20P              | 586                   | 1400                          | 25.0                          | 2011                            | 619.1                       | 15,478                                | 13,467              | 7.76                                 |
| 3  | 20 N from Urea + 21 N from NH\(_4\)SO\(_4\) [24-S] +20 P | 593                   | 1400                          | 25.0                          | 2018                            | 830.7                       | 20,768                                | 18,750              | 754.71                               |
| 4  | 41 N from NH\(_4\)SO\(_4\) [47-S] + 20 P | 600                   | 1400                          | 25.0                          | 2025                            | 866.2                       | 21,655                                | 19,630              | 125.71                               |

MRR = Marginal Rate of Return
Funding
The authors received no direct funding for this research.

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Cover Image
Source: Author.

Citation information
Cite this article as: Evaluation of urea and ammonium sulfate on yield and yield components of sesame (Sesamum indicum L.) under high pH vertisol of Western Tigray, Northern Ethiopia, Gebremedhin Berhe, Hailemariam Abraha & Welesenbet Haftu, Cogent Food & Agriculture (2019), 5: 1600461.

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