# Evaluation of micro-dosing fertilizer application on sorghum production in Wag-Lasta districts

Workat Sebnie, Merse Mengesha, Gebrehana Girmay, Belaynesh Asgedom, Gashaw Beza and Dereje Dejenie

Sekota Dryland Agricultural Research, Center, P.O. Box 62 Sekota, Ethiopia

## Abstract

A field experiment was conducted under rainfed conditions to evaluate micro-dosing application of N and P fertilizer on sorghum yields at Wag-Lasta, Amhara Region. The treatments were comprised of a factorial combination of three rates of recommended NP in micro dosing (25%, 50% and 75%) and three times of N application plus control (without fertilizer) and recommended NP. The experiment was laid down in a randomized complete block design with three replications. All DAP was applied at plating and urea was applied as per the treatment setup. Miskir sorghum variety was used as a test crop. Tie-ridging at 2 m interval was applied to all plots uniformly. Required data were collected and analyzed using SAS software and means were separated using least significant difference at 5% for significant treatment means differences. Application of 34.5 kg $P_2O_5$ ha$^{-1}$ and 30.75 kg N ha$^{-1}$ (N applied 1/3 at sowing, 1/3 at emergence and 1/3 first weeding or knee height) increased the grain yield by 122% over the control and 28.4% over the recommended NP and saves 25% of the recommended fertilizer at Aybra. While at Lalibela, application of 20.5 kg N ha$^{-1}$ and 23 kg $P_2O_5$ ha$^{-1}$ (N applied 1/3 at sowing, 1/3 at emergence and 1/3 at first weeding) increased the grain yield by 174% over the control and 15% over the recommended NP and saves 50% of the recommended fertilizer. Therefore, application of 75% of the recommended NP (N applied in three splits) is recommended for Aybra area and application of 50% of the recommended NP (N applied in three splits) for Lalibela area.

**Keywords:** application method, fertilizer, micro-dose, sorghum, Wag-Lasta

## Introduction

Low level of soil fertility because of land degradation and nutrient depletion has been a critical challenge to agricultural production in Ethiopia. On cultivated land, there is a continuous decline in soil quality resulted from reduced fallows and sub-optimal use of fertilizer inputs. Continuous cultivation coupled with nutrient depletion, poor crop residue management, and reduced crop rotation resulted in poor soil fertility (Heluf, 2005). Most soils in the semi-arid areas of northeastern Ethiopia are heavily depleted of plant nutrients and are characterized by low total nitrogen, available phosphorus (P) and organic carbon (OC) contents leading to substantial decline in crop productivity (Asnakew, 1994).

Drought along with low soil fertility due to excessive degradation and nutrient depletion are serious limitations to crop production in Ethiopia (FAO, 1999). Sorghum is one of the leading food crops in Ethiopia that comprises 17% of the total cereal production in the country. It is the second major cereal crop next to teff (*Eragrostis tef*) in consumption and area coverage. Sorghum accounts more than 16% of the total cultivated area in the Amhara Region (CSA, 2014). It is the dominant crop in semi-arid areas such as Wag-Lasta areas in the Amhara Region. The average yield of sorghum per unit area is not more than 1.0 t $ha^{-1}$ (CSA, 2014). Low , erratic and poorly distributed of the rainfall and poor soil fertility are some of the causes that limit crop productivity including sorghum in Ethiopian (Huluf, 2003).

Inorganic fertilizer is critically important to increase crop yield (Mwangi, 1995). Gruhnet al., (1995) suggested fertilizer rates must be increased to meet the ever increasing demand of food. Micro-dosing refers to the application of small quantities of fertilizer at planting time or as top dressing about three to four weeks after emergence. Micro-dosing fertilizer enhances fertilizer use efficiency and improves yields, while minimizing input and investment cost. This is an efficient way to apply fertilizer, because the fertilizer is applied adjacent to the seeds, thereby ensuring a high rate of uptake. Micro-dosing of fertilizers was found to increase yields by 44% to 120% and farmers’ income by 52% to 134% compared to traditional application methods (Tabo et al., 2006). Similar research finding in Niger shows micro-dose method increased yield with low cost and efficient (Hayashi et al., 2008). Ncube et al. (2007) showed that farmers could increase their yields by 50% by applying about 9 kg of nitrogen per hectare compared to no application in Zimbabwe. In addition rational use of fertilizer plays its own role to mitigate climate change (Hailemariam et al., 2013). However, there is no information on fertilizer application in a micro dosing in Amhara region and the study area. Therefore, this research was designed to evaluate micro-dosing fertilizer application techniques (N and P) on sorghum yields at moisture stressed areas of Waghimra and North Wollo zones of Amhara region.

## Materials and method

*Description of the study areas*

The study was conducted for two years at Aybera and Shimshaha areas of Waghimra and North Wollo zones of the Amhara Region; respectively (Figure 1). The location of the study areas was found within the range of altitude from 1921 to1947 m.a.s.l. The study areas are characterized with small (290 mm to700 mm) erratic annual rainfall.

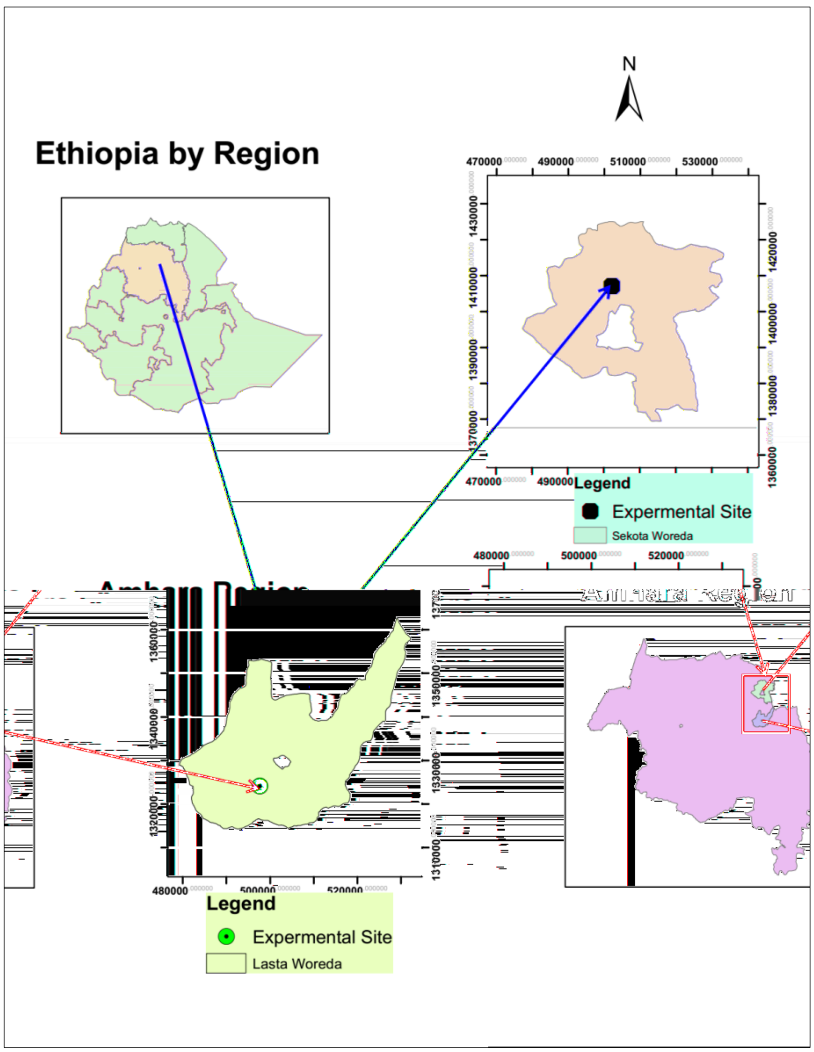


Figure 1. Location map of study area

*Experimental design*

The experiment was comprised of three rates of NP (25%, 50% and 75% of the recommended NP) factorialy combined with three nitrogen splitting times (1. half at sowing and half at emergence, 2. One third at sowing, One third at emergence and one third at first weeding (knee height), 3. Half at sowing and half at first weeding (knee height)) arranged in completely randomized block design (RCBD) with three replications. In addition, two treatments, control (without any nutrient) and recommended NP fertilizer were included and made a total of 11 treatments. DAP and urea were used as a source of phosphorus and nitrogen respectively. Each plot was having an area of 3.75m by 4m. The space between blocks was 1m while between plots was 0.5m. The space between plants and rows was 15 cm and 75 cm; respectively. Misker was sorghum variety was used as a test crop. Tie-ridge with 2 meter interval was uniformly applied. Similarly cultivation and weeding were done uniformly for all treatments.

*Data analysis*

Collected data were subjected to statistical analysis using SAS statistical software version 9.0 and treatment effects were compared using the Fisher's Least Significant Differences test at 5% level of significance.

*Soil sampling and analysis*

A composite soil sample was collected from 0-20 cm, air dried and passed through 2 mm sieve to determine most nutrients and through 0.5 mm for total nitrogen and organic carbon. The soil parameters were determined following standard laboratory procedures. Soil pH was determined in $H_2O$ using 1:2.5 soils to solution ratio using a combined glass electrode pH meter (Chopra and Kanwar, 1976). Organic carbon of the soils was determined following the wet digestion method as described by Walkley and Black (1934) while percent organic matter of the soils was determined by multiplying the percent organic carbon value by 1.724. Total N was analyzed by the Kjeldahal digestion and distillation procedure (Bremner and Mulvaney, 1982).

*Partial budget analysis*

The partial budget analysis was done to evaluate the economic feasibility of nitrogen and phosphorus application based on the manual developed by CIMMYT (1988). The fertilizer cost, mean price of sorghum, labor cost for each fertilizer application was collected from the two districts. For the purpose of partial budget analysis, yields were adjusted downward by 10% from the exact yield.

## Results and discussion

The soil pH of surface soil for Aybra and Lalibella was 6.3 and 6.4 respectively. Based on Tekalign, (1991), the reaction of the study areas is within slightly acidic class. The organic matter content of the soil was 1.0% for Aybra and 1.2% for Lalibella; which is extremely below the critical limit (3.45%). Similarly, the total nitrogen content was 0.01% for Aybra and 0.02% for Lalibella; which is extremely below the critical limit.

### *Effects on grain yield*

The Maximum grain yield (2476.4 kg $ha^{-1}$) was obtained from 75% recommended NP (34.5 kg $P_2O_5$ and 30.75 kg N $ha^{-1}$, N applied in three splits) while the minimum grain yield (1114.8 kg $ha^{-1}$) was obtained from the control (without fertilizer) at Aybra. Micro-dosing application increased the yield by 122% over the control and by 28.4% over the recommended NP (Table 1) at Aybra. Similarly, the maximum grain yield (2807 kg $ha^{-1}$) was obtained from 50% NP (20.5 kg N $ha^{-1}$ and 23 kg $P_2O_5$ $ha^{-1}$ (N applied in three splits)) whereas the minimum yield (1023 kg $ha^{-1}$) was obtained from the control (without fertilizer) at Lalibela (Table 1). In addition to the yield advantages over the recommended NP, micro dose application saved 25% fertilizer at Aybra and 50% fertilizer amount at Lalibela. The saved fertilizer amounts can be used for additional sorghum production from 1/3 ha at Aybra and from one ha at Lalibela in micro dose application. Our result is inline with findings of Tabo et al., (2006) and Osman et al., (2009) who reported sorghum yield increment ranging between 44 to 120% compared to control using micro-dose application. Similarly, Twomlow et al., (2010) reported that application of micro-dose of 10 kg nitrogen $ha^{-1}$ increased the yield by 30-100%. Three times split application of nitrogen with micro-dosing at: 1/3 at sowing, 1/3 at emergence and 1/3 at knee height was more efficient than the other application methods.

### *Effect on biomass yield*

Significantly heigher biomass yield at Aybra was also obtained from 75% recommended NP (34.5 kg $P_2O_5$ and 30.75 kg N $ha^{-1}$, (N applied in three splits)) and the minimum biomass yield (4246.3 kg $ha^{-1}$) was obtained from the control (Table 1). Micro-dose application increased the biomass yield by 57% compared to the control and by 21.6% over the recommended NP at Aybra and by 85% over the control and 10% over the recommended NP at Lalibela. The results are in line with the findings of Tabo et al. (2006) , Osman et al. (2009) and Abdalla et al., (2015) who reported increased sorghum biomass due to micro-dose application.

Table1. Effect of nitrogen and phosphorus on yield and yield component of sorghum

| DAP kg ha$^{-1}$ | Urea kg ha$^{-1}$ | Aybra | | | | | | Lalibella | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Grain yield kg ha$^{-1}$ | | | Biomass yield kgha$^{-1}$ | | | Grain yield kgha$^{-1}$ | | | Biomass yield kgha$^{-1}$ | | |
| | | Year-1 | Year-2 | Combined | Year-1 | Year-2 | combined | Year-1 | Year-2 | combined | Year-1 | Year-2 | combined |
| 0 | 0 | 1324.1 | 905.6 | 1114.8 | 4548.1 | 3944.4 | 4246.3 | 1573.9 | 472.2 | 1023.1 | 5933.5 | 1944.4 | 3939 |
| 25 | 12.5 SE | 1116.7 | 1911.1 | 1513.9 | 7225.3 | 6111.1 | 6443.1 | 1977.8 | 555.6 | 1266.7 | 7186.7 | 1333.3 | 4260 |
| 25 | 12.5 SEF | 1738.1 | 1662.2 | 1700.15 | 5572.5 | 5611.1 | 5591.8 | 1952.5 | 616.7 | 1284.6 | 7248.9 | 2777.8 | 5013 |
| 25 | 12.5 SFW | 1535.0 | 1861.1 | 1698.05 | 6486.5 | 5555.6 | 6021.0 | 1830.0 | 1026.6 | 1427.3 | 7775.2 | 3055.6 | 5415 |
| 50 | 25SE | 1760.0 | 2277.8 | 2018.9 | 5920.0 | 5833.3 | 5876.7 | 2833.6 | 1311.1 | 2072.4 | 10767 | 3222.2 | 6995 |
| 50 | 25 SEF | 2143.9 | 1777.8 | 1960.8 | 6216.9 | 5740.7 | 5978.8 | 2715.6 | 2900.0 | 2807.8 | 9863.1 | 4722.2 | 7293 |
| 50 | 25 SFW | 1960.3 | 2066.7 | 2013.5 | 7672.2 | 3888.9 | 5780.6 | 2101.9 | 2002.3 | 2045.1 | 8622.8 | 2500.0 | 5561 |
| 75 | 37.5 SE | 1540.8 | 2738.9 | 2139.9 | 6090.0 | 5000.0 | 5545.0 | 2329.6 | 2577.8 | 2453.7 | 9581.9 | 5185.2 | 7384 |
| 75 | 37.5 SEF | 2158.7 | 2794.4 | 2476.6 | 7219.4 | 5666.7 | 6668.2 | 2148.7 | 1700.0 | 1924.4 | 8628.1 | 5277.8 | 6953 |
| 75 | 37.5 SFW | 1816.5 | 2272.2 | 2044.4 | 5767.5 | 4111.1 | 4939.3 | 2017.8 | 2250.0 | 2133.9 | 8388.3 | 3888.9 | 6139 |
| 100 | 50 | 1952.2 | 1905.6 | 1928.9 | 6193.5 | 4777.8 | 5485.6 | 2280.6 | 2594.4 | 2437.5 | 8804.1 | 4444.4 | 6624 |
| CV (%) | | 12.89 | 15.23 | 21.47 | 9.54 | 13.22 | 17.73 | 7.73 | 11.92 | 24.74 | 10.3 | 14.87 | 27.82 |
| LSD (0.05) | | 380.25 | 535.52 | 474.2 | 1012.5 | 1144.6 | 1167.2 | 288.47 | 362.02 | 572.01 | 1464.3 | 878.06 | 3298.6 |

*SE stands for urea application at sowing and at emergence; SEF stands for urea application at sowing, at emergence and at first weeding, SFW stands for urea application at sowing and at first weeding(knee height)*

*Partial budget analysis*

Partial budget analysis of Aybra shows that application of 75% recommended NP (34.5 kg $P_2O_5$ and 30.75 kg N $ha^{-1}$ N applied in three splits) had the highest net benefit (1505.07 ETB $ha^{-1}$) with 1505% MRR at Aybra (Table 2). Whereas the partial budget analysis for Shumsha shows that application of 50% recommended NP (20.5 kg N and 23 kg $P_2O_5$ $ha^{-1}$ N applied in three splits) resulted in the highest net benefit (17844.01 ETB $ha^{-1}$) (Table 3) with MRR of 1822%.

Table2. Partial budget analysis for Aybra

| DAP kg $ha^{-1}$ | Urea kg $ha^{-1}$ | Unadjusted yield (kg $ha^{-1}$ | Adjust yield (kg $ha^{-1}$) | Total variable cost (ETB) | Gross benefit (ETB) | Net benefit (ETB) | MRR% |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 1114.8 | 1003.32 | 0 | 7023.24 | 7023.24 | |
| 25 | 12.5 SE | 1513.9 | 1362.51 | 633.76 | 9537.57 | 8903.81 | D |
| 25 | 12.5 SEF | 1700.15 | 1530.135 | 647.76 | 10710.945 | 10063.185 | 469 |
| 25 | 12.5 SFW | 1698.05 | 1528.245 | 633.76 | 10697.715 | 10063.955 | D |
| 50 | 25 SE | 2018.9 | 1817.01 | 1085.64 | 12719.07 | 11633.43 | 359 |
| 50 | 25 SEF | 1960.8 | 1764.72 | 1099.64 | 12353.04 | 11253.4 | D |
| 50 | 25 SFW | 2013.5 | 1812.15 | 1085.64 | 12685.05 | 11599.41 | D |
| 75 | 37.5 SE | 2139.9 | 1925.91 | 1537.51 | 13481.37 | 11943.86 | 69 |
| 75 | 37.5 SEF | 2476.6 | 2228.94 | 1551.51 | 15602.58 | 14051.07 | 1505 |
| 75 | 37.5 SFW | 2044.4 | 1839.96 | 1537.51 | 12879.72 | 11342.21 | D |
| 100 | 50 | 1928.9 | 1736.01 | 1876.94 | 12152.07 | 10275.13 | D |

*SE stands for urea application at sowing and at emergence; SEF stands for urea application at sowing, at mergence and at first weeding, SFW stands for urea application at sowing and at first weeding (knee height).*

Table 3. Partial budget analysis for Lalibella

| DAP kg ha$^{-1}$ | Urea kg ha$^{-1}$ | Unadjusted yield (kg ha$^{-1}$ | Adjust yield (kg ha$^{-1}$ ) | Total variable cost (ETB) | Gross benefit (ETB) | Net benefit (ETB) | MRR% |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 1023.1 | 920.79 | 0.0 | 6905.93 | 6905.93 | |
| 25 | 12.5 SE | 1266.7 | 1140.03 | 623.8 | 8550.23 | 7926.46 | 164 |
| 25 | 12.5 SEF | 1427.3 | 1284.57 | 634.3 | 623.76 | 9010.51 | 332 |
| 25 | 12.5 SFW | 1284.6 | 1156.14 | 656.8 | 8671.05 | 8014.29 | D |
| 50 | 25 SE | 2072.4 | 1865.16 | 1075.6 | 13988.70 | 12913.06 | 864 |
| 50 | 25 SEF | 2807.8 | 2527.02 | 1108.6 | 18952.65 | 17844.02 | 1822 |
| 50 | 25 SFW | 2045.1 | 1840.59 | 1304.4 | 1075.64 | 12728.79 | D |
| 75 | 37.5 SE | 2453.7 | 2208.33 | 1527.5 | 16562.48 | 15034.96 | 671 |
| 75 | 37.5 SEF | 2133.9 | 1920.51 | 1527.5 | 14403.83 | 12876.31 | D |
| 75 | 37.5 SFW | 1924.4 | 1731.96 | 1560.5 | 12989.70 | 11429.19 | D |
| 100 | 50 | 2437.5 | 2193.75 | 1883.9 | 16453.13 | 14569.18 | D |

*SE stands for urea application at sowing and at emergence; SEF stands for urea application at sowing, at mergence and at first weeding, SFW stands for urea application at sowing and at first weeding (knee height).*

## Conclusion and recommendation

Micro-dosing application for sorghum was found very important to increase the production and productivity of sorghum. Results from this study confirm that micro-dosing increased sorghum yields than drilling in rows. At Aybra, 75% of the recommended urea and DAP increased sorghum yield by 28.4% and 50% of the recommended urea and DAP increased sorghum yield by 15% over the recommended NP. Micro-dosing fertilizer application is simple and cheap with low risk to resource-poor farmers in the dry areas of Wag-Lasta. Therefore, application of 75 kg DAP and 66.8 kg urea (applied in three splits) ha$^{-1}$ for Aybra and 50 kg DAP ha$^{-1}$ and 44.6 kg urea (applied in three splits) $ha^{-1}$ for Lalibela are recommended for higher sorghum yield and economic utilization of fertilizers.

## References

Abdalla, E.A., Osman, A K, Maki, M A., Nur, F M., Ali S B. and Aune, J B. (2015). Effect of The Response of Sorghum, Groundnut, Sesame, and Cowpea to Seed Priming and Fertilizer Micro-Dosing in South Kordofan State, Sudan: Agronomy, 5(4), 476-490; doi:10.3390/agronomy5040476.

Asnakew Woldeab.(1994). Soil fertility and management in the dry lands. pp.70-81. In: Reddy, M.S. and Kidane G. (eds.). Development of technologies for the dry land farming areas of Ethiopia. Proceeding of the first national workshop on dryland farming research in Ethiopia, 26-28 November 1991, IAR and FAO, Nazeret, Ethiopia.

Central Statistical Authority (CSA). (2014). Agricultural sample survey, 2013/2014, area and production for major crops in private peasant holdings. Addis Ababa, Ethiopia.

CIMMYT (International maize and wheat improvement center). (1988). From agronomic data to farmers' recommendations:An economic work book, Mexico, D.F. CIMMYT.38-60p.

FAO.1999. Integrated soil management for sustainable agriculture and food security in Southern and East Africa. Proceedings of the Harare expert consultation, by H. Nabhan, M.A.Mashaliand A.R.Mermut,AGL/MISC/23/99. Rome, Italy. ftp://ftp.fao.org/agl agll/docs/misc23.pdf.

Gruhn, P., Goletti, F. and Yudelman, M. (1995). Fertilizer, plant nutrient management, and sustainable agriculture: Usage, problems and challenges. In Gruhn, P., F. Goletti, and R.N. Roy (eds.), Proceedings of the IFPRI/FAO workshop on plant nutrient management, food security, and sustainable agriculture: The future through 2020, International Food Policy Research Institute and United Nations Food and Agriculture organization, May 16-17, 1995, Viterbo, Italy.

Hailemariam Teklewold, Menale Kassie., Bekele Shiferaw, and Köhlin, G. (2013). Cropping system diversification, conservation tillage and modern seed adoption in Ethiopia: Impacts on household income, agrochemical use and demand for labor. Ecological Economics: (93), 85–93.

Hayashi, K., Abdoulaye, T., Gerard, B., Bationo, A. (2008). Evaluation of application timing in fertilizer micro-dosing technologyon millet production in Niger, west Africa. Nutrient cycling Agroecosystem: 80, 257-265.

Heluf Gebrekidan. (2003). Grain yield response of sorghum (Sorghum bicolor) to tied ridges and planting methods on Entisols and Vertisols of Alemaya Area, Eastern Ethiopian Highlands. Journal of Agriculture and Rural Development in the Tropics and Subtropics: (104)**,** 113-128.

Heluf Gebrekidan. (2005). Soil and water conservation practices (tied ridges and planting methods) oncultivated lands of Eastern Ethiopian Highlands: Experience of soil and water research program, Alemaya University. Soil Science Technical Bulletin No. 2. Department of Plant Sciences, ,Alemaya.

Mwangi, W. (1995). Low use of fertilizers and low productivity in Sub-Saharan Africa. Proceedings of the IFPRI/FAO Workshop on plant nutrient management, food security, and sustainable agriculture: The future through 2020, International Food Policy Research Institute and United Nations Food and Agriculture organization, May 16-17, 1995, Viterbo, Italy.

Tabo, R., Bationo, A., Diallo Maimouna, K., Hassane, O. and Koala, (S). (2006). Fertilizer micro-dosing for the prosperity of small-scale farmers in the Sahel: Final report. Global theme on agroecosystems. Report no. 23. PO Box 12404, Niamey, Niger: International Crops Research Institute for the Semi-Arid Tropics. 28 pp.

Twomlow, S., Rohrbach, D., Dimes, J., Rusike, J., Mupangwa, w., Ncube, B., Hove, l., Moyo, M., Mashingaidze, N. &Mahposa, P. (2010). Micro-dosing as a pathway to Africa's green revolution: evidence from broad-scale on-farm trials. Nutrient Cycling in Agroecosystems: (88)**,** 3-15.

Walkley, A. and Black, I.A. (1934). An examination of the degtjareff method for determining soil organic matter and proposed modification of the titration method. Soil Science:(37), 29-34