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Influence of Fertilizer Micro Dosing technology and application Methods on Growth and Yield of Maize

John J. John[1], Abdul B. Kudra[2]

[1]Tanzania Agricultural Research Institute (TARI)- Dakawa Center Box 1892, Morogoro
[2]Sokoine University of Agriculture, collage of agriculture, Department of Crop Science and Horticulture, P. O. Box 3005, Chuo-Kikuu, Morogoro, Tanzania.

Abstract
Maize yield has been declining in eastern part of Tanzania particularly in Morogoro region, due to different factors including declining soil fertility. A field experiment was conducted in two sites of Morogoro region, namely Ilonga and Dakawa. The objectives of the study were to determine the effect of fertilizer micro doses on growth and yield of maize crop and identify suitable fertilizer application method. The experimental design used was split-plot in Randomized Complete Block Design (RCBD), where the fertilizer application methods were main plot and fertilizer rates were subplot factor. In this experiment, the rates used were 0, 15, 30 and 60 $kgha^{-1}$ while fertilizer application methods included broadcasting, band and spot method and maize variety chollima1 (CH1) was a test crop. The results indicated that cob weight and grain yield varied significantly with fertilizer levels. The highest mean grain yield was recorded with 60 $kgNha^{-1}$ (5.7tha^{-1}) and 30 $kgNha^{-1}$ (5.28tha^{-1}) and 2.7 tha^{-1}, 3.8 tha^{-1}, at Dakawa and Ilonga, respectively. Growth parameters also varied significantly with fertilizer levels. Plants in the control took longer time (59.9 days) to attain 50% silking. Plant height increased with increase fertilizer levels. The results from combined analysis showed that at Dakawa site, maize grain yield (5.7tha^{-1}) was better than at Ilonga (3.8 tha^{-1}). At Dakawa, fertilizer placement method affected plant height significantly ($P \leq 0.04$). Based on these results, it is important farmers to apply the little dose that they can afford and recommend the rates between 30$kgNha^{-1}$ and 60$kgNha^{-1}$ to increase maize grain yield.

Key words: fertilizer-micro dosing, maize variety chollima 1,

1. Introduction

Tanzania soils have variations determined by different factors such as age, parent material, physiographic and climatic conditions. These soils vary in their inherent fertility and most suitable for crop production covering the least proportion of land area (Simfukwe, 2025). Agricultural productivity is strongly related to the quality of the soil resource base, other factors influencing productivity include climate, inputs eg fertilizer and crop management practices (Nanwatkar et al., 2025)

Declining contents of nitrogen and phosphorus in soils have been identified as the major problem affecting crop productivity while potassium is emerging as a potential problem in some parts of the country (Ndakidemi et al., 2015). Continuous intensive cropping with insufficient or no fertilizer input is a major

factor contributing to progressive decline in these soils' nutrients. This resulted from farm households becoming locked into a cycle of declining crop yields and poverty (Mkoma, 2024).

Among the factors contributing to soil fertility decline, soil erosion is the second major factor after crop production (Mkoma, 2024). However, smallholder farmers in African countries are aware of the reasons of declining trends in soil fertility, its impact on yields and household food security (Hellin, 2003); Saïdou et al., 2004). Many farmers have little knowledge of how to overcome and mitigate the situation. They could do that using different approaches, including agroforestry, crop rotation, improved fallows and biomass transfer (Hellin, (2003); and Jama et al., (2022). Rotation of leguminous and non-leguminous crops and land fallowing measures are failing because land is now a scarce resource. Use of organic matter is the best option of increasing soil fertility but this practice is difficult for large commercial farming due to bulkiness of the material. In addition, organic matter takes time to be decomposed release nutrients (Palm et al., 2001). On the other hand, most of these management practices are complicated and expensive to most of the smallholder farmers. Most of farmers in Tanzania are poor and cannot purchase the amount of fertilizer required to meet soil nutrient demand for optimum plant growth. Therefore, this study assessed fertilizer micro dosing technique to improve the crop yield as well as reducing the problem soil fertility of declining.

Fertilizer micro-dosing involves applying a small, affordable amount of fertilizer less than the recommended at planting time or as a top dressing three to four weeks after seedling emergence (ICRISAT, 2009). Micro-dosing technology has been developed by International Crops Research Institute for the Semiarid Tropics and partner institutions over a decade ago to promote the use of fertilizers in the semi-arid tropics (Chianu and Tsujii, 2005; Hayashi et al., 2008; Twomlow et al., 2010). The technique was developed after realizing that crop yields in the semi-arid areas of Sub-Saharan Africa have been declining over time due to decline in soil fertility, resulting from mono-cropping, lack of fertilizer use, unfavorable climatic conditions and low fertilizer use driven by the belief that inorganic fertilizers "burn crops" (Twomlow et al., 2010). In West Africa, ICRISAT (2009) showed that micro dosing increased sorghum and millet yields by 44 to 120% and family incomes by 130%. Recently, Winter- Nelson et al. (2013) found that micro dosing increased maize and sorghum yields in Zimbabwe by 30 and 50%, respectively. However, this technique has not been assessed in Tanzania. Therefore, the objective of this study was to assess the effect of micro doses technique on maize growth and grain yield. The study also determined the profitability of the technique.

2. Materials and Methods

Description of the experimental area

The study was conducted in two sites of Dakawa and Ilonga in Morogoro region. Dakawa is located at an altitude of 413 meters above sea level, 6° 26'S and 37° 32'E. Dakawa has a bimodal rainfall pattern, where short rains occur in October and end in January. The long rains fall between March and April, the mean annual rainfall in the area is between 600 – 800 mm per year. The soil color is dark having higher portion of clay fraction (Mussa, 2011).

Ilonga is located at an altitude of 506 m above sea level and lies at latitude 06º42'S and 37º02'E. The area is characterized by low and erratic rainfall in most parts which is unreliable and unevenly distributed and

ranges between 800 - 1400 mm per annum. It has binomial rainfall pattern which starts from November ending in January and March ending in the May. The soil color of ilonga is generally black with clay-loamy texture (George et al., 2013).

Soil sampling and analysis

Soil samples were collected at the depth of 0 – 20 cm at experimental locations for laboratory analysis. The samples were collected randomly to represent the experimental area. Soil analysis was carried out in the Department of Soil Science Laboratory, SUA, Morogoro. Soil analysis included texture, pH, organic carbon, total N, extractable P, exchangeable Ca, Mg, Na and K and Cation Exchange Capacity (CEC). Soil pH was measured in water using a pH meter at the ratio of 1:2.5 soil: water as described by McLean (1982). The CEC was determined using the Ammonium Acetate saturation method as explained by Chapman (1965).

The particle size analysis was determined by the hydrometer method after dispersion with sodium hexametaphosphate as explained by Day (1965). The textural class was determined using the USDA textural class triangle (USDA, 1975).

Total nitrogen was determined by Micro-Kjeldahl digestion-distillation method as explained Bremner and Mulvaney (1982). Available P was extracted by the Bray-1 procedure (Bray and Kurtz, 1945), and determined in the filtrates by Atomic Absorption Spectrophotometer at 884 nm following color development by the molybdenum blue method (Murphy and Riley, 1962).

DTPA extractable micronutrients in all soil samples were determined using procedure described by Lindsay and Norvell (1978). The extractant contained 0.005M DTPA (Diethylenetriaminepentaacetic acid), 0.01M $CaCl_2$, H_2O and 0.1 M TEA (Triethanolamine) adjusted to pH 7.3. 20g of air-dried soil were mixed with 40 ml of extracting solution and shaken for two hours and then filtered. The nutrients zinc, copper, calcium, magnesium, sodium and manganese were determined by Atomic Absorption Spectrophotometer.

Experimental design and treatments

The experiment was laid out in split plot in randomized complete block design (RCBD). The main plot treatments were fertilizer application methods (broadcast, band and spot application). Subplot treatment included different fertilizer levels (0, 15, 30, 60) $kgNha^{-1}$. However, the recommended dose for eastern zone is between 60 and 80 $kgNha^{-1}$ (Kanyeka et al., 2007). The test crop used in this study was maize variety, chollima1 (CH1). The land was cultivated using tractor, harrowed and 0.75m row ridges were constructed. Four rows with two seeds per hole were planted at spacing of 0.75m by 0.3m making plot size of $2.7m^2$ and replicated 3 times. N-Fertilizer was applied three weeks after seedling emergence

Data collection and analysis

Plant growth parameters were measured and recorded on weekly basis, however for days to 50% tasseling were recorded when 50% of plants produced tassels while the days to maturity was counted when 85 % of plants matured. Other growth parameters measured at harvesting included plant height and plant biomass. The yield parameters measured included number of plants per unit area, number of cobs per plot, cob weight and grain yield ($kgha^{-1}$). Data collected were subjected to analysis of variance (ANOVA) using GenStat statistical software. Means separation was done using Duncan New Multiple Range Test at 5% level.

3. Results

Soil characteristics

The results of soil analysis showed that Dakawa and Ilonga sites contained very low nitrogen concentration i.e., 0.15 and 0.07%, respectively. The available P <10, 11-31, 32-56, >56 ppm was rated as low, medium, high and very high, respectively. The results showed that total available soil P level was high at Dakawa (37.65 P mg/kg) and low at Ilonga (4.01 P mg/kg) (Table 2.1).

The exchangeable potassium (K^+) was very low for both Dakawa and Ilonga i.e. 0.22 and 0.04 Cmol/kg respectively (Table 2.1). Magnesium ($Mg^{2+)}$ at Dakawa was very high (6.81 $Cmol^+$/kg) and low at Ilonga (0.26 $Cmol^+$/kg). On the other hand, Cation exchange capacity (CEC) at Dakawa was rated as moderate (21 $Cmol^+$/kg) and at Ilonga was rated as low (6.24 $Cmol^+$/kg). Percentage Organic carbon at Dakawa was rated as medium (3.53 %); the soil pH in water was neutral. The soil textural class was silt clay loam (scl) with particle size distribution of 58%, 15% and 27%, respectively at Dakawa and 82%, 5% and 13%, respectively at Ilonga (Table 2.1). Basing on these results Dakawa soil is better compared to Ilonga soils

Table 2.1: Soil characteristics of the study areas

Dakawa				Ilonga			
Parameter	Amount	Parameter	Amount	Parameter	Amount	Parameter	Amount
P (mg /kg)	37.65	Na^+($Cmol^+$/kg)	0.26	P mg/kg	4.01	Na^+ ($Cmol^+$/kg)	0.15
Clay (%)	27	Cu (mg /kg)	1.07	Clay (%)	13	mg (Cu/kg)	0.87
Silt (%)	15	Zn (mg /kg)	0.45	Silt (%)	5	mg (Zn/kg)	0.45
Sand (%)	58 scl	Mn (mg /kg)	15.46	Sand (%)	82 scl	mg (Mn/kg)	15.46
N (%)	0.15	Fe (mg /kg)	247.52	N (%)	0.07	mg (Fe/kg)	247.52
O. C (%)	3.53	CEC ($Cmol^+$/kg)	21	O.C (%)	1.78	CEC ($Cmol^+$/kg)	6.24
Ca^{2+} ($Cmol^+$/kg)	15.1	pH (H_2O)	6.88	Ca^{2+} ($Cmol^+$/kg)	42.29	pH (H_2O)	6.48
Mg^{2+} ($Cmol^+$/kg)	6.81	pH ($CaCl_2$)	6.25	Mg^{2+} ($Cmol^+$/kg)	0.26	pH ($CaCl_2$)	5.54
K^+($Cmol^+$/kg)	0.22			K^+ ($Cmol^+$/kg)	0.04		

Effects of N-fertilizer rates and application methods on maize performance

Results indicated that some plant growth parameters such as days to 50% flowering, days to 50% silking, days to maturity and ear height were not significantly affected by fertilizer application methods. At Dakawa, the plant height varied significantly with fertilizer application methods. The highest plant height was observed in band application method followed by spot application (Table 2.2).

Number of plants, plant biomass, number of cobs and cob weight were not significantly affected by fertilizer application method at both sites. Results showed that fertilizer levels had no effect on days to 50% flowering and days to maturity, for both sites (Tables 2.2 and 2.3). However, days to 50% silking, plant height and ear height were affected significantly by fertilizer levels. Plots with 15, 30 and 60kgNha^{-1} had a significantly higher plant height than the control plot. The highest mean ear height was recorded

with 30kgNha^{-1} and the lowest mean ear height was observed from control plots which was not significantly different from plots treated with 15 and 60 kgNha^{-1}. Fertilizer addition reduced 3 to 5 days to silking compared to control plots at both sites. There was significant difference ($p<0.002$) in plant biomass between treatments in both sites. The highest biomass was recorded from plots with 60kgNha^{-1} (25.21 tha^{-1}) and lowest in the control (11.2tha^{-1}) (Table 2.2) at Dakawa. Similar trend was observed from Ilonga site (Table 2.3).

There was significant ($P\leq0.001$) difference in cob weight among treatments. Results showed that the highest mean cob weight was observed at an application rate of 30kgNha^{-1} (10.067 tha^{-1}) and 60kgNha^{-1} (10.344 tha^{-1}) while the lowest mean cob weight was observed in the control plots (4.744 tha^{-1}) (Table 2.2).

At Ilonga, fertilizer levels affected the number of cobs significantly. The highest number of cobs was observed from 15kgNha^{-1} (71605 cobs ha^{-1}) (Table 2.3).

Table 2.2: Effects of fertilizer levels and application methods on yield components of maize at Dakawa

Main treatment	Days to 50% flowering (Days)	Days to 50% silking	Days to maturity (Days)	Plant height (cm)	Cob height (cm)	Plants/ha (No.)	Biomass (t/ha)	cobs/ha (No.)	cob wt. (t/ha)
BR	50.83a	56.83 a	103.2a	188.3 a	98.92a	56296a	20.42a	46666a	8.608a
BA	50.08a	56a	102.8a	210.4 b	98.75a	53703a	19.57a	46296a	8.592a
SA	51.33a	56.33 a	106.7a	190a	101.92a	49629a	17.02a	45185a	7.025a
Mean	50.75	56.39	104.19	196.2	99.9	53209	19	46049	8.07
CV (%)	4.5	5.9	8	4	22.4	25.8	38.9	22.7	18
SE	2.275	3.311	8.376	7.93	22.36	13733.6	7.39	10449.3	1.45
Sub treatment									
Control	52.22a	59.89 b	105.7a	174.4 a	91.67a	48888a	11.2a	38518a	4.744a
15 kgN/ha	50.67a	56.78 a	104.1a	199.3 b	98.78ab	48888a	17.32ab	44938a	7.144b
30 kgN/ha	49.56a	54.44 a	103a	200.2 b	107.11b	57777a	22.3bc	50370a	10.067 c
60 kgN/ha	50.56a	54.44 a	104a	211b	101.89a b	57283a	25.21c	50370a	10.344 c
Mean	50.75	56.39	104.19	196.2	99.9	53209	19	46049	8.07
CV %	3.4	1.6	1.7	2.6	8.8	16.9	21.5	20.7	18.9
SE	1.751	0.908	1.75	5.66	8.75	9011.4	4.08	9514.9	1.528

*Means with the same letter within the column and treatment level are not significant different (P ≤0.05) using DNMRT
Key: BR- Broadcasting, BA- Band application, SA- Spot application, CV – coefficient of variation and SE- standard error.

Table 2.3: Effects of fertilizer levels and application method on yield components of maize at Ilonga

Main treatment	Days to 50% flowering (Days)	Days to 50% silking	Days to maturity (Days)	Plant height (cm)	Cob height (cm)	Plants/ha (No.)	Biomass (t/ha)	Cob/ha (No.)	cob wt. (t/ha)
BR	54.83a	60.83a	107.2a	133.3a	61.54a	50370a	12.1a	67778a	6.25a
BA	54.08a	60a	104.1a	122a	57.42a	44444a	12.1a	58889a	6.29a
SA	55.33a	60.33a	104.7a	141.1a	63.75a	48148a	12.32a	64815a	6.44a
Mean	54.75	60.39	105.33	132.1	60.9	47654	12.17	63827	6.33
CV %	4.2	5.5	6.5	12.5	26.4	13.7	2.5	27.2	4
SE	2.275	3.311	6.839	16.57	16.08	6536.8	0.301	17377.8	0.252
Sub treatment									
control	56.22a	63.89b	106.7a	106.6a	47.94a	45926a	9.32a	63704a	3.95a
15 kgN/ha	54.67a	60.78a	105.1a	129.6b	58.33a	52346a	11.94b	71605b	5.23b
30 kgN/ha	53.56a	58.44a	104a	133.1b	56.22a	47407a	13.27c	57778a	7.80c
60 kgN/ha	54.56a	58.44a	105.6a	159.3c	81.11b	44938a	14.16c	62222a	8.34c
Mean	54.75	60.39	105.33	132.1	60.9	47654	12.17	63827	6.33
CV (%)	3.2	1.5	1.6	7.6	21.8	6.4	4.4	6.7	9.7
SE	1.751	0.908	1.66	10.09	13.3	3034.1	0.535	4298	0.61

*Means with the same letter within the column and treatment level are not significant different (P ≤0.05) using DNMRT
Key: BR- Broadcasting, BA- Band application, SA- Spot application, CV – coefficient of variation and SE- standard error

Fertilizer application method did not have a significant effect on maize yield at Dakawa (Fig. 2.1). At Ilonga, however, fertilizer application method significantly affected maize yield. The highest grain yield was recorded with band application method (Fig 2.4). Yield was lower in broadcast plots than band and spot placement method. Fertilizer levels affected grain yield significantly at both sites. The highest grain yield was recorded with 60kgNha^{-1} and the lowest grain yield was recorded from control plots (Figs. 2.2 and 2.3).

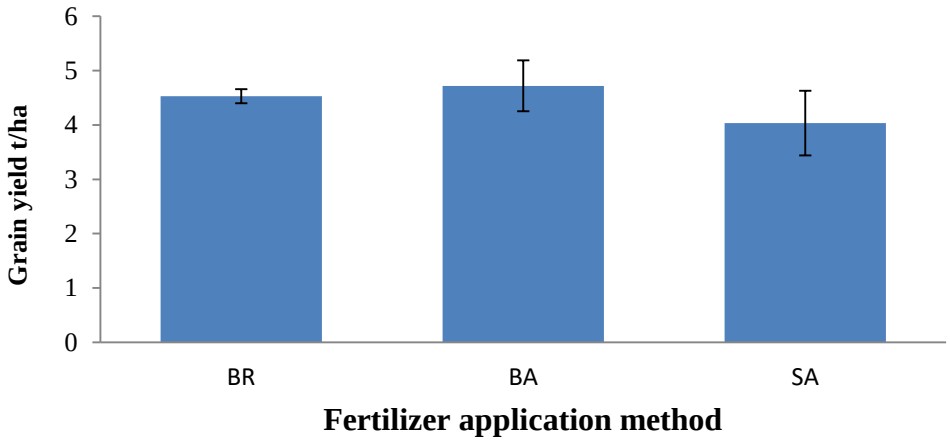


Figure 2.1: Effects of fertilizer application method on grain yield at Dakawa

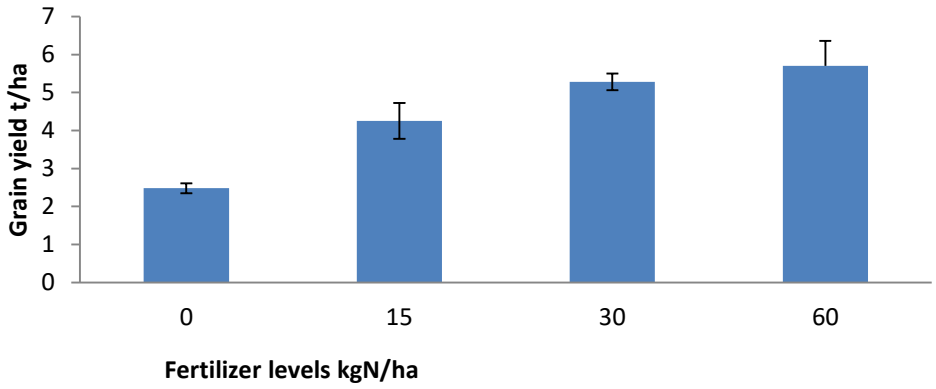


Figure 2.2: Effects of fertilizer Levels on grain yield at Dakawa

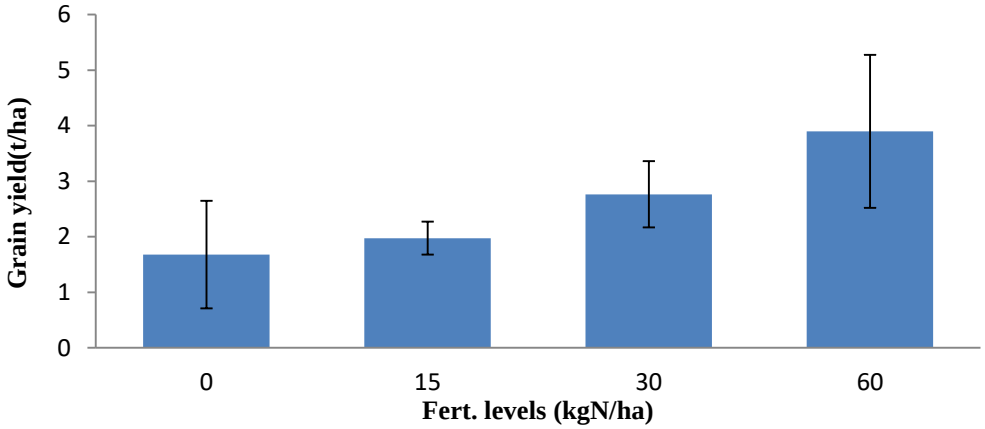


Figure 2.3: Effects of fertilizer Levels on grain yield at Ilonga

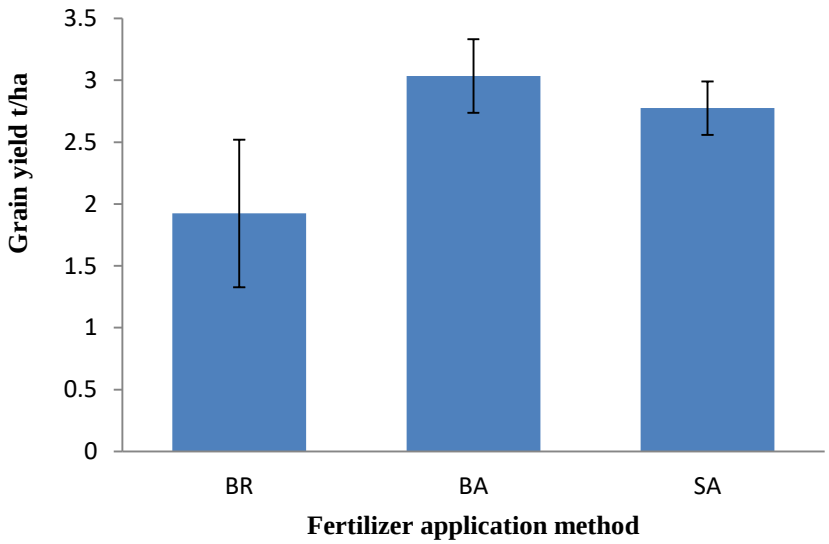


Figure 2.3: Effects of fertilizer application methods on grain yield at Ilonga

Table 2.4: Effects of location on growth and yield parameters

	Parameters									
Site	Days to 50% flowering (Days)	Days to 50% silking (Days)	Days to maturity (Days)	Plant H (Cm)	Ear H (Cm)	plants/ha (Cm)	Biomass (tha^{-1})	Cobs/ha (No.)	Cob wt (tha^{-1})	Grain yield (tha^{-1})
Dakawa	50.75	56.39	104.2	196.2	99.86	53209	19.01	46049	8.075	4.428
Ilonga	54.75	60.39	105.3	132.1	60.9	47654	12.17	63827	6.327	2.577
pr.	< 0.001	< 0.001	0.431	< 0.001	< 0.001	0.057	< 0.001	< 0.001	0.008	< 0.001

Parameters in the table above with probability < 0.001 are significantly different using T-test

Effects of location on growth, yield and yield components of maize

There was a significant difference in days to 50% flowering, days to 50% silking, plant height or ear height between the sites (Table 2.4). The days to 50% flowering and days to 50% silking were relatively longer at Ilonga than at Dakawa sites (Table 2.4). Plant height and ear height were higher at Dakawa than at Ilonga. However, the days to maturity did not vary significantly at either site (Table 2.4).

Plant biomass, number of ears per hectare, cob weight and grain weight varied significantly ($P< 0.001$) between the sites. The mean biomass, cob weight and grain weight were high at Dakawa than at Ilonga while number of plants/ha and cob weight were not significantly different (Table 2.4).

Cost-Benefit Analysis of using Micro Doses on Maize Production

Results indicated that the highest total cost was obtained with 60kgNha^{-1} while the lowest was from no fertilizer application (Table 2.5). The highest gross benefit was also obtained with 60kgNha^{-1} and the lowest with 15kgNha^{-1}. The latter was, however, outperformed by the gross benefit obtained from the control. The highest marginal return was obtained with 60kgNha^{-1} and the highest with 30kgNha^{-1}. The benefit cost ratio was the same for 15 and 60kgNha^{-1}. The lowest marginal return and benefit cost ratio were observed from the control. The highest marginal rate of return with an application of 15kgNha^{-1} and the lowest with 60kgNha^{-1}.

Table 2.5: Cost-benefit analysis of micro doses on maize production

	At absolute control	At 15 kgN/ha	At 30 kgN/ha	At 60 kgN/ha
Variable	(Tsh per ha)	(Tsh per ha)	(Tsh per ha)	(Tsh per ha)
1. Variable costs land preparation	172,500/-	172,500/-	172,500/-	172,500/-
labor	210,000/-	210,000/-	210,000/-	210,000/-
weeding	100,000/-	100,000/-	100,000/-	100,000/-
pesticide	Nil	Nil	Nil	Nil
seeds	90,000/-	90,000/-	90,000/-	90,000/-
Total fertilizer (kg per ha) @1000	Nil	65.2kg x 1000/- = 65 200/-	130.4 kg x 1000/- =130 400/-	290.9 kg x 1000 = 290 900/-
Total variable cost (TVC)	572 500/-	637 700/-	702 900/-	863400/-
2.Gross benefit (GB)	2480 kg @600 = 1 488 000	4253 kg @600 = 2 550 000/-	5280 kg @600 =3,168,000/-	5700 kg @600 = 3 420 000/-
3. Marginal return (MR) = GB -TVC	915 000/-	1 912 300/-	2,465,100/-	2, 556, 600/-
4. Benefit cost ratio (BCR) =GB/TVC	2.6	4	4.5	4
5. Marginal rate of return (MRR)		16.3	12.9	6.6
	MRR = (GB with fert-GB without fert)/(TVC with fert - TVC without fert)			

4. Discussions

Soil fertility

The results of soil analysis showed that N content at Dakawa and Ilonga were 0.15 and 0.07% respectively, this amount is considered as very low hence supplementation of N-fertilizer was necessary for maize growth in order to attain the optimum yield. The result also showed that available P at Dakawa was

37.7mg/kg soil and was 4.0mg/kg soil at the Ilonga site. Tekalign (1991) described soils with available P <10, 11-31, 32-56, >56 ppm as low, medium, high and very high, respectively. Therefore, this result showed that total available soil P was high at Dakawa and low at Ilonga, Potassium was very low at both Dakawa and Ilonga sites. Phosphorus is an important macro element in plants supporting root growth and development while Potassium is important for grain quality, grain filling and yield (Havlin et al., 2014 and Marschner, 2012). Thus, due to essentiality of these major elements then supplementation is necessary in areas with insufficient quantities. Magnesium(mg) contents were 6.81meq/100 g soil at dakawa which was very high and at Ilonga it was 0.26 meq/100 g soil which was low according to Marx (1999).

Cation exchange capacity at Dakawa was 21 $cmol^{+}$/kg. This is rated as moderate and at Ilonga the CEC was 6.24 $cmol^{+}$/kg which was rated as low (Pam et al., 2007). Organic carbon at Dakawa was 3.5% and 1.78% at Ilonga, which according to Hazelton and Murphy (2007), these amounts were rated as medium. The soil pH in water was neutral. The soil textural class was sandy silt clay with particle size distribution of 58%, 15% and 27%, respectively, at Dakawa site and 82%, 5% and 13%, respectively at Ilonga site. The soil pH is more suitable for maize production, on the other hand, the texture of the soil for both sites were fine with smaller particle size, which have high moisture holding capacity.

Days to 50% flowering, silking and physiological maturity

Days to 50% flowering, silking and days to maturity are genetical traits of the particular hybrids (Abimbola et al., 2015). Thus, they were not affected by fertilizer levels or placement method, and in some cases the physiological factor such as drought and temperature may enhance the plant metabolism by influencing anthesis and senescence of the crop (Taiz et al., 2010 and Barnabás et al., 2008). Maize is a warm weather crop and is not grown in areas where mean daily temperature is less than 19°C or where mean of the summer months is below 23°C (Jean, 2009). Study by Maruschka (2023) highlighted that crop heat unit (CHU) closely predicted days to silking than other flowering traits.

Plant height and ear height

Plant height increased with increase fertilizer levels. Nitrogen is the most limiting factor on yield and plays an important role in quality of forage crops (Marschner, 2012). Positive response of N fertilizers has been reported by Omer (1998) and Gasim (2001). Sharma (1973) observed that addition of N fertilizer increased plant height. Increase in plant height resulted in an increase in leaf number per plant as reported by Akintoye (1996). Gasim (2001) indicated that increase in plant height with N fertilizer is because nitrogen promotes plant growth, increases number of internodes and length of internodes which results in a progressive increase in plant height. Koul (1997) reported similar results. Zamil et al. (2010) also reported that increasing levels of N positively influenced plant height, foliage coverage and yield. Koul (1997) observed that N application resulted in greater plant height, leaf area and stem diameter of fodder maize. Ear height was highest with application of 30 followed by 15 and 60 $kgNha^{-1}$ and shortest without N at Dakawa. At Ilonga the highest ear height was observed with application of 60 $kgNha^{-1}$ which was not significantly different from 0, 15 and 30 $kgNha^{-1}$.

Cob weight

Cob weight increased with increased fertilizer levels. The highest cob weight was recorded with of 30 and 60$kgNha^{-1}$ whereas the lowest was obtained from the control. These results are similar to those of Shahzad

et al., (2015) who reported that cob weight increased with increase in fertilizer level. The grains are strong sinks for synthesized carbohydrate in the plant, thus accounting for the observed increase in ear weight with increased fertilizer levels.

Effects of fertilizer application methods and fertilizer levels on grain yield

Grain yield increased with increased fertilizer levels whereby highest mean grain yield was obtained with application of 60 kgNha^{-1} and the lowest mean grain yield was obtained from the control. Abdissa (2012) reported that with increase in the amount of farm yard manure and phosphorus, root diameter also increased progressively and attributed this to enhanced availability of micronutrients as well as organic carbon as food for soil micro-organisms. Grain yield was higher at Dakawa than at Ilonga. Based on soil analysis, the levels of N, P, K and other micro elements were relatively higher at Dakawa than at Ilonga, which might account for the grain yield differences between the sites.

Increased grain weight with increased fertilizer levels might be due to the formation of greater leaf area, which contributed to increased intercepting light and producing carbohydrates in the process of photosynthesis. These are translocated and stored into heavy sink (grain) and resulted in increased grain weight than the control. Kidisit (2013) also reported that with increased N-level from 0 to 174 kg ha^{-1}, the 1000 kernel weight in maize increased significantly from 358.9 to 448.9 (g). Similarly, Hamid et al. (2011) and Akmal et al. (2010) reported higher 1000-kernel weight due to increasing N-levels application. Similarly, increased thousand kernels weight has been reported with increase in N-levels up to 200 kg Nha^{-1} (Dawadi and Sah, 2012). In a study conducted by Mehdi and Bahram (2014), significant reduction in grain weight was observed in treatments that received lower doses of N fertilizer than those that received higher doses. Dinh et al. (2015) also reported that with increasing N level from 0 to 240 kgha^{-1}, 1000 kernel weight of maize increased significantly. Similarly, Sorkhi and Fateh (2014) reported that maximum thousand kernels weight (400.19g) was recorded with 250 kg N ha^{-1}.

The band application practice gave greater yields than broadcasting or spot placement. Band application improved accessibility of plant nutrients its being placed near but not in contact with the plant roots as compared to the spot placed where the fertilizer might have come in contact the plant root or seeds causing inefficiency in plant nutrients absorption. Similarly, in the study conducted by Waga (2011), grain yield obtained from band method of application was 28% higher than that obtained from spot application method.

5. Conclusion

This study revealed that fertilizer micro-dose significantly increased plant growth and grain yield. However, on increasing fertilizer levels grain yield increased while the cost of production also increased. Therefore, it is important for farmers to apply the little dose they can afford rather than rising crop without fertilizer addition. Similar study using the rates above 60 kgNha^{-1} are proposed to see if they can improve maize yield at minimum fertilizer cost

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