Research Journal of Agriculture and Forestry Sciences E-ISSN 2320-6063
Vol. **4(7),** 6-12, July **(2016)** *Res. J. Agriculture and Forestry Sci.*

Optimized Nitrogen Fertility of the Soil for Maize Production in a Semi-Coral Ecology in Eastern Pemba

Ali M.O.[1] and Msuya D.G.[2*]
[1]Department of Food Security and Nutrition, Ministry of Agriculture and Natural Resources, P.O. Box 159 Zanzibar
[2]Department of Crop Science and Horticulture, Sokoine University of Agriculture, P.O. Box 3005 Chuo Kikuu, Morogoro, Tanzania
dmsuya@suanet.ac.tz

Available online at: www.isca.in, www.isca.me
Received 10th May 2016, revised 17th June 2016, accepted 6th July 2016

Abstract

Improving crop yields through soil fertility management is one of the best known conventional practices of modern agriculture. An experiment was conducted in a semi-coral area in Eastern Pemba to test different rates of Nitrogen fertilizer application for their influence on maize crop performance. Four rates 23, 46, 70 and 90kgN/ha were top-dressed on different varieties of the maize crop during the long rainy cropping season in 2013. Results show a very significant response of the crop to the levels of N application. Dry matter yield increased significantly with each level of N nutrient increase seemingly due to alike increase in plant height. Grain yield increased with N to highest level (4.39 t/ha) at 70kgN/ha thereafter it declined. No statistically significant grain yield difference ($P \leq 0.05$) existed with fertilizer rate change from 46kgN/ha to 90kgha^{-1}, a clear indication of an optimum application rate around 70kgN/ha. Differential response trends were observed with the varieties used in the experiment. Variety Staha showed best interaction with N application, giving highest yield record of 6.06 t/ha observed at 70kgN/ha while the worst record interaction (2.61 t/ha) was of variety Situka with 23kgN/ha. Two varieties, JKU and TMV-1 showed exclusive interaction respectively for dry matter and grain yields. The rest of the varieties showed individually significant ($P \leq 0.05$) response to N levels for dry matter yield but for JKU the response was insignificant. Likewise for grain yield, response to N levels was insignificant for variety TMV-1 contrary the rest of the varieties.

Keywords: Optimum, Differential response, Interaction, Grain yield, Application rate.

Introduction

Maize is leading in importance as a food crop produced in the semi-coral livelihood zone of Pemba, an area running all along the eastern side of the Island and also covering part of the North West. Pemba forms part of the Zanzibar archipelago in the Indian Ocean territorial waters of Tanzania. Production of maize in the island suffers very poor yields of about 1.0 ton/ha[1], and for this reason production has never met demand. Potential yield of maize in the area can at least double and it has been reported from the Kizimbani research station in Zanzibar that it can range from 2.0 – 3.9 t/ha[1]. One of the very good reasons for poor yield is low soil fertility especially Nitrogen deficiency.

Improving crop yields through soil fertility management is one of the best known conventional practices of modern agriculture. Vast number of literatures document about application of fertilizers as a sure way of increasing or securing crop yields. Generalizations that nutrient inputs are responsible for between 30 and 50 % of crop yields have been made[2]. This however depends on numerous attributes including crop species, nutrients level already present in the soil, nutrients mobility, climatic conditions and production practices. In micro-dosing fertilizer field trials in semi-arid croplands in Zimbabwe, grain yield increases of 50 – 200 % were noted in maize and sorghum as compared to conventional systems used by farmers[3]. Similarly, it has been reported that because of fertilizers, yield of maize for farmers who participated in fertilizer trials more than doubled from 1.5 – 3.5 t/ha and pigeon pea 0.6 – 1.4 t/ha in Tanzania while in Kenya yield of sorghum increased from 300 to 1,000 kg/ha[4]. Also on experiments conducted in Kenya, mean annual returns to top-dressing fertilizers, amounting to 69.5 % net, are documented[5].

Of all fertilizer nutrients nitrogen (N) is often the most limiting in annually cultivated crop fields. Most fertilizer nutrient applications therefore involve Nitrogen. Maize responds very well to applied N in deficient soils. Two-folds (100 %) maize grain yield increase has been reported arising from N fertilizer application[6]. Rates of application for this crop can be very high depending on status of the nutrient in the soil. About 250kg N/ha as an optimum application rate has been recommended in Pakistan for maize under the semi-arid environment of the country[7].

In Texas, yield of maize was found to increase with increasing N up to 168kg N/ha[8]. Yielding 8.3 t/ha; maximum return of maize grains has been found at 154 kg N/ha[9]. Almost similarly, maximum yield of the crop at 150 kg N/ha has been reported[6].

In Canada, on the other hand, yield of maize was observed to increase as N increased, up to 120 kg N/ha[10].

With the reported very low average yield (1.0t/ha)[1], prospects to increase maize yield in Zanzibar have always been very high. While improved varieties, proper plant density, perhaps supplemental moisture supply through irrigation and protecting the crop against diseases, insect pests and weeds could be other ways of increasing yield, this paper focuses on improving the crop production through fertilizer N application as one of most advocated but also very limiting attributes of assuring high yields.

Materials and Methods

An experiment during long rains season (March – June) was conducted at Kangagani village in Pemba Island, located 20 meters above sea level at latitude 5^0 09′ South and longitude 39^0 46′ East. Mean, maximum and minimum temperatures for the area are respectively 28, 32 and 22°C. Average humidity is 71.5% while average evaporation is 5.72 mm day^{-1}. A Randomized Complete Block Design was used for the experiment, in split plot arrangement and replicated three times. Four different Nitrogen fertilizer rates (23, 46, 70 and 90kg N/ha) were used for the test. Four varieties of maize (Staha, Situka, TMV-1 and JKU) were used, among which the first three are improved, selected from the maize varieties recommended for the Eastern zone of Tanzania, and the other one, JKU, is a local variety which is commonly grown in the semi-coral area in Pemba.

Each treatment unit was planted on a 3m x 4m plot. Seeds were planted two per hill then seven days after emergence seedlings thinned to one in each hill. The field was managed optimally up to harvest. Prior to planting, triple superphosphate (TSP 46 % P_2O_5) 20kg P/ha, was applied uniformly in all plots. Urea (46 % N) was used as a source of Nitrogen, applied in two splits, 50% at four weeks after seedlings emergence and another 50% three weeks later.

Before ploughing, samples of soil were randomly taken from the experimental plot from zero to 20 cm depth, according to described procedures[11]. Composite soil sample was analyzed for pH, electrical conductivity, particle sizes density (texture), organic carbon, total nitrogen, extractable P, as well as mineral contents K, Mg, Ca, Na, Zn, Fe, Cu and Mn. The physicochemical soil characteristics were determined according to the following methods: pH and electrical conductivity by suspension method at 1:2.5 v/v soil: water ratio[12,13], particle sizes density by Bouyoucos hydrometer method[14]. Total N was analysed by Micro-Kjeldahl digestion-distillation procedure[15]. Organic C determination was performed using the modified method of Walkely-Black[16]. The Olsen method was used to analyse for extractable Phosphorus[17]. Exchangeable bases were extracted with NH_4OAc according to Chapman[18]. Table-1 after the text presents records of the soil tests.

Table-1
Physicochemical characteristics of the soil of the experiment site

Characteristic	Amount	Remarks
Physical characteristics		
% Clay	31	
% Silt	3	
% Sand	66	
Texture	Sandy clay loam	Ideal for maize production
Chemical characteristics		
Organic matter (%)	2.98	Medium
Organic carbon (%)	1.74	Low
Total nitrogen (%)	0.16	Low
Extractable P (mg/kg)	3.83	Deficient
pH	7.50	High but ideal for maize crop
Electric conductivity EC (mS/cm)	0.22	
CEC (cmol/kg)	22.39	Medium
Potassium (K^+) (cmol/kg)	0.28	Low
Sodium (Na^+) (cmol/kg)	0.24	Low
Calcium (Ca^{2+}) (cmol/kg)	17.50	Medium
Magnesium (Mg^{2+}) (cmol/kg)	1.11	Sufficient
Copper (Cu^{2+}) (mg/kg)	0.48	Low
Zinc (Zn^{2+}) (mg/kg)	0.49	Low
Manganese (Mn^{2+})	2.10	Low
Iron (Fe^{2+})	1.87	Low

Results and Discussion

This study results show positive response of the maize crop to the various levels of Nitrogen fertilizer. These are shown in Tables-2 and 3. The minimum application rate (23Kg N/ha) resulted into minimum values in all evaluated parameters except for the harvest index. This observation was statistically significant for most parameters. Increased level of nitrogen significantly and consistently increased days to 50% flowering and maturity, plant height and dry matter yield ($P \leq 0.05$). For these four parameters, each nitrogen level was significantly different from another. Tallest plants were those supplied with the highest fertilizer rate (90kg N/ha). The rate also significantly delayed days to 50% flowering and physiological maturity which were respectively 63.28 and 123.6 days from emergence. Plants flowered and matured significantly ($P \leq 0.05$) earlier (55.5 and 112.7 days, respectively) at 23kg N/ha. Similarly, the highest nitrogen level (90Kg N/ha) produced significantly highest quantity dry matter (7.619 tons ha^{-}), and the lowest dry matter yield (6.379 tons ha^{-1}) was experienced at the lowest (23kg/ha) N level.

Cob and grain parameters also were very responsive to the level of Nitrogen fertility, whereby application of 70kg N ha^{-1} significantly ($P \leq 0.05$) and consistently was better over other levels (Table-3). The results also revealed that, from 70kg N/ha a change in N level (either increased or decreased) significantly affected the values of all these parameters. Coincidentally this suggests 70kg N/ha to be near optimum if not itself the optimum level of N application for maize production in the semi-coral soils. Minimum values for the cob and grain parameters were cob length 17.21 cm, cob weight 187.8 g, grain weight cob^{-1} 134.9 g, 100 grain weight 25.69 g, grain yield 3.406 tons ha^{-1}; and were all recorded from the lowest rate of N (23Kg ha^{-1}). Highest grain yield was about 4.386 tons/ha (at 70kg N/ha) and this was, so said before, significantly higher than yield at any other level of N application even 90 kg/ha. No statistically significant difference ($P \leq 0.05$) in grain yield on the other hand existed between 46kg N/ha and 90kg N/ha, a clear indication of an optimum application rate around 70 kg/ha.

Table-2
Mean effect of soil nitrogen fertility on growth parameters, dry matter accumulation and harvest index of maize grown in semi-coral area

Nitrogen level (Kg N/ha)	Plant height (cm)	Days to 50% flowering	Days to 50% maturity	Dry matter yield (t/ha)	Harvest index (%)
23kgN/ha	1.699	55.50	112.7	6.379	52.95
46kgN/ha	1.776	58.14	115.7	7.020	53.13
70kgN/ha	1.845	61.33	120.0	7.261	59.25
90kgN/ha	1.906	63.28	123.6	7.619	50.72
Mean	1.806	59.56	118.0	7.070	54.01
S.E.D	0.01837	0.676	0.885	0.0954	1.016
CV (%)	4.3	4.8	3.2	5.7	8.0
$L.S.D_{0.05}$	0.036	1.347	1.764	0.188	2.026

Table-3
Mean effect of nitrogen on cob, grain and grain yield parameters of maize grown in semi-coral area

Nitrogen level (Kg N/ha)	Cob length (cm)	Cob weight (g)	Grain weight per cob (g)	100 grains weight (g)	Grain yield (tons/ha)
23kgN/ha	17.21	187.8	134.9	25.69	3.406
46kgN/ha	18.06	195.8	137.2	27.29	3.762
70kgN/ha	18.40	214.4	152.1	28.00	4.386
90kgN/ha	17.29	186.6	129.9	24.50	3.902
Mean	17.74	196.1	138.5	26.37	3.864
S.E.D	0.1269	8.24	5.81	0.672	0.0763
CV (%)	3.0	17.8	17.8	10.8	8.4
$L.S.D_{0.05}$	0.253	16.420	11.570	1.339	0.152

Results of this study have also shown a differential response of the test varieties of maize to the various levels of Nitrogen fertilizer applied. Though in most evaluation parameters the varieties showed similar response trends to the applied N levels, differential trends were observed especially on cob parameters and duration to flowering. Table-4 shows overall significance of the interaction effects of varieties and fertilizer levels on the data parameters of the crop. Generally, statistically significant interactive effect ($P \leq 0.05$) existed on height of the plants, dry matter accumulation, days to flowering and maturity, cob length, cob weight and grain yield.

Table-4
Interaction effect of varieties and nitrogen levels on growth parameters, yield and yield components

Variety	Nitrogen levels (kg N ha^{-1})	Plant height (m)	Days to 50% flowering	Days to maturity	Cob length (cm)	Cob weight (g)	Dry matter yield (t/ha)	Grain yield (t/ha)
Staha	23 kg/ha	1.761 cdef	60.00 de	119.6 de	18.42 ef	228.2 bcd	6.464 bcd	3.966 cd
	46 kg/ha	1.864 fghi	63.33 efgh	121.8 def	19.69 gh	267.2 d	7.966 ghi	4.806 e
	70 kg/ha	1.931 hi	64.67 efghi	125.7 fg	20.40 h	254.8 cd	8.267 hi	6.063 f
	90 kg/ha	1.957 i	67.11 ghi	127.4 fg	18.79 ef	212.4 abcd	8.698 i	4.976 e
Situka	23 kg/ha	1.636 abc	65.00 fghi	123.9 efg	16.25 ab	148.5 a	6.253 abc	2.614 a
	46 kg/ha	1.748 cdef	67.89 hi	125.7 fg	16.68 abc	171.2 ab	6.647 bcde	2.772 a
	70 kg/ha	1.794 defg	68.56 i	129.4 g	17.11 bc	193.6 abc	6.871 def	3.489 bc
	90 kg/ha	1.819 defgh	73.56 j	139.3 h	16.12 a	183.6 ab	7.236 efg	2.846 ab
TMV-1	23 kg/ha	1.830 efghi	54.00 bc	107.0 bc	16.13 a	170.0 ab	5.650 a	3.068 ab
	46 kg/ha	1.911 ghi	56.89 cd	111.8 c	17.27 cd	164.3 ab	5.938 ab	3.174 ab
	70 kg/ha	1.955 i	60.89 def	118.0 d	17.06 bc	200.9 abcd	6.251 abcd	3.282 abc
	90 kg/ha	2.130 j	63.11 efg	119.6 de	16.10 a	159.0 a	6.747 cde	3.128 ab
JKU	23 kg/ha	1.568 a	43.00 a	100.4 a	18.02 de	204.3 abcd	7.350 efg	3.977 cd
	46 kg/ha	1.580 ab	44.44 a	103.6 ab	18.59 ef	180.6 ab	7.530 fgh	4.299 de
	70 kg/ha	1.701 bcd	51.22 b	106.8 bc	19.03 fg	208.2 abcd	7.656 gh	4.709 e
	90 kg/ha	1.720 cde	49.33 b	108.0 bc	18.17 ef	191.4 abc	7.794 gh	4.659 de
Mean		1.806	59.56	118.0	17.74	196.1	7.070	3.864
S.E.D		0.03579	1.256	1.604	0.2523	19.15	0.2991	0.2362
CV (%)		4.2	4.5	2.9	3.0	20.7	9.8	12.9
F prob.		0.030	0.034	0.003	0.028	0.042	<.001	<.001

Means in a column followed by the same letter are not significantly different. Mean separation by Tukey at 0.05 probability level

Table-5
Parameter trends for different varieties against increasing levels of N

Parameter and N increment	**Response trend for different varieties**			
	Variety Staha	**Situka**	**TMV-1**	**JKU**
Grain yield				
23 – 46 kg N ha^{-1}	Increased	Increased	Increased	Increased
46 – 70 kg	Increased	Increased	Increased	Increased
70 – 90 kg	Decreased	Decreased	Decreased	Decreased
Dry matter yield				
23 – 46 kg N ha^{-1}	Increased	Increased	Increased	Increased
46 – 70 kg	Increased	Increased	Increased	Increased
70 – 90 kg	Increased	Increased	Increased	Increased
Plant height				
23 – 46 kg N ha^{-1}	Increased	Increased	Increased	Increased
46 – 70 kg	Increased	Increased	Increased	Increased
70 – 90 kg	Increased	Increased	Increased	Increased
Cob length				
23 – 46 kg N ha^{-1}	Increased	Increased	Increased	Increased
46 – 70 kg	Increased	Increased	**Decreased**	Increased
70 – 90 kg	Decreased	Decreased	Decreased	Decreased
Cob weight				
23 – 46 kg N ha-1	Increased	Increased	Decreased	Decreased
46 – 70 kg	**Decreased**	Increased	Increased	Increased
70 – 90 kg	Decreased	Decreased	Decreased	Decreased
Days to 50% silking				
23 – 46 kg N ha-1	Increased	Increased	Increased	Increased
46 – 70 kg	Increased	Increased	Increased	Increased
70 – 90 kg	Increased	Increased	Increased	**Decreased**
Days to maturity				
23 – 46 kg N ha-1	Increased	Increased	Increased	Increased
46 – 70 kg	Increased	Increased	Increased	Increased
70 – 90 kg	Increased	Increased	Increased	Increased

Table-5 shows the response trends of evaluation parameters to increasing levels of Nitrogen for each specific variety. Whatever the variety growth in height, dry matter accumulation and maturation duration increased continuously with increasing level of N fertility. Days to 50% flowering increased continuously except for the control (traditional) variety JKU. With JKU, the days to flowering increased only to 70 kg N/ha, then as N increased from 70 – 90 kg/ha the plants flowered earlier (49. 3 days from 51.2 days at 70 kg N/ha). This is quite an un-expected character, for with most varieties heavy application of N would be expected to increase vegetative growth such that flowering would be delayed but in the contrary it was hastened.

Differential response trends were also demonstrated on cob parameters for varieties Staha and TMV-1. As N level increased from 46 – 70 kg/ha cob length increased in all varieties except for variety TMV-1 where cob length decreased instead. At the same level of increasing N (46 – 70 kg/ha) cob weight for variety Staha declined while for other varieties it increased. The rest of the response trends were similar among varieties.

Table-6 shows significance of the response among varieties to the various levels of N. It shows that the significance of the response was variety dependent for some parameters while for others it was independent of variety. As it appears in the Table, differences caused by N level were significant for all varieties combined and within each individual variety for days to 50% flowering and maturity, height of plants and cob length.

The differences were insignificant for cob weight no matter what was the variety but when the varieties data are combined response to N levels was significant ($P = 0.042$).

Local variety, JKU, and TMV-1 showed exclusive interaction with the fertilizer levels respectively for dry matter and grain yields. While the rest of the varieties showed individually significant ($P \leq 0.05$) response to N levels for dry matter yield, the response for JKU was insignificant. Likewise for grain yield, response to rates of N was insignificant for variety TMV-1 contrary the rest of the varieties.

Conclusion

This study results have shown significant yield advantage of incremental levels of N application on maize to highest yield at 70kg N/ha, thereafter yield was lower at 90kg/ha. This indicates that optimum N application rate for the semi-coral soil is around 70 kg N/ha. The significant response, on the other hand, seems to be relevant not to all varieties.

In this study, with variety TMV-1 the increasing levels of N could not increase the grain yield significantly. This irresponsiveness suggests high nutrient economy for the variety, and poses a challenge for more research to establish economic break-even point for the fertilizer N use in the semi-coral agro-ecosystem.

Acknowledgement

Authors of this paper thank the EPINAV ("Enhancing Pro-poor Innovation in Natural Resources and Agricultural Value Chains") Programme at Sokoine University, Morogoro, Tanzania, for financially supporting the study that this research forms part.

Table-6
Significance of response to different levels of N as displayed by different varieties of maize

Parameter	Significance of differences between N levels in different varieties				Overall probability
	Staha	Situka	TMV-1	JKU	
Plant height	Significant	Significant	Significant	Significant	0.030
Days to 50% silking	Significant	Significant	Significant	Significant	0.034
Days to maturity	Significant	Significant	Significant	Significant	0.003
Dry matter yield	Significant	Significant	Significant	Not significant	<.001
Cob length	Significant	Significant	Significant	Significant	0.028
Cob weight	Not significant	Not significant	Not significant	Not significant	0.042
Grain yield	Significant	Significant	Not significant	Significant	<.001

References

1. Shin-Gu K., Yussuf J.K., Mariam J.A., Soon-Kwon K. and Tae-Seon P. (2011). Introduction and selection of improved open-pollinated maize varieties in Zanzibar, Tanzania. *Korean Journal of International Agriculture,* 23(1), 102-108.
2. Stewart W.M. (2002). Fertilizer contributions to crop yield. News and Views, A Regional newsletter published by the Potash and Phosphate Institute (PPI) and the Potash and Phosphate Institute of Canada (PPIC), 2.
3. Busani B. (2014). Small fertilizer amounts boost crop yields in Zimbabwe. *SciDev Net*, 11th April 2014.
4. Adhiambo M. (2014). Fertile soil could double, triple crop yields. *Sci Dev Net*, 19th Sept. 2014.
5. Duflo M., Kremer M. and Robinson J. (2008). How high are rates of return to fertilizer? Evidence from Field Experiments in Kenya. American Economic Association Meetings, New Orleans, January 2008.
6. Abbasi M.K., Tahir M.M., Sadiq A., Iqbal M. and Zafar M. (2012). Yield and N use efficiency of rain-fed maize response to splitting and N rates in Kashmir, Pakistan. *Agronomy Journal* 104(2), 448 – 457.
7. Hammad H.M., Ahmad A., Khaliq T., Farhas W. and Mubeen M. (2011). Optimizing rate of N application for higher yield and quality in maize under semi-arid environment. *Crop Environ.,* 2, 38-41.
8. Tobert H.A., Potter K.N. and Morrison J.E. (2001). Tillage system, fertilizer N rate and timing effect on corn yields in the Texas Black land prairie. *Agron J.,* 93, 1119-1124.
9. Hoben J.P., Gehl R.J., Millar N., Grace P.R. and Robertson G.P. (2011). Non-linear nitrous oxide (N_2O) response to nitrogen fertilizer in on-farm corn crops of US Midwest. *Global Change Biology* 17(2), 1140-1152.
10. Ma B.L., Subedi K.D. and Costa C. (2005). Comparison of crop-based indicators with soil nitrate test for corn nitrogen requirement. *Agron J.,* 97, 462-471.
11. Walworth J.L. (2011). Soil sampling and analysis. [cals.arizona.edu/pubs/crops/az1412.pdf]. Site visited on 19 May, 2012.
12. Blakemore L.C., Searle P.L. and Daly B.K. (1987). Methods for Chemical Analysis of Soils. New Zealand Soil Bureau Scientific Report 80, 103.
13. Sonmez S., Buyuktas D., Okturen F. and Citak S. (2008). Assessment of different soil to water ratios (1:1, 1:2.5, 1:5) in soil salinity studies. *Geoderma,* 144(1-2), 361-369.
14. Bouyoucos G. (1962). Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal,* 54, 464-465.
15. Guebel D.V., Nudeland B.C. and Giulietti A.M. (1991). A Simple and micro-Kjeldahl method for total nitrogen analysis. *Biotechnology Techniques,* 5(6), 42-430.
16. Schumacher B.A. (2002).Methods for the determination of total organic carbon (TOC) in soils and sediments. NCEA-C- 1282, EMASC-001.
17. Carter M.R. and Gregorich E.G. (2006). Soil Sampling and Methods of Analysis. 2nd Edition, CRC Press, Taylor and Francis Group, Broken Sound Parkway NW, 198.
18. Chapman H.D. (1965). Total Exchangeable Bases. In: Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties (Edited by Norman, A. G.), 1965, American Society of Agronomy, Soil Science Society of America, Madison, USA. pp. 902-904.