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Full Length Research Paper

Effect of different sources of nitrogen fertilizers on yield and quality of dark fire cured tobacco

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Soil acidification with Sulphate of Ammonia fertilizer was a big challenge to dark fire cured tobacco growers in Tanzania. A trial was conducted for three years from 2004 to 2007 in Ruvuma region, located in Southern Highlands of Tanzania. The trial was conducted to evaluate different sources of nitrogenous fertilizers in order to get a suitable alternative source of nitrogen for dark fire cured tobacco yield and quality. Fertilizers involved were Sulphate of Ammonia (SA) as control, NPK 20:10:10, Di-ammonium phosphate (DAP), Urea and Calcium Ammonium Nitrate (CAN). Seventeen farmers' fields were involved in the research trial. Each farmer was a replicate. Results showed that 70.6% of soils had moderate acidity (pH 5.1 to 6.0). In all seasons, NPK 20:10:10 gave the longest leaves and the highest dry leaf yield (1108.4, 2563.5 and 2054.4 kg ha^{-1}). In this trial, NPK 20:10:10 showed the combined effect of the macroelements which influenced the increase in yield and quality of tobacco leaves. The NPK 20:10:10 gave highest leaf quality as was reflected by grade indices, which were 859.7 and 887.7 in seasons 2005/2006 and 2006/2007 respectively. Urea and CAN had poor performance when rainfall was erratic in December 2005 and January 2006. More so, when Urea and CAN were applied on tobacco, the leaves produced were small and short when compared with SA, NPK 20:10:10 and DAP and hence they produced low yield and quality of dark fire cured tobacco. Therefore NPK 20:10:10 could be the best alternative to SA in DFC production in Ruvuma region.

Key words: Dark fire, tobacco, nitrogenous fertilizers, Tanzania.

INTRODUCTION

Fire cured tobacco was introduced in Tanzania in the 1930. Songea District peasant farmers are growing fire cured tobacco since then. Tobacco is grown in small plots of 0.5 to 4 acres (0.2 - 1.6 ha) (Ishuza, 1984). Yield per acre under peasant management conditions ranges from about 240 to 660 kg/ha (TTB, 2000). The only fertilizer in use since fire cured tobacco was introduced in Tanzania was Sulphate of Ammonia (SA). This fertilizer has a tendency of acidifying the soil (FAO, 1984).

Nitrogen is a very important macronutrient element for dark fire cured tobacco production. It is required for plant growth and development. Nitrogen is vital for protein formation, cell multiplication and plant growth. It plays a part in the formation of particular molecules such as chlorophyll and alkaloids (nicotine). Nitrogen deficiency leads to poor growth and causes stems and leaves to remain small with a light green colour due to low chlorophyll content.

Phosphorus is another macronutrient which is needed relatively in large amount by plants. Phosphorus is involved in energy and growth regulation, and stimulates young root development (Hodges, 2012). Most of the inorganic P added to soils in fertilizers and manures is usually absorbed initially, but it may become absorbed by diffused penetration of phosphate ions into soil components (Spectrum Analytic Inc., 2010). According to

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Spectrum Analytic Inc. (2010), the residual P contributes to the readily plant-available pool, but the rate of release may not be sufficient to maintain the critical value required to meet the P requirements.

Potassium is also a very important nutrient required by plants in approximately the same or slightly larger amounts as nitrogen. Uptake of K occurs in the K^+ form. Most of K functions in the plant are indirect in that, K is necessary for other chemical reactions to operate properly (Hodges, 2012). Calcium is a structural component of plant cell walls and most abundant in plant leaves. It is involved in cell growth, both at the plant terminal and at the root tips, and apparently enhances uptake of nitrate-N (Hodges, 2012).

Lo´pez-Lefebre et al. (2001) worked to analyze the dynamics of the nutritional state and biomass production of tobacco plants. Results show that Ca accumulated progressively with increase in the application of the element. There was a slight increase in the concentration of organic N but there was hardly any change in the concentration of K and Na. In contrast, increasing Ca application caused a decline in P and Mg concentrations. The concentration of micronutrients Fe, Mn, Zn, Cl and B were influenced positively with Ca treatment, but the Cu concentration declined significantly. A significant synergistic relationship was found between Ca and B. The authors also observed an increase of biomass in the tobacco leaves.

Mahdav and Gholizadeh (2008) reported that increasing nitrogen levels increased length and width of leaves, green leaf yield and cured leaf yield, nicotine and total nitrogen.

Xiao-Tang et al. (2008) conducted an experiment and confirmed that nitrogen supply is the most important factor affecting yield and quality of flue-cured tobacco. A field experiment and an *in situ* incubation method were used to study the effects of soil N mineralization in the later stages of growth on yield and nicotine content of flue-cured tobacco in Fenggang, Jinsha and Guizhou Provinces in China. According to Xiao-Tang et al. (2008), the order of soil N contribution to N buildup in different parts of leaves was: upper leaves > middle leaves > bottom leaves. The NPK fertilizers have combined effect of N, P and K which are macronutrients.

There are different types of nitrogenous fertilizers which have different characteristics. Some few fertilizers are: Ammonium sulphate (SA), Calcium ammonium nitrate, Di ammonium phosphate and Urea. Nitrogen can be part of mixed fertilizers like NPK. Ammonium sulfate (21% N) is mostly available as a by-product of some industries. Ammonium sulfate [(NH4)2SO4], white or gray, small crystals, water soluble low hygroscopic capacity, strongly acidic to be used only in alkaline, calcareous soils and for crops having high acid tolerance (Vitosh, 2005).

Ammonium sulfate contains sulfate which is a good source of sulfur. It is a good material for high pH soils (pH>7.0) and can be used where sulfur deficiency is suspected (Sardi et al., 2012).

The general objective of this study was to improve dark fire tobacco yield and quality. The specific objective of this study was to investigate the effect of Di-ammonium phosphate (DAP), NPK 20:10:10, Urea and Calcium Ammonium Nitrate (CAN) on fire cured tobacco yield and quality as compared to Sulfate of Ammonia (SA) which has the disadvantage of being the most acidifying form of N fertilizer which requires to be replaced by other N fertilizers.

MATERIALS AND METHODS

The trial was carried out on red clay and sandy loam soils in Songea and Namtumbo districts, Ruvuma region. The trial consisted of farmers managed and implemented. Five primary societies were selected with the assistance of district extension staff and cooperative society personnel. In this process, responsibilities of the farmers and researchers in execution of the trials were spelt out and the farmers were involved only after mutual agreement.

Soil sampling

Seventeen farmers' fields were used in the research trial. In each farm, composite soil samples were taken. The composite soil samples representing the fields were taken at 0 – 20 cm depth. Soil samples were sent to Sokoine University Agriculture (SUA) for determination of the nutrient contents. The analysis involved total nitrogen (TN), extractable P, K, Ca, Mg, Zn, Cu, Mn, Fe and Cation Exchange Capacity (C.E.C).

Trial design and management

A tobacco variety called Heavy Western was planted in a randomized complete block design (RCBD) with individual farmers as replicates. The gross plot size was 110 m^2 while the net plot was 90 m^2. Table 1 shows the treatment structure of the trial.

Sulphate of ammonia was the control treatment and was applied at a rate of 250 kg/ha (22.5 g/plant). All recommended practices for production of fire cured tobacco were followed. Farmers were responsible for general tending of the trial including weeding and pest control. Researchers, extension staff and farmers participated in critical operations including transplanting, fertilizer application, harvesting, curing and grading.

The following data were collected: weight of green leaves, weight of dried cured leaves and tobacco leaf grades.

RESULTS AND DISCUSSION

Results show soil sample from trial sites (Table 2). About

Table 1. Treatments summary.

Treatment	Fertilizer rate (kg/ha)	N rate (kg/ha)	Fertilizer rate (kg/plot)	Fertilizer rate (g/plant)
Sulphate of ammonia (Control)	250	52.5	2.50	22.5
N:P:K (20:10:10)	264	52.5	2.64	23.8
DAP	292	52.5	2.92	26.3
Urea	114	52.5	1.14	10.3
Calcium ammonium nitrate (CAN)	195	52.5	1.95	17.6

Table 2. Soil nutrients results for Songea and Namtumbo farmers' trial sites.

Sampled fields*	pH (H_2O)	TN (%)	P (mg/kg)	K	Ca	Mg (mg/kg)
				Meq/100 g		
1	5.6	0.16	9	0.86	5.79	1.96
2	5.7	0.09	7	0.44	3.28	1.72
3	5.6	0.1	30	0.51	5.92	1.32
4	5.9	0.2	7	0.74	10.18	2.64
5	6	0.07	7	0.36	3.2	1.86
6	6.1	0.06	15	0.19	0.84	0.68
7	6	0.05	6	0.18	1.32	1.08
8	5.9	0.04	24	0.22	1.6	1.16
9	5.6	0.09	10	0.49	4.04	1.98
10	5.9	0.07	7	0.47	3.52	2.16
11	5.9	0.06	16	0.27	2.16	1.92
12	5.5	0.13	29	0.64	5.79	1.96
13	5.7	0.07	10	0.36	4.24	1.16
14	5.6	0.07	14	0.4	3.6	1.24
15	5.5	0.08	2	0.39	3.36	0.92
16	5.4	0.07	2	0.39	2.84	0.88
17	5.3	0.11	12	0.41	4.32	1.2
Averages	5.7	0.09	12.18	0.43	3.88	1.52

*Numbers representing owners of farms (Appendix 1).

70.6% of soils had moderate acidity (pH 5.1 to 6.0). On the other hand, 23.5% of analyzed soils were strongly acidic (5.1 to 5.5), while 5.9% of the sampled soil was slightly acidic (pH 6.1 to 6.5).

Results show that 70.6% of analyzed soil had very low total nitrogen (0 - 0.1) while 29.4% had low nitrogen (0.1 - 0.2%). About 11.8% of the sampled soil from the two districts had very low extractable P (0 - 3 mg/kg), low P (3 - 7 mg/kg) was 29.4%, medium P (7 - 20 mg/kg) was 41.2%, while high P (>20) was 17.6%.

About 47% of the sampled soil had medium potassium (0.4 - 1.2), 41.2% of the sampled soil had low potassium (0.2 - 0.4) and 11.8% only of the sampled soil had very low potassium.

About 17.6% of the sampled soil had very low Ca (<2 me/100 g), 58.8% had low Ca (2 - 5 me/100 g), 17.6% had medium Ca (5 - 10 me/100 g), while 6% only of the sampled soils had high Ca (10 - 20 me/100 g)

Effect of different sources of N on leaf growth

Results showed that leaves from plots treated with NPK 20:10:10 were the longest at the bottom, middle and top of the plants followed by plants treated with DAP (Table 3). Leaves from plots treated with Urea were the shortest at the bottom, middle and top of the plants. There were significant differences in leaf length between NPK 20:10:10 and Urea ($P<0.05$). The results implied that application of N as a single element or in combination with P and K has a lot of influence on leaf growth. Salardini (1975) found out that compound fertilizers were equal or excelled in efficiency when compared with the

Table 3. The effect of different sources of N on leaf length across sites in Songea and Namtumbo districts in three seasons.

Treatment	Leaf length (cm) in three growing seasons								
	2004/2005			2005/2006			2006/2007		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
SA	38.3[ab]	58.1[ab]	48.0[ab]	47.5[b]	60.1[ab]	54.7[a]	47.5[b]	56.1[ab]	57.0[a]
NPK (20:10:10)	41.0[ab]	62.6[a]	52.1[a]	55.0[a]	62.1[a]	57.5[a]	55.0[a]	61.4[a]	58.7[a]
DAP	41.6[a]	62.2[a]	48.5[ab]	48.2[ab]	59.8[ab]	50.5[a]	48.2[ab]	56.8[ab]	44.8[ab]
Urea	35.3[b]	46.9[b]	31.0[c]	38.5[c]	41.9[c]	36.1[b]	38.5[c]	46.9[b]	41.5[b]
CAN	39.6[ab]	56.1[ab]	45.4[b]	42.5[bc]	49.1[bc]	50.2[a]	42.5[bc]	50.0[b]	52.6[ab]
Mean	39.2	57.2	45.0	46.4	54.6	49.8	46.4	54.2	50.9
LSD 0.05	5.3	11.0	5.8	7.1	10.8	7.2	7.1	9.6	13.2
CV (%)	18.6	10.2	6.8	8.1	10.5	7.7	8.1	9.4	13.8

single fertilizers applied separately. Cho et al. (1972) noted that at the highest fertilizer rate of 100 kg N/ha, the largest leaf length and width and the largest stem size were obtained. At this rate, the highest yield was obtained; the maximum yield was obtained when P and K were also applied at the rate of 430 kg P and 570 kg K/ha. It implied that the three nutrient elements N, P, and K are important for leaf growth and development as NPK 20:10:10 had the best performance in terms of leaf length (Table 3). A good supply of N is associated with vigorous growth and deep green colour.

Effect of different sources of N on tobacco dry weight yield

Season 2004/2005

According to Table 4, results show that NPK (20:10:10) gave the highest dry leaf weight of 1108.41 kg/ha, followed by DAP (1016.98 kg/ha), while the lowest yield came from CAN (785.11 kg/ha). Statistically, there was significant difference between NPK (20:10:10) and CAN ($P < 0.05$). The order of performance was NPK > DAP > Urea > SA > CAN.

Season 2005/2006

In season 2005/2006, the results obtained were similar to the results of the previous season. According to Table 4, results show that NPK (20:10:10) gave the highest dry leaf weight of 2992.71 kg/ha, followed by DAP (2745.83 kg/ha), while the lowest yield came from CAN (2119.79 kg/ha). Statistically, there was significant difference between NPK (20:10:10) and CAN only at $P < 0.05$. The order of performance was NPK > DAP > Urea > SA > CAN as seen in season 2004/2005.

Season 2006/2007

According to Table 4, results show that DAP gave the highest dry leaf weight of 2208 kg/ha, followed by NPK 20:10:10 (2054.67 kg/ha), while the lowest yield came from Urea (1465.56 kg/ha). Poor performance for Urea and CAN could be due to erratic rainfall in December 2005 and January 2006 (Appendix 2). Statistically, there was significant difference between DAP, CAN and Urea at $P < 0.05$. The order of performance was DAP > NPK > SA > CAN > Urea.

The trial performance across seasons

According to Table 4, results show that DAP gave the highest yield (2208 kg/ha), followed by NPK 20:10:10 which gave 2054.67 kg/ha, while the lowest yield came from Urea (1465.56 kg/ha). Di-ammonia phosphate differed with Urea and CAN significantly at $P<0.05$ while NPK 20:10:10 and SA differed significantly with Urea at $P<0.05$. The order of performance was DAP > NPK > SA > CAN > Urea.

In the third season, DAP was followed by NPK 20:10:10 and SA although they were statistically non-significant and different. High performance of DAP was possibly contributed by presence of K in the available form and fixed form in the red clay soils of Songea and Namtumbo districts. Scherer et al. (2003) commended that plants are fed not only from K in the soil solution and from exchangeable K but also from non-exchangeable K.

It came into view that DAP potential for tobacco production in Songea and Namtumbo districts was boosted by K available in the soils (Appendix 1) although it could not exceed the influence of NPK potential for fire cured tobacco.

Results in the three seasons showed that the application of N, P, and K are very important for tobacco production. In the three seasons, NPK showed the potential in tobacco yield and quality followed by DAP. The crop responded to fertilizers because 70.6% of analyzed soil had very low total nitrogen, 41.2% of sampled soils had low to very low extractable P and 53%

Table 4. Effect of different sources of N on barn dry weight of tobacco across sites in Songea and Namtumbo districts in three growing seasons.

Fertilizer	2004/2005	2005/2006	2006/2007
	Barn dry weight (kg/ha)	Barn dry weight (kg/ha)	Barn dry weight (kg/ha)
SA	949.46[ab]	2563.54[ab]	2050.0[ab]
NPK (20:10:10)	1108.41[a]	2992.71[a]	2054.67[ab]
DAP	1016.98[ab]	2745.83[ab]	2208.0[a]
Urea	987.65[ab]	2666.67[ab]	1465.56[c]
CAN 27%	785.11[b]	2119.79[b]	1683.78[bc]
Mean	969.52	2617.71	1892.40
L.S.D	244.80	661.09	408.25
CV (%)	35.71	35.71	29.5

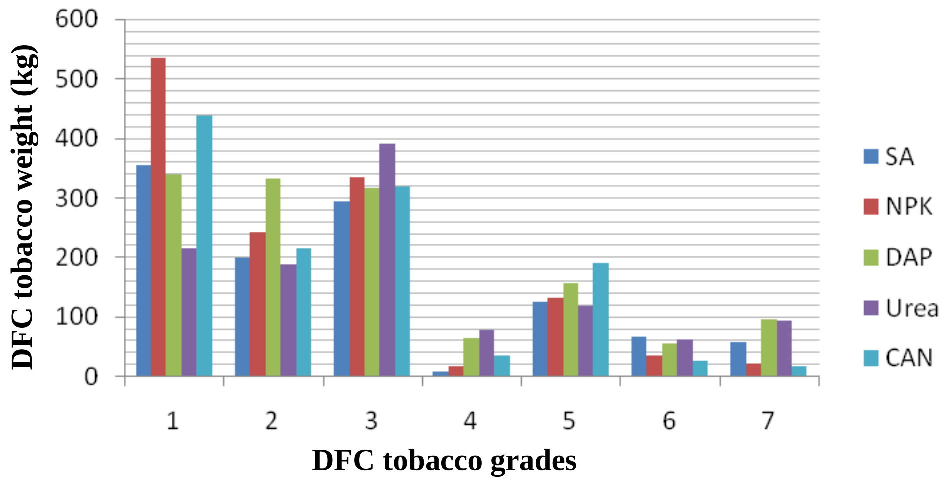

Figure 1. Dark fire tobacco grades for each fertilizer treatment across sites.

of soil samples had low to very low potassium (Table 2).

According to Litchfield (2010), nitrogen is directly involved with chlorophyll production. It is the key building block for proteins and enzymes. It promotes cell division and causes darker green plants and rapid growth. Nitrogen boosts plant protein levels. Phosphorus is essential in several biochemical that control photosynthesis, respiration, cell division and plant growth and development processes (Hodges, 2012). According to Hodges (2012), K is used by a plant in photosynthesis, carbohydrates transport, water regulation and protein synthesis; therefore proper K nutrition improves diseases resistance and is vigorous. Results show that plants responded positively to N, P and K supplied because soil results showed that some sites had very low N, P and K.

Cho et al. (1972) obtained maximum yield at P and K rates of 430 and 570 kg/ha respectively. Jones and Tramel (1979) found out that there was an increase in tobacco production with increasing nitrogen N rates from 78 to 179 kg/ha and that 145 kg/ha was optimum for the production of Virginia dark fire tobacco. This gives evidence that application of N, P, and K is necessary for better yields of tobacco as shown by NPK 20:10:10. Good performance by plots treated with DAP could had been because of the amount of K in the soils which was possibly available to tobacco plants at the growing season.

Effect of different sources of N on tobacco grades in season 2004/2005

Grade index is the ratio between tobacco value and barn weight of the same leaves after curing. The high ratio reflects tobacco quality and vice versa. In season 2004/2005, application of N played an important role in tobacco quality. Results (Figure 1) show that NPK

Table 5. Effect of different sources of N on tobacco leaf grade indices in seasons 2005/2006 and 2006/2007.

Treatment	Grade indices in two seasons	
	2005/2006	2006/2007
Sulphate of ammonia (Control)	711.7[b]	760[b]
N:P:K (20:10:10)	859.7[a]	887.7[a]
DAP	616.0[b]	703.7[b]
Urea	711.0[b]	672[b]
Calcium ammonium nitrate (CAN)	710.6[b]	681.3[b]
Mean	721.8	740
l.s.d	129.4	91.5
CV (%)	9.5	6.6

fertilizer gave the highest grade of tobacco followed by CAN. The order of grade indices was NPK>CAN>SA>DAP>Urea.

Effect of different sources of N on tobacco leaf grade indices in seasons 2005/2006 and 2006/2007

Results (Table 5) show that in two seasons (2005/2006 and 2006/2007), NPK 20:10:10 gave the highest grade indices which were 859.7 and 887.7 of tobacco leaf respectively. High grade indices reflect the best tobacco leaf quality. The lowest grade index (672) came from DAP in season 2005/2006, while in season 2006/2007, Urea gave the lowest grade index (616). The order of performance of the fertilizer sources was NPK>SA>Urea>CAN>DAP and NPK>SA>DAP>CAN>Urea in seasons 2005/2006 and 2006/2007 respectively. There were significant differences between NPK 20:10:10 and other treatments at $P<0.05$ in the two seasons. The remaining treatments were not statistically different among themselves in the two saesons. The possible reasons for NPK 20:10:10 to give high quality tobacco leaves could be largely due to the combined effect of N, P and K (Litchfield, 2010).

Fisher et al. (2008) reported that nitrogen has a greater effect on tobacco yield and quality than any other nutrient. According to Litchfield (2010), phosphorus promotes rapid root development from seeds planted, improves uniformity of crop maturity and quality, and water use efficiency. According to the authors, potassium controls plant respiration, improves leaf quality, builds disease resistance, helps to control water loss during drought and helps regulate many enzyme reactions and other plant functions.

CONCLUSION AND RECOMMENDATIONS

Results from this research trial show that NPK 20:10:10 and DAP showed the potential to produce high yield. In all seasons, NPK 20:10:10 gave the highest dry leaf yield. In the three seasons, NPK 20:10:10 gave high quality tobacco leaves. Leaf length is of grades attributes in tobacco classification and NPK 20:10:10 excelled in leaf length. The NPK 20:10:10 compound fertilizer showed the combined effect of the macroelements in increasing yield and quality of tobacco leaves. In the three seasons, NPK 20:10:10 gave the highest quality as was reflected by grades and grade indices. The NPK 20:10:10 fertilizer could be a good alternative fertilizer to Sulphate of Ammonia. Apart from N, NPK 20:10:10 fertilizer supplied P and K in the soil. Phosphorus are important to Songea and Namtumbo soils because 11.8% of the sampled soil had very low P. The use of NPK 20:10:10 at the right rate will improve DFC tobacco yield and quality in Ruvuma region. Urea and CAN had no good performance as compared to other fertilizers when used alone.

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Appendix 1. Soil nutrients results for Songea and Namtumbo farmers' trial sites.

Farmers field	pH (H_2O)	TN (%)	P (mg/kg)	K	Ca	Mg
				Meq/100 g		
Yairus Ngindo	5.6	0.16	9	0.86	5.79	1.96
Hassani pili	5.7	0.09	7	0.44	3.28	1.72
Thabiti Mustafa	5.6	0.1	30	0.51	5.92	1.32
Dominicus Ndundu	5.9	0.2	7	0.74	10.18	2.64
Henrick Luambano	6	0.07	7	0.36	3.2	1.86
Nkwanda Issa	6.1	0.06	15	0.19	0.84	0.68
Riziwani Gowao	6	0.05	6	0.18	1.32	1.08
Shabani Mapondele	5.9	0.04	24	0.22	1.6	1.16
Adeodatus Hala	5.6	0.09	10	0.49	4.04	1.98
Fabian Gama	5.9	0.07	7	0.47	3.52	2.16
Joseph Mapunda	5.9	0.06	16	0.27	2.16	1.92
Aidan moyo	5.5	0.13	29	0.64	5.79	1.96
Selemani Ngwenya	5.7	0.07	10	0.36	4.24	1.16
Valencia Monji	5.6	0.07	14	0.4	3.6	1.24
Amin Salum	5.5	0.08	2	0.39	3.36	0.92
Hamisi Hassani	5.4	0.07	2	0.39	2.84	0.88
Iddi Mputa	5.3	0.11	12	0.41	4.32	1.2
Averages	5.7	0.09	12.18	0.43	3.88	1.52

Appendix 2. Average rainfall data for trial sites in Ruvuma (2004 - 2008).

Season	Rainfall (mm)								
	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	TOTAL (mm)
2004/2005	-	-	-	253	296	204	211	24.3	988.3
2005/2006	-	-	-	245	213	229	207	04	898
2006/2007	-	-	108.7	349.6	444.9	109.5	96.5	13.7	1122.9