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RESEARCH ARTICLE

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Tobacco Farming Using Organic and Inorganic Fertilizers Effect on Soil Quality in Migori County

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Abstract

In Kenya, tobacco is grown in several counties like Migori, Bungoma and Meru counties, the largest producer being China, followed by the USA and India. Whereas tobacco industry argues that tobacco cultivation is a lucrative economic venture for smallholder farmers, studies show the risks associated with tobacco growing outweigh its benefits. These includes the destruction of groundwater resource, river sedimentation systems, soil infertility among others. This study aims to assess effect of soil amendments – organic and inorganic fertilizers- on soil quality. The study was carried out in four sites in Migori County - Mabera, Bondo, Kakrao and Masaba. Tobacco was grown using inorganic fertilizer (DAP and CAN) (TF) at a recommended rate of 60 kg P/ha and 30 kg N/ha; organic fertilizer (manure) (TOM) was applied at recommended rate of 4 t/ha; and Control (TO). Tobacco was planted in a 10 m^2 plots, laid in RCBD, with three replicates. Land preparation was done by hand digging using a hoe. Variety 583V was used in the four sites - Bondo, Kakrao, Mabera and Masaba. Normal agronomic practices were carried out throughout the experiment period. Data was collected management on tobacco yield. Soils data was also collected on soil pH, P, SOC and total N. Data was analyzed using GLM and subjected to ANOVA using GENSTAT 12. Means were separated using Tukeys at 5%. On average, soil pH at planting in season one was between 4.72 and 5.51. At harvest, soil pH measured between 4.57 to 5.41. In season two, there was no significant difference ($p \leq 0.05$) in the measured soil pH at planting. In season three, mean soil pH at planting stood at 4.89a under T. Masaba soils recorded the lowest soil pH mean under TF (4.72), followed by Kakrao (4.82). Generally, soil pH increased significantly ($p \leq 0.05$) TF and TOM when compared to the control, where pH levels decreased marginally. This indicates that high manure in the soil has the ability to absorb or bind hydrogen ions in its humic forms, whereas N fertilizers (DAP) add hydrogen ions to the soil, resulting in high acidity. Slight increase in pH in the control in season three may be due to H^+ ions absorbed from the soil solution by humic substances. Highest mean tobacco yield in season two was recorded under TF. This was in Bondo in season two with a mean of 2.740 t/ha. Most high tobacco yields come from TF treatments which are in the forms of diammonium phosphate or DAP. The rapid growth of tobacco is due to phosphorus and nitrogen uptake. Excessive amounts H^+ ions in reduced soil pH results to fixation and limitation of phosphorus uptake, and this has general adverse effects on tobacco yield. In conclusion, increasing the soil pH inhibited the growth of tobacco plants. Lower soil pH decreased the leaf weight by 0.3%-21.29%. Soil pH is an important factor that affects the growth of tobacco plants as well as the quality and yield of tobacco leaves, and this differs under different soils and climatic conditions.

Keywords: Tobacco, Organic and Inorganic Fertilizer, Soil pH, Soil Quality

INTRODUCTION

In Kenya, tobacco is grown in several counties including Migori, Bungoma and Meru counties (Kweyuh, 1994), the largest producer being China, followed by the USA and India (WHO, 2017a). It is estimated that the number of tobacco farmers contracted by tobacco processing companies in Kenya has been on the rise every year since 1972 (GoK, 2004). The level has increased by 67% in the period 2009 to 2017 (Kibwage et al., 2008). In Kenya, 80% tobacco production is done in Migori County where approximately 28,000 small-scale farmers grow tobacco on 7,000 hectares of land. Whereas tobacco industry argues that tobacco cultivation is a lucrative economic venture for smallholder farmers, studies seem to suggest the risks associated with tobacco growing outweigh its benefits. Evidence shows that tobacco cultivation has negative environmental and social effects, besides a serious risk to occupational health and safety. Tobacco cultivation is also associated with the destruction of groundwater resource, river sedimentation systems, over exploitation of groundwater, biodiversity destruction, soil infertility and species extinction due to the exploitation and habitat fragmentation (WHO, 2017b). These environmental impacts cause huge loss to the human livelihood and health. Tobacco plants need more chemical fertilizer and pesticides. Tobacco plants absorbs phosphorus, potassium and nitrogen more than any other crops, which decrease soil fertility than any other cultivating crops. Topping and suckering are two types of specific cultivation methods use to gain high level of nicotine and more leaves that also reduce the soil fertility a lot (Geist, 2009). Tobacco related deforestation in some certain producing countries and developing countries is felt rapidly (Geist, 2019).

This study aims to look at the inter-linkage between tobacco production and their impact on soil acidity status in Migori County soils. This study therefore assessed effect of soil amendments – organic and inorganic fertilizers- on soil quality.

METHODOLOGY

The study was carried out in four localities in Migori county. These are Mabera, Bondo, Kakrao and Masaba sites.

Field Experimental Treatments

The tobacco was grown using inorganic fertilizer (DAP and CAN) at a recommended rate of 60 kg P/ha, and nitrogen at 30 kg N/ha. The tobacco crop was grown using organic fertilizer (manure) at a recommended rate of 80 kg P/ha and 30 kg N/ha.

Organic fertilizer/matter was applied as manure at a recommended rate of 4 t/ha for tobacco crop. This was replicated three times.

Experimental Design and Layout

The experiment involved planting of tobacco in a 10 m by 10 m square plots. The test crop was tobacco (T). This was grown using inorganic fertilizer (TF) and organic fertilizer/matter (TOM). The absolute control treatment (TO) was included. The experiment was laid out in a randomized complete block design (RCBD), with three replicates (fig 1).

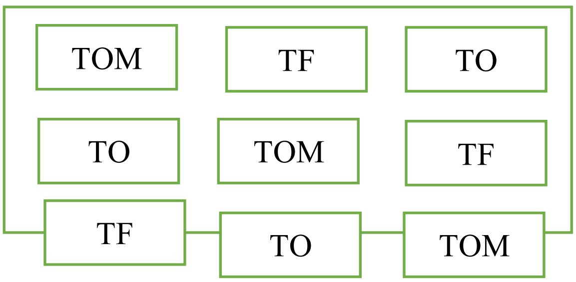

Figure 1: Field experimental layout.

Initial Land Preparation and Planting

Land preparation was done by hand digging using a hoe to open up the 0-20 cm layer. Certified tobacco variety 583 V from British American Tobacco (BAT) was used in the four sites - Bondo, Kakrao, Mabera and Masaba. Normal agronomic management practices e.g. weeding, pest control was carried out on the experimental plots at appropriate stages of plant growth in the respective treatments.

Data Collection

Data was collected on tobacco yield. Soils data was also collected on soil pH, available P, organic carbon and total N using procedures by Okalebo et al. (2002).

Data Analysis

Data obtained from the experimental variables was analyzed using General Linear Model (GLM) and subjected to analysis of variance (ANOVA) using GENSTAT 12, 2012 statistical package. Means were separated by Tukeys at 5% level of significance (Gomez & Gomez, 1984). Relationships between crop yields and the treatments were also drawn. Changes in the soil chemical properties and microorganisms' population counts over time under different treatments were also determined.

RESULTS AND DISCUSSION

The study sites revealed an acidic soil with pH of 4.39-4.48, and deficient of most of the nutrients (Table 1). The soils were low in major elements including phosphorus, potassium and Soil Organic Carbon (SOC).

Table 1: Initial Site characteristics

Parameter	Bondo	Kakrao	Mabera	Masaba
Latitude	-1.11365	-1.0219113	-1.115967	-1.121669
Longitude	34.40726	34.4811729	34.42835	34.523537
Altitude (m.a.s.l)	1200-1600	1200-1500	1300-1600	1400-1500
Total annual rainfall (mm)	1500 mm to 1800	1700 mm to 2000	1500 mm to 1800	1700 mm to 2000
Daily temperatures (^{0}C)	25	26	26	26.5
Soil type	Ferralsol	Ferralsol	Ferralsol	Ferralsol
% Sand: Silt: Clay ratio	61: 7: 32	62: 10: 28	63: 6: 31	60: 8: 32
Soil Textural Class	Sandy-Clay-Loam	Sandy-Clay-Loam	Sandy-Clay-Loam	Sandy-Clay-Loam
pH (1:2.5H_2O)	4.48	4.45	4.46	4.39

Effect of Treatments on soil pH across the Four Sites

On average, soil pH at planting in season one was between 4.72 and 5.51 (Table 2). Bondo recorded soil pH that was tending towards neutral, at 5.37d. This was significantly high ($p \leq 0.05$) above the soils from other three sites (Table 2). It was followed by Kakrao and Masaba with soil pH at 5.33c and 5.31b respectively. However, there was no significant difference ($p \leq 0.05$) between the soil pH recorded between treatments TOM and TF having soil pH 5.33b each (Table 2).

At harvest, soil pH measured between 4.57 and 5.41. The highest mean soil pH at harvest was recorded under treatment TO in Mabera at 5.41 (Table 2). There was, however, no significant difference ($p \leq 0.05$) between Mabera and Kakrao sites in the soil pH recorded (5.08a and 5.09a, respectively) at harvest. The highest overall soil pH mean at harvest was 5.17c recorded in Bondo soils (Table 2). This was significantly high ($p \leq 0.05$) above Masaba with a mean soil pH of 5.15b.

Table 2: Soil pH at planting and harvesting in season one

	Planting				At Harvest			
	Treatment (TRT)				Treatment (TRT)			
SITE (S)	**TF**	**TO**	**TOM**	**Mean site**	**TF**	**TO**	**TOM**	**Mean site**
Bondo	5.41	5.37	5.32	**5.37d**	4.90	5.38	5.24	**5.17c**
Kakrao	5.34	5.28	5.37	**5.33c**	4.67	5.20	5.39	**5.09a**
Mabera	5.30	5.28	5.31	**5.30a**	4.57	5.41	5.26	**5.08a**
Masaba	5.28	5.33	5.33	**5.31b**	4.89	5.28	5.29	**5.15b**
Mean TRT	**5.33b**	**5.32a**	**5.33b**		**4.76a**	**5.32 c**	**5.30b**	
	SITE	***TRT***	***S*TRT***		***SITE***	***TRT***	***S*TRT***	
e.s.e.	0.002	0.002	0.004		0.002	0.00 2	0.004	
s.e.d.	0.383	0.309	0.513		0.003	0.00 3	0.005	
l.s.d.	0.647	0.517	1.103		0.006	0.00 5	0.011	
%CV	**26.3**				**10.12**			

Significant at p≤0.05; **Significant at p≤0.01; ***Significant at p≤0.001; ns-Not significant:* ***Means* *in columns/rows with same letter have no significant difference (p≤0.05:* ***Treatments:*** *TO-Control, TF-DAP Fertilizer, TOM-Organic Fertilizer.*

Among the treatments, the highest soil pH was recorded under TO (control) having mean pH 5.32c. Treatment TF recorded a slightly acidic soil pH at 4.76a, which was significantly low (p≤0.05) among the treatments (Table 2).

Effect of Treatments on Soil pH across the Four Sites in Season Two

In season two, there was no significant difference (p≤0.05) in the measured soil pH at planting among the four sites (Table 3). The highest soil pH measured was in Bondo, followed by Masaba and Mabera. The lowest mean soil pH was recorded in Kakrao at 5.24a (Table 3). Among the treatments, the highest soil pH mean was recorded from TO (5.34a), followed by TOM at 5.31a. Soil pH under TF was 5.25a, and this was not significantly different (p≤0.05) from the TO and TOM (Table 3).

However, at harvest, soil pH results indicated a significant difference (p≤0.05) among the treatments. Under TO treatment, soil pH at harvest was 5.31b (Table 3). This was not significantly different (p≤0.05) from TOM treatment (organic fertilizer) with a pH of 5.30b. Soil pH under treatment TF (inorganic fertilizer) was 4.82a, which significantly low compared to the other two treatments (Table 3). Also at harvest, there was no significant difference in the soil pH levels recorded across the four sites. However, the highest mean soil pH was recorded in Bondo. This was followed by Mabera and Masaba which both recorded a soil pH of 5.13a. The lowest soil pH mean was recorded at Kakrao, with pH of 5.09a (Table 3).

Table 3: Soil pH at planting and harvesting in season two

	Planting				At Harvest			
	Treatment (TRT)				Treatment (TRT)			
SITE (S)	**TF**	**TO**	**TOM**	**Mean site**	**TF**	**TO**	**TOM**	**Mean site**
Bondo	5.38	5.34	5.33	**5.35a**	5.02	5.39	5.26	**5.22a**
Kakrao	5.15	5.27	5.30	**5.24a**	4.63	5.24	5.40	**5.09a**
Mabera	5.23	5.36	5.29	**5.29a**	4.82	5.33	5.25	**5.13a**
Masaba	5.25	5.40	5.34	**5.33a**	4.82	5.29	5.29	**5.13a**
Mean TRT	**5.25a**	**5.34a**	**5.31a**		**4.82a**	**5.31b**	**5.30b**	
	SITE	***TRT***	***S*TRT***		***SITE***	***TRT***	***S*TRT***	
e.s.e.	0.039	0.034	0.068		0.035	0.031	0.061	
s.e.d.	0.056	0.048	0.096		0.05	0.043	0.087	
l.s.d.	0.116	0.1	0.2		0.104	0.09	0.18	
%CV	**12.1**				**11.9**			

Significant at p≤0.05; **Significant at p≤0.01; ***Significant at p≤0.001; ns-Not significant: **Means in columns/rows with same letter have no significant difference (p≤0.05: **Treatments:** TO-Control, TF-DAP Fertilizer, TOM-Organic Fertilizer.*

Effect of Treatments on Soil pH across the Four Sites in Season Three

In season three, mean soil pH at planting stood at 4.89a under TF treated plots. Mabera soils recorded the lowest soil pH mean under TF plots (4.72), followed by Kakrao (4.82) (Table 4). Mean soil pH under TO and TOM did not differ significantly (p≤0.05), recording soil pH at 5.40b and 5.41b respectively. Bondo and Masaba soil pH was at 5.27b for each site (Table 4). This was followed by Kakrao and Mabera at 5.21a and Mabera 5.20a (Table 4).

Table 4: Soil pH at planting and harvesting in season three

	Planting				At Harvest			
	Treatment (TRT)				Treatment (TRT)			
SITE (S)	**TF**	**TO**	**TOM**	**Mean site**	**TF**	**TO**	**TOM**	**Mean site**
Bondo	5.03	5.43	5.35	**5.27b**	5.33	4.82	5.30	**5.15a**
Kakrao	4.82	5.28	5.51	**5.21a**	5.15	5.33	5.28	**5.26b**
Mabera	4.72	5.51	5.38	**5.20a**	5.27	5.25	5.31	**5.28b**
Masaba	5.02	5.38	5.41	**5.27b**	5.30	4.82	5.28	**5.13a**
Mean TRT	**4.89a**	**5.40b**	**5.41b**		**5.29b**	**5.06a**	**5.29b**	
	SITE	***TRT***	***S*TRT***		***SITE***	***TRT***	***S*TRT***	
e.s.e.	0.007	0.006	0.012		0.299	0.239	0.348	
s.e.d.	0.01	0.008	0.017		0.320	0.218	0.537	
l.s.d.	0.02	0.017	0.034		0.628	0.521	1.030	
%CV	**9.4**				**19.5**			

Significant at p≤0.05; **Significant at p≤0.01; ***Significant at p≤0.001; ns-Not significant: **Means in columns/rows with same letter have no significant difference (p≤0.05: **Treatments:** TO-Control, TF-DAP Fertilizer, TOM-Organic Fertilizer.*

At harvest in season three, lowest soil pH was recorded under TO (control) in Bondo and Masaba, with both recording soil pH of 4.82 (Table 4). Kakrao and Mabera recorded highest soil pH means at 5.26b and 5.28b (Table 4). This did not however differ significantly (p≤0.05). It was followed by Bondo and Masaba, recording 5.15a and 5.13a respectively (Table 4). Among the treatments tested, TO recorded the lowest mean soil pH at 5.06a. Treatments TF and TOM did not differ significantly ($p \leq 0.05$) and both recorded soil pH of 5.29b (Table 4).

Soil pH increased significantly ($p \leq 0.05$) in plots treated with inorganic (TF) and organic (TOM) fertilizers when compared to the control, where pH levels decreased marginally. This indicates that high manure in the soil has the ability to absorb or bind hydrogen ions in its humic forms, whereas N fertilizers (DAP) add hydrogen ions to the soil, resulting in high acidity. These findings are consistent with those of Kang (1993) and Mugendi et al. (1999), who reported a general decrease in acidity following the application of organic and mineral fertilizers.

The slight increase in pH in the control in season three may be due to H^+ ions absorbed from the soil solution by humic substances (Tisdale et al., 1993). This is due to the fact that soil acidification is a natural process in high rainfall areas, where leaching gradually acidifies soil over time. Soluble basic salts such as Ca, Mg, K, Na are leached away by drainage water, leaving insoluble acidic residues primarily composed of oxides and silicates of iron, silicon, and aluminum, which accumulate in significant amounts. Because these salts react acidically, the soils become acidic.

Intensive agriculture and the use of inorganic fertilizer (TF) accelerate soil acidification through a variety of processes, including increased leaching, fertilizer addition, produce removal, and the accumulation of soil organic matter, when compared to the use of organic fertilizers (TOM). Also, in season three, TF treatment recorded the highest mean yield at 2.616 t/ha, in Kakrao. The least mean yields were recorded under treatment TO (Control). This is probably due to use of ammonium as a source of potassium and rapid adsorption of base captions and release of H^+ ions. The similar trend was also found by Kutub and Falgunee (2017) in Bangladesh.

Treatments Effect on Tobacco Yield (t/ha)

In season one, the highest mean tobacco yield was at 2.638 t/ha, which was recorded in Kakrao under TF treatment. The highest mean tobacco yield in season two was recorded under TF (Inorganic Fertilizer) treatment. This was in Bondo in season two with a mean of 2.740 t/ha (Fig 2).

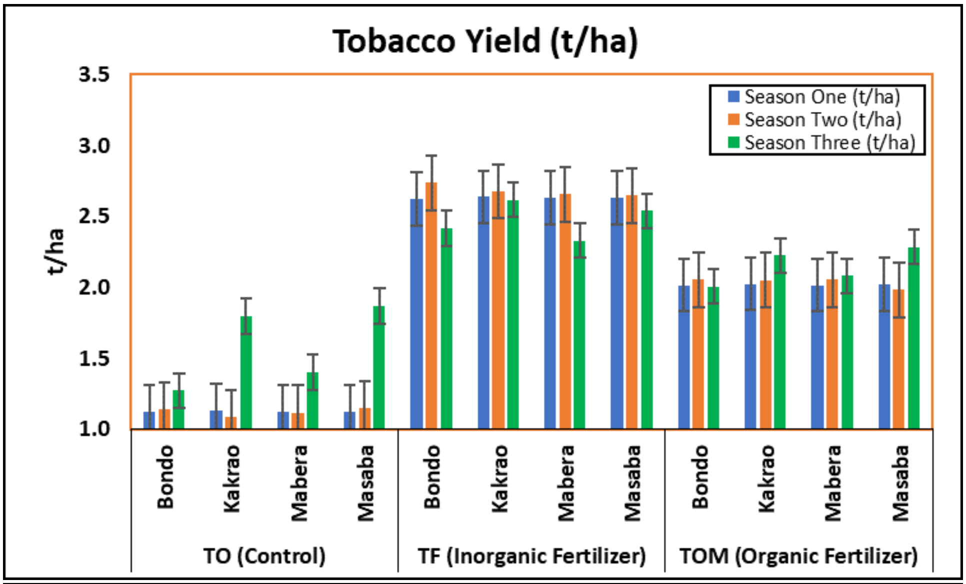

Fig 2: Treatment effect on tobacco yield across the sites.

Most high tobacco yields come from TF treatments which are in the forms of diammonium phosphate or DAP. The rapid growth of tobacco is due to phosphorus and nitrogen uptake. Phosphorus also affects the growth of tobacco by decreasing the time required for the plants to reach maturity. Excessive amounts of H^+ ions in soils results into reduced soil pH, leading to fixation and limitation of phosphorus uptake, and this has general adverse effects on tobacco (Lewis & Nicholson, 2017). On the other hand, low amounts of phosphorus resulted in lower leaf yields than heavier applications (Lewis & Nicholson, 2017). This was evident in the TO treatment with zero phosphorus application.

Also, inorganic fertilizer application (TF) when not knowing soil nutrient levels cannot only be costly but can greatly increase the salt concentration of the soil and even decrease the soil pH if too much fertilizer is applied. This could cause damage to the plant root and adversely affect the growth and yield of the tobacco crop. This could be the reason as to why some of the plots having inorganic fertilizer recorded lower yields.

This research showed that there were significant differences in the yield of tobacco due to fertilizer treatments. The best yields were obtained in the two treatments that included fertilizer application -TF and TOM.

CONCLUSION AND RECOMMEDATION

- Increasing the soil pH inhibited the growth of tobacco plants, and excessively high pH values significantly decreased the leaf weight of the tobacco. Compared with soil at pH 7.0, higher soil pH values decreased the single-leaf weight by 0.3%-21.29%.
- Excessively high soil pH decreased the quality of the tobacco leaves grown in the soil. The P, N and water levels gradually decreased with increasing pH values.
- Soil pH is an important factor that affects the growth of tobacco plants as well as the quality and yield of their tobacco leaves. It determines both the distribution of soil microbes and the nutrient absorption of tobacco. The soil pH for achieving higher quality tobacco is different under different soil and climatic conditions.

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COMPETING INTERESTS

Authors have declared that there are no existing competing interests.

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