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Tobacco Cultivation Effects on Soil Fertility and Heavy Metals Concentration on Smallholder Farms in Western Kenya

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ABSTRACT

This study was conducted to determine the effect of tobacco cultivation on soil fertility status (pH, nitrogen (N), phosphorus (P), potassium (K) and organic carbon (OC)) and heavy metals (cadmium (Cd), lead (Pb), cobalt (Co), copper (Cu), chromium (Cr), manganese (Mn), nickel (Ni) and zinc (Zn)) concentration on selected smallholder tobacco farms and virgin lands in Migori County, Kenya. Tobacco farms had low soil fertility (pH; 4.3-5.29, N; 0.04-0.16%, Olsen P; 4.3-7.4 mg/kg, OC; 0.54- 0.21% and exchangeable K^+; 0.3-0.8 cmol/kg) than virgin lands (pH; 5.7-6.5, N; 0.16 - 0.29%, Olsen P; 6.8-9.4 mg/kg, OC; 2.24-3.80% and exchangeable K^+; 0.5-1.6 cmol/kg). Tobacco farms had higher heavy metals concentration (Cu; 1.02-2.1; Pd; 1.01-2.6, Cr; 0.58-1.03, Zn; 0.32-1.02; Mn; 0.33-0.99, Ni; 0.55-1.09; Cu; 1.07-2.31 and Co; 1.02-2.31 µg/g soil) than virgin lands (Cu; 0.05-0.29; Pd; 0.03-0.19, Cr; 0.45-0.95, Zn; 0.29-0.99; Mn; 0.29-0.9, Ni; 0.39-0.9; Cu; 0.35-0.98 and Co; 0.22-0.49 µg/g soil). All tobacco farms had Cd, Pb, Cu and Co contamination while the levels of Zn, Cr, Ni and Mn were below the maximum permissible limits. Therefore, tobacco production leads to soil fertility depletion and heavy metals contamination in soils.

Key Words: Soil, fertility depletion, heavy metal concentrations, tobacco.

INTRODUCTION

Tobacco (*Nicotiana tabacum*) production in Kenya has increased over the years and is mainly cultivated by smallholder farmers (SHF). Between 1972 and 1991, the number of tobacco growing farmers increased by 67%, between 1991 and 2000 by 36% and between 2001 and 2005 by 15% (Kibwage, et al., 2009). In Kenya, about 35,000 SHF are growing the crop on 4500 ha of land with a production of approximately 16,000 tons per year. Increased land acreage under tobacco has led to decrease in the availability of land for production of food crops (such as maize, cassava, millet and sweet potatoes) therefore giving rise to food insecurity in tobacco growing areas (Ministry of Agriculture, 2004). Although cash crop, increased acreage under production by farmers has not improved the livelihoods of the SHF, because the profits are too little to make any significance difference in the lives of the poor farmers compared to the benefit enjoyed by the Tobacco Companies (Kweyuh, 1997). In Kenya, tobacco is cultivated in Migori, Homa Bay, Bungoma, Busia, Kirinyaga, Muranga, Meru and Machakos Counties mainly by SHF. Majority (80%) of its production is carried out in Migori and Homa Bay Counties (Kibwage et al., 2008).

Tobacco cultivation has a lot of impact on the environment such as deforestation, environmental pollution due to use of agrochemicals and soil fertility depletion (Yanda, 2010). The crop is a heavy feeder on soil nutrients and as a result depletes soil nutrient very fast compared to other crops, thereby making such soils unsuitable for healthy plant growth (Trenbath, 1986; Yanda, 2010). Its depletes soil nutrients so much fast such that subsequent food crops do not benefit from the residual fertilizer applications (Geist, 1999). The use of agrochemicals such as insecticides and herbicides is another factor that contributes a lot in the accumulation of heavy metals in the soil (Kibwage et al., 2008). When heavy metals are present in the soil, they have the potential to interfere with the activity of soil organisms, pollutes food crops, water bodies, wildlife and humans (Kutub and Falgunee, 2015). Heavy metals are considered dangerous because of their persistence and toxicity (Adriano, 2001). Soil serves as a medium for heavy metals transportation through sorption, complexation and precipitation reactions (Yong et al., 1992). The study aimed at determining the effect of tobacco cultivation on soil fertility and heavy metals concentrations on selected smallholder farms in Migori County, Kenya.

MATERIALS AND METHODS

Site Description

This study was carried out on selected smallholder farmers' fields in Uriri, Suna East, Kuria West and Suna West sub-counties in Migori County, Kenya. Migori County has a mean rainfall of about 660 - 1200mm per annum with bimodal distribution pattern with long rains from March to June and short rains from September to December. The area of study receives a mean rainfall of 336mm during the long rains and 204mm in the short rains which are considered adequate for crops cultivated by farmers. It has a mean annual temperature of 14 - 22°C (Jaetzold and Schmidt, 1983; Migori Monthly Climate Average, Kenya, 2016). In this county, farmers plant maize mainly during the long rains and tobacco on the same farm during the short rainy periods.

Soil Sampling and Analysis for Fertility Evaluation

Nine sub-soil samples were taken with a soil auger from the top (0–30cm) soil depth in a zig - zag manner from twenty five (25) small scale tobacco farms and adjacent virgin lands in March, 2014. Soils from both tobacco farms and virgin lands were separately and thoroughly mixed and about 1.0 kg composite samples were packed in clean polythene bags, properly labeled and taken to the laboratory for chemical analyses. A total of 25 samples each from both tobacco farms and virgin lands were collected. The samples were air-dried and analyzed for pH, total N (N%), Olsen P, exchangeable potassium (K^+) and organic carbon (OC%) as reported by Okalebo et al. (2002).

Soil Sampling and Analysis for Heavy Metal Concentration

Prior to ploughing in March, 2014, soil samples were collected from both tobacco farms and virgin lands in the same manner at the same time into sterile polypropylene containers from 0-20 cm depth according to the procedure described by ISO10381-6 (2009). The concentration of heavy metals (Cd, Pb, Cu, Co and of Zn, Cr, Ni and Mn) were determined using atomic absorption spectroscopy (Shimadzu model) following the methods described by Akoto et al. (2008).

Statistical Analysis of Data

The generated soil data were subjected to analysis of variance (Two-ways ANOVA) using General Statistics (GenStat, 2010). Means were separated using pooled standard error of difference of means (SED) whenever treatment effects were significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Soil Fertility Status

Results for soil fertility of the study sites are shown on Table 1. Soil pH, N, P and organic carbon were significantly higher ($p \leq 0.05$) on virgin lands compared to tobacco farms. Soil exchangeable potassium (K^+) was higher on virgin land than tobacco farms, however the differences were not significantly different ($p \leq 0.05$). Soils in tobacco cultivated farms were more acidic with pH of 4.3-5.2 than virgin lands with pH of 5.7-6.5. This was probably due to rapid absorption of base cations and release of H^+ ions from their roots leading to soil acidification (Tisdale et al., 1990). Thus, all the tobacco farms had soil pH below the optimum range (5.5-6.5) suitable for the staple food (maize) production as well as other food crops (The Mossaic Company, 2013). Excess H^+ ions found in acid soils such as these are toxic to plant roots, it negatively affect root membrane permeability thus interfering with ion transport and could lead to loss of the previously absorbed cations and organic constituents (Foy, 1984). Majority (72%) of tobacco farms had soil pH ≤ 5.5 and are likely to have high exchangeable Al^{3+} levels that are toxic to plants (Tisdale et al., 1990). Extremely low soil pH under tobacco crop cultivation compared to other soils have been reported in Bangladesh (Kutub and Falgunee, 2015). Therefore it is apparent that tobacco cultivation leads to soil acidification and its related constraints likely to negatively affect crop production.

Both tobacco farms and virgin lands had low soil N, P and OC, since soil N < 0.25%, Olsen P < 10 mg/kg and OC < 4% levels are classified as low (Okalebo et al., 2002). The virgin lands showed higher levels of N, P and OC compared to tobacco farms. About 44% of tobacco farms had low soil K since levels of K^+ ions < 0.5 cmol/kg are considered low (Landon, 1984),while all the virgin lands had adequate K levels. Low soil nutrient levels similar to the current study have been reported in Tanzania (Geist, 1999; Yanda, 2010), since tobacco plants are known to absorb more N, P and K than any other crops. Its high nutrient requirement makes

Table 1. Soil fertility status of selected tobacco growing farm lands and virgin lands.

Sub-County	FN	Soil pH		Total N (%)		Olsen P (mg/kg)		OC (%)		Exchangeable K (cmol/kg)	
		Tobacco Farm	Virgin Land	Tobacco Farm	Virgin Land	Tobacco Farm	Virgin Land	Tobacco Farm	Virgin Land	Tobacco Farm	Virgin Land
Uriri	1	4.50	6.60	0.08	0.16	5.6	8.1	0.85	2.55	0.3	0.5
	2	4.70	6.70	0.12	0.20	6.2	8.7	1.20	2.90	0.4	0.6
	3	5.20	6.90	0.07	0.15	5.8	8.3	1.62	3.32	0.6	0.8
	4	5.00	6.70	0.09	0.17	6.1	8.6	1.51	3.21	0.7	0.9
	5	4.90	6.60	0.13	0.21	4.9	7.4	1.40	3.10	0.3	0.5
	6	5.30	7.00	0.10	0.18	6.7	9.2	1.39	3.09	0.4	0.6
	7	5.60	6.80	0.05	0.13	6.2	8.7	1.88	3.58	0.5	0.7
	8	5.60	6.90	0.15	0.23	5.0	7.5	1.80	3.50	0.6	0.8
Suna East	9	4.30	6.40	0.07	0.15	6.2	8.7	1.16	2.86	0.4	0.6
	10	5.70	6.70	0.16	0.27	6.3	8.8	1.80	3.50	0.4	0.7
	11	5.90	6.40	0.09	0.17	7.4	9.4	1.70	3.40	0.7	1.1
	12	5.70	6.80	0.04	0.12	6.0	8.5	1.69	3.39	0.4	0.6
	13	5.60	6.70	0.10	0.28	5.1	7.6	2.10	3.80	0.6	0.8
Suna West	14	4.80	5.90	0.06	0.14	4.3	6.8	1.12	2.82	0.6	0.8
	15	5.00	6.10	0.05	0.13	6.0	8.5	2.10	3.80	0.5	0.7
	16	5.70	6.80	0.07	0.29	5.5	8.0	1.83	3.53	0.7	0.9
	17	5.30	6.40	0.09	0.17	6.7	9.2	0.74	2.44	0.3	0.5
	18	4.70	5.80	0.06	0.24	5.2	7.7	1.77	3.47	0.4	0.6
	19	5.90	7.00	0.07	0.15	6.3	8.8	2.01	3.71	0.6	1.3
	20	5.00	6.10	0.05	0.13	5.7	8.2	0.81	2.51	0.6	0.8
Kuria West	21	4.60	5.70	0.06	0.14	4.8	7.3	1.08	2.78	0.4	0.6
	22	5.40	6.50	0.05	0.13	4.7	7.2	1.51	3.21	0.8	1.0
	23	5.90	7.00	0.05	0.13	4.7	7.2	1.51	3.21	0.7	1.6
	24	5.50	6.60	0.12	0.20	5.3	7.8	1.63	3.33	0.4	0.6
	25	5.10	6.20	0.09	0.17	6.5	9.0	0.54	2.24	0.3	0.7
Minimum		4.3	5.7	0.04	0.16	4.3	6.8	0.54	2.24	0.3	0.5
Maximum		5.9	7.0	0.16	0.29	7.4	9.4	0.21	3.80	0.8	1.6
Mean		5.2	6.5	0.08	0.18	5.7	8.2	1.47	3.17	0.5	0.8
%CV		22		19		24		25		18	
SED		0.4		0.03		1.5		0.32		0.2	

FN= Farmer number, **OC** = Organic carbon, **CV**= Coefficient of variation and **SED** = Standard error of difference of means.

subsequent food crops not to benefit from its residual fertilizer use (Geist, 1999). Research has revealed that soil degradation is severe in Tanzanian tobacco cultivated areas compared to other crops (Abdallah et al., 2007; Yanda, 2010.

Soil Heavy Metals Status

Table 2 shows data on heavy metal concentrations of the study sites. All tobacco farms had higher heavy metals concentrations than virgin lands. Only the levels of Cd, Pb and Co were significantly higher in tobacco farms compared to virgin lands. All tobacco farms had Cd, Pb, Cu and Co concentrations higher than the acceptable limits since levels of Cd ≥ 0.3, Pb ≥ 0.2, Cu ≥ 1.0 and Co ≥0.5 µg/g are considered above maximum permissible limits (MPL) (WHO, 2004). However, levels of Zn, Cr, Ni and Mn were low since Zn ≤ 1.0, Cr ≤ 1.5, Ni ≤ 1.5 and Mn ≤ 2.0 are within the permissible limits by WHO. The increased heavy metals in the tobacco studied farms beyond the permissible levels could be attributed to the heavy metals contained in the agrochemicals used during tobacco production such as reported in this study (Kibwage et al., 2008). Maobe et al. (2012) detected some metals on the plants sprayed with pesticides. Normally water extractable, exchangeable and organically bound fractions of heavy metals particularly, Cd, Pb and Zn are considered most toxic in soils in terms of the food chain input (Šmejkalová, et al., 2003). These metals may cause contamination of food crops planted after tobacco cultivation,which may lead to health problems in human beings and other animals. A positive correlation between soil and plant heavy metal concentration has been reported in India (Rajesh, et al., 2007). This therefore requires attention because heavy metals above their maximum permissible limits are a threat to environment, plant and animal life. Increased heavy metal concentration negatively affects soil microbial population, which may have direct negative effect on soil fertility. Environmental pressure resulting

Table 2. Soil heavy metal concentrations (µg/g soil) on selected tobacco farm lands and virgin lands.

Sub-County	FN	**Cd**		**Pd**		**Cr**		**Zn**		**Mn**		**Ni**		**Cu**		**Co**	
		TF	VL	TF	VL	TF	VL	TF	VL	TF	VL	TF	VL	TF	VL	TF	VL
Uriri	1	1.19	0.26	1.74	0.12	0.99	0.73	0.55	0.53	0.79	0.66	0.80	0.76	1.70	0.96	1.41	0.36
	2	1.77	0.22	2.21	0.18	0.67	0.54	0.33	0.32	0.66	0.54	0.92	0.64	2.11	0.89	1.77	0.24
	3	1.80	0.25	1.41	0.17	0.86	0.79	0.79	0.78	0.57	0.43	0.83	0.73	1.07	0.74	1.67	0.33
	4	1.71	0.16	2.60	0.03	0.78	0.65	0.97	0.95	0.59	0.45	1.09	0.65	1.89	0.94	2.08	0.45
	5	1.42	0.21	1.39	0.09	0.92	0.86	0.92	0.80	0.69	0.59	0.87	0.69	1.49	0.75	1.29	0.49
	6	1.84	0.29	1.71	0.18	1.03	0.59	1.02	0.99	0.99	0.90	0.67	0.66	1.99	0.92	1.54	0.44
Suna	7	1.25	0.17	1.85	0.11	0.74	0.61	0.77	0.74	0.66	0.61	0.95	0.71	1.20	0.76	1.12	0.31
East	8	1.59	0.14	2.20	0.18	0.72	0.69	0.82	0.81	0.78	0.59	0.85	0.69	1.55	0.81	1.97	0.29
	9	1.48	0.27	1.19	0.15	0.91	0.88	0.76	0.75	0.78	0.78	0.66	0.63	1.53	0.79	1.47	0.48
	10	1.87	0.12	2.20	0.19	0.92	0.79	0.32	0.29	0.61	0.59	0.89	0.88	2.31	0.77	1.66	0.49
	11	1.51	0.24	2.40	0.10	0.58	0.45	0.77	0.76	0.39	0.35	0.89	0.45	1.69	0.95	1.88	0.25
Suna	12	1.90	0.22	1.62	0.08	0.73	0.60	0.92	0.90	0.90	0.60	0.82	0.70	1.69	0.95	1.21	0.30
West	13	1.32	0.23	1.29	0.11	0.82	0.78	0.82	0.79	0.59	0.69	0.77	0.71	1.39	0.65	1.19	0.39
	14	2.10	0.15	1.37	0.13	0.67	0.54	0.39	0.38	0.73	0.54	0.82	0.64	2.21	0.47	2.01	0.24
	15	1.06	0.21	1.67	0.07	0.73	0.60	0.69	0.68	0.69	0.60	0.70	0.70	1.72	0.98	1.04	0.30
	16	1.74	0.19	1.61	0.09	0.93	0.87	0.92	0.89	0.89	0.80	0.57	0.90	1.89	0.97	1.44	0.22
	17	1.33	0.12	1.72	0.19	0.72	0.70	0.78	0.75	0.33	0.29	0.96	0.39	1.61	0.87	2.07	0.29
	18	1.81	0.26	1.70	0.17	0.98	0.95	0.99	0.96	0.72	0.65	0.83	0.75	1.60	0.86	1.26	0.35
Kuria	19	1.71	0.16	1.43	0.05	0.70	0.67	0.82	0.79	0.79	0.57	0.86	0.67	1.30	0.56	1.02	0.27
West	20	1.50	0.05	1.01	0.18	0.81	0.77	0.67	0.65	0.81	0.68	0.67	0.66	1.40	0.66	1.95	0.38
	21	1.40	0.15	1.60	0.07	0.69	0.64	0.98	0.97	0.88	0.56	0.95	0.78	1.50	0.76	1.34	0.26
	22	1.02	0.13	1.42	0.18	0.88	0.85	0.97	0.96	0.45	0.35	0.55	0.45	1.09	0.35	1.08	0.45
	23	1.21	0.14	1.38	0.11	0.91	0.89	0.58	0.57	0.77	0.68	0.91	0.78	2.07	0.73	1.21	0.48
	24	1.74	0.19	2.20	0.18	0.89	0.76	0.78	0.78	0.61	0.56	0.62	0.56	2.12	0.98	2.31	0.46
	25	1.69	0.14	1.58	0.12	0.86	0.83	0.87	0.84	0.60	0.43	0.71	0.83	1.48	0.84	1.14	0.43
Minimum		1.02	0.05	1.01	0.03	0.58	0.45	0.32	0.29	0.33	0.29	0.55	0.39	1.07	0.35	1.02	0.22
Maximum		1.90	0.29	2.60	0.19	1.03	0.95	1.02	0.99	0.99	0.90	1.09	0.90	2.31	0.98	2.31	0.49
Mean		1.57	0.19	1.71	0.13	0.82	0.72	0.76	0.74	0.69	0.58	0.81	0.68	1.67	0.79	1.54	0.36
MPL		0.3		0.2		1.5		1.0		2.0		1.5		1.0		0.5	
% CV		20		27		19		32		25		17		11		23	
SED		0.5		0.61		0.23		0.15		0.12		0.17		0.45		0.22	

TF= Tobacco cultivated farms, **VL**= Virgin land, **FN**= Farm number and **MPL**= Maximum permissible limits, **CV**= Coefficient of variation and **SED** = standard error of difference of means.

from the contamination may reduce the biodiversity of microorganisms and disturb the ecological balance (Šmejkalová et al., 2003).

CONCLUSION

Tobacco cultivation led to soil acidification and depletion of N, P, K and organic carbon since virgin lands had high pH, N, P, K and organic carbon than the cultivated lands. All tobacco farms were contaminated with Cd, Pb, Cu and Co while the levels of Zn, Cr, Ni and Mn were within the acceptable limits set by WHO. Therefore, tobacco cultivation leads to soil fertility depletion and contamination with heavy metals. There is therefore need to trace these heavy metal contaminants in water bodies and food crops grown after tobacco cultivation to ascertain its impact on the environment.

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