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Effect of complying with food safety standards on soil fertility in smallholder french bean farms in Kenya

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Abstract

Compliance with Food Safety Standards (FSS) for production of export vegetables involves the application of manure, agro-chemicals and other inputs which influence soil fertility. A study was conducted in Kirinyaga County, Central Kenya to investigate the effect of compliance with FSS for production of French beans on soil fertility in smallholder farms. The study was done in three different agro-ecological zones; upper (Gichugu), middle (Ndia) and lower (Mwea) zones. A total of 230 farmers were selected of which 76 were compliant, 87 non-compliant and 67 non-French bean growers. Surface soil (0-30cm) was sampled from their farms to assess soil quality; samples were subjected to analysis of selected chemical properties in the laboratory. Chemical analysis results show that soil pH for Gichugu and Ndia is strongly acid (5.35-5.51), while for Mwea it is medium acid (5.83-5.97), but not significantly different among compliance levels. In all three zones and compliance levels, carbon (1.49-1.86%) and total nitrogen (0.16-0.18%) contents were not significantly different. However, Mwea had relatively higher levels of carbon content (1.86%, 1.72% and 1.79% for compliant, non-compliant and non-grower farmers respectively). Phosphorus and potassium contents were medium to high, but not significantly different among zones and compliance levels. Calcium content in the soil was medium whereas magnesium content was high in all the zones and compliance levels. Compliant farms of French beans had higher levels of copper, iron, and manganese in the soil. Therefore, the results show that compliance with FSS had no significant effect on soil fertility within the current farming and management systems. Farmers should increase levels of organic and inorganic fertilizer depending on the levels of nutrients in the soil and intensity of cropping, to increase the amounts of nitrogen and carbon in the soil and therefore, the soil quality.

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Introduction

The horticultural industry (including fresh cut-flowers, fruits and vegetables) is an important source of foreign exchange earnings. Under the vegetable category, French bean is the leading export vegetable and contributor to the rapidly growing and highly successful vegetable export sector in Kenya (HCDA, 2007). However, for small-scale producers horticultural export is becoming increasingly competitive and sophisticated. Consumers require high quality produce and as a result small-scale producers have to comply with Food Safety Standards (FSS) (Jensen, 2004). Global GAP standards are the guidelines that reflect a harmonization of the existing safety, quality, and environmental guidelines of the major European retailers (Global GAP, 2008).

In the adoption of Food Safety Standards (FSS), it is assumed that the conditions of soils will be affected through management. This is because the compliance with FSS is associated with continuous use of certain agro-chemicals and other inputs which change the conditions of soils in the farms. Such inputs include organic and inorganic fertilizers that influence soil quality. Soil quality is the integrated effect of management on most soil properties that determine crop productivity and sustainability (Sharma *et al.*, 2004).Soil quality assessment has been suggested as a tool for evaluating sustainability of soil and crop management practices (Hussain *et al.*, 1999). According to Onduru *et al.* (2008), soil quality is the foundation of successful crop production. Decline in soil physical, chemical and biological properties are an indicator of poor soil quality. Soil quality cannot be measured directly, but is evaluated using indicators which can be physical, chemical or biological characteristics of the soil (Kimigo, 2008).

Indicators are measured to monitor management induced changes in the soil (USDA, 2001). These indicators are related to the soil functions which are in turn related to the soil quality (Doran and Zeiss, 2000). Ideal soil quality indicators integrate soil physical, chemical and biological properties and are accessible to many users and be sensitive to management (Doran *et al.*, 1996). Maintaining soil quality at a desirable level is a very complex issue due to involvement of climatic, soil, plant and human factors and their interactions (Sharma *et al.*, 2004). The objective of the study was to determine difference in soil fertility in French bean growers and non-growers under different farming systems and compliance levels using selected soil chemical properties.

Materials and methods

Study site

Kirinyaga County is an administrative area located at Latitude 0° 36' 01" S and Longitude 37° 17' 17" E. It has an average elevation of 1638 meters above the sea level. The area was chosen since it is one of those that have the largest share of exported horticultural crops in the country. The distribution of rainfall is typically bimodal with two distinct rainy seasons: the first one with its peak in April and the second with a peak in November (Jaetzold *et al.*, 2006). The average annual temperatures are 19-22^{o}c and annual rainfall ranges between 850-1500 mm. The soils found in Kirinyaga County vary with altitude; and Nitisols and Andosols are found in upper and middle zones, while Vertisols are the predominant soils in the lower zone.

Soil sampling and laboratory methods

In order to generate information on soil fertility in compliant and non-compliant farms, soil samples were collected and analysed. A total of 230 farms were sampled, and the farms were mapped with GPS (Table 1). Soil sampling was carried out in selected farms within the County. The area was divided into an upper (Gichugu), middle (Ndia) and a lower zone (Mwea) to reflect the differences in agro-ecology. Within each zone, several farms were selected based on compliance and non-compliance using information from a survey done in the area to categorize farmers in the two groups. There were three groups: compliant farmers with FSS, non-compliant farmers (control for the French beans growing farmers) and non-French beans growers (overall control for compliant and non-compliant farmers).

Selected soil chemical properties (carbon, nitrogen, phosphorus, calcium, magnesium, potassium, sodium and pH) were assessed by comparing their levels in compliant and non-compliant farms.

From each selected farm, disturbed soil samples were taken from six spots. Soil samples were collected to a depth of 0-30 cm at each of the six auger points. Samples from each of the auger points were transferred into a clean bucket and thoroughly mixed to make a composite sample. From this, about 2 kg soil was scoped and placed in a sampling bag. The bags were labeled indicating the date the sample was collected, the depth of sampling and field designation number. During sampling, land use data was collected for the three zones. The samples were transported to the Kenya Agricultural Research Institute (KARI) - National Agricultural Research Laboratories (NARL) – Kabete for analysis.

Soil analysis was done on the following properties as described by Okalebo *et al.* (2002). Soil pH was measured on a 1:2.5 soil suspension, total N was determined by the Kjeldahl method, available soil P was determined by Olsen method, organic carbon was determined by Walkley-Black oxidation method, exchangeable calcium (Ca) and magnesium (Mg) were determined using atomic absorption spectrophotometer while potassium (K) and sodium (Na) were measured using flame photometry.

Data analysis

To assess the effect of compliance with FSS on soil fertility, soil data was analyzed using Gen Stat 13th Edition.

The experimental design used was one-way ANOVA (completely randomized design) and treatment differences were evaluated using least significant difference (LSD) at 5% level of significance.

Results

There was no significant difference ($P<0.05$) for all the soil characteristics examined except for magnesium levels among the compliant, non-compliant and non-growers farms.

Table 1. Number of smallholder farmers in different categories in each agro-ecological zone.

Zones	Compliant	Non-compliant	Non-growers	Total
Upper	21	13	8	42
Middle	32	11	20	63
Lower	23	63	39	125
Total	76	87	67	230

The soils in all the compliance categories were found to be strongly acid. In compliant farms, pH range was (4.60-6.43), while in non-compliant and non-grower farms pH range was (4.55-5.88) and (4.9-5.88) respectively. Available phosphorous was found to be highest (11.1ppm) in compliant farms and lowest (70.2ppm) in non-compliant farms (Table 2).

Table 2. Chemical properties of soil from farms in different farming categories in Gichugu.

Soil characteristics	Compliant	Non-compliant	Non-grower	$Lsd_{5\%}$	P-value
$pH_{(water)}$ (1 : 2.5)	5.38	5.35	5.40	0.351	0.967
Avail. P (ppm)	111.10	70.20	96.60	40.730	0.070
Exc. K (Cmol kg^{-1})	0.71	0.54	0.60	0.324	0.438
Exc. Na (Cmol kg^{-1})	0.56	0.45	0.48	0.193	0.373
Exc. Ca (Cmol kg^{-1})	7.88	8.82	8.45	4.396	0.874
Exc. Mg (Cmol kg^{-1})	4.96	4.77	3.60	0.991	0.028
Total N (%)	0.17	0.17	0.18	0.031	0.772
Organic C (%)	1.72	1.85	1.82	0.297	0.527

Key**:** Exc. = Exchangeable, P= Phosphorous, K= Potassium, Na= Sodium, Ca= Calcium, Mg= Magnesium, N= Nitrogen, C= Carbon, Lsd= Least significant difference at 0.05 probability level, ppm= parts per million, Cmol kg^{-1} = centimoles of charge per kilogram of soil.

Exchangeable potassium was very low to high with complaint farms having the highest (0.71Cmol/kg) exchangeable potassium while non-complaint had the lowest (0.54Cmol/kg). Exchangeable sodium was very low to high with the highest recorded (0.56Cmol/kg) being in complaint farms and lowest (0.45Cmol/kg) in non-complaint. Exchangeable calcium was very low to high with the highest recorded (8.82Cmol/kg) in non-complaint and lowest (7.88Cmol/kg) in complaint farmers. Magnesium levels were medium to very high and were significantly different between complaint farms and non-growers, with complaint farms having the highest magnesium levels (4.96Cmol/kg) and non-growers having the lowest (3.6Cmol/kg). Total nitrogen was low to medium. Non-growers had the highest nitrogen levels (0.18%) while compliant and non-compliant had the lowest (0.17%) nitrogen levels. Organic carbon was low to high. The Organic carbon was highest for non-complaint farms and lowest in complaint farms (Table 2).

There was no significant difference recorded for soil acidity, phosphorous, exchangeable sodium, exchangeable calcium, exchangeable magnesium and organic carbon among complaint, non-complaint and non-growers farmer groups in Ndia. The pH of the soils in Ndia suggested that the soils were strongly acidic. Compliant farms had a range of (4.61-6.96), non-compliant (4.98-5.88) and non-grower (4.96-6.39). Available phosphorus was low to high with non-growers farmers having the highest (98.2ppm) available phosphorous and non-complaint had the lowest (92.4 ppm). Exchangeable sodium was very low to medium while exchangeable calcium varied from low to high. Exchangeable magnesium was medium to very high and organic carbon was very low to medium (Table 3).

Table 3. Chemical properties of soil from different farms in Ndia.

Soil Characteristics	Compliant	Non-compliant	Non-grower	$Lsd_{5\%}$	P-value
$pH_{(water)}$ (1 : 2.5)	5.48	5.43	5.51	0.296	0.880
Avail. P (ppm)	95.00	92.40	98.20	30.680	0.933
Exc. K (Cmol kg^{-1})	0.65	0.40	0.68	0.214	0.041
Exc. Na (Cmol kg^{-1})	0.49	0.37	0.49	0.172	0.363
Exc. Ca (Cmol kg^{-1})	8.64	5.20	8.13	3.067	0.085
Exc. Mg (Cmol kg^{-1})	4.39	4.04	4.57	0.781	0.454
Total N (%)	0.17	0.14	0.16	0.021	0.014
Organic C (%)	1.59	1.49	1.58	0.193	0.568

Key**:** Exc. = Exchangeable, P= Phosphorous, K= Potassium, Na= Sodium, Ca= Calcium, Mg= Magnesium, N= Nitrogen, C= Carbon, Lsd= Least significant difference at 0.05 probability level, ppm= parts per million, Cmol kg^{-1} = centimoles of charge per kilogram of soil.

There were significant differences recorded for total nitrogen and exchangeable potassium for complaint, non-complaint and non-growers farms in Ndia. Total nitrogen was low to medium while potassium levels were very low to high. Complaint farms had the highest calcium, nitrogen and organic carbon of 8.64Cmol kg^{-1}, 0.17% and 1.59% respectively. Non-complaint farms had the lowest pH level, available phosphorous, exchangeable potassium, exchangeable sodium, exchangeable calcium and total nitrogen of 5.43, 92.4ppm, 0.4 Cmol kg^{-1}, 0.37 Cmol kg^{-1}, 5.2 Cmol kg^{-1} and 0.14% respectively. Non-grower farms had the highest Phosphorous level and magnesium level of 98.2ppm and 4.57Cmol kg^{-1} respectively (Table 3).

In Mwea the soils in all the compliance categories were found to be medium acid. In compliant farms, pH range was (5.15-6.50), while in non-compliant and non-grower farms were (4.68-7.65) and (4.90-8.48). Available phosphorous was found to be highest (338ppm) in non-grower farms and lowest (240ppm) in compliant farms. Exchangeable potassium was very low to high with non-complaint farms having the highest (4.60Cmol/kg) while complaint had the lowest (3.80 Cmol/kg). Exchangeable sodium was very low to high with the highest recorded (1.94Cmol/kg) being in non-complaint farms and lowest (1.28Cmol/kg) in complaint. However, exchangeable calcium was very low to high with the highest recorded (20.1Cmol/kg) in non-growers and lowest (17.7Cmol/kg) in complaint and non-compliant farmers. Magnesium levels were medium to very high with complaint farms having the highest magnesium levels (4.96Cmol/kg) and non-growers having the lowest (3.6Cmol/kg).

Total nitrogen was low to medium. Non-growers had the highest nitrogen levels (0.18%) while compliant and non-compliant had the lowest (0.17%) nitrogen levels. Organic carbon was highest for complaint farms and lowest in non-complaint farms (Table 4).

Table 4. Chemical properties of soil from different farms in Mwea.

Soil Characteristics	Compliant	Non-compliant	Non-grower	$Lsd_{5\%}$	P-value
$pH_{(water)}$ (1 : 2.5)	5.87	5.83	5.97	0.283	0.505
Avail. P (ppm)	126.60	92.20	99.20	33.410	0.127
Exc. K (Cmol kg^{-1})	1.73	1.32	1.57	0.425	0.117
Exc. Na (Cmol kg^{-1})	0.57	0.51	0.56	0.213	0.812
Exc. Ca (Cmol kg^{-1})	8.15	7.47	8.37	2.112	0.568
Exc. Mg (Cmol kg^{-1})	5.15	4.64	4.47	0.884	0.361
Total N (%)	0.17	0.16	0.17	0.017	0.400
Organic C (%)	1.86	1.72	1.79	0.216	0.446

Key: Exc. = Exchangeable, P= Phosphorous, K= Potassium, Na= Sodium Ca= Calcium, Mg= Magnesium, N= Nitrogen, C= Carbon, Lsd= Least significant difference at 0.05 probability level, ppm= parts per million, Cmol kg^{-1} = centimoles of charge per kilogram of soil.

In overall, there was no significant difference (P < 0.05) in the soil chemical properties for the compliant, non-compliant and non-French bean growers in Kirinyaga County (Table 5).

Table 5. Overall chemical properties of soil from different farms in Kirinyaga County**.**

Soil Characteristics	Compliant	Non-compliant	Non-grower	$Lsd_{5\%}$	P-value
$pH_{(water)}$ (1 : 2.5)	5.57	5.71	5.76	0.178	0.097
Avail. P (ppm)	109.00	88.90	98.60	19.150	0.104
Exc. K (Cmol kg^{-1})	0.99	1.09	1.19	0.260	0.360
Exc. Na (Cmol kg^{-1})	0.53	0.49	0.53	0.116	0.657
Exc. Ca (Cmol kg^{-1})	8.28	7.38	8.31	1.450	0.336
Exc. Mg (Cmol kg^{-1})	4.78	4.58	4.40	0.502	0.350
Total N (%)	0.17	0.16	0.17	0.011	0.060
Organic C (%)	1.70	1.71	1.73	0.128	0.924

Key: Exc. = Exchangeable, P= Phosphorous, K= Potassium, Na= Sodium, Ca= Calcium, Mg= Magnesium, N= Nitrogen, C= Carbon, Lsd= Least significant difference at 0.05 probability level, ppm= parts per million, Cmol kg^{-1} = centimoles of charge per kilogram of soil.

There was significant difference in Zinc (P<0.05) in the compliant and non-compliant farms. However, there were no significant differences for copper, iron and manganese for complaint, non-complaint and non-growers. The complaint farms had the highest copper, iron and zinc levels of 8.95ppm, 113.2ppm and 25.54Cmol kg^{-1} respectively, while non-growers had the lowest levels of copper and iron with 5.94ppm and 85.89ppm respectively. Non- complaint farms had the lowest levels of manganese and zinc of 1.27Cmol kg^{-1} and 16.1Cmol kg^{-1} respectively (Table 6).

Discussion

Soils in Gichugu and Ndia are strongly acid while in Mwea they are medium acid. In Gichugu, the low soil pH is due to the type of soils found in this area. The soils in this area exhibit the characteristics of nitisols which tend to have low soil pH. This can be attributed to leaching of soluble bases. This finding agrees with the study done by Gachene and Kimaru (2003) who reported that most nitisols are acidic with a pH below 5.5 due to the leaching of soluble bases. The low levels of sodium in non-complaint farms can be attributed to leaching of soluble salts common in Nitisols. This can also be due to the fact that these farmers apply lower amount of lime than the recommended rates or no lime at all.

Phosphorus, calcium and magnesium levels were high especially in compliant farms due to application of both organic and inorganic fertilizers. Compliant farms had highest levels of phosphorus in the three zones owing to the fact that organic fertilizer application for production of French beans is one of the requirements for compliance with FSS. This concurs with a study done by Edmeades (2003), where he found that the use of manures relative to fertilisers can result in soils becoming excessively enriched with some nutrients, particularly P, K, Ca and Mg.

The non-growers had the highest N levels compared to the rest since they practise mixed farming and grow common beans which help in nitrogen fixation. On the other hand, complaint and non-complaint farmers apply lower rates of fertilizer. French beans are heavy consumers of nitrogen, and if the soil nitrogen is not replenished it end up having low levels of the nutrient. This agrees with a study done by Schuler (2004), in which he found that fertilizer application by horticultural farmers is usually below recommended levels of about 40-50 kg Nitrogen/ha. This affects yields and is a threat to soil fertility in the long run.

There was a significant difference in the magnesium levels between complaint and non-growers due to the fact that complaint farmers use lime to correct low soil pH. In Ndia, the levels of calcium were high to very high whereas the levels of magnesium and phosphorus were high. Like in Gichugu, this could have been because of farmers using both organic (manure) and inorganic fertilizers (CAN and DAP). The levels varied due to variations in the amounts of fertilizer used by farmers and also depending on the cropping intensity. Fertilizer and manure application varies in that in some areas there is low application of both fertilizer and manure, while in other areas manure application are in large quantities (Jaetzold *et al.*, 2006).

In all sites, carbon levels were medium due to low organic matter in the soil while phosphorus and potassium levels ranged from medium to high. Mwea had the highest mean for phosphorus and potassium levels probably due to high amounts of DAP, NPK and manure applied and the nature of the parent rock. Calcium levels were medium while magnesium levels were high in all the three zones as a result of continuous use of manure. This could also be due to the characteristic of vertisols soil which has a high Cation Exchange Capacity (CEC) and base saturation percentage (BS). This concurs with Jaetzold *et al.* (2006) in that Mwea farmers make use of fertilizer and manure on the farm so as to maintain the yields over the years. Manure is the most widely used organic fertilizer in the area by approximately 80% of households (Makokha *et al.*, 2001).

The soil chemical properties for the different categories of farmers in the entire Kirinyaga County had no significant difference. This could be attributed to the uneven application of organic and inorganic fertilizer by horticultural farmers to maintain soil fertility (Cheruiyot *et al.,* 2001; Schuler, 2004). In the central highlands of Kenya, soil nutrient depletion is enormous (Mugwe *et al.*, 2002).

Use of inorganic fertilizers to replenish the soil nutrients is one of the major ways of counterbalancing this nutrient depletion but farmers in central Kenya use insufficient amounts of inorganic fertilizers due to their high costs (Woomer and Muchena, 1996).

Compliant farms had higher levels of copper, iron and manganese compared to the non-compliant and non-growers though the differences were quite low. French bean farmers complying with FSS apply foliar sprays to supply micronutrients to the crop. Spraying with trace elements like iron, zinc, copper and manganese which leads to high quality crops and increase yields. Application of foliar feeding is considered useful for introducing trace elements by direct application to leaves. Micronutrients uptake from the soil is low thus, most of the micronutrient needed by the plant is supplied through foliar feeds. This results to micronutrients level in the soil being high.

Conclusion

In summary, the data obtained shows that compliance to FSS has no significant effect on soil fertility within the current farming system. This can be attributed practices of crop rotation, intercropping and application of fertilizer below recommended rates.

It is, therefore, recommended that farmers should be guided to practice clearly defined crop rotations and intercropping for French beans production. Recommended rates of CAN and NPK should be applied for French bean production so as to increase the yields and maintain soil fertility. Farmers should increase levels of organic and inorganic fertilizer depending on the levels of nutrients in the soil and intensity of cropping, to increase the amounts of nitrogen and carbon in the soil and therefore, the soil quality.

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