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Potential of Coffee Grounds as a Sandy Soil Amendment and its Effect on Growth and Fruit Quality of Strawberry

Joyce Nababi[a*], Marius Murongo[b], Samuel Obeng Apori[c], Issa Balde[d] , Joseph Ssemakula[e]

[a,b,d,e]*African Center of Excellence in Agroecology and Livelihood System, Faculty of Agriculture, Uganda Martyrs University, Nkozi, Uganda*

[c]*School of Food Science Environmental Health, Technological University Dublin, Ireland*

[a]*Email: nabjoy@gmail.com,* [a]*Email: mmurongo@umu.ac.ug*

Abstract

Coffee grounds are discarded as solid waste in landfills which makes them an environmental hazard since it contains great quantities of caffeine and tannins. The efficiency of coffee grounds use in sandy soils is still scientifically unsupported and still lacks confirmation on its effect on fruit crops. The study aimed at assessing the potential of Coffee grounds (fresh FCG vs. composted CCG) as a sandy soil amendment and its effect on strawberry growth and fruit quality. The experimental design was a two factorial design conducted in a green house in a Randomized Block Design. Treatment ratios were 3kg of sandy soil as constant mixture with 1kg and 2kg of Coffee Grounds (composted and fresh) and control (Co), replicated 16 times for each treatment. The sandy soil nutrient content (N, P, K, Mg and Ca levels) were significantly high (P-value < 0.05) in CCG (2kg) and FCG (2kg) than in the FCG (1kg), CCG (1kg) and control (Co) at post-harvest analysis. Both CCG treatments produced strawberry plants with highest germination percentage and seed vigour indexat 14 days after planting. FCG treatments inhibited plant growth in the first 2 weeks after planting which improved greatly thereafter with no significant difference with the CCG treatments in plant vegetative growth by week 12. CCG (2kg) produced the best significant value for total number of fruits at 86.33 and fruit weight at 7.907. The FCG (2kg) and CCG (2kg) had the highest titratable acidity, soluble sugars and total soluble solids. CCG (2kg) had the highest mean value at 64.61 of ascorbic acid.This study delivered new understanding that experimental treatment of composted coffee grounds in rates of (2kg) gave significantly better results for strawberry in sandy soils compared to the lower rates of (1kg) and the control treatments.

Keywords: Coffee grounds; fruit quality; sandy soil; soil nutrient.

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* Corresponding author.

1. Introduction

Coffee Grounds are the primary coffee by-product whereby 45% of coffee grounds are generated after brewing coffee powder through hot water using different coffee brewing equipment [1]. Coffee grounds are usually dumped in landfills by incorporating them into municipal wastes which makes them an environmental hazard since coffee grounds contain great quantities of caffeine and tannins [2, 3] Indicated that composting the coffee grounds showed a considerable reduction in the total amounts of tannins and phenolic substances hence reduced emission of methane and nitrous oxide.

As an alternative to coffee grounds disposal as waste, different studies have suggested that coffee grounds may have great potential for agricultural use both by direct addition to soil or by mixing it in composting piles [4, 5]. [6], studied coffee grounds application effect no growth of lettuce, [7], shows its effect on chlorophyll and carotenoid content in lettuce, [8], demonstrates its effect in amending it with clayey soils, [9], determined the caffeine content in edible mushrooms grown in coffee residues, [10], considered coffee grounds as feedstock for vermicomposting for urban soils and [11], studied how it affects sunflower and sorghum when mixed with horse manure. However, the efficiency of adding coffee grounds to sandy soils is still scientifically unsupported for fertilization use and still lacks confirmation for fruit crops.

Sandy soils are associated with low agricultural productivity because of the soil's low nutrient content usually due to nutrient leaching [12] and poor water retention [13]. Therefore, addition of nutrient rich material such as coffee grounds to the sandy soils may highly be a solution to reduce the soils fragility as [14], established that coffee grounds increased water retention in the sandy loam soils from 43.2mm to 53.3mm.

Strawberry (*Fragaria X ananassa* Duch) is a broadly grown horticultural crop cultivated worldwide mostly for its esteemed characteristic red bright colour, flavour, easy adaptableness to different environments [15] and major position in the fruit world market [16, 17], noted that strawberries offer numerous health benefits as shown by the amassing proof on its anti-hypertensive, anti-inflammatory and antioxidant effect. Sandy soils have been observed to support strawberry growth though due to the development speed of strawberry, the plants need to absorb adequate macronutrients which are largely inclined by fertilization [18].

Strawberry production requires cautious attention to many management practices comprising nutrient management [19, 20].

The increased anxiety in protection and management of the environment has motivated the recycling of solid residues from both industrial and agricultural sectors which can significantly improve waste proper disposal. Therefore, understanding the effect of coffee grounds on sandy soil properties, strawberry growth and fruit quality performance is vastly important to increase its applicability in food production. The knowledge from this study shows evidence that coffee grounds can be applied as a sandy soil amendment and its possible effect on strawberry.

2. Materials and methods

The experiment was conducted at Uganda Martyrs University at the Faculty of Agriculture in Nkozi, Mpigi District, in the Central Region of Uganda. The coordinates of this campus are 0°00'13.0"N, 32°00'52.0"E (Latitude: 0.003611; Longitude: 32.014444). The experiment was conducted in the green house at the Faculty of Agriculture.

2.1. Coffee grounds composting

The fresh coffee grounds were composted using the “Bucket Method” as described by [21]. Put in a plastic bucket with drilled holes in it to ensure constant aeration and in an open place with direct sunshine. The lid of the bucket was partially closed and stirred twice daily for 90 days.

2.2. Sandy soil and coffee grounds analysis

The sandy soil samples were randomly collected from the university farm and were for one week air-dried. The samples were then sieved using a 2mm sieve and taken for analysis in the laboratory.

Kjeldahl oxidation method was used to determine the soil Total Nitrogen (N), Flame photometer was used to analyse Potassium (K), exchangeable magnesium (Mg^{2+}) and calcium (Ca^{2+}) was obtained by extraction in 1M NH4OAc solution in atomic absorption spectrophotometer, pH was determined using ionized water with a soil to water ratio of 1:2.5, Available Phosphorus (P) with $Bary^{-1}$ method.

2.3. Experimental design and treatments

The coffee grounds were mixed in the sandy soil and packed in the experimental pots. Sandy soil was collected and packed in the required proportions in black plastic bags of 50mm thick and 5kg capacity.

The chandler strawberry variety seeds were planted in pots by drilling shallow holes in the middle of the pots and placed the strawberry seeds. Covered with soil and then gently firmed to remove air pockets. The pots were at a spacing of 40cm X 30cm and a spacing of 1m between the blocks as recommended by [22].

The experimental design was a 2X2 factorial design conducted in a green house in a Randomized Block Design (RBD). Each treatment was replicated 16 times hence having 16 experimental units for each block making them 80 total populations of experimental plots.

The experiment had five blocks represented as Composted coffee grounds (CCG) ratios 2kg: 3kg sand soil (A1) and (CCG)1kg: 3kg sandy soil (A2), Fresh coffee grounds (FCG) ratio 2kg: 3kg sand soil (B1), (FCG)1kg: 3kg sand soil (B2) and Control (Co) treatment with sandy soil alone 5kg.

All treatments were replicated 4 times making them 16 replicates in each block giving the total experimental units to be 80. All treatments were randomly assigned and the sample size was estimated using the Krejcie and Morgan, (1970).

2.4. Plant parameters

Growth parameters: Total fruit weight (g), Total number of flowers plant^{-1}, Number of Fruits Plant^{-1}, Fruit Size (cm), Total Fruit Yield per plant (g), plant height(cm),Number of Runners Plant^{-1}, (Vigour Index Seedling Length (cm) VI = (MRL + MSL) x PG……equation (*i*) , Where, VI = Vigour index; MRL= Mean root length; MSL= Mean shoot length; PG = Percentage germination).

Fruit quality parameters: Total Soluble Solids (Brix^0) using hand refractro-meter, Titratable sugars (%) using neutralization reaction, Ascorbic Acid (mgml^{-1}) through dye method and Titratable acidity (%) using pH meter.

2.5. Data analysis

The data analysis was done using one-way Analysis of variance (ANOVA) to determine the statistical differences in the parameters using Genstat statistical package. To compare treatment means at P< 0.05, Fisher's Unprotected LSD was used.

3. Results

Table 1: The mean physical-chemical properties of the sandy soil, coffee ground compost and fresh coffee ground used for the experiment.

Parameters	Sandy soil	CCG	FCG
pH	5.9	5.7	5.5
Avai. P (mg Kg^{-1})	11.01	0.49	0.37
K (mg Kg^{-1})	0.13	0.87	0.65
Na (cmol Kg^{-1})	0.3	NA	NA
Ca (cmol Kg^{-1})	3.11	NA	NA
Mg (cmol Kg^{-1})	1.26	NA	NA
TN	0.11	2.45	2.90

NA (not applicable) TN = total nitrogen, Avai. P = available P, Ca= exchangeable calcium, Mg = exchangeable magnesium, K= exchangeable potassium

Table 2: Effect of composted coffee grounds and fresh coffee grounds on soil physical-chemical properties of sandy soil at harvest.

Treatment	pH	TN	Avai. P	K	Mg	Na	Ca
		(%)	($mgkg^{-1}$)	(cmol kg^{-1})			
Control	6.300cd	0.085a	9.12a	0.090a	2.030a	0.200a	2.610a
FCG (2Kg)	5.650a	0.140b	12.40c	0.145b	2.155a	0.300b	3.180b0
FCG(1Kg)	5.800ab	0.160bc	12.70cd	0.150bc	3.06b	0.310bc	3.025b
CCG(2kg)	6.150cd	0.256d	12.85d	0.170bc	3.075b	0.340b	3.885c
CCG(1Kg)	6.300cd	0.165c	11.85d	0.156bc	3.060b	0.320bc	3.810c
P value	*NS*	***	***	*	***	**	**
S.E.D	0.153	0.009	0.113	0.061	0.06	0.014	0.008

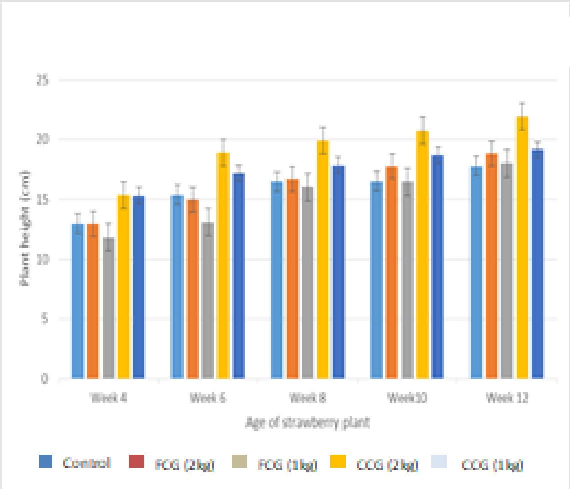
= significant at $P < 0.05$= significant at $P < 0.01$, ***= significant at $P< 0.001$, NS= not significant. Means followed by the same letter in each column are not significantly different at $P \leq 0.0$ 5 using Fisher's unprotected LSD.*

The physical-chemical properties of the CCG, FCG and sandy soil before planting show that the coffee grounds contained higher N, P, K nutrient levels compared to the sandy soil. The coffee grounds and the sandy soils had the required pH levels ranging from 5.9-5.5 (Table 1). The pH levels for all treatments at post-harvestwere not significant ranging from 5.6-6.3.The CCG (2kg) had the highest N, P, K levels followed by the FCG (2kg) treatment. The secondary nutrients included Calcium (Ca) which was highest in the CCG (2kg) and (1kg) treatments at 3.88 and 3.81 respectively, followed by FCG (2kg) treatments at 3.18 and the control treatment at 2.61. Magnesium (Mg) in both CCG (2kg) andCCG (1kg) was at 3.0, FCG (2kg) and FCG (1kg) at 2.1 and control treatment at 2.0 as shown in (Table 2).

Table 3: Effect of composted coffee grounds and fresh coffee grounds on germination and vigor index of strawberry seeds at 14 days after sowing.

Treatment	Germination (%)	shoot length	Root length	Vigor index
Control	61.52a	2.097a	2.067a	173.1a
FCG (2Kg)	55.22a	1.433a	1.567b	163.8a
FCG(1Kg)	60.15ab	2.117a	2.000b	154.3a
CCG(2kg)	95.56c	3.767b	3.433c	372.8c
CCG(1Kg)	85.39b	3.417b	3.067c	294.7b
P value	***	***	**	***
S.E.D	4.92	0.2137	0.1856	22.66

= significant at P < 0.05= significant at P < 0.01, ***= significant at P< 0.01*



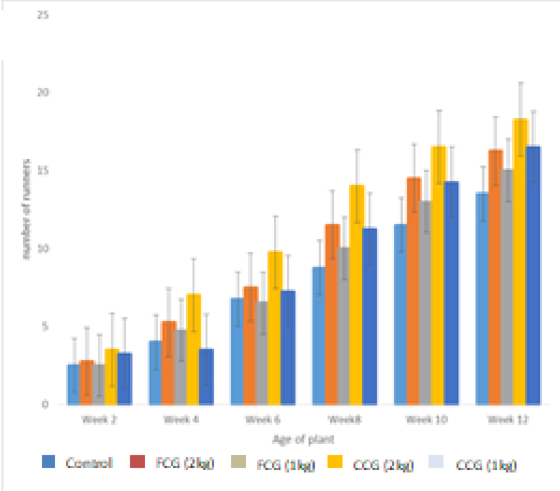


Figure 1: shows the plant height.

Figure 2: Shows number of runners.

Strawberry seeds in the FCG treatment (2kg) and (1kg) rates had the lowest germination percentages at an average rate of 52.6% thus exhibiting slower growth rate compared to the control treatment at 61.2%. The CCG (2kg) treatment impacted a significantly ($P < 0.001$) higher germination percentage, shoot length, root length and vigour index than the rest of the treatments as shown in (Table 3).Plant heights measured during the 4th, 6th 8th, 10th and 12th week of the experiment show significant ($P>0.05$) differences among the treatments as CCG (2kg) recorded the highest plant height than the other treatments.There was increased plant height throughout the growing season with CCG(2kg) having the highest gradual increment at an average of 2cm every 2 weeks followed by the CCG (1kg) at the average of 1cm increase in height (Fig 1). Number of runners measured wasn't significant in week 2 but was highly significant in the consequent weeks (Fig 2).The FCG treatments (1kg) and (2kg) plants exhibited a much slower growth of the strawberry that's the height and also the number of runners for the first 4 weeks of planting and at week six the growth greatly improved.

Table 4: Shows the effect of CCG and FCG treatments on strawberry yield.

Treatment	**Total number of fruit (g)**	**Fruit size (cm)**	**Average Fresh fruit weight (g)**	**Yield/plant (g)**	**Total number of flowers plant $^{-1}$**
Control	56.33a	4.697a	4.713a	332.2a	59.18a
UCCH(2KG)	74.34c	6.91c	6.117b	486.6bc	73.63ab
UCCH(1KG)	66.00b	5.447b	6.017b	456.5b	69.81ab
CCH(2KG)	86.33c	8.083d	7.907c	539.1d	92.18d
CCH(1kg)	77.67c	7.737d	7.293c	509.3cd	81.79cd
P value	***	***	**	***	***
S.E.D	3.85	0.2693	0.403	15.66	4.82

The total yield per plant, fruit diameter and fruit weightin the CCG (2kg) amended sandy soils was significantly higher ($P < 0.05$) than the rest of the treatments. The highest total number of fruits was in the CCG (2kg) was at

86.3g and the CCG (1kg) at 77.6g with no significant difference between the two treatments followed by the FCG (2kg) at 74.3g and FCG (1kg) at 66.09g (Table 4).

Table 5: Qualitative parameters of strawberry fruit as affected by composted coffee grounds and fresh coffee grounds.

Treatment	**Total soluble Solids (Brix)**	**Titratable sugars (%)**	**Ascorbic acid (mg)100^{-1}ml Juice**	**Titratable acidity (%)**
Control	6.705a	4.990a	51.08a	0.6650a
FCG (2Kg)	6.730	5.600b	59.09b	0.5050ab
FCG(1Kg)	6.680	5.450b	59.02b	0.5550b
CCG(2kg)	6.890	5.810b	64.61d	0.5650d
CCG(1Kg)	6.815	5.770b	62.62c	0.5200c
P value	**	**	***	**
S.E.D	0.1545	0.1966	0.1109	0.01265

The control treatment had the lowest Total soluble solids (TSS) at 6.70, Titratable sugars (TS) at 4.99, ascorbic acid 51.08 and Titratable acidity (TA) at 0.665 compared to the rest of the treatments. Titratable sugars (TS) were highest in the CCG (2kg) at 5.81, the CCG (1kg) at 5.71, FCG (2kg) at 5.6 and FCG (1kg) at 5.4. Ascorbic acid content was significant at ($P < 0.05$)with the highest in the CCG (2kg) at 64.6, CCG (1kg) at 6.26 having a slight difference from FCG (2kg) and FCG (1kg) at an average of 59.0.

3.1. Discussion

There was a high statistical significant difference ($P <0.05$) in all the treatments for the total Nitrogen (TN) ranging from 0.08 lowest in control (Co) to the highest 0.25 in CCG(2kg) treatment (Table 2). CCG (2kg) had a significantly higher effect on NPK enrichment in the sandy soils at post-harvest which was supported by [11] who specified that application of organic manure in slightly higher quantities may increase the NPK levels of the soil. The sandy soils were weekly acidic in all treatments with lowest at 5.6 to highest 6.3 which was supported by [23] who stated that the optimum pH range for most agricultural crops is 5.5 to 7.5. The pH levels of weakly acidic soils improve retention of nutrients in the soil [24, 25] mentioned weakly acidic soils increase soil Phosphorus availability.

The dominance of both CCG (2kg) and CCG (1kg) treatments at 14 days after sowing in shoot length, root length, seed vigour index (Table 3) and vigorous vegetative growth in plants in both CCG treatments in plant height (Fig.1) and number of runners (Fig. 2) maybe due to its high (N,P,K) supply in the soil which are highly important in seed germination and providing vigour to plants were readily taken up by the plants compared to the control treatment as shown in (Table 1). The results were in line with [26] who indicated that increased Potassium (K) levels increase cell production and division leading to plant elongation in beans, [27] mentioned that higher (K) resulted in vigorous strawberry growth through increased canopy size.[19] showed higher levels of Nitrogen significantly increased the number of runners in strawberry and [16] cited that Phosphorus and Nitrogen increased photosynthesis in strawberry leaves resulting in optimal plant growth well as [28] reported boosted decomposition of the organic matter and mineralization of nutrients in composted manure leading to improved growth in tomatoes and [29] reported same results in green gram. Growth inhibition observed in the FCG (2kg) and (1kg) treatmentsby the seeds in the first 14 days after planting might have been due to delayed release of nutrients as supported by [30] stated that fresh organic manure may have nitrogen immobilization, [31, 32] showed that Potassium absence reduces the development of plants and [33] indicated results of much slower release of nutrients from fresh manure. Also, FCG are known to have high quantities of toxic compounds like chlorogenic acids, tannins and caffeine [34] which would ultimately reduce growth of plants.

The increased fruit number, fruit weight and yield per plant for the treatments of CCG (2kg) and FCG (2kg) as shownin (Table 4) may be attributed to the uptake of nutrients in the soil which supports plant yield and application of coffee grounds in slightly higher amounts. [35] mentioned that nutrients like Mg provided energy for fruit formation in kiwifruits and [36] revealed that soil nutrients promotedsynthesis of protein which are used in flower induction. [37], noted that Nitrogen promoted fruit bud formation which increases flower development. The results also agree with [30] specified that higher rates of the applied organic fertilizers provided better yields in rice and [38] described increased plant yield of pepper resulting from application of high rate of chicken manure. [39] Indicated that organic manure contains favourable amounts of micro nutrients which can enhance the synthesis of carbohydrates in strawberry which confirms the higher yields in the both the FCG and CCG treatments compared to the control. The results presented that the fruit quality properties of strawberry were significantly different, which resulted into dissimilarities in the nutritional quality of the strawberry fruits. The difference in fruit quality of the FCG (2kg) and CCG (2kg) treatments compared to the control treatment imply that the medium that was used for growing the strawberry induced improved change in the TSS, TA and TS of the strawberry fruits because it contained more nutrients. Comparable results were witnessed by [27] who stated that there was a positive correlation of fruit sugar with Available P accumulation through improved fruit set and [40], indicated that (K) enhanced the photosynthetic efficiency of the plant leaves improving fruit ripening, [35], Mg increased the concentration of sugars and firmness in fruits. [41] Stated that Ca and Na improved the titratable acidity and soluble solids concentration in tomatoes. [42] Showed that the major factor for vitamin C in pepper was Potassium which was highest in the CCG (2kg) (Table 2). [43] Studied carrots indicating that quality attributes such as total sugars and ascorbic acid content significantly increased with the higher level of N substitution.

4. Conclusion

The sandy soils amended with composted coffee grounds CCG (2kg) showed superior effects on strawberry growth, yield and fruit quality. It significantly improved strawberry vegetative growth, fruit per plant and fruit quality. The FCG affected plant development in the early stages of seed germination but later developed fully.

Therefore, composted coffee grounds in rates of 2:3 sandy soils can be used to grow strawberry since there was increased soil fertility in sandy soils and positive effect on the fruits of strawberry. Further studies are needed to understand how coffee grounds affect fruit crops in open fields.

4.1 Limitation

There was lacking information especially about the strawberry cultivation in the tropical areas which made difficult to create comparisons. So this prompted the researcher to physically visit some strawberry farmers in order to get some information.

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