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Effect of aqueous extract of clove basil (*Ocimum gratissimum L.*) and soil amendment with cassava peels compost on nutrients, pesticide residues, yield and antioxidant properties of sweet pepper (*Capsicum annuum L.*)

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Abstract

Natural agricultural inputs in sweet pepper cultivation can be beneficial for nutritional quality, and environmental and food safety. This research assessed the effect of the combined use of clove basil (*Ocimum gratissimum*) aqueous extract and cassava peel compost on the nutrients, pesticide residues, yield and antioxidant properties of sweet pepper fruits. The experiment was a split plot design of 04 blocks with 03 plots each and 03 repetitions, conducted in pots and in the field. The soil was amended with compost at 1kg/4kg and 2kg/3kg in pots, with 3kg/plot and 6kg/plot on field experiment, and 26.3 g of NPK (20.10.10) per plant was used as an inorganic amendment both in pots and field. Plants in both experiments were sprayed with clove basil extract, insecticide lambda-cyhalothrin or water. Sweet pepper fruits cultivated with composts and sprayed with clove basil extract exhibited the highest values of nutritional parameters, antioxidant properties and increased the yield by 93% in pots and 187% on field, as compared with synthetic fertilizer treatments. Organic fruits were free from pesticide residues and had the best values of Na/K and Ca/P ratios which are good indicators of their nutritional values. Sweet pepper plants sprayed with lambda-cyhalothrin or from farmers contained lambda-cyhalothrin at concentration of 0.0199 mg/kg. These results show that organic treatments improved the fruit nutrients, health-promoting properties and safety, and could be used to enhance the nutritional quality of sweet pepper while providing an efficient way of sustainable agriculture.

Keywords: Antioxidant, Organic fertilizer, Clove basil extract, Essential minerals, Malnutrition.

1. Introduction

Malnutrition is the consequence of disease poverty, hunger, war, and natural catastrophe and more than 1 billion people suffered from malnutrition (Cederholm et al., 2019). In Africa, the estimated number of undernourished people increased to 821 million (10.9%) in 2017, up from 784 million (10.6%) in 2015. In 2017 worldwide, malnutrition affected 151 million children (22.2%) and 51 million children under five (7.5%) suffered from wasting (FAO et al., 2020). Micronutrient deficiencies have been identified as major public health problems affecting a large part of the world's population with pregnant women and children under 5 years at the highest risk (Manjeru et al., 2019). On the other hand, many other illnesses are known to be associated with malnutrition, such as stroke, Parkinson’s disease and diseases of the mouth and throat (Wells et al., 2003 and Suominen et al., 2005). One of the main causes of malnutrition is the deficiencies in the minerals calcium, iodine, iron, selenium, zinc, and vitamins such as folate and vitamin A (WHO and UNICEF, 2017 and Galani et al., 2020a). Micronutrients play important roles in human health and can retard growth and cognitive development, impair immunological functioning and increase the risk of non-communicable diseases including skeletal, cardiovascular and metabolic disorders (WHO/FAO 2003, Fairweather-Tait et al., 2011; Galani et al., 2020a). Moreover, It was reported that about half of all anemia is attributable to iron deficiency depending on the geographic and disease environment (Darnton-Hill & Mkparu 2015). One of the principal means to reduce malnutrition could be the increase in food intake and the cultivation of fruits and vegetables that are rich in micro- and macronutrients like tomato, okra, carrot, eggplant, chilli and peppers (Dhaliwal et al., 2017), including sweet pepper.

Sweet pepper (*Capsicum annuum L.*) is a spice plant native to South America, now cultivated in almost every country in the world. In 2016, the global production of sweet pepper reached 34.5 million tonnes, with 1 million tonnes in West Africa (FAOSTAT, 2018). Sweet peppers are generally rich in carotene (precursor of vitamin A) and vitamin C. It also contains high amount of vitamins PP, B1 and B2 as well as mineral elements such as calcium and iron, and therefore, can contribute to control malnutrition and metabolic diseases. Like most tropical crops, peppers are affected by many viral diseases, among them, the green variegation of peppers which is one of the most important, particularly in West Africa (Meghwal et al., 2011). It also faces diseases caused by fungi like Colletotrichum spp and *Phytophthora capsici*; bacteria (*Erwinia carotovora* subsp, *Carotovora* and *Xanthomonas campestris* pv. *vesicatoria*) and pests (aphids, fruit flies and moths) (Dagnoko et al., 2013), which can affect 50 to 100% of plants in fields (FAO, 2018). Besides, its cultivation requires a soil rich in organic matter. In Cameroon, various field surveys have revealed that pepper cultivation is affected with several major constraints such as (i) fruit drop before maturity, due to flies attacks (Ceratitis spp., Bactrocera spp., etc.), (ii) Fusarium attack causing a fungal disease characterized by senescence followed by the sudden death of the whole pepper plant and (iii) a viral disease transmitted by whiteflies (*Bemisia tabaci*) characterized by leaf discolouration leading to severe leaf distortions or an irreversible plant growth retardation. Those constraints are present in all pepper production zones in Cameroon and are also responsible for significant yield losses (Segnou et al., 2013). To solve this problem, farmers around the world and in Africa use mineral fertilizers and synthetic pesticides for pests and diseases control (Savci, 2012, Sharma et al., 2017 and Kumar et al., 2019).

The above solutions have shortcomings such as (1) the accumulation of heavy metals and pesticide residues, environmental pollution (water, soil and atmosphere), (2) the appearance and generalization of resistance mechanisms in pathogens, (3) ecological imbalance since many of these synthetic compounds have a broad spectrum of action, destroying not only harmful agents, but also other useful microorganisms of the ecosystem (4) intoxication of farmers and consumers and (5) problems of postharvest conservation of agricultural products, (Akram, 2008; Brühl et al., 2019; Mancini et al., 2019, Galani et al., 2020b). To avoid the health hazard caused by pesticide residues, regulatory authorities in many countries have established maximum residue limits (MRLs) for various agricultural products. However, the above MRL residue violations often indicate breaches of Good Agricultural Practices but only in very rare circumstances represent cases of health concern. Galani et al., (2020b) reported that all the 11 Cameroonian food items contained pesticide residues, the highest contamination rates (12.8%–5.0%) were found in white pepper, maize, Egusi seeds and groundnuts, while groundnuts, Egusi seeds, maize and soybeans showed the highest residue concentrations (1.46–1.37 mg/kg). It is therefore critical to consider organic farming, with natural inputs, for producing nutritious and safe sweet peppers, while preserving the environment. This will concern the usage and development of biopesticides (Akram, 2008), more specifically the management of diseases using biopesticides such as products derived from plants which are rich in secondary metabolites (Olanya et al., 2006); the use of bio-inputs by revalorizing urban and rural waste through composting since more than 75% of the waste produced in African cities like the city of Yaoundé that is made up of organic materials (Ngnikam & Tanawa, 2006). Moreover, many types of compost suppress soil-borne plant diseases (Nibod et al., 2015). This study aimed to evaluate the effect of the combined use of the aqueous extract of *Ocimum gratissimum* as biopesticide, and cassava peels compost as organic fertilizer, on the nutrient, pesticide residue content, , yield and antioxidant properties of sweet pepper fruits.

2. Materials and methods

2.1 Composts materials

The composts used were produced from cassava peels, in proportions of 50 kg, 70 kg, 90 kg and 110 kg labelled C1, C2, C3 and C4, respectively, at the University of Yaoundé I, Yaoundé, Cameroon after 3 months of composting. For compost preparation, fresh cassava peels were collected from various sources in Yaounde Cameroon, air-dried for one week, and shredded to particles size 0.1-1.5 mm. Composting was carried out at the University of Yaounde I, an area with a hot and humid climate, with average temperature between 20 and 23°C. Composting took place in barrels of 120 litres during 3 months. To prevent excessive heat loss during composting, the barrels were wrapped with plastic tilt. Additional holes were drilled around the barrels to provide improved aeration. To ensure adequate oxygen levels inside the barrels, they were rolled every two weeks. The temperature inside the barrels was monitored weekly for the whole composting period, at 9.am, at a depth of 65 cm inside the piles. The water content of barrels was maintained at 60% of their water holding capacity throughout the 3-months experiment: depending on the level of humidity, water was added when required, and mixed by rolling the barrels. The compost was matured by the end of the 12^{th} week, the temperature dropped and remained unchanged, with the composted material having no peculiar smell. At the end of the composting process, three subsamples were taken randomly from within each barrel, they were bulked and homogenised, air-dried and stored for analysis (Onguene et al., 2021).

The leaves of fresh plants of *O. gratissimum* were collected from the city of Monatele located at the Centre Region of Cameroon, around houses and the identity of the collected specimen was confirmed at the Cameroon National Herbarium in Yaoundé, according to the deposited voucher specimen (No Letouzey 5817/SRF/Cam.-1966). The collected fresh leaves were dried at room temperature (approx. 25 ^{o}C) for three weeks. The dried leaves were powdered using a household blender. To prepare the aqueous extract of *O. gratissimum*, 50 g of the powder was weighed and soaked into 1 l water for 24 hours, then the mixture was filtered, and the supernatant was used as a biopesticide spray on sweet pepper plants.

2.2 Experimental site

The study was carried out from June to September 2020 at Nkolbisson (3˚52'N and 11˚27'E) peri-urban vegetable farming sites, West of Yaoundé. The annual rainfall distribution is bimodal, lighter rains between March and June and a more intense rainy season between September and November, with peak rainfall in May and October. The area has a mean annual rainfall of approximately 1500-2000 mm and a mean annual temperature of 24.7 °C. The relative humidity range between 50 and 80% in the dry season and 70 and 90% in the rainy season. The type of soil is ferritic with a pH of 6.5 (Mfopou et al., 2017 and Ndonkeu et al., 2021).

2.3 Nursery

Sweet pepper seeds of variety Yolo Wonder were bought from an Agroshops of Mokolo market (Yaoundé-Cameroon). The seeds were sown in nursery beds amended with the mixture of cow dung manure at the dose of 250 g/m^2 (Ndonkeu et al., 2021). Seedlings at 45 days with 4 to 5 true fully expended leaves were transplanted in pot and field experiments.

2.4 Pot experiments

The pot experiment was performed at ambient temperature, under net, in plastic pots of 5 litres each, aerated with 5 holes in the bottom, and was laid out in a split plot design, with 4 blocks. Each block had 3 plots (09 pots) with three repetitions. Each plot contained 03 pots with one sweet pepper plant each. The interval of 40 cm was in between plots. The pot experiment contained an overall of 36 pots.

2.4.1. Soil sampling, composts, sand and soil mixing

The soil used for the pot experiment was sampled from the field experiment site at a depth of 0-20 cm in three different areas diagonally (Ndonkeu et al., 2021). All sampled soils were mixed to form a composite soil. The soil characteristics are presented in table 1. The sand used was the Sanaga sand. One and 2kg of composts respectively collected from C1 and C2 were mixed separately with the composite soil and sand in ratios of 4:1 and 3:2 (kg: kg). Then, each mixture was respectively transferred in 09 plastic buckets of 5 L, which overall gave 18 plastic buckets. Then, 26.3 g of NPK (20.10.10) was also mixed with soil and sand in a ratio of 3:2 (kg:kg) and introduced in 09 plastic buckets of 5 L. Finally, a mixture of soil and sand in a ratio of 3:2 (kg:kg) without any amendment (control) was introduced in 09 plastic buckets of 5 L.

Table 1. Physicochemical characteristics of the soil used for plant growth

Parameters	Units	Values
pH	-	6.5±0.5
EC	($\mu S.cm^{-1}$)	76.7±0.74
Organic carbon	(%)	5.53±0.32
Total N	(%)	0.18±1.15
C/N	ratio	30.7±0.9
P	(mg/kg)	58±02
K	(mg/kg)	4.24±0.3
Na	(mg/kg)	1.42±0.1
Mg	(mg.kg)	0.01±0.9
Ca	(mg/kg)	0.03±0.4
Cu	(mg/kg)	720±2.3
Fe	(mg/kg)	83100 ±0.8
Mn	(mg/kg)	520±0.3
Zn	(mg/kg)	10±0.2

Values are means ± standard deviations of 3 repetitions.

2.5 Field experiment

The field experiment was also laid out in a split plot design with 4 blocks. Each block was in triplicate. Each block contained 54 sweet pepper plants, given, 06 sweet pepper plants per plot. Sweet pepper seedlings transplanting was done at an interval of 40 cm in between seedlings and 50 cm between plots, the area of each plot was 240 cm^2. Six holes were dug on each plot of the first and the second block and were respectively amended with 3 Kg and 6 kg of composts collected from C3 and C4. On the other hand, 06 holes were also dug on each plot of the third block and receive an amendment of 26.3 g of NPK (20.10.10) one week before seedlings transplantation and the fourth block remained without any amendment (control).

2.6 Treatments used in pot and field experiments

In total there were 09 treatments, and each of them had three replications (Table 2).

Table 2: Treatments of soil amendment and spraying of sweet pepper plants

	Soil amendment		**Plant spraying**
Treatments	**Pot experiment**	**Field experiment**	**Pot and field experiments**
CP1-B	Compost at 1kg/4kg in a mixture of soil (3kg) + sand (1kg)	Compost at 3kg/plot	5% of aqueous extract of *O. gratissimum*
CP1-E			Water
CP1-S			K-optimal (0.27% Lambda-cyhalothrin)
CP2-B	Compost at 2kg/3kg in a mixture of soil (2kg) + sand (1kg)	Compost at 6kg/plot	5% of aqueous extract of *O. gratissimum*
CP2-E			Water
CP2-S			K-optimal (0.27% Lambda-cyhalothrin)
NPK-B	26.3g of NPK (20.10.10) per plant	26.3g of NPK (20.10.10) per plant	5% of aqueous extract of *O. gratissimum*
NPK-E			Water
NPK-S			K-optimal (0.27% Lambda-cyhalothrin)

Foliar sprays started a week after transplantation and were performed until harvest of fruits, they were made every 14 days for pot experiment, and every 7 days for field experiment, using knapsack sprayer. Spraying was performed in the morning around 8.am, under steady wind condition, and the whole sweet pepper plant (leaves, stems and fruit) was sprayed. All plants undertaken in this study received the regular agricultural and horticultural practices that usually carried out in the vegetable crops such as hilling, hoeing and weeding.

2.7 Sweet pepper harvesting

Sweet peppers were harvested at 58 days after transplanting, when the fruits showed the sign of maturity (mature green). Immediately after harvesting, the fruits were taken to the laboratory, carefully selected to ensure that fruits free of defects such as injured fruits, softening, surface pitting were chosen (Marin, 2004 and Butnariu, 2014).

2.8 Determination of yield

The yield was measured directly in the field by weighing the total freshly harvested fruits per replicate, using a digital scale balance. At the end of the experiment, all weights for each replicate were summed (Abu-Zahra, 2012), and the yield was expressed in $kg.m.^{-2}$

2.9 Analysis of nutritional quality of sweet pepper fruits

After removing seeds and stalk from each fruit, the determination of water content, pH, vitamin C, was directly run after grinding fresh sweet pepper fruits. The flesh was chopped in 5-10 mm pieces. Then, 400 g aliquot from each sample was dehydrated in an oven, at a temperature of 38°C for 14 days until constant weight; next, the samples were kept at 24°C in the dry atmosphere (Butnariu, 2014).

2.10 Proximate analysis.

The determination of water and ash content, Total fibre and protein content, total sugars content, and vitamin C were respectively determined by the method described by (A.O.A.C ,1980), (Kjedhal A.O.A.C, 1980), (A.O.A.C, 1990), the flame atomic absorption spectrophotometry method of Jones and Case (1990) and the titration method of (Katz , 2013).

2.11 Total polyphenol content assessment

Total phenolic content was determined following the method described by (Singleton & Rossi, 1965) with some modifications. Folin-Ciocalteu reagent was used with gallic acid as the standard phenolic compound. About 0.5 mL of an extract of the dry matter of sweet pepper fruits was introduced into test tubes followed by 2.5 mL of 10% Folin-Ciocalteu reagent. The tubes were vigorously homogenized on a shaker and the mixture was allowed to stand for 30 minutes and absorbance read at 765 nm. Total phenol content was expressed as milligram of gallic acid equivalent (GAE) per gram of dry matter extract (mg GAE/g DM).

2.12 Total flavonoid content assessment

The colorimetric method described by (Aiyegoro & Okoh, 2010) with aluminium chloride was used to evaluate the total flavonoid content. To 0.2 mL of aluminium chloride (AlCl3, 10%), was added 0.2 mL aliquot of an extract of the dry matter of sweet pepper fruits followed by the successive addition of 0.2 mL of potassium acetate (CH_3COOK, 1M) and 1.12 mL of distilling water. The whole mixture was well homogenized and incubated at room temperature and the absorbance was read at 415 nm against the reagent blank 30 minutes later. Quercetin (0-1000 µg/mL) served as a standard and the results were expressed as (mg QE/g DM).

2.13 DPPH (2,2-diphenyl-1-picrylhydrazyl)-reducing antioxidant activity

The radical scavenging activity of fruit was assessed using the 2, 2′-diphenyl-1-picrylhydrazyl (DPPH) test as described by Brand-Williams, Cuvelier, and Berset (1995). An extract of the dry matter of sweet pepper fruits (50 µl) was added to 2.95 mL of an ethanolic solution of DPPH (55 µM), kept in the dark for 15 min at room temperature and then the decrease in absorption was measured at 517 nm using a UV–Vis spectrophotometer. Absorption of a blank sample containing 50 µL of ethanol 80% and 2.95 mL of an ethanolic solution of DPPH was measured. The experiment was carried out in triplicate. Ascorbic acid was used as the standard antioxidant. The Radical scavenging ability of the extracts was calculated as:

DPPH radical scavenging activity (%) = $((Abs\ of\ control - Abs\ of\ sample)/Abs\ of\ control) \times 100$

2.14 FRAP (Ferric Reducing Antioxidant Power) assay

The method of (Oyaizu, 1986) was used to assess the reducing power of the sweet pepper fruit extracts. A volume of 1 mL of extract was mixed with 2.5 mL of a 0.2 M sodium phosphate buffer (pH 6.6), 2.5 mL of 1% potassium ferrocyanide and incubated in a water bath at 50 °C for 20 min. Then, 2.5 ml of 10% trichloroacetic acid was added to the mixture that was centrifuged at 650 rpm for 10 min. The supernatant (2.5 mL) was then mixed with 2.5 mL distilled water and 0.5 mL of 0.1% ferric chloride solution. The intensity of the blue-green colour was measured at 700 nm. Ascorbic acid was used as a standard at concentrations ranging from 0 to 0.30 mg/ mL.

2.15 Determination of Total Antioxidant Capacity

Total antioxidant activity of the extract was evaluated by the formation of phosphomolydenum complex (Prieto et al., 1999). To this effect, 0.1 mL solution of extract was added to 1.9 mL of reagent solution (0.6 M H2SO4, 28 mM sodium phosphate and 4 mM ammonium molybdate). The absorbance was measured at 695 nm after boiling for 60 minutes. Ascorbic acid was used as a standard and total antioxidant capacity was expressed as micrograms of ascorbic acid equivalent (AAE) per 100 g of an extract of dry matter (mg AAE/g DM).

2.16 Determination of pesticide residues

Three samples of sweet pepper fruits were taken from each treatment. The equipment used for the harvest of sweet pepper fruits was previously cleaned with water and gloves to avoid any contamination. Samples from each treatment were packaged in aluminum foil and freezer plastic bags, labelled, and transported the same day to the MINADER Laboratory, in a cooler containing small ice plastics. In the laboratory, samples were stored at -21°C in a refrigerator (Mahugija, 2017).

Sample extraction and dispersive solid-phase extraction (d-SPE) sample clean-up were run using the QuEChERS method and analysis by gas chromatography coupled to a detector (Agilent 5975 C TAD VL MSD). Each sample (two fresh sweet pepper fruits per treatment) was cut into a small pieces and ground using respectively a knife and a household grinder. Each time the grinder was thoroughly washed to avoid cross-contamination between samples. After grinding, 15 g of homogenized product was weighed into a clean 50 mL tube and 15 mL of 1% acetic acid in acetonitrile (v/v) was added and an appropriate amount of an internal standard solution. After that, (6.0 g ± 0.3 g) of anhydrous magnesium sulfate and 1.5 g sodium acetate was added into the tubes to remove water in the sample. The content of the tubes was homogenised and vortexed for 1 min. This was followed by the centrifugation at 4000 rpm for 1 min. To remove any organic acids, polar pigments, and other compounds that could interfere with the analysis, 8 mL of the supernatant was collected and introduced into 15 mL d-SPE tube containing 1.2 g of MgSO4 and 0.4 g of primary secondary amines (PSA). Then the tube was vigorously mixed for 30 s, vortexed for a minute before the centrifugation at 400 rpm within 1 minute. Supernatant (01 mL) was introduced into a 1.5 mL chromatography vial for injection on gas chromatography.

The apparatus used was an Agilent Technology 7890A gas chromatograph comprising an automatic injector G4513A, an Agilent 5975 C TAD VL MSD mass detector equipped with three detection axes, and an Agilent J and W GC capillary column of 30 m length, 0.250 mm diameter and a film of 0.25 µm. This equipment was controlled by a microcomputer equipped with The Agilent GC Chemstation Plus version G1701EA E.02.02.1431 software. The injection (1 µl) was carried out in spitless mode and helium was used as carrier gas at 1.2 mL/min (column flow rate). The operating conditions of the GC were as follows: initial temperature of the injector: 150°C; temperature of the detectors: 310°C; the column was initially set at a temperature of 70°C, then increased at a rate of 25°C/min to 280°C and held for 5 min.

2.17. Statistical analysis

All the assays were carried out in triplicate. The results are expressed as mean values and standard error (SE) of the mean. The differences in between treatments were analysed using one-way analysis of variance (ANOVA) followed by Tukey's tests. For all analyses, p-values $P<0.05$ were considered statistically significant. Data were analysed using SPSS version 16 software.

3. Results and discussion

3.1 Fruit yield in pot and field experiments

Figure 1 showed that all the plants cultivated with compost (CP) and respectively sprayed with *O. grastissimum* (B), water (E) and lambda-cyhalothrin (S) (CP1-B, CP1-E, CP1-S, CP2-B, CP2-E and CP2-S) had the maximum fruits yield per m^2 greater than the plants grown with inorganic fertilizer (NPK-B, NPK-E and NPK-S) both in pot and field experiments. The highest fruits yield per m^2 was: pot experiment, 10.6 kg/m^2 and 9.9 kg/m^2 and field experiment, 11.6 kg/m^2 and 9.93 kg/m^2, respectively, in CP2-B and CP1-B plots. The medium fruits yield per m^2 were: pot experiment, 7.2 kg/m^2 and 7.3 kg/m^2 and field experiment,7.9 kg/m^2 and 7.55 kg/m^2, respectively, in CP1-S, CP2-S plots. Also, the lowest fruits yield was produced in NPK-E plots, pot experiment: 3.43 kg/m^2 and field experiment: 3.44 kg/m^2

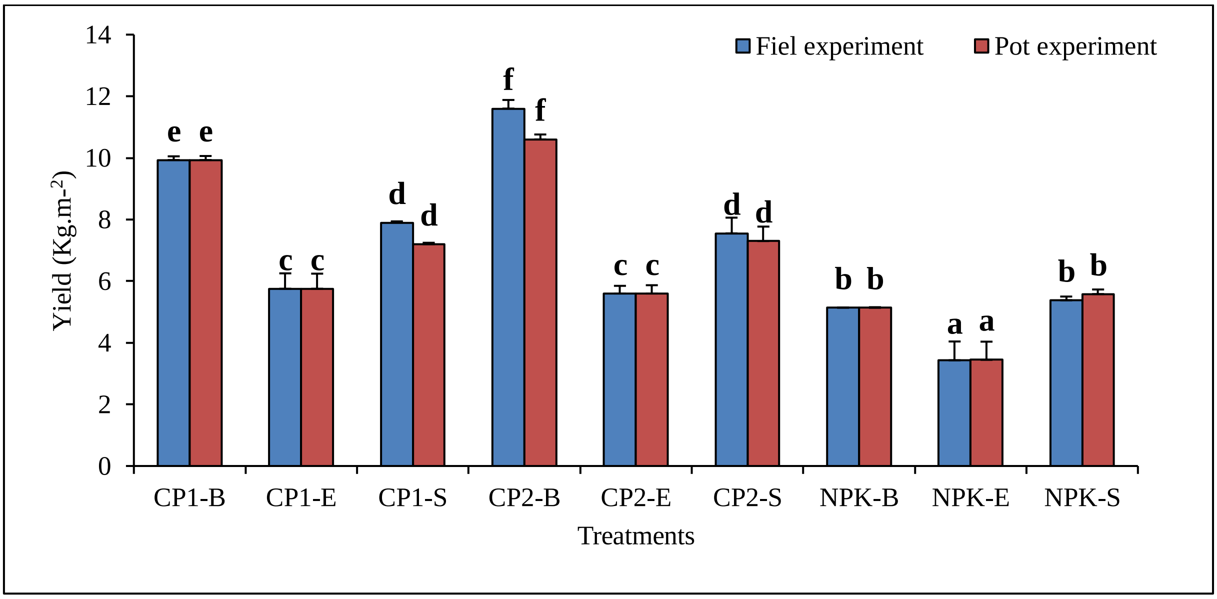

Figure 1 Effects of soil amendment and spray treatments on fruit yield of sweet pepper / Bar charts with the same letter are not significantly different at P<0.05 both in pot and field experiments.

CP1-B, CP1-E and CP1-S: Compost at 1kg/5kg (pot experiment), 3kg/plot (field experiment) + 5% *O. gratissimum* aqueous extract spray **(B)**, water spray **(E)** and lambda-cyhalothrin spray **(S). CP2** represents the double of the quantity of the compost used in **CP1** following the same protocol. **NPK-B, NPK-E and NPK-S:** Soil amended with 26.3g of NPK (20.10.10) per plant (in pot and field experiments) + 5% *O. gratissimum* aqueous extract spray, water spray and lambda-cyhalothrin spray.

Treatments CP1-B and CP2-B all having compost amendment and *O. grastissimum* spray increased the yield, respectively, by 66% and 93%, in pot experiment and by 125% and 187%, in field experiment. These increases could be due to the foliar spraying of clove basil aqueous extract, which might have stimulated the production of ascorbic acid in sweet pepper plants, which in turn improved the physical characteristics of pepper plants. This is in accordance with the results obtained by Wassel et al. 2007, who stated that the increase of fruits yield might be due to the auxinic action of ascorbic acid on enhancing the cell division and elongation, therefore, reflected positively on the leaf area. Also, this effect could be attributed to the increase supply of cassava peels compost of phosphorus and potassium to the soil, which improves the soil fertility. In addition, cassava peels compost has much higher nitrogen and humic acid which stimulate the plant growth therefore, fruit yield increase. Similar results were obtained by El-Bassiony et al., 2010. Its positive effect on plant growth may be due to the presence of Azotobacter and Azospirillum, which produced adequate amounts of Indole-3-acetic acid (IAA) and cytokinin, thus increased the surface area per unit of root length and responsible for root hair branching with an eventual increase in uptake of nutrients from the soil (Jagnow et al., 1991). In 2008, Medina-Lara et al. stated that the higher fruit set from inorganic sweet pepper plants could be explained by the effect on initial stimulation of the flowering process via the inorganic nitrogen release by the application of organic fertilizers, which leads to greater fruits formation as well as fruits yield.

3.2 pH

Data from the Figure 2 illustrates that in pot experiment, all the fruits harvested from the plants cultivated with compost (CP) and respectively sprayed with *O. grastissimum* (B), water (E) and lambda-cyhalothrin (S) had the pH in between 4.32 and 4.54, which was significantly lower than those harvested from the inorganic fertilizer treatments (NPK-B : 5.16, NPK-E: 5.26 and NPK-S: 5.39). The same pattern was also observed in the field experiment.

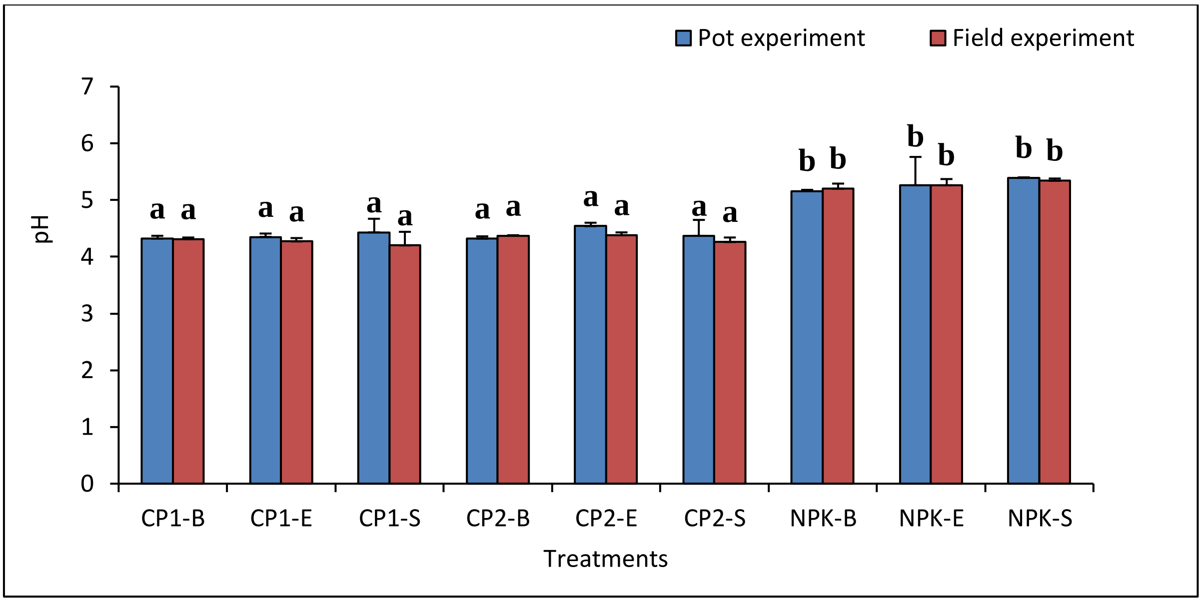

Figure 2: Effects of soil amendment and spray treatments on the pH of sweet peppers fruits. Bar charts with the same letter are not significantly different at $P<0.05$ both in pot and field experiments.

CP1-B, CP1-E and CP1-S: Compost at 1kg/5kg (pot experiment), 3kg/plot (field experiment) + 5% *O. gratissimum* aqueous extract spray **(B)**, water spray **(E)** and lambda-cyhalothrin spray **(S). CP2** represents the double of the quantity of the compost used in **CP1** following the same protocol. **NPK-B, NPK-E and NPK-S:** Soil amended with 26.3g of NPK (20.10.10) per plant (in pot and field experiments) + 5% *O. gratissimum* aqueous extract spray, water spray and lambda-cyhalothrin spray.

pH of fruits harvested from CP1-B, CP1-E, CP1-S, CP2-B, CP2-E and CP2-S (all having compost amendment and respectively sprayed with *O. grastissimum*, water and lambda-cyhalothrin) both in pot and field experiments was around 4.32 lower than the 5.26 recorded from inorganic treatments. This could be due to supply of organic carbon by cassava peels compost that might have been used for the production of organic acids like citric acid, (the primary organic acid found in most fruits) and malic acid, which are responsible for the acidity of fruit (Mitchell., et al 2007). These results are in accordance with the previous workers findings of Wang and Lin (2002) and Aminifard et al., 2013 who argued that organic fertilizers increased the levels of organic acids in pepper fruits. Also, Wang and Lin (2002) showed that fruits with low pH value, grown in organic fertilizers, indicate more citric acid, which is responsible for the low pH and beneficial for human consumption. Moreover, it could be due to the nitrification of ammonium nitrogen (Vasconcelos et al ., 2004).

3.3 Sweet pepper nutrients content

3.3.1 Macronutrients

The percentage of the water content of fruits produced from the soil amended with cassava peels compost and respectively sprayed with *O. grastissimum*, water and lambda-cyhalothrin ,which ranged from 89.03 to 89.33% in pot experiment and 89.23 to 89.28% in field experiment was significantly lower than those harvested from the inorganic fertilizer treatments (NPK-B, NPK-E and NPK-S), which respectively ranged from 94.23-96.97% in pot experiment and 94.88-95.53% in field experiment. Cassava peels compost soil amendment significantly decreased the water content of the fruits compared to the conventional treatment which produced fruits with the highest water content. The former had the percentage of the total lipid ranged in pot experiment from 14.22 to 15.22% and under field from 14.15 to 15.32%, significantly higher than the percentage for the fruits harvested from the inorganic fertilizer treatments, with the highest concentration in fruits from CP1-B and CP2-B plots. The highest concentration of proteins was found in fruits from CP1-B (pot experiment: 0.85 g/100 g and field experiment: 0.88 g/100 g) and CP2-B (pot experiment: 0.97 g/100 g and field experiment: 0.98 g/100 g). The concentration of the total ash, total sugar as well as the percentage of the total fibre from sweet pepper fruits obtained from plots treated with cassava peels compost and respectively sprayed with *O. grastissimum*, water and lambda-cyhalothrin were significantly higher than those observed from inorganic fertilizer treatments both in pot and field experiments (Table 3).

Table 3: Effects of soil amendment and spray treatments on proximate composition of sweet pepper fruits.

			Pot experiment			
T	**Total sugar (mg/100g)**	**Total lipids (%)**	**Crude fibre (%)**	**water content (%)**	**Protein (g/100g)**	**total ash (g/100g)**
CP1-B	5.60±0.01^{a}	14.49±0.02^{b}	14.15±0.02^{a}	89.22±0.19^{b}	0.85±0.01^{b}	0.91±0.06^{a}
CP1-E	5.51±0.01^{a}	14.22±0.07^{b}	14.03±0.01^{a}	89.31±0.13^{b}	0.80±0.01^{b}	0.90±0.05^{a}
CP1-S	5.61±0.01^{a}	14.29±0.04^{b}	14.34±0.04^{a}	89.03±0.06^{b}	0.84±0.01^{b}	0.92±0.01^{a}
CP2-B	5.69±0.01^{a}	15.11±0.08^{a}	14.31±0.06^{a}	89.24±0.10^{b}	0.96±0.01^{a}	0.93±0.02^{a}
CP2-E	5.31±0.01^{a}	15.02±0.05^{a}	14.42±0.05^{a}	89.25±0.05^{b}	0.91±0.05^{a}	0.94±0.13^{a}
CP2-S	5.72±0.02^{a}	15.01±0.01^{a}	14.52±0.01^{a}	89.33±0.01^{b}	0.92±0.003^{a}	0.95±0.23^{a}
NPK-B	4.45±0.01^{b}	13.89±0.05^{c}	13.87±0.05^{b}	95.48±0.06^{a}	0.75±0.01^{c}	0.79±0.04^{b}
NPK-E	4.58±0.04^{b}	13.78±0.08^{c}	13.76±0.49^{b}	94.23±0.02^{a}	0.70±0.01^{c}	0.78±0.01^{b}
NPK-S	4.61±0.04^{b}	13.95±0.06^{c}	13.69±0.60^{b}	96.97±0.02^{a}	0.74±0.03^{c}	0.78±0.21^{b}
			Field experiment			
T	**Total sugar (mg/100g)**	**Total lipids (%)**	**Crude fibre (%)**	**water content (%)**	**Protein (g/100g)**	**total ash (g/100g)**
CP1-B	5.71±0.01^{a}	14.33±0.15^{b}	14.51±0.16^{a}	89.25±0.01^{b}	0.88±0.01^{b}	0.96±0.01^{a}
CP1-E	5.61±0.01^{a}	14.15±0.13^{b}	14.27±0.06^{a}	89.26±0.02^{b}	0.81±0.01^{b}	0.95±0.01^{a}
CP1-S	5.68±0.005^{a}	14.21 ±0.01^{b}	14.46±0.11^{a}	89.28±0.06^{b}	0.83±0.01^{b}	0.94±0.01^{a}
CP2-B	5.71±0.01^{a}	15.32±0.01^{a}	14.64±0.04^{a}	89.23±0.20^{b}	0.98±0.005^{a}	0.95±0.01^{a}
CP2-E	5.70±0.005^{a}	15.11±0.02^{a}	14.12±0.01^{a}	89.35±0.38^{b}	0.92±0.01^{a}	0.93±0.01^{a}
CP2-S	5.70±0.005^{a}	15.23±0.15^{a}	14.30±0.01^{a}	89.27±0.04^{b}	0.94±0.01^{a}	0.96±0.01^{a}

NPK-B	4.81±0.78ᵇ	13.58±0.01ᶜ	13.11±0.01ᵇ	94.80±0.32ᵃ	0.76±0.005ᶜ	0.78±0.09ᵇ
NPK-E	4.38±0.01ᵇ	13.38±0.20ᶜ	13.31±0.01ᵇ	95.53±0.14ᵃ	0.74±0.01ᶜ	0.72±0.15ᵇ
NPK-S	4.63±0.04ᵇ	13.58±0.005ᶜ	13.41±0.01ᵇ	94.88±0.02ᵃ	0.77±0.005ᶜ	0.75±0.01ᵇ

Means±SD followed by the same letter in a column are not significantly different at P<0.05

CP1-B, CP1-E and CP1-S: Compost at 1kg/5kg (pot experiment), 3kg/plot (field experiment) + 5% *O. gratissimum* aqueous extract spray **(B)**, water spray **(E)** and lambda-cyhalothrin spray **(S). CP2** represents the double of the quantity of the compost used in **CP1** following the same protocol. **NPK-B, NPK-E and NPK-S:** Soil amended with 26.3g of NPK (20.10.10) per plant (in pot and field experiments) + 5% *O. gratissimum* aqueous extract spray, water spray and lambda-cyhalothrin spray.

All the plants cultivated with compost (CP) and respectively sprayed with *O. grastissimum* (B), water (E) and lambda-cyhalothrin (S) had the lowest fruits water content, a constituent of food, which affects food safety, stability, quality and physical properties. A mean water content of 89% recorded was significantly lower than the 96% obtained from inorganic treatments. These results are in accordance with Abu-zahra et al., 2012, who stated that the application of organic fertilizers decreases the water content of the sweet pepper fruits, which reflected in increasing fruit dry matter, compared to the conventional treatment which produced the highest water content. Besides, the low levels of water contents in those sweet pepper fruits could be attributed to their richness in fibrous which is slightly woody (Ekwere et al., 2016).

The fruits from plots treated with cassava peels composts and respectively sprayed with *O. grastissimum*, water and lambda-cyhalothrin had the highest concentration in terms of protein. The increase of the protein content might be the result of compost application which promoted plant growth by increasing nitrogen availability, which role is to promote protein synthesis and increasing the meristematic activity. This is in line with (Kanwar & Paliy*al*, 2002) and Mohammed et al., 2016, who demonstrated that the application of compost led to the increase protein content of sweet pepper fruits. Also, the increase in protein content could be attributed to the increase in the number of leaves would have increased photosynthetic surfaces and the current photosynthates produced would have enhanced the physiological activities leading to the production of more assimilates used to significantly increased protein content (Alabi et al., 2006). Moreover, Alabi et al., 2006 have also reported that the increase in protein content in pepper fruits lea to an increase of nitrogen fertilizers.

The increase in total ash content of the sweet pepper fruits harvested from plots amended with composts and sprayed with *O. grastissimum*, water and lambda-cyhalothrin could be due to the application of cassava peels compost that released organic and inorganic minerals in the soil (Ihemeje et al., 2013 and Akinyem et al., 2018).This is in accordance with the result obtained by Guilherme et al., 2020 who reported that the ash content of the sweet pepper fruits obtained from the organic agriculture was found significantly greater that those obtained from the conventional agriculture.

The increase in total sugar content observed from of the sweet pepper fruits harvested from the plants grown with cassava peels compost and sprayed with *O. gratissimum* might be due to the increase of the microorganisms in the soil that had a positive effect in converting the unavailable forms of nutrient elements to available forms. Those microorganisms produced growth-promoting substances resulting in more efficient absorption of nutrients, which are main components of photosynthetic pigments and consequently the carbohydrate (Gomaa & Abou-Aly, 2001 and Mohammed et al., 2013). These results are in accordance with those obtained by Mohammad et al., 2013 and Copetta, et al. 2011 who reported that compost application improved carbohydrate content. The foliar application of *O. gratissimum* aqueous extract may have induced the production of secondary metabolites (phenolic and terpenoid compounds) in fruits to protect them against biotic and abiotic stresses and increased their organoleptic properties , such as sweetness, which is that of the total sugars content (Pott et al., 2019 and 2020).

The high fibre content obtained from the organic sweet pepper fruits could be due to its greater organic or inorganic minerals content (Ihemeje et al., 2013 and Akinyem et al., 2018), which makes them essential for little children, pregnant women and nursing mothers (Ihemeje et al., 2013). Minerals enhance the important functions of maintaining acid-base balance and proper osmotic pressure in the body (Ihemeje et al., 2013). Minerals are also required for normal functioning of the nerves and also muscular contraction and relaxation. Hence sweet pepper fruits could be a fair and cheap source of these essential minerals. (Ihemeje et al., 2013)

3.3.2 Micronutrients

3.3.2.1 Vitamin C

The highest concentrations in vitamin C were recorded in fruits harvested from of CP1-B plot (pot experiment: 110.18 mg/100g and field experiment: 114.94 mg/100g) and CP2-B plot (pot experiment: 111.21 mg/100g and field experiment: 115.83 mg/100g), compared with those obtained from the other treatments. they were followed by fruits obtained from plants treated with CP1-E (pot experiment :100.60 mg/100g and field experiment:100.23 mg/100g) , CP1-S(pot experiment: 100.44mg/100g and field experiment: 1103.66 mg/100g), CP2-E (pot experiment :101.86 mg/100g and field experiment: 100.23mg/100g) and CP2-S (pot experiment: 104.99mg/100g and field experiment: 10.3.66 mg/100g), (Figure 3).

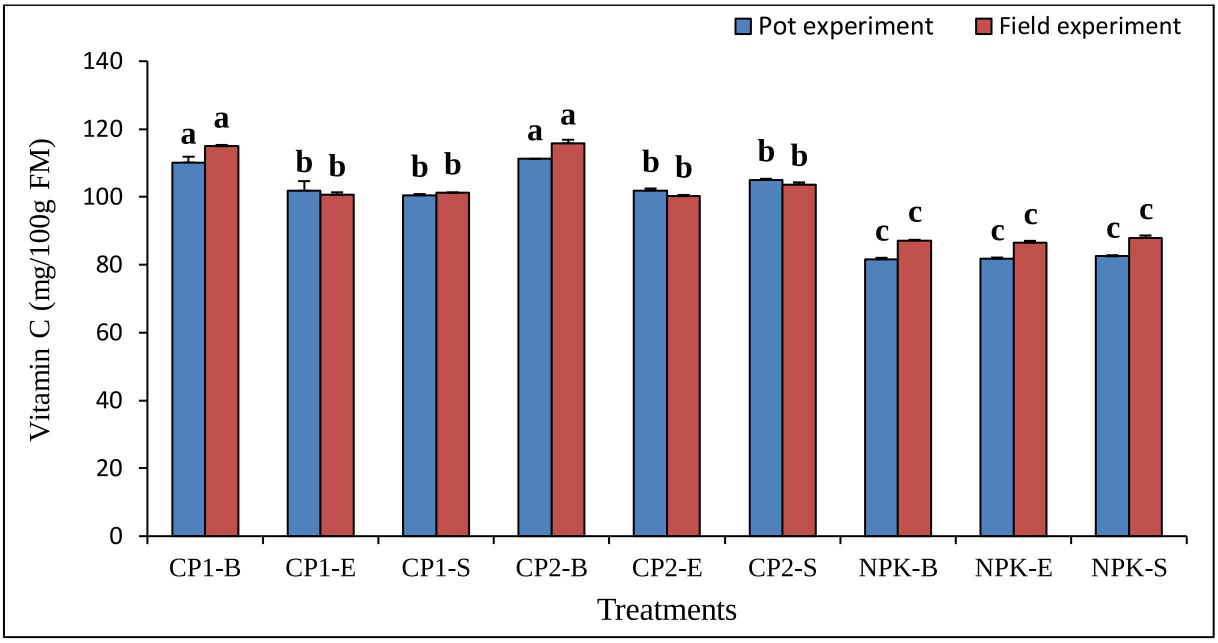

Figure 3: Effects of soil amendment and spray treatments on the concentration of vitamin C. Bar charts with the same letter are not significantly different at P<0.05 both in pot and field experiments.

CP1-B, CP1-E and CP1-S: Compost at 1kg/5kg (pot experiment), 3kg/plot (field experiment) + 5% *O. gratissimum* aqueous extract spray **(B)**, water spray **(E)** and lambda-cyhalothrin spray **(S). CP2** represents the double of the quantity of the compost used in **CP1** following the same protocol. **NPK-B, NPK-E and NPK-S:** Soil amended with 26.3g of NPK (20.10.10) per plant (in pot and field experiments) + 5% *O. gratissimum* aqueous extract spray, water spray and lambda-cyhalothrin spray.

The high significant concentration of vitamin C (105.6mg/100g of FM), found in fruits harvested from the plants grew with compost (CP) and respectively sprayed with *O. grastissimum* (B), water (E) and lambda-cyhalothrin (S) both in pot and field experiments was in accordance with the findings of Taiwo, et al., 2007, who reported that compost application improved vitamin C content of fruits. They are also in agreement with the work reported by Abu-Zahra, 2014 and Shahein et al., 2015, who obtained the highest amount of vitamin C from plots amended with the sheep manure and the lowest amount from the conventional agriculture. The increase in vitamin C observed could be due to the high amount of potassium contained in cassava peels, which play a great role in plant metabolism and many important regulatory processes in the plant (El-Bassiony et al., 2014). Vitamin C has antioxidant properties and so have the potentials to reduce the risk of cardiovascular diseases, hypertension, chronic inflammatory diseases, diabetes and some forms of cancer (Ayodele et al., 2015). Besides, sweet pepper fruits have exceptionally high vitamin C content, the major water-soluble antioxidant in plant cells, which plays a major role in protecting cells against free radicals and oxidative damage (Wang et al., 2003). Plants and most animal species synthesize their own vitamin C, but humans cannot, although they require 60-100 mg a day of this vitamin and, therefore, it must be obtained from the diet (Pascual., et al., 2010). The role of Ascorbic acid (ASC) in the human diet is thought to be significant in preventing common degenerative conditions (Pascual., et al., 2010). Because the bioavailability of ASC in fruits and vegetables is equal to the availability of synthetic L-ascorbic acid, plant sources of vitamin C are considered to be more beneficial to human health because they provide other essential nutrients and phytochemicals. (Pascual., et al., 2010).

3.3.2.2 Minerals content

The concentrations of Ca, Mg, K, Na, Zn and Mn were significantly higher in sweet pepper fruits harvested from the treatments CP1-B, CP1-E, CP1-S, CP2-B, CP2-E and CP2-S (plants cultivated with compost (CP) and respectively sprayed with *O. grastissimum* (B), water (E) and lambda-cyhalothrin (S)) than those obtained from fruits harvested from inorganic fertilizer treatments both in pot and field experiments. The concentrations in fruits from the former treatments in P and Cu were significantly lower (Table 4). The Na/k ratios of the fruits obtained from plants cultivated with compost, and respectively sprayed with *O. grastissimum*, water and lambda-cyhalothrin were significantly lower than the fruits harvested from inorganic fertilizer treatments, while their Na/k ratios, ranged, respectively, from 0.72 to 0.83 in pot experiment and 0.69 to 0.72 under field experiment. On the contrary, they had the highest Ca/P ratios which varied, respectively, from 2.46 to 2.49 in pot experiment and 2.31 to 2.45 in field experiment (Table 4).

Table 4: Effects of soil amendment and spray treatments on the minerals content of sweet pepper fruits

	Pot experiment : (mg/100g of DM)									
T	**Ca**	**P**	**Mg**	**K**	**Na**	**Cu**	**Zn**	**Mn**	**Na/K**	**Ca/P**
CP1-B	87,5±0,02^{a}	35.12±0.02^{b}	15.77±0.001^{a}	277.38±16.44^{a}	201,84±2,04^{a}	47.7±0.90^{b}	388.01±0.04^{a}	230.94±0.37^{a}	0.72±0.02^{b}	2.49±30.2^{a}
CP1-E	86,5±0,02^{a}	35.08±0.07^{b}	15.76±0.001^{a}	268.27±0.06^{a}	203.61±5.84^{a}	48.2±0.50^{b}	387.09±0.23^{a}	228.76 ± 0,38^{a}	0.75±0.04^{b}	2.46±45.1^{a}
CP1-S	87,4±0,31^{a}	35.23±0.002^{b}	15.69±0.001^{a}	259.10±0.70^{a}	200.98±0.57^{a}	48.7±0.1^{b}	389.33±2.08^{a}	229.68±0.18^{a}	0.77±0.05^{b}	2.48±50.7^{a}
CP2-B	87,9±0,04^{a}	35.26±0.001^{b}	15.54±0.02^{a}	271.96±12.58^{a}	207.96±1.49^{a}	49.5±0.60^{b}	398.02±0.89^{a}	230.48±0.09^{a}	0.76±0.03^{b}	2.52 ±65.4^{a}
CP2-E	87,4±0,03^{a}	35.30±0.002 ^{b}	15.71±0.002^{a}	244.89±12.85^{a}	203.60±3.50^{a}	49.5±0.55^{b}	387.12±0.32^{a}	231.54±0.04^{a}	0.83±0.07^{b}	2.47±0.58^{a}
CP2-S	87,5±0,05^{a}	35.31±0.05^{b}	15.72±0.001^{a}	258.96±1.30^{a}	206.51±1.58^{a}	49.1±0.52^{b}	384.10±0.43^{a}	232.5±0.01^{a}	0.79±0.04^{b}	2.47±45.^{9a}
NPK-B	78.4±5,32^{b}	40.65±0.60^{a}	11.84±0.002^{b}	116.04±0.71^{b}	192.52±6.49^{b}	57.7±0.20^{a}	185.15±0.54^{b}	199.97±0.16^{b}	1.65±0.15^{a}	1.92±0.18^{b}
NPK-E	78,9±5,43^{b}	39.9±0.005^{a}	11.78±0.002^{b}	115.56±0.25^{b}	198.50±1.16^{b}	57.7±0.32^{a}	190.11±3.60^{b}	198.56±0.02^{b}	1.71±0.63^{a}	1.97±0.48^{b}
NPK-S	79,6±0,19^{b}	40.1±0.18^{a}	11.85±0.007^{b}	116.53±1.02^{b}	195.27±5.24^{b}	57.4±2.25^{a}	190.02±2.24^{b}	199.19±0.12^{b}	1.67±0.9^{a}	1.98±0.56^{b}
	Field experiment : (mg/100g of DM)									
	Ca	**P**	**Mg**	**K**	**Na**	**Cu**	**Zn**	**Mn**	**Na/k**	**Ca/p**
CP1-B	82.53±0.02^{a}	34.6±0.43^{b}	14.2±0.1^{a}	272.9±2.34^{a}	195.9±5.77^{a}	43.2±0.76^{a}	231.1±0.01^{a}	215.3±0.24^{a}	0.71±0.01^{b}	2.38±45.8^{a}
CP1-E	80.20±4.03^{a}	34.6±0.10^{b}	14.0±0.04^{a}	270.7±0.39^{a}	195.1±5.54^{a}	42.5±0.52^{a}	248.1±34.74^{a}	211.5±1.57^{a}	0.72±0.02^{b}	2.31±40.9^{a}
CP1-S	80.36±0.31^{a}	34.1±0.10^{b}	14.4±0.1^{a}	260.1±11.8^{a}	188.3±1.02^{a}	43.2±0.04^{a}	228.2±0.10^{a}	215.1±0.15^{a}	0.72±0.05^{b}	2.35±36.7^{a}
CP2-B	84.62±0.62^{a}	34.6±0.41^{b}	14.7±0.01^{a}	282.8±4.66^{a}	199.3±0.15^{a}	45.36±0.22^{a}	230.6±0.50^{a}	217.7±2.54^{a}	0.70±0.06^{b}	2.44±35.7^{a}
CP2-E	84.48±0.03^{a}	34.4±0.40^{b}	14.6±0.15^{a}	272±0.99^{a}	188±0.79^{a}	43.8±1.18^{a}	230.4±0.66^{a}	219.6±1.39^{a}	0.69±0.6^{b}	2.45±40.9^{a}
CP2-S	84.54±0.05^{a}	34.5±0.15^{b}	14.5±0.15^{a}	271.9±1.50^{a}	189.5±0.07^{a}	46.6±2.85^{a}	230.2±0.27^{a}	216.5±0.55^{a}	0.69±0.8^{b}	2.43±0.57^{a}
NPK-B	79.13±0.65^{b}	42.6±0.55^{a}	12.1±1.26^{b}	100.2±1.07^{b}	159.2±1.17^{b}	49.8±4.99^{b}	198.2±0.27^{b}	191.05±3.87^{b}	1.58±0.7^{a}	1.85±0.02^{b}
NPK-E	79.40±0.52^{b}	41.9±0.17^{a}	12.6±0.05^{b}	132.1±5.11^{b}	161.7±0.37^{b}	51.2±0.84^{b}	197.5±0.31^{b}	191.3±7.39^{b}	1.22±0.25^{a}	1.89±0.014^{b}
NPK-S	79.31±0.45^{b}	43.13±0.09^{a}	11.5±0.41^{b}	123.9±4.47^{b}	157.9±0.34^{b}	50.1±0.11^{b}	193.1±11.20^{b}	191.9±6.26^{b}	1.27±0.30^{a}	1.83±0.013^{b}

Means±SD followed by the same letter in a column are not significantly different at $P<0.05$

CP1-B, CP1-E and CP1-S: Compost at 1kg/5kg (pot experiment), 3kg/plot (field experiment) + 5% *O. gratissimum* aqueous extract spray **(B)**, water spray **(E)** and lambda-cyhalothrin spray **(S)**. **CP2** represents the double of the quantity of the compost used in **CP1** following the same protocol. **NPK-B, NPK-E and NPK-S:** Soil amended with 26.3g of NPK (20.10.10) per plant (in pot and field experiments) + 5% *O. gratissimum* aqueous extract spray, water spray and lambda-cyhalothrin spray.

The significant high concentrations of Ca, Mg, K, Mn, Zn and Na, recorded in the sweet pepper fruits harvested from the fruits obtained from plants cultivated with compost and respectively sprayed with *O. grastissimum*, water and lambda-cyhalothrin both in pot and field experiments may be attributed to the quick availability of Ca, Mg, K, Mn, Zn and Na elements and the slow release of minerals by cassava peels compost during the crop growing cycle. According to Suge et al., 2011, the high concentration in minerals could be due to the fact that organic matter improved the minerals cycling and availability to the plants especially, N and P, which improved root development and subsequently vegetative growth. Similar results were reported by Abul-Soud et al., 2014; Elsadig et al., 2017 and Omar et al., 2018. Moreover, that difference might be due to the presence of nitrogen and potassium in the cassava peels compost, which may have increased the amount of Ca, Mg, K, Mn, Zn and Na in the sweet pepper fruits. This is in accordance with the findings of (Heidari & Mohammad, 2012) and Elsadig et al., 2017, who reported that by increasing nitrogen levels, the values of microelements content increased in fruits. In addition, the higher concentration of Ca, Mg, K and Na in organic sweet pepper fruits may be due to the cassava peels manure application, which could enhance soil fertility, resulting in increasing minerals availability and their uptake by plants (Ofosu-Anim et al., 2006). Furthermore, the application of cassava peels compost might provide supplemental exchangeable cations such as potassium, calcium, magnesium and ammonium, mainly due to organic manure mineralization and release of these basic cations into the soils (Al-Kahtani et al., 2012).

It is interesting to note that the Na/K ratio for all the fruits obtained from organic sweet pepper plants in this study was less than 1. This suggests that they are suitable as condiments in the preparation of diets for hypertensive patients. In addition, their Ca/P ratios were above 1 therefore could be considered good for the formation and development of bone or the calcification during skeletal formation (Aremu et al., 2011, Sobowale et al., 2011 and Ogunlade et al., 2012). Similar results were also obtained by Houndji et al., 2018. Therefore, the values of the Na/K and Ca/P ratios of this research confirmed that organic sweet pepper fruits could be useful to fight against cardiovascular diseases by promoting cardiovascular functioning and health and play an important role in the mechanism of calcification and skeletal integrity.

The high increase of the heavy metals (Cu, Zn and Mn) in fruits harvested from plants treated with compost and respectively sprayed with *O. grastissimum*, water and lambda-cyhalothrin compared to plants grew with inorganic fertilizer treatments might be due to the presence of those elements in the composts. But the concentration of those heavy metals was below the authorized critical limits of Value (USDA, 2016) that could affect the health. Therefore, it could be concluded that the application of cassava peels compost for the culture of sweet pepper has no risks of heavy metals toxicity.

3.3.2.3 Total polyphenols and flavonoids content of sweet pepper fruits

The highest total polyphenols content was recorded in sweet pepper fruits harvested from CP2-B plot (pot experiment: 39.81mg/100g and field experiment: .42.72mg/100g), CP1-B (pot experiment: 33.35mg/100g and field experiment: 37.83 mg/100g). The lowest total polyphenol content was obtained from fruit harvested from the treatments NPK-B (pot experiment: 29.84mg/100g and field experiment: 29.99 mg/100g), NPK-E (pot experiment: 27.05 mg/100g and field: 27.89mg/100g) and NPK-S (pot experiment: 28.98mg/100g and field experiment: 30.17mg/100g). The highest concentration in total flavonoids was recorded from CP1-B (pot experiment : 110.3 mg/100g and field experiment: 125.4 mg/100g) and CP2-B (pot experiment: 113.1mg/100g and field experiment: 133.4 mg/100g) and the lowest concentration was observed in fruits harvested from NPK-B (pot experiment: 95.3 mg/100g and field experiment: 98.5mg/100g), NPK-E (pot experiment: 90.7 mg/100g and field experiment: 95.6 mg/100g) and NPK-S pot experiment :95.9 mg/100g and field experiment: 98.8 mg/100g), (Figure 4**).**

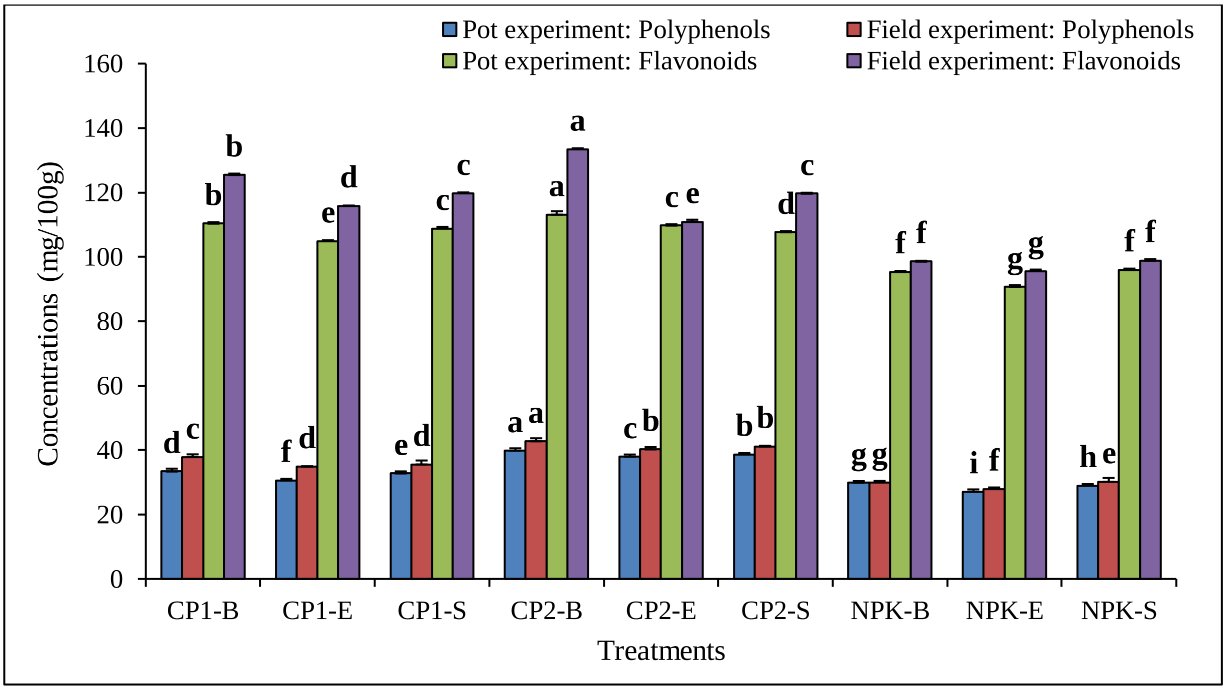

Figure 4: Effects of soil amendment and spray treatments on the total polyphenol and flavonoid content of sweet pepper fruits. Bar charts with the same letter are not significantly different at P<0.05 both in pot and field experiments.

CP1-B, CP1-E and CP1-S: Compost at 1kg/5kg (pot experiment), 3kg/plot (field experiment) + 5% *O. gratissimum* aqueous extract spray **(B)**, water spray **(E)** and lambda-cyhalothrin spray **(S). CP2** represents the double of the quantity of the compost used in **CP1** following the same protocol. **NPK-B, NPK-E and NPK-S:** Soil amended with 26.3g of NPK (20.10.10) per plant (in pot and field experiments) + 5% *O. gratissimum* aqueous extract spray, water spray and lambda-cyhalothrin spray.

The result indicated that total polyphenols and flavonoids content increased with compost soil amendment and plants spray with *O. grastissimum* aqueous extract. The highest total polyphenolic content was recorded with the highest level of compost (CP2-B). These results are in agreement with those obtained by Asami, et al., 2003 and Estiarte, et al.,1994. It has been reported that plants cannot simultaneously allocate resources to growth and defence and that there is a competition between proteins and phenolics in plants for the common precursors involved in their biosynthesis (Riipi, et al., 2002). These results suggested that sweet pepper plants might benefits from compost for their protein synthesis and growth development. These findings are in agreement with the results of Aminifard et al., 2013 on the effect of compost on antioxidant components and fruit quality of sweet pepper and found that compost act as precursors or activators of phytohormones and growth substances and secondary compounds in plants. In the same line, these results also agree with Mitchell, et al., 2007, who reported that organic crop management practices increased the content of flavonoids in tomatoes. Moreover, the increasing amount of total polyphenols and flavonoids could also due to plants spray with *O. gratissimum* aqueous extract, that played the role of elicitor by inducing the defence systems of the pepper plant which in turn increased the synthesis of the secondary metabolites such as polyphenols and flavonoids (Pott et al., 2019)

Polyphenolic compounds represent the most important group of natural antioxidants (Goncalves et al., 2017). One of the most common phenolic compounds is flavonoids. It has been reported that phenolic and flavonoid compounds act as antioxidants to exert antiallergic, anti-inflammatory, antidiabetic, antimicrobial., antipathogenic, antiviral., antithrombotic, and vasodilatory effects and prevent diseases such as cancer, heart problems, cataracts, eye disorders, and Alzheimer's (Zübeyir et al., 2017). Also, the most important features of flavonoids include their ability to protect against oxidative diseases, activate or inhibit various enzymes bind specific receptors, and protect against cardiovascular diseases by reducing the oxidation of low-density lipoproteins (Zübeyir et al., 2017).

3.4 Antioxidant potential

3.4.1 Radical scavenging activity of sweet pepper fruit extracts

The results of DPPH inhibition of the extracts of fruits harvested from different treatments are summarized in (Figure 5), which shows that extracts of fruits harvested from the treatments CP1-B (pot experiment: 80.9% and field experiment: 84.9%) and CP2-B (pot experiment:81.3% and field experiment: (85.1%) were the most effective DPPH radical scavengers**.** The extracts of fruits harvested from treatments NPK-B were also good radical scavengers with the inhibition of 71.2% and 72.9 %, respectively, in pot and field experiments. The fruits harvested from NPK-E (pot experiment: 55.1% and field experiment: 58.5 %) were considerably less effective radical scavengers compared to CP1-E (pot experiment: 61.9% and field experiment: 62.01%) and CP2-E (pot experiment: 61.1% and field experiment: 62.9 %).

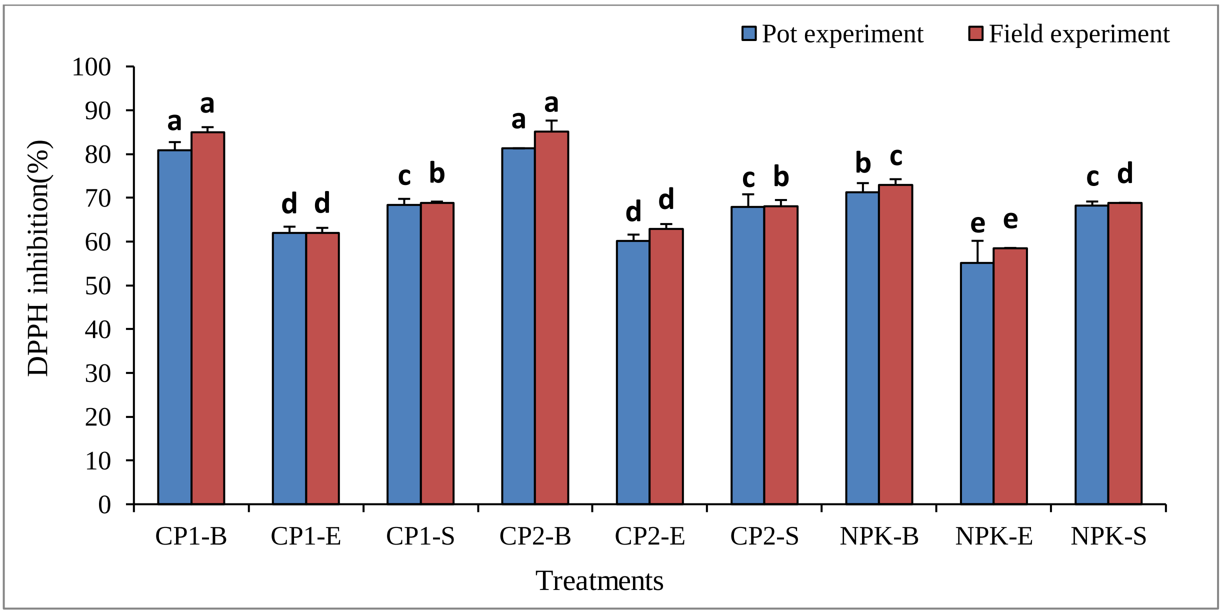

Figure 5: DPPH absorption inhibition (%) of sweet pepper fruit extracts. Bar charts with the same letter are not significantly different at P<0.05 both in pot and field experiments.

CP1-B, CP1-E and CP1-S: Compost at 1kg/5kg (pot experiment), 3kg/plot (field experiment) + 5% *O. gratissimum* aqueous extract spray **(B)**, water spray **(E)** and lambda-cyhalothrin spray **(S). CP2** represents the double of the quantity of the compost used in **CP1** following the same protocol. **NPK-B, NPK-E and NPK-S:** Soil amended with 26.3g of NPK (20.10.10) per plant (in pot and field experiments) + 5% *O. gratissimum* aqueous extract spray, water spray and lambda-cyhalothrin spray.

The results of DPPH inhibition of extracts of fruits harvested from sweet pepper plants grown organically (CP1-B and CP2-B) were the most effective DPPH radical scavengers than the one obtained from the plants grown conventionally (NPK-S)**.** This is in accordance with the findings of Aminifard et al., in 2013, on the effect of compost on antioxidant components and fruit quality of sweet pepper and Radames Trejo et al., 2018, who found that organically grown fruits and vegetables have high levels of antioxidant activity than conventionally grown products. Those results might be due to the high total polyphenol and flavonoid content that was observed in the treatments (CP1-B and CP2-B) or because plants cannot simultaneously allocate resources to growth and defense and that there is a competition between proteins and secondary metabolites in plants for the common precursors involved in their biosynthesis (Riipi, et al., 2002). That might be the reason why pepper plants might utilize benefits from compost fertilizer for their protein synthesis and growth development.

Organic fertilizers (compost) act as precursors or activators of phytohormones and growth substances and secondary compounds in plants (Vernieri, et al., 2006, Mitchell, et al., 2007, and Szafirowska et al., 2008). Another hypothesis explaining increases of antioxidant compounds in organic sweet pepper fruits was the lack of the utilization of synthetic insecticide, fungicide, and herbicide that allowed plants to devote greater resources to fight pathogen attacks, which, includes generation of antioxidant compounds (Winter & Davis, 2006). In addition, it could be due to the positive influence of cassava peels compost on sweet pepper fruit quality in terms of antioxidant and defence molecules of sweet pepper. Or it might also be explained considering the nutrient released in the soil by the cassava peels compost application, which could have increased the activity of antioxidant enzymes related to the synthesis of polyphenols and flavonoids by plants as a defence mechanism to counteract the negative effects of oxidative stress (Nur et al., 2013, Meloni et al., 2008 and Valencia et al., 2018). These results may be also be explained by the effect of *O. gratissimum* extract spray, which induced the synthesis of secondary metabolites such as polyphenols and flavonoids compounds in sweet pepper. Moreover, the aqueous extract of *O. gratissimum* could provide some phytonutrients for the nutrition of the pepper plants and increased the quality of fruits therefore, the greatest antioxidant capacity (Trejo et al., 2018).

3.4.2 Total Antioxidant Capacity (TAC) of sweet pepper fruit extracts

In general all the fruits harvested from sweet pants cultivated with compost (CP) and respectively sprayed with *O. grastissimum* (B), water (E) and lambda-cyhalothrin (S) (CP1-B, CP1-E, CP1-S, CP2-B, CP2-E and CP2-S) had the total antioxidant capacity significantly higher than the fruits collected from the inorganic fertilizer treatments. The highest value of TAC was obtained from the fruits harvested from CP2-B (pot experiment: 118,86g/100g and field experiment: 120.5g/100g) and CP1-B (pot experiment:112.84g/100g and field experiment: 113.3g/100g) compared to those harvested from NPK-B (pot experiment: 98.99g/100g and field experiment: 99.89g/100g), NPK-E (pot experiment: 94.66 g/100g and field experiment: 98.95 g/100g) and NPK-S (pot experiment: 99.46 g/100g and field experiment: 99.97g/100g). Also, the TAC increased with the increasing amount of the compost mass (Figure 6).

The highest value of TAC was obtained from fruits harvested from sweet pepper plants grown with CP1-B and CP2-B, as the results obtained from DPPH and FRAP assays. These results are in agreement with several findings that reported that organic fertilizers give the best values of TAC over the conventional fertilizers (Din et al., 2007) and organic fertilizers may increase the content of ascorbic acid and total phenolics in tomato. Organic fertilizers could be responsible for producing high yields of broccoli with high quality of heads (Abou El-Magd et al., 2006 and Bimova et al., 2009). The above studies are cited in support of the nutritional benefit of organic fertilizers. Bímová et al., 2009, had the same results, from the study on the impact of organic fertilizers on total antioxidant capacity in head cabbage.

An antioxidant can be defined as a substance that can avoid or refrain the oxidation of biological substrates. They react with free radicals and neutralize them. According to a biological point of view, antioxidant compounds can protect the cellular system from the harmful effects which cause excessive oxidation. Thus, the consumption of organic sweet pepper fruits will avoid oxidative stress, which is the imbalance between concentrations of reactive oxygen species (ROS) and antioxidants. Therefore, fight against many disease states, such as cancer, diabetes, cardiovascular disease, atherosclerosis, and neurodegenerative diseases; etc.

3.4.3 Ferric Reducing Antioxidant Power (FRAP) of sweet pepper fruit extracts

It is illustrated in figure 6 that, FRAP was significantly higher from fruit harvested from the plants of plots CP1-B (pot experiment: 25.32g/100g and field experiment: 27.95g/100g) and CP2-B (pot experiment: 26.90g/100g and field experiment: 29.89g/100g). The sweet pepper fruits of the treatments NPK-B (pot experiment: 18.89 g/100g and field experiment: 19.20g/100g), NPK-E (pot experiment: 14.41g/100g and field experiment: 15.97g/100g) and NPK-S (pot experiment: 20.98g/100g and field experiment: 21.89 g/100g) had the FRAP value significantly lower.

The highest antioxidant power exhibited from fruit extracts of the plot CP2-B followed by CP1-B could be due to the richness of pepper fruits in vitamin C, flavonoids, and polyphenols content or the presence of hydroxyl groups in the polyphenolic compounds that might provide the essential component as a radical scavenger. Or the capability of those compounds to reduce oxygen-derived free radicals by contributing a hydrogen atom or an electron to the free radical (Wanasundara & Shahidi, 1998).It could also be due to the supplement root colonizing microorganisms of the sweet pepper via the application of compost such as Trichoderma spp, Bacillus spp, and Pseudomonas spp, which could have activated the biological pathways in plants to produce compounds such as lignins, phenolics, polyphenolics, and enzymes involved in plant defence mechanisms (Stone et al., 2003). Or as stated above it might be also due either to the elicitor effect of the aqueous extracts of *O. gratissimum* on sweet pepper plants or their richness in phytochemical components such as tannins, steroids, flavonoids; etc. (Prabhu et al., 2009). These results are in accordance with numerous authors that have also indicated a similar pattern in the antioxidant potential in various crops grown in soils fortified with organic wastes, signifying that compost causes variations that favor the increase of antioxidants (Martins et al., 2005 and Siddiqui et al., 2020). Additionally, organic fertilizers and manuring have been demonstrated to enhance the antioxidant content of plants while inorganic fertilizers are reported to cause a drop in the antioxidant contents (Dumas et al., 2003 and Siddiqui et al., 2020). Moreover, Lakhdar et al., 2011 has also reported that the manuring effect of the amended organic matter significantly improved the antioxidant property of plants (Siddiqui et al., 2020).

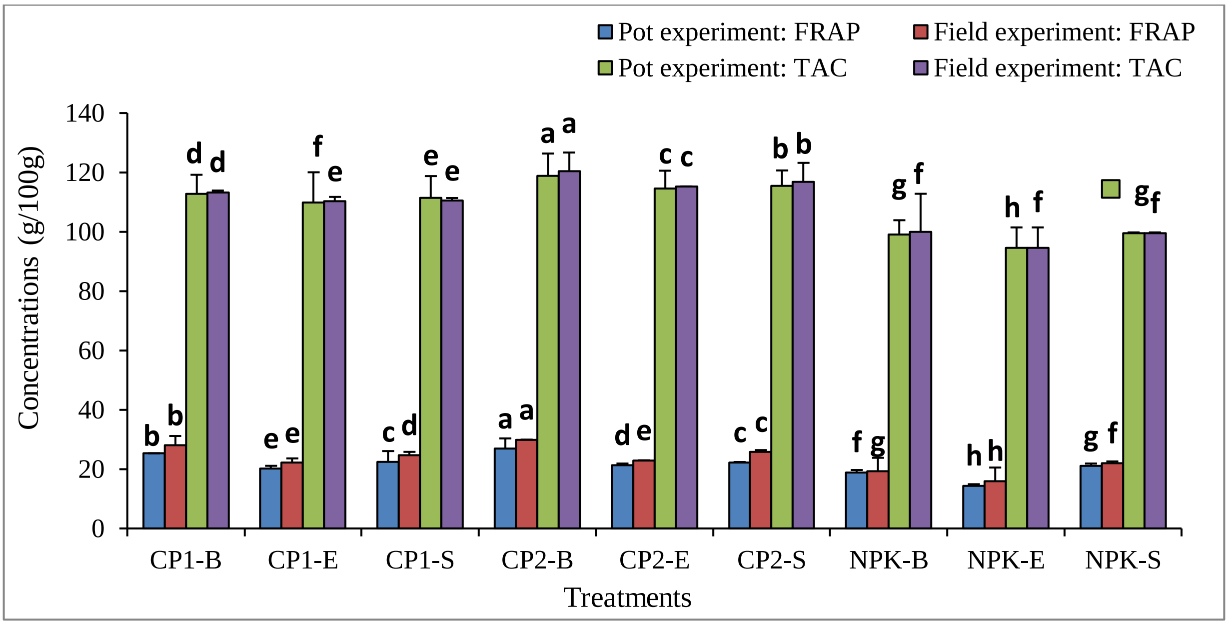

Figure 6: Ferric Reducing Antioxidant Power (FRAP) (g/100g) and Total Antioxidant Capacity (TAC) (g/100g) of sweet pepper fruit extracts. Bar charts with the same letter are not significantly different at P<0.05 both in pot and field experiments.

CP1-B, CP1-E and CP1-S: Compost at 1kg/5kg (pot experiment), 3kg/plot (field experiment) + 5% *O. gratissimum* aqueous extract spray **(B)**, water spray **(E)** and lambda-cyhalothrin spray **(S). CP2** represents the double of the quantity of the compost used in **CP1** following the same protocol. **NPK-B, NPK-E and NPK-S:** Soil amended with 26.3g of NPK (20.10.10) per plant (in pot and field experiments) + 5% *O. gratissimum* aqueous extract spray, water spray and lambda-cyhalothrin spray.

3.5 Pesticide residues of sweet pepper fruit extracts

Results from the Table 5 revealed that extracts of the fruits harvested from the plants of plots NPK-S, CP1-S and CP2-S contained pesticide residues while those harvested from the plants cultivated with compost, inorganic fertilizer and respectively sprayed with *O. grastissimum*, and water did not contain any pesticide residues. The concentrations of lambda-cyhalothrin detected in those fruits ranged, respectively, from: in pot experiment (0.098 mg/kg and 0.095 mg/kg) and in field experiment (0.189 mg/kg and 0.194 mg/kg). The fruits harvested from the field experiment had the highest concentration of lambda-cyhalothrin, which was above the authorized maximum residue limits (MRLs) of 0.05 mg/kg. The concentrations of lambda-cyhalothrin (0.199 mg/kg) detected from the extracts of farmers' fruits was similar to that obtained from the current field trial.

Table 5: Residues of lambda-cyhalothrin detected in sweet pepper fruits

Lambda-cyhalothrin residues (mg/kg)		
Treatments	**Pot experiment**	**Field experiment**
CP1-B	0	0
CP1-E	0	0
CP1-S	0.095±0.007[a]	0.190±0.003[a]
CP2-B	0	0
CP2-E	0	0
CP2-S	0.093±0.004[a]	0.189±0.003[a]
NPK-B	0	0
NPK-E	0	0
NPK-S	0.098±0.001[a]	0.194±0.004[a]
Fruits from farmers' fields		0.199±0.004[a]

Means±SD followed by the same letter in a column are not significantly different at P<0.05

CP1-B, CP1-E and CP1-S: Compost at 1kg/5kg (pot experiment), 3kg/plot (field experiment) + 5% *O. gratissimum* aqueous extract spray **(B)**, water spray **(E)** and lambda-cyhalothrin spray **(S). CP2** represents the double of the quantity of the compost used in **CP1** following the same protocol. **NPK-B, NPK-E and NPK-S:** Soil amended with 26.3g of NPK (20.10.10) per plant (in pot and field experiments) + 5% *O. gratissimum* aqueous extract spray, water spray and lambda-cyhalothrin spray.

According to the results obtained from the pesticide residues analysis in pot and field experiments, fruits harvested from the plants sprayed with lambda-cyhalothrin (non-systemic insecticide) or treated with, NPK-S, CP1-S and CP2-S treatments and farmer fruits contained pesticide residues of lambda-cyhalothrin above the CODEX maximum residue limit (MRL) of 0.05 mg/kg. This is in accordance with the findings of Sopkoutie, et al., 2021 who found that all the samples of tomatoes collected from Foumbot were contaminated by lambda-cyhalothrin and residue concentrations above the MRL were found in all the positive samples of lambda-cyhalothrin. This might be due to the ability of this insecticide to have a local systemic effect (penetrative insecticide) (Shalaby, 2017). Also, although lambda-cyhalothrin is well documented as a non-systemic insecticide, such local systemic effect may result from the penetration of lambda-cyhalothrin through lenticels on the surface of pepper fruits where it acts on certain biochemical systems. Alternatively, lambda-cyhalothrin being a lipophilic compound could dissolve in the cell membrane (Shalaby, 2017).

The highest concentration of lambda-cyhalothrin obtained from fruits harvested under field experiment and from farmers fruits compared with those collected from the pot experiment might be due to the multiple spray frequencies, which were respectively in pot experiment after every two weeks and after a week of interval in field experiment.

In general, the presence of lambda-cyhalothrin in fruits might be due to the harvesting period of time after the last day of K-optimal spraying and the result of the spraying frequency as stated above that was applied during this study, which was the same as the Cameroonian farmers. This is in line with the findings of Galani et al., 2020a, who found that pesticide residues obtained in foods sampled from Yaoundé, Douala and Bafoussam could be justified by the lack of Good Agricultural Practices leading to appropriate applications of pesticides by farmers. Therefore, this result confirms the assumption that the frequency of pesticides spraying and the harvesting of fruits the following day or two days after plants spraying can affect the fruits quality in terms of pesticide residues content.

The presence of the pesticide residues could also be the result of the lowest microelements and macro-elements contained in sweet pepper fruits harvested from the plants treated with K-optimal because, several literature reviews reported that pesticide residues could interfere with biochemical and physiological processes in plants retarding the growth of the plant and decreasing the yield. Also, they might reduce the fruit quality and may even prevent its use as food by affecting its quality parameters (Shalaby, 2017). Moreover, Radwan et al., 1995, 2001 and 2004 reported that pirimphos-methyl residues appeared to have significant adverse effects on the total soluble sugars and ascorbic acid content of tomato fruits and broad bean seeds. Besides, Shalaby, 2017, found that lambda-cyhalothrin residues significantly decreased the levels of all tested quality parameters (total soluble sugar, glucose, acidity, total soluble solids, ascorbic acid, β-carotene, and protein) in pepper fruits, including the microelements comparing with untreated ones. These results are also in harmony with those obtained by Shalabey et al., 1991, Shalaby and

Eisa, 1992, Salem, 2011 and Shalaby, 2016 working with different insecticides on the same vegetables and field crops.

4. Conclusion

From the above-mentioned results, it could be concluded that sweet pepper cultivated with cassava peels compost and sprayed with *O.gratissimum* aqueous extract significantly increased nutrients content such as vitamin C (by 34.97 % to 36.23 % in pot and 31.82% to 32.84% in field); sweet pepper fruits yield (by 66% to 93 % in pot and 125% to 187% in field) and antioxidant properties such as TAC (by 13.99% to 20.05% in pot and 13.42% to 20.63% in field) which increased with the increasing amount of compost. Compost at 2kg/3kg and 6kg/plot and plants sprayed with 5% of *O. gratissimum* aqueous extract were the best treatments both in pot and field experiments. The spray of K-optimal appeared to be one of the main causes that decreased the levels of the all tested quality parameters in sweet pepper fruits, including the microelements. Sweet pepper fruits sprayed with the same insecticide contained lambda-cyhalothrin as pesticide residues, which were above the MRLs both in pot and field experiments. Therefore, the combined use of *O gratissimum* aqueous extract as pesticide of plant origin and soil amendment with cassava peels compost at 2kg/3kg and 6kg/plot could be used as alternative to conventional agrochemicals to increase the yield, the nutritional values or quality of fruits and vegetables. Furthermore, organic sweet pepper fruits are good ingredients to fight against malnutrition and metabolic diseases.

CRediT authorship contribution statement

J. Nguefack: Supervision, Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Funding acquisition. **D. Onguene**: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Funding acquisition. **J.B. Lekagne Dongmo:** Conceptualization, Visualization Formal analysis. **C.D. Dakole:** Visualization, Formal analysis. **N. G. Mangoumou:** Resources. **YJH Galani**: Validation, Data curation, Writing - review & editing.

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