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Growth, Yield and Yield Characteristics of Three Pepper Cultivars to Fertilizers Application in the Mount Cameroon Region

Andrew Enow Egbe[1,2*], Marietta Solange Nkeutcha Soupi[1], Francis Nkede[1], Angèle Pegalepo Ndogho[1]

[1]Department of Plant Science, Faculty of Science, University of Buea, Buea, Cameroon
[2]Faculty of Agriculture and Veterinary Medicine, University of Buea, Buea, Cameroon
Email: *egbe1@yahoo.com, msoupi@yahoo.fr, nkedefrancis1@gmail.com, ndogho693@yahoo.fr

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Abstract

This study determined the effects of organic and inorganic fertilizers on growth and yield of three pepper cultivars in the Mount Cameroon Region. Pepper seedlings were treated with six treatments (T_1 = no fertilizers (control), T_2 = 250 Kg/ha NPK 20:10:10, T_3 = 350 Kg/ha NPK 20:10:10, T_4 = 450 Kg/ha NPK 20:10:10, T_5 = 20 Mg/ha poultry manure (PM), T_6 = 30 Mg/ha PM). The effects of fertilizers had a significant effect on vegetative growth and yield of *Capsicum chinense* cv. "Big Sun" plants had the maximum plant height (39.09 cm) and mean collar diameter (6.02 mm) in plots treated with poultry manure at 20 Mg/ha (T_5) and 30 Mg/ha (T_6) respectively. The highest yield (33.63 Mg/ha) was in *Capsicum chinense* cv. Safi plants supplied with 30 Mg/ha poultry manure (T_6) and the lowest yield (10.44 Mg/ha) was in *Capsicum frutescens* in control plots (T_1). The highest fruit diameter (11.08 mm) and longest fruits (18.39 mm) were observed in *Capsicum chinense* cv. Big Sun plants supplied with 30 Mg/ha poultry manure. *Capsicum frutescens* fruits had the highest concentration of N (2.39%), P (0.42%) and K (3.06%). Essential oils analysis shows that there were 179 essential oils from pepper fruits of *Capsicum chinense* cv. Safi, with major essential oil been 3,4-dimethyl-benzaldehyde and main essential oils were alpha Terpinene and alpha Pinene based on their abundance. Fruits of *Capsicum chinense* cv. Big Sun had two-hundred and eight essential oils with major essential oil been 1,3,5-Trimethyl-1-H-pyrazol-4-amine and main essential oils were Caryophyllene oxide and Cymene, based on their abundance. Fruits of *Capsicum frutescens* had one-hundred and eighty-one essential oils with major essential oil been Limonene, and main essential oils were Carvacrol and D-limonene with respect to abundance. Results show that 20 Mg/ha poultry manure was the most cost effective in the production of pepper in Buea Cameroon.

Keywords

Capsicum Species., Organic Fertilizers, Inorganic Fertilizers, Yield, Oil Analysis

1. Introduction

The decline in soil fertility as result of continuous cultivation and high cost of inorganic fertilizers has led to renewed interest in the use of organic fertilizers for soil fertility management as it is ecologically sound and sustains productivity of the soil. Increase in world population is increasing pressure on land leading to unsustainable systems such as short duration fallow, sedentary agriculture on small-scale holdings, and expansion of agriculture into marginal areas and forest reserves [1]. Adoption of these inappropriate farming methods has thus resulted in land degradation and deterioration of the environment. Deforested land, if not managed, could lead to soil erosion, soil compaction, loss of soil fertility and poor underground water quality. Therefore, in order to achieve sustainable agricultural production, it is imperative to explore alternative soil and nutrient management practices which minimize soil degradation.

Pepper is an annual crop from the Solanaceae that originated from Central America. The genus *Capsicum* presents several varieties among which five are domesticated. The diversity of the colorific profile testifies to the presence of carotenoids which can be used as a natural colourant and antioxidant. Pepper is considered as a source of bioactive compounds such as polyphenols and flavonoids [2]. It is a very important fruit vegetable in the tropics and the world's second most important vegetable after tomatoes [3]. Pepper has increased in popularity and importance over a long period, thus making it an indispensable part of the daily diet of millions of people. Pepper is normally used as a spice in the preparation of soups and stews when cooked with tomatoes and onions. It can also be used as a condiment and extensively in flavouring of processed meat, colouring certain food preparations and also used for medicinal purposes [4].

Ethiopia is the highest global producer of pepper (374,413 ton). Its production has increased for 8% in five years meanwhile Cameroon production is quite stable at 93 Metric Tons from 2014 to 2019 [5].

Generally, Solanaceous vegetables require large quantities of macro-nutrients such as nitrogen (N), phosphorus (P) and potassium (K), Calcium (Ca), magnesium (Mg) and sulphur (S) for better growth, fruit and seed yield. These nutrients have specialized functions and should be supplied to the plant at the right time and in right quantity. Pepper like other crops, produces well when it is adequately supplied with the essential nutrients through fertilization [6]. One of the ways of increasing the yield is by boosting the soil nutrient content either with the use of organic materials such as poultry manure, animal waste, and use of compost or with the use of inorganic fertilizers [7] [8]. There is little or no

information on the required amount of organic or inorganic fertilizers for the production of the *Capsicum frutescens*, *Capsicum chinense* cv Big Sun and *C. chinense* cv Safi in Cameroon and especially in the Mount Cameroon. This study therefore investigates which fertilizer type(s) and quantity that shall enhance the productivity of pepper in the Mount Region of Cameroon.

2. Materials and Methods

2.1. Study Area

This research was carried out at the University of Buea Research Farm in the Department of Botany and Plant Physiology. Buea is located in the South West Region of Cameroon between latitude 3˚57' to 4˚27'N and longitude 8˚58' to 9˚25'E. Buea is located on the eastern slope of Mount Cameroon with mean annual rainfall of about 2800 mm, received monthly between June and September. The mean annual temperature, mean relative humidity and sunshine are 28˚C, 86% and 900 to 1200 hours per annum respectively [9]. Buea is mountainous with thick evergreen forest vegetation and transitional changes along altitudinal gradient. Agriculture is the major activity in this region and this is mostly carried out by land rotation and organized commercial plantations by the Cameroon Development Corporation (CDC) [9]. Soil type is basically volcanic [10] though soil fertility has seriously declined due continuous cropping of the area.

2.2. Treatments and Experimental Design

The experiment consisted of six treatments (T_1 = No fertilizers (control plot), T_2 = 250 Kg/ha NPK 20:10:10, T_3 = 350 Kg/ha NPK 20:10:10, T_4 = 450 Kg/ha NPK 20:10:10, T_5 = 20 Mg/ha poultry, T6 = 30 Mg/ha poultry). The experiment was laid out in a complete randomized block design with three replications.

2.3. Soil and Poultry Manure Analysis

Surface soil samples were collected randomly at 30 spots at a depth of 0 - 20 cm in the experimental plot before commencement of the experiment. The soils were bulked and mixed thoroughly to have a homogenous sample. A subsample of 200 g was taken and air dried and later sieved with a 2 mm sieve. The sample was coded and taken to the Institute of Research for Agricultural Development (IRAD) Ekona Cameroon for routine chemical and particle size analyses. Particle size was determined by Bouyoucos method [11]. Soil pH was measured in 2:1 soil/water suspension as well as in soil/KCl suspension (1:2) using a glass-electrode pH meter [12]. Soil organic carbon was determined using Walkley-Black method [13]. Available phosphorus was extracted with Bray-2 solution and read at a wavelength of 882 nm, while in the exchangeable bases (K^+, Na^+, Ca^{2+}, Mg^{2+}) were extracted with 1N ammonium acetate (NH_4OA) (pH 7). Sodium, Potassium, Calcium and Magnesium (Na^+, K^+, Ca^{2+}, Mg^{2+}) were read with an atomic absorption spectrophotometer. Cation Exchange Capacity (C.E.C) was read with a colori-

meter at a wavelength of 650 nm [14].

Poultry manure used for the experiment was collected from a poultry farm in Buea. The manure was air-dried, crushed and sieved with a 0.2 mm sieve and a sample of 200 g was taken to IRAD Ekona Cameroon for chemical analysis as described for soil samples.

2.4. Land Preparation and Transplanting of Seedling

The land was cleared, raked and laid out using pegs, tape and strings. The field was divided into plots. Each plot was laid out and pegs were placed where each hole was to be dug. The holes were 3 cm deep and 3 cm wide. The land was divided into three replicates of 690 m^2 with each replicate having 18 plots of 2 × 2 m. The plots were 1 m apart while the replicates blocks were 2 m apart.

2.5. Transplanting of Seedlings

Before transplanting, the seedlings were watered to enhance easy uprooting and to reduce root damage. The seedlings were transplanted at a spacing of 75 × 40 cm. Seedlings were transplanted into the various plots at 7 weeks after germination in nursery. Twelve seedlings were transplanted per plot. Thirty-six (36) seedlings were transplanted per treatment, making two hundred and sixteen (216) seedlings per species and a total of 648 seedlings were transplanted for the three pepper cultivars.

2.6. Fertilizer Application

Poultry manure was applied to the marked plots 7 days before transplanting of the seedlings and incorporated to a soil depth of 15 cm and later covered with top soil to allow for mineralization. NPK fertilizer was applied by ringing method and in two splits; the first application was two weeks after transplanting (WAT) and the second during flowering [15].

The experiment consisted of six treatments (T_1 = No fertilizers (control plot), T_2 = 250 Kg/ha NPK 20:10:10, T_3 = 350 Kg/ha NPK 20:10:10, T_4 = 450 Kg/ha NPK 20:10:10, T_5 = 20 Mg/ha poultry manure, T6 = 30 Mg/ha poultry). The experiment was a Factorial experiment with three replications.

Weeds were controlled by using roundup herbicide before transplanting and hand weeding was carried out regularly once a forthnight. The fruits were hand harvested once every 2 weeks for 10 weeks from commencement of fruiting; clipped from the plant above the calyx as they reach marketable size.

2.7. Data Collection and Analysis

The following growth and yield parameters were collected following the method described in [16] and [17].

The plant height was measured from the base of the plant to the terminal growing point of the main stem using a meter rule and expressed in centimetres (cm) to the nearest 0.1. The collar diameter was measured with a veneer calliper (Mitutoyo, Aurora, IL). Six (6) plants per plot were selected and the collar di-

ameters were measured to the nearest 0.02 mm and the average determined. The number of branches was determined by counting the number of branches on the 6 selected plants per subplot and the average number was recorded. The number of fully opened leaves were counted for each plant and recorded. The length and width of fully open leaves were recorded using a ruler and their average taken in centimetres (cm). These values were used in calculating relative leaf area according the equation RLA = 1/2 LW.

When flowering was noticed in three of six tagged plants, it was considered as 50 percent flowering and time taken at this stage was considered as days to 50 percent flowering. The number of flowers was determined by counting the number of flowers of the tagged plants in each treatment, summed up and mean recorded.

2.8. Mean Fruits Weight per Plant (g)

One hundred freshly collected fruits for each species and treatments were collected per harvest and weighed with an electronic balance (Ohaus Scout TM Pro) to the nearest 0.1 g and recorded immediately after each harvest, before losing weight and the average weight recorded to obtain mean fruit fresh weight per plant [10].

The fruit yield per hectare was determined by extrapolating the fruit yield per net plot.

$$\text{Yield}\ (\text{Mg/ha}) = \frac{\text{weight of harvest pepper}}{\text{surface area of plot}} \times 10000\ \text{m}^2 \quad [10] \qquad (1).$$

The diameter of the fruits was measured at the middle with a veneer calliper. The fruit length was measured from the tip to the bottom of the fruits using a veneer caliper.

At the end of the experiment, six pepper plants from each treatment were uprooted and washed with tap water repeatedly to remove all the soil particles. The pepper plants were partitioned into roots, stems and leaves and their fresh weights recorded with an electronic balance (Ohaus Scout TM Pro) to the nearest 0.01 g. These were oven dried to constant weight at 70˚C and the dry weight recorded. Harvest index was calculated using the formula below:

$$HI = \frac{\text{Fruit yield}}{\text{Fruit yield} + \text{Vegetative yield}} \times 100 \quad [18] \qquad (2).$$

2.9. Macronutrient Analysis of Fruits of the Pepper Species

Fresh pepper fruits were harvested from the various species, washed to remove any particles and dried in an air flow oven (Gallenhamp Hotbox) at 65˚C for 48 hrs. Two-hundred grams (200 g) of dried pepper fruit for each species were separately milled with a blender, passed through a 0.5 mm sieve and sent to the International Institute of Tropical Agriculture (IITA), Yaoundé for routine chemical analysis.

Basic cations, Ca, Mg, K and Na were determined using atomic absorption

spectrophotometer [19]. Phosphorus was read colorimetrically in a spectrophotometer at 382 nm. Total N was determined by wet acid digestion [20].

2.10. Extraction of Essential Oils from Fruits of the Two Pepper Species

Fresh pepper fruits were harvested from the different species, washed to remove any particles and dried in an air flow oven (Gallenhamp Hotbox) at 65˚C for 72 hrs. The dried fruit samples were separately milled with a blender, passed through a 0.5 mm sieve. One hundred grams (100 g) of the dried pepper fruits of each species were package and coded and sent to the University of Fort Hare Laboratory, South Africa for analysis of essential oils. The essential oils were extracted using steam distillation. In this method, the plant material (dried pepper fruits) was placed in water and heated directly in a Clevenger type distillation apparatus. The essential oils whose boiling points normally range up to 300˚C were distilled with steam and both were condensed and separated. The distillation is usually done at atmospheric pressure, although vacuum processes are used if the oil is known to be subject to hydrolysis [21]. Analyses of essential oils were determined by Gas chromatography-Mass spectrometer (GC-MS) as described by [22]. Interpretation of mass spectroscopy was conducted using data base of National Institute Standard and Technology (NIST) having more than 62,000 patterns. The spectrum of the unknown component was compared with the spectrum of the known component stored in the NIST library [22].

2.11. Statistical Analysis

Data were tested for normality and homogeneity of variance. Data that were not normally distributed were subjected to Johnson transformation. A GLM ANOVA was conducted to test effects of NPK level, poultry manure and cultivars as well as their interactions on height, collar diameter, number of leaves, relative leaf area, number of branches per plant, days to flowering, number of flowers per plant, mean fruits weight, fruit yield per hectare, and data on harvest indices, were collected only at harvest, were subjected to GLM ANOVA. Data on disease incidence was analyzed using Kruskal Wallis non-parametric ANOVA. All analyses were done using the Minitab statistical package (ver. 16, Minitab Inc., Bellefonte, PA). Significant interactions were used to explain results.

3. Results

3.1. Soil and Poultry Manure Analysis

Result on soil analysis (**Table 1**) shows that the experimental site was relatively acidic with a pH of 5.93. The physical analysis of the soil reveals that the soil was clay loam in texture. The soil fertility was low, since nutrients were below the soil fertility range (**Table 1**). Poultry manure had high level of nitrogen (1.1%) and organic carbon (49.2%) (**Table 1**). It should therefore be expected that the fertility status of the soil would benefit from poultry manure application.

Table 1. Physico-chemical properties of soil and chemical properties of poultry manure used in the study.

Physical properties of soil	Soil	Chemical properties of PM (%)	Soil with low fertility range *
Particle size		-	-
Sand (%)	17.39	-	-
Silt (%)	17.39	-	-
Clay (%)	65.22	-	-
Soil texture	Clay loam	-	-
Chemical properties			
pH (H_2O)	5.93	7.2	5.0 - 5.7
Total N (%)	0.2	1.1	0.1 - 0.2
Av. P (mg/Kg)	10	0.6	4.0 - 29
CEC (cmol/Kg)	11.31	42.91	5.0 - 15.0
K^+ (cmol/Kg)	0.27	0.7	0.12 - 0.3
Ca^{2+} (cmol/Kg)	2.3	0.14	2.0 - 5.0
Mg^{2+} (cmol/Kg)	1.35	0.23	0.5 - 1.5
Organic carbon (%)	1.05	49.2	Not Available

* Source [23], PM = Poultry manure.

3.2. Effects of Inorganic and Organic Fertilizers on Growth Patterns of Cultivated Pepper Cultivars

The growth pattern with respect to height showed that there was a sharp increase in height in seedlings for *Capsicum chinense* cv. Safi treated with 20 Mg/ha poultry manure (T_5) at 8th week after application (**Figure 1**). Seedlings of *Capsicum chinense* cv. Big Sun showed a sharp increase in height as from the 2nd and 4th weeks from plants in the control plots (T_1) and plants treated with 20 Mg/ha poultry manure (T_5) respectively. Seedlings of *Capsicum frutescens* (Bird pepper) showed a sharp increase in height as from the 4th week after treated with 20 Mg/ha poultry manure (T_5) (**Figure 1**). Collar diameter growth pattern for all two pepper cultivars showed a sharp increase as from the 4th week after fertilizer application (**Figure 1**).

Leaf number showed a sharp increase as from the 4th week of treatment for *Capsicum chinense* cv. Big Sun and *Capsicum frutescens* except for plants in the control plot (**Figure 2**). The growth pattern for relative leaf area (RLA) showed a sharp increase as from the 4th week for treated seedlings of *Capsicum chinense* cv. Safi and *Capsicum chinense* cv. Big Sun treated with 20 Mg/ha poultry manure (T_5) and *Capsicum frutescens* treated with 450 Kg/ha NPK 20:10:10 (T_4) (**Figure 2**).

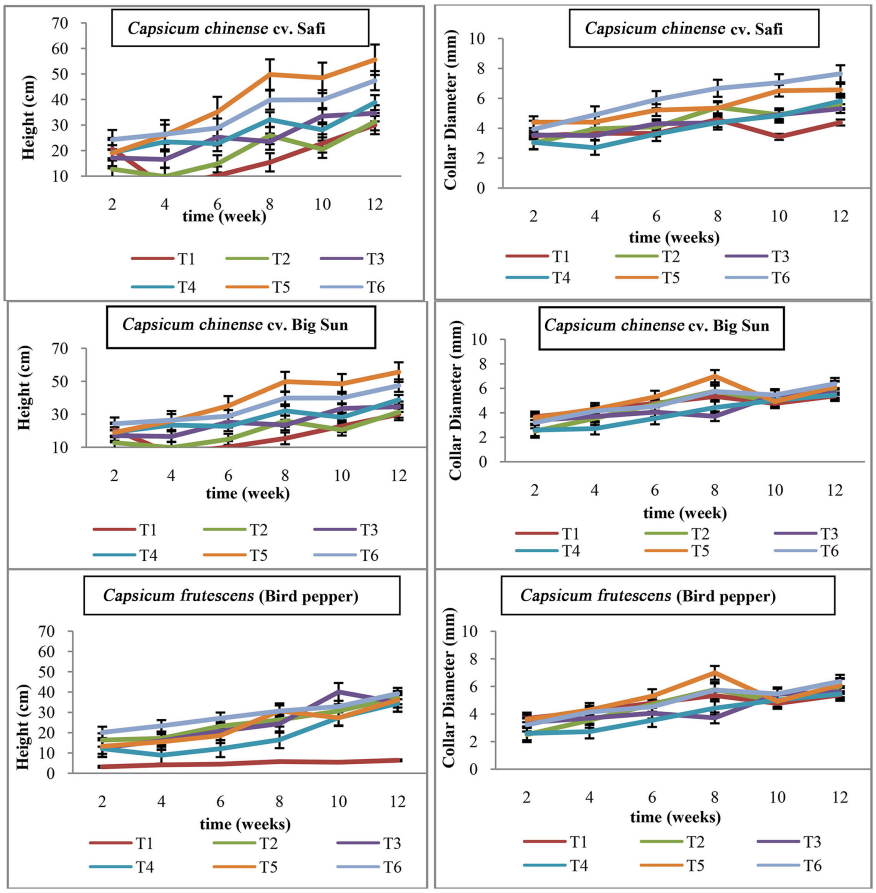

Figure 1. Growth patterns for height and collar diameter of the three pepper cultivars treated with inorganic and organic fertilizers. T_1 = control (no application of fertilizers), T_2 = 250 Kg/ha NPK 20:10:10, T_3 = 350 Kg/ha NPK 20:10:10, T_4 = 450 Kg/ha NPK 20:10:10, T_5 = 20 Mg/ha PM, T_6 = 30 Mg/ha PM.

3.3. Effect of Organic and Inorganic Fertilizers on Vegetative Growth of Characteristics of Three Pepper Cultivars

Result from the study (Table 2) shows that fertilization resulted to increases in some vegetative growth characteristics when compared to those in the control plot. The tallest plants (39.04 cm) were observed in *Capsicum chinense* cv. Big Sun treated with 20 Mg/ha poultry manure (T_5) and the shortest plants (15.84 cm) were observed in *Capsicum frutescens* plants treated with 450 Kg/ha NPK (T_4) (Table 2). The highest mean collar diameter (6.02 mm) was obtained in *Capsicum chinense* cv. Big Sun plants treated with 30 Mg/ha poultry manure (T_6) and the minimum mean collar diameter of 3.61 mm was observed in *Capsicum frutescens* plants treated with 450 Kg/ha NPK (T_4) (Table 2). The maximum number of leaves per plant of 99.0 was obtained in *Capsicum frutescens* plants treated with 250 Kg/ha NPK (T_2) while the minimum number of leaves (19) was noted in *Capsicum chinense* cv. Safi plants treated with 250 Kg/ha NPK (T_2) (Table 2). The maximum relative leaf area (26.77 cm^2) was found in *Capsicum chinense* cv. Safi plants treated with 20 Mg/ha poultry manure (T_5) and the minimum RLA (0.22 cm^2) was in *Capsicum frutescens* plants treated

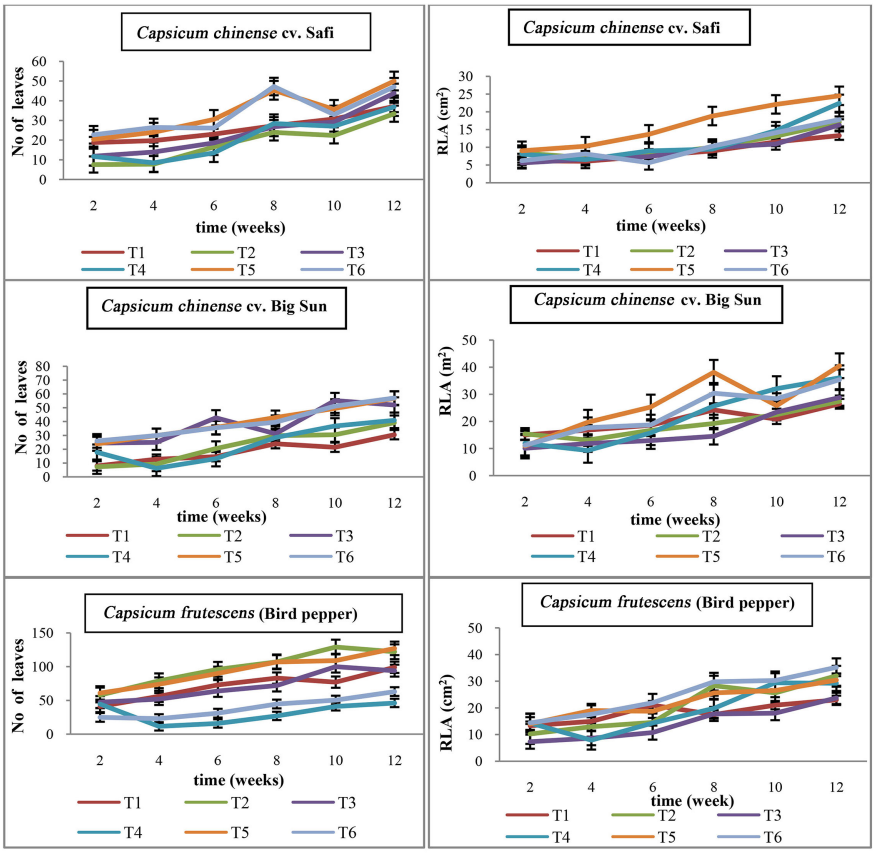

Figure 2. Growth patterns of number of leaves and relative leaf area of the three pepper cultivars treated with inorganic and organic fertilizers. T_1 = control (no application of fertilizers), T_2 = 250 Kg/ha NPK 20:10:10, T_3 = 350 Kg/ha NPK 20:10:10, T_4 = 450 Kg/ha NPK 20:10:10, T_5 = 20 Mg/ha PM, T_6 = 30 Mg/ha PM.

with 250 Kg/ha NPK (T_2). The highest root/shoot ratio (1.27) was noted in *Capsicum frutescens* plants treated with 250 Kg/ha NPK (T_2) and the least root/shoot ratio of 0.10 was noted in *Capsicum chinense* cv. Big Sun plants treated with 450 Kg/ha NPK (T_4) (Table 2).

There were no significant differences ($P > 0.05$) across treatments with respect to days to flowering and number of branches per plant. However, there were significance differences in the number of flowers per plant for the three pepper cultivars. The maximum days to flowering (31.08 days) was recorded in *Capsicum chinense* cv. Safi plants in the control plots (T_1) and the lowest days to flowering of 26.42 days was in *Capsicum chinense* cv. Safi plants treated with 20 Mg/ha poultry manure (T_5). The highest mean number of branches (14) was observed in *Capsicum chinense* cv. Safi plants treated with 20 Mg/ha poultry manure (T_5) and the lowest mean number of branches (9) was noticed in *Capsicum chinense* cv. Big Sun plants in the control plots (T_1) (Table 2). Plots on which *Capsicum frutescens* plants were treated with 30 Mg/ha poultry manure (T_6) had the highest mean number of flowers per plant of 91 flowers, and the lowest mean number of flowers per plant of 31 flowers was recorded in *Capsicum chinense* cv. Big Sun plants in the control plots (Table 2).

Table 2. Effects of fertilizers and species on growth characteristics of the three pepper cultivars.

Species (sp)	T	H (cm)	CD (mm)	NL	RLA (cm^2)	R/s	NB	DF	NF
Capsicum chinense. Cv Safi									
1a	T1	28.89^{abc}	4.69^{abcdef}	26.11^{d}	20.32^{abcd}	0.26^{def}	10.75^{a}	31.08^{a}	30.88^{a}
1a	T2	25.23^{bcde}	4.58^{bcdef}	18.63^{d}	19.07^{abcd}	0.96^{ab}	11.75^{a}	30.42^{a}	37.83^{a}
1a	T3	24.74^{bcde}	4.32^{bcdef}	24.03^{d}	16.93^{cde}	0.30^{de}	11.33^{a}	30.33^{a}	41.96^{b}
1a	T4	18.62^{def}	3.964^{ef}	21.06^{d}	21.86^{abcd}	0.19^{ef}	13.67^{a}	27.92^{a}	58.13^{ab}
1a	T5	23.62^{cdef}	5.21^{abcde}	34.33^{bcd}	26.77^{a}	0.24^{def}	13.92^{a}	30.00^{a}	63.33^{ab}
1a	T6	27.97^{abcde}	4.91^{abcde}	33.86^{bcd}	23.67^{abc}	0.67^{h}	12.67^{a}	26.42^{a}	66.88^{ab}
Capsicum chinense cv. Big Sun									
1b	T1	27.67^{abcd}	3.88^{ef}	18.91^{d}	18.71^{abcd}	0.17^{ef}	9.42^{a}	28.17^{a}	30.80^{a}
1b	T2	18.96^{def}	4.51^{bcdef}	22.68^{d}	20.32^{abcd}	1.08^{ab}	11.17^{a}	29.50^{a}	41.08^{b}
1b	T3	25.10^{bcde}	4.33^{bcdef}	38.29^{bcd}	14.58^{def}	0.30^{de}	11.67^{a}	27.75^{a}	44.08^{abc}
1b	T4	17.54^{ef}	4.08^{def}	23.92^{d}	19.20^{bcd}	0.10^{gh}	14.25^{a}	29.42^{a}	46.83^{abc}
1b	T5	39.04^{a}	5.41^{abc}	39.83^{bcd}	22.40^{abc}	0.59^{bc}	13.17^{a}	28.50^{a}	60.29^{abc}
1b	T6	34.47^{ab}	6.02^{a}	39.88^{bcd}	24.91^{ab}	0.87^{h}	13.83^{a}	30.75^{a}	61.63^{abc}
Capsicum frutescens (Bird pepper)									
2	T1	36.80^{a}	4.34^{bcdef}	72.00^{abc}	8.95^{f}	0.25^{def}	11.75^{a}	28.25^{a}	56.96^{ab}
2	T2	37.34^{a}	5.16^{abcd}	98.90^{a}	0.22^{ef}	1.27^{a}	12.50^{a}	28.17^{a}	54.58^{ab}
2	T3	30.51^{abc}	4.31^{bcdef}	72.08^{ab}	9.48^{f}	0.35^{cd}	13.25^{a}	27.75^{a}	63.00^{abc}
2	T4	15.84^{f}	3.61^{f}	31.64^{cd}	11.89^{ef}	$0.15f^{g}$	13.42^{a}	27.92^{a}	66.17^{abc}
2	T5	29.45^{abc}	5.82^{ab}	95.10^{a}	16.42^{cde}	0.29^{de}	13.83^{a}	28.17^{a}	73.54^{de}
2	T6	25.44^{bcde}	4.22^{cdef}	39.64^{bcd}	10.37^{f}	0.77^{h}	12.17^{a}	27.25^{a}	90.79^{ef}

Turkey post-hoc HSD test at $\alpha = 0.05$. Means with the same letter within the column are not statistically different. T = treatments, T_1 = control (0 Kg/ha fertilizer), T_2 = 250 (Kg/ha) NPK 20:10:10, T_3 = 350 (Kg/ha) NPK 20:10:10, T_4 = 450 (Kg/ha) NPK 20:10:10, T_5 = 20 (t/ha) PM, T_6 = 30 (t/ha) PM. CD = collar diameter, H = Plant height, NL = number of leaves, RLA = Relative Leaf Area, R/s = Root/shoot ratio, DF = days to 50% flowering, NB = number of branches per plant, NF = number of flowers per plant.

3.4. Effects of Inorganic and Organic Fertilizers on Yield and Related Attributes of Cultivated Pepper Cultivars

Result from Table 3 shows that fertilizers have significant ($P \leq 0.05$) effect on total fruit yield and its related attributes. *Capsicum chinense* cv. Big Sun had the highest mean fresh fruit weight (54.4 g) when treated with poultry manure at 30 Mg/ha as well as the highest harvest index (0.78) while those treated with poultry manure at 20 Mg/ha (Table 3). *Capsicum chinense* cv. Safi produced the highest fresh fruit yield (33.63 Mg/ha) when 30 Mg/ha poultry manure was applied (Table 3). On the other hand, *Capsicum frutescens* produced the lowest mean fresh fruit weight (26.1 g) as well as the lowest harvest index (0.51) and the lowest fresh fruit yield (10.44 Mg/ha) in absence of any form of fertilizer (Table 3). The

highest fruit diameter of 11.08 mm was observed in *Capsicum chinense* cv. Big Sun plants treated with 30 Mg/ha poultry manure while the least fruit diameter of 7.19 mm was noted in *Capsicum frutescens* plants in the control plots (Table 3). The longest fruits (18.39 mm) were obtained in *Capsicum chinense* cv. Big Sun plants treated with 30 Mg/ha poultry manure and the shortest fruits of 11.21 mm were observed in *Capsicum frutescens* plants in the control plots (Table 3).

3.5. Macro-Nutrient Contents of Fruits of the Studied Pepper Species

Results from Table 4 shows that *Capsicum frutescens* fruits (Bird pepper) had the highest concentration of Nitrogen (N), Phosphorus (P) and Potassium (K) when compared to the other pepper cultivars. In case of Magnesium (Mg) and Calcium (Ca) concentrations, the highest concentration was in *Capsicum chinense* cv. Safi fruits and *Capsicum chinense* cv. Big Sun fruits respectively.

Table 3. Effects of fertilizers and species on fruit weight, harvest index, yield, fruit diameter and fruit length of three pepper cultivars at time of harvest.

cultivars	Treatments	Mean fw (g)	HI	Fresh fruit yield (Mg/ha)	Mean FD (mm)	mean FL (mm)
1a	T1	34.9^{ef}	0.66^{cde}	12.52^{hi}	7.74^{efg}	13.60^{cde}
1a	T2	36.9^{cde}	0.58^{de}	19.79^{defg}	9.53^{bcd}	15.15^{abcde}
1a	T3	47.8^{b}	0.70^{abc}	23.49^{cde}	9.18^{cd}	14.71^{abcde}
1a	T4	46.8^{b}	0.71^{ab}	28.36^{abc}	9.72^{abcd}	15.13^{abcde}
1a	T5	48.6^{ab}	0.78^{ab}	32.09^{a}	10.05^{abcd}	15.93^{abcd}
1a	T6	54.4^{a}	0.67^{abcd}	33.63^{a}	10.74^{ab}	16.34^{abcd}
1b	T1	35.3^{def}	0.71^{abc}	12.16^{hi}	7.67^{fg}	13.76^{bcde}
1b	T2	37.2^{cde}	0.56^{e}	20.62^{defg}	9.97^{abcd}	15.89^{abcd}
1b	T3	40.3^{c}	0.65^{bcde}	21.60^{def}	9.03^{def}	15.50^{abcd}
1b	T4	38.6^{cd}	0.75^{ab}	25.50^{bcd}	10.28^{abcd}	16.56^{abcd}
1b	T5	45.2^{b}	0.58^{de}	29.73^{ab}	10.50^{abc}	17.70^{abc}
1b	T6	46.5^{b}	0.66^{bcd}	32.99^{a}	11.08^{a}	18.39^{a}
2	T1	26.1^{g}	0.51^{a}	10.44^{i}	7.15^{g}	11.21^{e}
2	T2	26.9^{g}	0.61^{cde}	15.03^{ghi}	9.49^{bcd}	13.44^{bcde}
2	T3	27.7^{g}	0.60^{de}	17.24^{fgh}	9.13^{cde}	12.93^{de}
2	T4	29.4^{g}	0.59^{de}	18.94^{efg}	10.19^{abcd}	13.55^{bcde}
2	T5	33.1^{f}	0.63^{cde}	22.18^{def}	9.64^{bcd}	13.19^{de}
2	T6	33.1^{f}	0.62^{cde}	23.05^{cdef}	10.35^{abcd}	17.71^{ab}

Turkey post-hoc HSD test at $\alpha = 0.05$. Means with the same letter within the column are not statistically different, T_1 = Control, T_2 = 250 Kg/ha NPK 20:10:10, T_3 = 350 Kg/ha NPK 20:10:10, T_4 = 450 Kg/ha NPK, T_5 = 20 Mg/ha poultry manure, T_6 = 30 Mg/ha poultry manure, FD = fruit diameter, FL = fruit length, Sp1a = *Capsicum chinense* cv. Safi, Sp1b = *Capsicum chinense* cv. Big Sun, Sp2 = *Capsicum frutescens* (Bird pepper).

Table 4. Macro-nutrient concentration (%) of fruits of three pepper cultivars.

Pepper cultivars	N%	P%	K%	Mg%	Ca%
Capsicum chinense cv. Safi	2.25	0.34	2.89	0.29	0.12
Capsicum chinense cv. Big Sun	2.09	0.31	3.03	0.16	0.19
Capsicum frutescens	2.39	0.42	3.06	0.22	0.17

3.6. Essential Oils from Fruits of the Three Pepper Cultivars

Figure 3 shows that there were 179 essential oils from pepper fruits of *Capsicum chinense* cv. Safi. The main essential oils included alpha-pinene, cis-3-Hexenyllactate, 2-pentyl-furan, isocytosine; 1,1,3-trimethyl-cyclohexane, (E)-12-Tetradecenal; 1,6-Octadiene, D-Limonene, Limonene, Benzene acetaldehyde; 3,7-dimethyl-1; 6-Octadien-3-ol; 1-Hexadecen-3-ol; 1-Cyclopentylethanol; (E)-2-Nonenal and 2H-pyran, based on their abundance. The major essential oil was Limonene, which was more abundant with respect to the mass/charge ratio and retention time as shown by the highest peaks.

Figure 4 shows that there were 208 essential oils identified from *Capsicum chinense* cv. Big Sun fruits with Benzene acetaldehyde; 3,7-dimethyl-1; 6-Octadien-3-ol; n-Amyl isovalerate; (E)-2-Nonenal; 3,4-dimethyl-Benzaldehyde; 2,6,6-trimethyl-1; 3-Cyclohexadiene-1-carboxaldehyde; Hexyl n-valerate; Neopentyliden cyclohexane; alpha-ethylidene-Benzene acetaldehyde; 2,6-dimethyl-2; 6-Octadiene; Cyclohexane; alpha-Cubebene; Copaene; (E)-5-Undecene; Caryophyllene oxide; and Cymene as the main essential oils with respect to abundance. The major essential oil was 3,4-dimethyl-benzaldehyde, which has the highest abundance with respect to the mass/charge ratio and retention time, as shown by the highest peaks.

Figure 5 shows that there were 181 essential oils identified from *Capsicum frutescens* fruits with 3,4,4-trimethyl-2-Pentene; Benzaldehyde; alpha-hydroxyl-Benzene acetonitrile; alpha-Pinene; α-Terpinene; Benzaldehyde; 1,3,5-Trimethyl-1-H-pyrazol-4-amine; cis-2-(2-Pentenyl) furan; 3-Decyne; 3-Hexadecyne; (E)-Octenal; (E)-2-Tridecenal; (Z)-3-Tridecene; 2-[(1-methylethyl) thio]-Pentane; alpha-Phellandrene; (E)-2-Nonenal; 1-Methoxyadamantane; α-Caryophyllene; and Tricyclo [4. 4. 0. 0. (2, 8)] decane as the main essential oils with respect to abundance. The major essential oil was 1, 3, 5-Trimethl-1-H-pyrazol-4-amine, which has the highest abundance with respect to the mass/charge ratio.

4. Discussion

The highest growth parameters: plant height, fruit length, diameter and weight are obtained with poultry manure at different concentrations. This highlights the fact that organic fertilizer optimizes plant growth more than inorganic fertilizers in pepper like in other plants. In sweet pepper, it has been reported that, poultry manure alone increased plant height, yield and yield component [24]. In the same line, [25] have shown that the application of organic fertilizer affects the

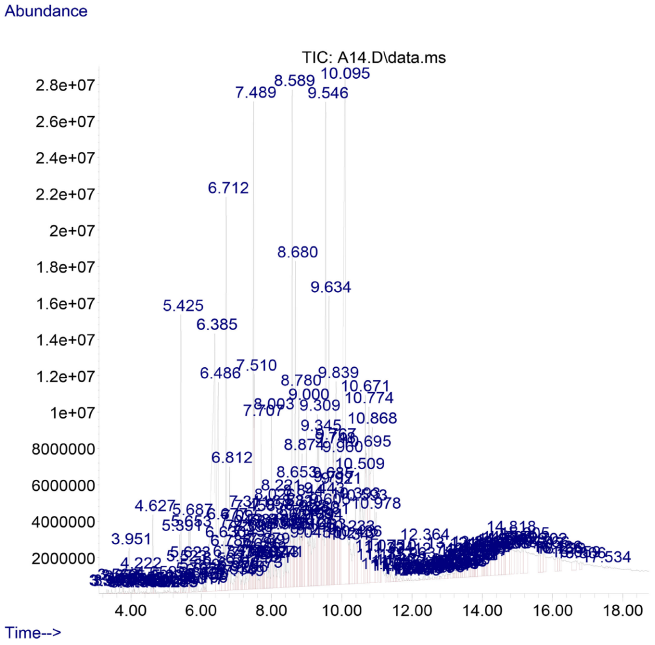

Figure 3. Chromatogram of essential oils extracted from pepper fruits of *Capsicum chinense* cv. Safi.

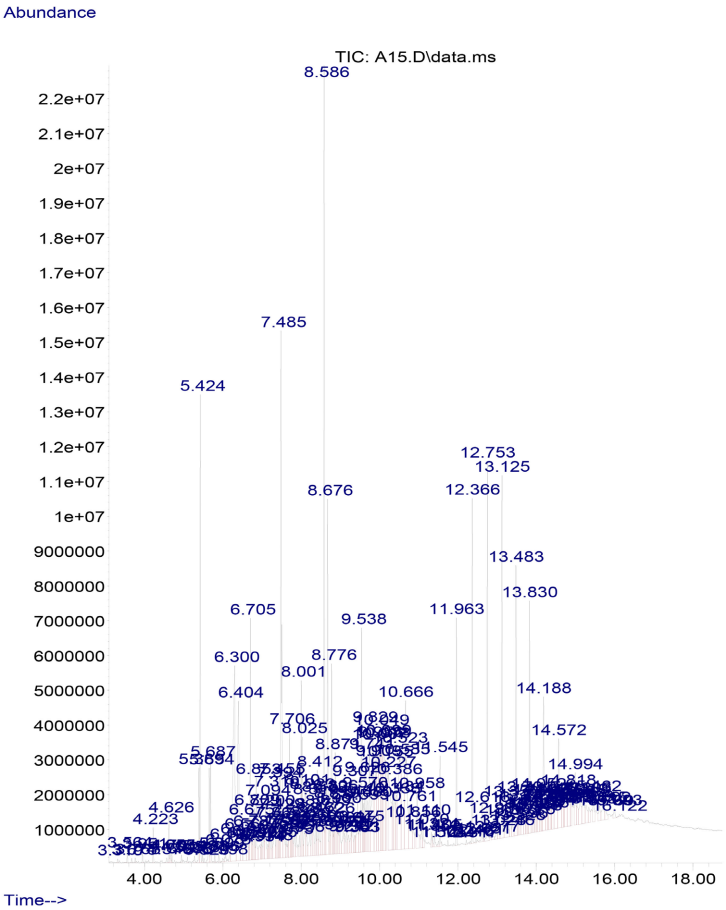

Figure 4. Chromatogram of essential oils extracted from pepper fruits of *Capsicum chinense* cv. Big Sun.

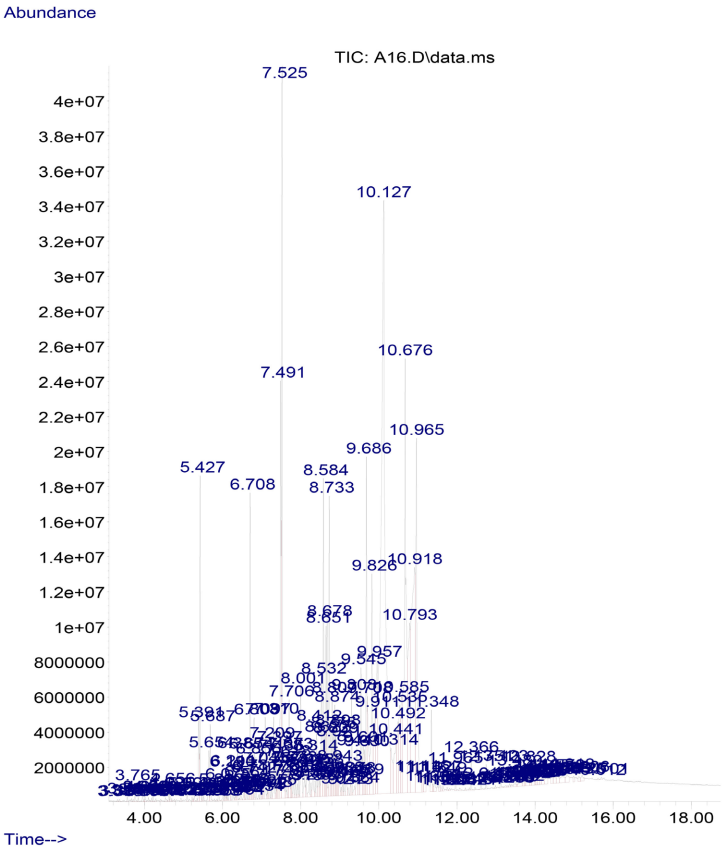

Figure 5. Chromatogram of essential oils extracted from pepper fruits of *Capsicum frutescens* (Bird pepper).

growth of soybeans. The increase in growth with poultry manure might be due to increase in nutrients supply that improved on the crop growth and the high level of organic matter also enhances the physico-chemical properties of the soil. Organic manures release nutrients slowly and are not easily leached producing a long residual effect in the soil for better uptake of nutrients by plant which enhances growth and development. The humus content in organic fertilizers improves on the water holding capacity of the soil and soil structure, thereby promoting better root development and prevents desiccation of roots in the soil. This is in line with the observation of [26] who worked on pepper and [27] on tomato. The number of days to flowering of the pepper plants treated with fertilizers was reduced but it was not significantly different from control. The same findings have been shown by [28] who asserted the decline in the number of days of flowering might be due to continued decomposition organic amendment used. This might also be due to higher net assimilation rate due to supply of nutrients leading to production of gibberellins earlier in optimum level that enables flower bud initiation.

The yield increased with increasing fertilizer rates. Organic manure produced better yield than NPK fertilizer and control. This might be ascribed to increase amount of nutrients supplied which might have led to increased formation of plant metabolites that help in building the plant tissue. Poultry manure improves

soil tilth and aeration, increase soil water holding capacity and stimulate the activity of micro-organisms, which makes nutrients readily available in the soil for plants uptake. All these might have accelerated the synthesis of carbohydrates and its better translocation from source to sink and might have led to improvement of yield. These results are in accordance to findings by [7] [15] [29] [30], who reported significant increase in yield of pepper with increased in manure rates.

There was variation in macro-nutrient contents and major essential oils in the three pepper cultivars. This might be due to genetic make-up of the different pepper cultivars. These results are consistent with findings by [31] [32], who reported that essential oils might have different properties due to presence of different genes. Limonene, *α*-Caryophyllene and *α*-Pinene found in the fruits of this plant are cytotoxic to cancer cells [33] [34]. Also, anti-bacteria properties of Caryophyllene oxide, *α*-Terpinene and Cymene found in the fruit of these plants has been reported in *Dennettiatripetala* fruit [35].

5. Conclusion

This study showed that 20 Mg/ha poultry manure is best for successful production of pepper in Mount Cameroon Region of Cameroon. *Capsicum frutescens* fruits (Bird pepper) were richest in macro-nutrient concentration and there were variations in concentration of the main essential oils of all three pepper cultivars. The fruits of the pepper cultivars were rich in essential oils, especially Alpha Terpinene, Alpha Pinene, Alpha Caryophyllene, Limonene, Cymene, and Carvacrol, which have medicinal properties. We therefore recommend for small scale farms of one hectare and less 20 Mg/ha of poultry manure should be used while in large scale pepper fields 450 Kg/ha NPK fertilizer is good for optimum productivity in the study area.

Contributions of Authors

Egbe Enow Andrew did the research concept, design, and the methods used in the field and reviewed the manuscript, Nkeutcha Marietta Solange Soupi did the supervision of field work and data collection, guided analysis and reviewed the manuscript, Nkede Francis did the data collection, and prepared the draft manuscript. Pegalepo Angèle Ndogho, involved in data analysis and the drawing of Tables and Figures and reviewed the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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