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Fertilizer effect on proximate composition and nutritive value of exotic/minor vegetable crops

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ABSTRACT

Purpose: A study was conducted on the effect of single-based fertilizers and compound fertilizers on the nutritive quality potential of lettuce (var. Eden), sweet pepper (var. Yellow wonder), and carrot (var. Bahia). **Research method:** This was accomplished following Completely Randomized Design (CRD) with four replications. Lettuce, sweet pepper, and carrot were fertilized using 71 kg, 100 kg, and 128 kg of ammonium sulphate (20.5 % N, 23.4 % S)/ha, 350 kg of NPK (15-15-15)/ha, and Control/No fertilizer application; 81 kg, 100 kg, and 138 kg of 6-24-12 NPK/ha, 225 kg of NPK (15-15-15)/ha, and Control; and on 43 kg, 71 kg, and 100 kg of 10-10-30 NPK/ha, 225 kg of NPK (15-15-15)/ha, and Control; respectively. **Findings:** Compound fertilizer resulted in high Fe content in lettuce whiles Single 2 treatment was in favour of that in carrot and sweet pepper. Single 3 treatment resulted in high Ca content in lettuce and sweet pepper whiles Single 2 treatment was in favour of that in carrot. Compound fertilizer resulted in high Mg content in lettuce whiles Single 3 treatment was in favour of that in carrot and sweet pepper. Crude protein content of lettuce, carrot, and sweet pepper was significantly high in the single-based fertilizer treatments. Compound fertilizer treatments recorded high carbohydrate content for lettuce and sweet pepper. All treatments recorded high moisture and high fat content. **Limitations:** No limitations. **Originality/Value:** Proximate composition patterns were strikingly dissimilar in all test crops.

INTRODUCTION

Vegetables are diverse in their cultivated, semi-cultivated, and wild states. Generally, all over the world, vegetables are used either as a whole meal or as a complement to the main meal. In Ghana, vegetables constitute an important component in the diet of the people. They are used to complement the basic staple foods. Majority of farmers who seem to be involved in vegetable crop production in Ghana are mostly the small-scale producer type. The fact that vegetables play a very important role in supplying the necessary nutrients can neither be ignored nor over emphasized. In addition to maintaining alkaline reserves in the body, vegetables are sources of vitamins, minerals, carbohydrates, protein, energy, water, roughage, and of medicinal properties, and thus are important protective foods (Fageria, 2009). The different categories of vegetable crops were leafy vegetables, fruit vegetables, and root vegetables using lettuce (var. Eden), sweet pepper (var. Yellow wonder), and carrot (var. Bahia) respectively as reference crops were studied.

Seidu (2018) stated that lettuce (*Lactuca sativa* L.) is most often grown as a leafy vegetable, but sometimes for its stem and seeds. Lettuce is most often used for salads, although it is also seen in other kinds of food, such as soups, sandwiches, and wraps; it can also be grilled (Seidu, 2018). In general, fresh bell peppers (sweet pepper of commerce) are treated just like any other vegetables in the kitchen. Their firm, crunchy texture together with the delicate sweet flavor makes them one of the most sought-after vegetables for cooking. In addition to the traditional use of peppers in the cuisine of several cultures, peppers are also important as a source of natural pigments, used in pharmaceutical industries and in food preparations, as antioxidants (colored bell peppers) (Ishikawa, 2003), and as ornamental plants (Stommel & Bosland, 2006). Pathirana (2013) stated pepper's importance based on historic, general use (fresh vegetable, condiment, ornamental), and medicinal use.

According to Swiader et al. (1992), sweet pepper is grown for its green fruits and is used in salads for meat stuffing which are common dishes in Europe and the United States. Sweet pepper is grown purely for the city markets as it is not widely known in many villages in West Africa. It is not hot or pungent as hot pepper and can be eaten fresh. The fruits have very few seeds and about 90 % of the interior consist of a large air space, giving the fruits a puffy appearance (Sinnadurai, 1992).

Carrots are reported to have high anti-oxidants and contain a lot of pro-vitamins. The edible root contains water, protein, ash, vitamins, and minerals (Shibairo et al., 2015), which is helpful to promote good health in consumers. Carotene, a famous ingredient in carrot, has powerful healing properties for diseases such as acne, asthma, anemia, inflammation, and can also be added to layer feed to improve the color of the egg yolk (Kahangi, 2004).

Optimal fertilizer management and efficient use of N, P, and K are necessary to improve the yield and nutritive quality and to reduce production cost in vegetable crop production (Fageria, 2009). Although some studies indicate that adequate lettuce yield can be achieved with low N application rates (Soundy & Smith, 1992), others suggest that high rates of N might be required to achieve maximum yields (Tittonell et al., 2003). Although high nitrate uptake generates high nitrite accumulation and improved leaf morphology (eg leaf length and width), leaf thickness can be significantly reduced. Therefore, nitrate content in leaf tissues at harvest affects lettuce nutritive quality (Tittonell et al., 2001). The authors added that high N content in lettuce and other vegetable crops generally leads to storage disorders including the potential for rapid postharvest decay which is a major source of financial loss for producers. Studies indicate that high N availability in the soil can affect lettuce nutritive quality (Tittonell et al., 2001).

Appropriate pepper fruit development for quality nutrition depends on adequate flower development, pollination, fruit set, fruit growth, and maturity/ripening. Favorable soil conditions for the proper growth and development of the fruit organs are, therefore, a requirement to ensure high fruit set, yield, and nutritive quality (Pathirana, 2013). The authors added that assimilate accumulation and cell number/size are determined by several factors, including temperature and amount of fertilizer application.

Tittonell et al. (2001), Mallareddy (2007), and Barman et al. (2015) recommended a pH range of 5.5 to 7.0, 5.8 to 7.0, and 5.0 to 7.0 respectively as conducive for cultivation of lettuce, carrot, and sweet pepper respectively.

Seidu (2018) observed that one most important limiting factor in the almost neglected vegetable crop production sector which is to the detriment of development in Ghana, is ''the lack of research in the sector''. The author added that there has not been satisfactory research on most of the minor/exotic vegetables introduced in Ghana, thus limiting their demand to only the expatriate and a few affluent Ghanaians.

Since farmers who seem to be involved in vegetable crop production in Ghana are mostly the small-scale producer type and many a time with small capital coupled with exhausted soils, there is the need for this research to include different fertilizer trials such as compound and single-based fertilizers both of which are necessary but are of high-cost and low-cost respectively.

Hence, the need to research into the effect of single-based fertilizers and compound fertilizers on some representative minor/exotic vegetable crops taking into consideration the different categories of vegetable crops (leafy vegetables, fruit vegetables, and root vegetables). For the experiment we used lettuce (var. Eden), sweet pepper (var. Yellow wonder), and carrot (var. Bahia) as reference crops with the objective to determine their nutritive quality potential for the fresh market.

MATERIALS AND METHODS

Soil test

The experimental soil was tested for N (%), P (mg/kg), K (mg/kg), Ca (Cmol+/kg), Mg (mg/kg), pH, and E. C. (µs/cm) to determine the nutrient status of the soil; for the fact that some of these elements were included in the different fertilizers applied; and also for the reason that some of these elements were among the nutrient elements intended to be determined of the different test crops after harvest. Soil pH was also tested for, before land preparation since it is a determinant of soil fertility status (Wang et al., 2008) and as well reflects the degree of acidity or alkalinity of the soil (Shibairo, 2015). The results of the soil analyses dictated the types of basic fertilizers and quantities applied, taking into account the requirements specific to each test crop (Sinnadurai, 1992; Fageria, 2009).

Experimental treatments

There were five treatments in each case of a test crop as follow:

Lettuce

1. 50 g of ammonium sulphate (20.5 % N 23.4 % S)/plot of 2.7 × 2.6 m equivalent to 71 kg of ammonium sulphate (20.5 % N 23.4 % S)/ha,
2. 70 g of ammonium sulphate (20.5 % N 23.4 % S)/plot of 2.7 × 2.6 m equivalent to 100 kg of ammonium sulphate (20.5 % N 23.4 % S)/ha,
3. 90 g of ammonium sulphate (20.5 % N 23.4 % S)/plot of 2.7 × 2.6 m equivalent to 128 kg of ammonium sulphate (20.5 % N 23.4 % S)/ha and
4. 246 g of NPK (15-15-15)/plot of 2.7 × 2.6 m equivalent to 350 kg of NPK (15-15-15)/ha (Swiader et al., 1992; Fageria, 2009).
5. Control = No treatment/fertilizer application per plot of 2.7 × 2.6 m

Sweet pepper

1. 57 g of 6-24-12 NPK/plot of 2.7 × 2.6 m equivalent to 81 kg of 6-24-12 NPK/ha,
2. 77 g of 6-24-12 NPK/plot of 2.7 × 2.6 m equivalent to 100 kg of 6-24-12 NPK/ha,
3. 97 g of 6-24-12 NPK /plot of 2.7 × 2.6 m equivalent to 138 kg of 6-24-12 NPK /ha and
4. 158 g of NPK (15-15-15)/plot of 2.7 × 2.6 m equivalent to 225 kg of NPK (15-15-15)/ha (Swiader et al., 1992; Fageria, 2009).
5. Control = No treatment/fertilizer application per plot of 2.7 × 2.6 m

Carrot

1. 30 g of 10-10-30 NPK /plot of 2.7 × 2.6 m equivalent to 43 kg of 10-10-30 NPK/ha,
2. 50 g of 10-10-30 NPK /plot of 2.7 × 2.6 m equivalent to 71 kg of 10-10-30 NPK/ha,
3. 70 g of 10-10-30 NPK /plot of 2.7 × 2.6 m equivalent to 100 kg of 10-10-30 NPK/ha and
4. 158 g of NPK (15-15-15)/plot of 2.7 × 2.6 m equivalent to 225 kg of NPK (15-15-15)/ha (Swiader et al., 1992; Fageria, 2009).
5. Control = No treatment/fertilizer application per plot of 2.7 × 2.6 m

Treatments 1, 2, 3, 4, and 5 were designated as Single 1, Single 2, Single 3, Compound, and Control respectively, in each case of the three (3) different test crops for convenience in results' presentation, observation, and subsequent discussion.

Sampling and determination of nutritive value

Freshly harvested mature lettuce, sweet pepper, and carrot were sampled for the nutritive value assessments. Tests were carried out at different times for the different test crops depending upon their maturity times. Criteria and methods that were used for the determination of the nutritive values of the lettuce, sweet pepper, and carrot cultivated for the fresh market included: Tests for minerals {Calcium (Ca), Iron (Fe), and Magnesium (Mg)} as outlined by Marschner (1995), and Proximate analyses on carbohydrates, C, protein, ash, fat, and moisture (AOAC, 2005). All determinations were replicated four times.

Laboratory studies

Laboratory studies were conducted to ascertain the nutritive value of lettuce, sweet pepper, and carrot cultivated for the fresh market; as influenced either by a single-based fertilizer or a compound fertilizer.

The studies were carried out at the Chemistry Laboratories of the Savannah Agricultural Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR), Nyankpala - Tamale, Northern Ghana; Water Research Institute (WRI), Tamale, Ghana; and the Spanish Laboratory of UDS, Nyankpala Campus, Tamale, Ghana; since these laboratories were relatively well equipped for the required studies. It is also for the reason that these laboratories were comparatively near the field-study area for convenience and ease of transportation.

For every harvest, a representative sample of fruits was immediately road-transported at ambient temperature (29-35 °C) from the field to the laboratory for the assessments. Distances of one and a half kilometres (1.5 km), fifteen kilometres (15 km), and one hundred meters (100 m) to the laboratories at SARI, WRI, and UDS, respectively, were covered from the field. The experiment was conducted following Completely Randomized Design (CRD) with four replications.

Statistical analyses

All data were analyzed using the Analysis of Variance (ANOVA) technique with the GENSTAT statistical program. Least Significant Difference (LSD) at 5 % probability level was used to determine treatment differences among different test crops.

RESULTS

Nutritive value of lettuce, carrot, and sweet pepper as influenced by compound and single-based fertilizers

Results in Table 1 show that iron (Fe) content was significantly ($p < 0.0001$) higher in lettuce cultivated on the Compound fertilizer treated plot than in lettuce cultivated on the other treatments. Fe content of lettuce ranged from 1.3 - 3.26 mg/100 g across the various treatments. Single 1 (1.89mg/100 g) and Single 2 (1.87 mg/100 g) were significantly indifferent in Fe content for lettuce but were significantly higher when compared to Single 3 (1.56 mg/100 g) and when compared to Control. Single 3 was, however, significantly higher when compared to Control (1.30mg/100 g). For carrot and sweet pepper, the Single 2 treatment was significantly ($p < 0.0001$) higher in Fe content than in the Control, Single 1, Compound, and Single 3 treatments. Fe content of carrot ranged from 0.1 - 0.39 mg/100 g (Table 2) while that of sweet pepper ranged from 0.2 - 1.2 mg/100 g (Table 3) across the different treatments. When carrot was considered, Fe content was significantly indifferent for Single 3 (0.30 mg/100 g), Single 1 (0.27 mg/100 g), and Compound (0.30 mg/100 g) but all three treatments were significantly ($p < 0.0001$) higher when compared to Control (0.10 mg/100 g) (Table 2). For sweet pepper, Fe content in Single 3, Single 1, Compound, and Control were significantly indifferent (Table 3).

Calcium (Ca) content in lettuce was significantly ($p < 0.0001$) different among all five treatments (Table 1). The changes were in a descending order of Single 3, Compound, Single 1, Control, and Single 2. Calcium content in carrot was also significantly different among all five treatments and changes were a in descending order of Single 2, Single 3, Compound, Single 1, and Control (Table 2). The results in Table 3 show that Ca content of sweet pepper ranged from 5 - 17.01 mg/100 g across the different treatments. The Single 3 treatment recorded a significantly ($p < 0.0001$) higher Ca content of almost 1.7 and 3.4 times higher than Compound fertilizer treatment and the Control, respectively (Table 3). Generally, the Ca content in sweet pepper was significantly ($p < 0.0001$) different among all five treatments but in a descending order of Single 3, Single 2, Single 1, Compound, and Control (Table 3).

The concentration of Magnesium (Mg) ranged from 43.75 - 45.45 mg/100 g in lettuce (Table 1), 32.37 - 37.57 mg/100 g in carrot (Table 2), and 5 - 17.01 mg/100 g in sweet pepper (Table 3) across the different treatments. For lettuce, the Mg content was significantly ($p < 0.0001$) different among all five treatments except for Single 3 and Single 2 which were not significantly different, however, in a descending order of Compound, Control, Single 1, Single 2/Single 3 (Table 1). In the case of carrot, the Mg content was significantly ($p < 0.0001$) different among all five treatments, however, in a descending order of Single 3, Single 2, Compound, Single 1, and Control (Table 2). With sweet pepper, except for Single 1 and Compound which were not significantly different in Mg content, there were significant differences among the other treatments but in a descending order of Single 3, Single 2, Single 1, Compound, and Control (Table 3).

The carbohydrate (CHO) content of lettuce ranged from 5.8 - 7.24 % (Table 1) while that of carrot and sweet pepper ranged from 11.29 - 14.21 % (Table 2) and 4.72 – 8.98 % (Table 3) respectively, across the different treatments. For carrot, the CHO content was significantly ($p < 0.0001$) different among all five treatments, however, in a descending order of Control, Single 1, Single 3, Compound, and Single 2 (Table 2). In the case of sweet pepper, the CHO content was significantly ($p < 0.0001$) different among all five treatments, however, in a descending order of Compound, Control, Single 2, Single 1, and Single 3 (Table 3). For both lettuce and carrot, the Control recorded significantly ($p <0.0001$) higher CHO content when compared to the other treatments. However, the CHO content of sweet pepper grown on Compound fertilizer treated soils was significantly ($p < 0.0001$) higher when compared to the Control, Single 1, Single 2, and Single 3 treatments.

Results in Tables 1, 2, and 3 show that the protein content of lettuce, carrot, and sweet pepper ranged from 1.27 - 1.87 %, 0.94 - 1.47 %, and 0.58 - 1.44 % respectively, across the different treatments. In the case of lettuce, the protein content was significantly ($p < 0.0001$) different among all five treatments, however, in a descending order of Single 2, Control, Single 1, Single 3, and Compound (Table 1). For carrot, the protein content was significantly ($p < 0.0001$) different among all five treatments, however, in a descending order of Single 3, Single1, Single 2, Compound, and Control (Table 2). With sweet pepper, except for Single 1 and Compound which were not significantly different in protein content, there were significant ($p < 0.0001$) differences among the other treatments but in a descending order of Single 3, Single 2, Single 1/Compound, and Control (Table 3). For lettuce, the Compound fertilizer treatment had a significantly ($p < 0.0001$) lower protein content when compared with the other treatments; with almost 1.5 times lower than the Single 2 treatment that gave the highest protein content (Table 1) across the different treatments. The protein content of carrot and sweet pepper was significantly ($p < 0.0001$) higher in Single 3 treatment relative to Compound, Control, Single 1, and Single 2 treatments in each case of the carrot and the sweet pepper.

The ash content of lettuce, carrot, and sweet pepper ranged from 1.46 - 2.43 %, 0.42 - 2.22 %, and 0.58 - 1.44 % respectively, across the different treatments. With reference to lettuce, the ash content was significantly ($p < 0.0001$) different among all five treatments, however, in a descending order of Single 2, Single 3, Compound, Single1, and Control (Table 1). The ash content was also significantly ($p < 0.0001$) different among all five treatments for carrot but in a descending order of Single 2, Single1, Single 3, Compound, and Control (Table 2). With sweet pepper, Compound and Single 1 were not significantly different in ash content; the others were, but in a descending order of Single 3, Single 2, Compound/Single1, and Control (Table 3). The ash content of lettuce and carrot for the Single 2 treatment gave a significantly ($p < 0.0001$) higher value than the Control, Compound, Single 1, and Single 3 treatments. However, the ash content was significantly ($p < 0.0001$) higher in Single 3 treatment for sweet pepper relative to the other treatments.

The fat content of lettuce and carrot ranged from 0.39 - 0.68 % (Table 1) and 0.18 - 0.49 % (Table 2) respectively, while that of sweet pepper ranged from 0.12 - 0.29 % (Table 3). With the exception of Single 1 and Control which were not significantly different, the other treatments were significantly ($p < 0.0001$) different in fat content among the lettuce treatments. These were, however, in a descending order of Single 2, Single 3, Single 1/Control, and Compound (Table 1). In the case of carrot, the fat content was significantly ($p < 0.0001$) different among all five treatments, however, in a descending order of Single 3, Single 1, Compound, Control, and Single 2 (Table 2). For sweet pepper, Compound and Single 1 were not significantly different in fat content, but the other treatments were, but rather in a descending order of Single 3, Single 2, Single 1/Compound, and Control (Table 3). The Single 2 treatment resulted in producing significantly higher ash content than in the other treatments with respect to lettuce (Table 1). However, the ash content of carrot and sweet pepper was significantly ($p < 0.0001$) higher in Single 3 treatment when compared to the Control, Compound, Single 1, and Single 2 treatments of the two test crops.

Table 1. Effect of various fertilizer treatments on the nutritive value of lettuce on "as is" basis/fresh weight basis

Treatment	Fe (mg/100g)	Ca (mg/100g)	Mg (mg/100g)
Compound	3.26±0.025[a]	37.80±0.007[b]	45.45±0.046[a]
Control	1.30±0.025[d]	35.08±0.007[d]	43.75±0.046[b]
Single 1	1.89±0.025[b]	35.47±0.007[c]	44.31±0.046[c]
Single 2	1.87±0.025[b]	31.09±0.007[e]	43.79±0.046[d]
Single 3	1.56±0.025[c]	39.55±0.007[a]	44.75±0.046[d]
p-value	< 0.0001	< 0.0001	<0.0001

Values (means ± SEM; *n* = 3). Means in a column with the same letters are not significantly different at $p > 0.05$

Table 1. Continued.

Treatment	CHO (%)	Carbon (%)	Protein (%)	Ash (%)	Fat (%)	Moisture (%)
Compound	5.80±0.005[e]	80.83±0.011[c]	1.27±0.007[e]	1.77±0.009[c]	0.39±0.002[d]	90.70±0.015[a]
Control	6.61±0.005[d]	85.95±0.011[a]	1.81±0.007[b]	1.46±0.009[e]	0.47±0.002[c]	89.58±0.015[d]
Single 1	6.08±0.005[a]	82.79±0.011[b]	1.54±0.007[c]	1.68±0.009[d]	0.47±0.002[c]	90.15±0.015[b]
Single 2	7.24±0.005[a]	79.90±0.011e	1.87±0.007[a]	2.43±0.009[a]	0.68±0.002[a]	87.70±0.015[e]
Single 3	6.17±0.005[c]	80.42±0.011[d]	1.42±0.007[d]	1.93±0.009[b]	0.52±0.002[b]	89.84±0.015[c]
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Table 2. Effect of various fertilizer treatments on the nutritive value of carrot on "as is" basis/fresh weight basis

Treatment	Fe (mg/100g)	Ca (mg/100g)	Mg (mg/100g)
Compound	0.30±0.011[b]	13.53±0.009[c]	35.45±0.014[c]
Control	0.10±0.011[c]	9.41±0.009[e]	32.37±0.014[e]
Single 1	0.27±0.011[b]	11.28±0.009[d]	32.86±0.014[d]
Single 2	0.39±0.011[a]	16.53±0.009[a]	36.16±0.014[b]
Single 3	0.30±0.011[b]	15.70±0.009[b]	37.57±0.014[a]
p-value	< 0.0001	< 0.0001	<0.0001

Values (means ± SEM; n = 3). Means in a column with the same letters are not significantly different at $p > 0.05$

Table 2. Continued.

Treatment	CHO (%)	Carbon (%)	Protein (%)	Ash (%)	Fat (%)	Moisture (%)
Compound	11.93±0.004[d]	94.00±0.077[b]	0.97±0.002[d]	0.83±0.002[d]	0.26±0.001[c]	86.12±0.02[a]
Control	14.21±0.004[a]	97.32±0.077[a]	0.94±0.002[e]	0.42±0.002[e]	0.24±0.001[d]	84.22±0.02[d]
Single 1	12.53±0.004[b]	92.71±0.077[d]	1.30±0.002[b]	1.12±0.002[b]	0.37±0.001[b]	84.61±0.02[c]
Single 2	11.29±0.004[e]	84.94±0.077[e]	1.13±0.002[c]	2.22±0.002[a]	0.18±0.001[e]	85.16±0.02[b]
Single 3	12.36±0.004[c]	93.39±0.077[c]	1.47±0.002[a]	1.03±0.002[c]	0.49±0.001[a]	84.58±0.02[c]
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Table 3. Effect of various fertilizer treatments on the nutritive value of sweet pepper on "as is" basis/fresh weight basis

Treatment	Fe (mg/100g)	Ca (mg/100g)	Mg (mg/100g)
Compound	0.31±0.129b	10.00±0.100c	10.00±0.100c
Control	0.20±0.129b	5.00±0.100d	5.00±0.100d
Single 1	0.30±0.129b	10.00±0.100c	10.00±0.100c
Single 2	1.20±0.129a	13.51±0.100b	13.51±0.100b
Single 3	0.60±0.129b	17.01±0.100a	17.01±0.100a
p-value	< 0.0001	< 0.0001	<0.0001

Values (means ± SEM; n = 3). Means in a column with the same letters are not significantly different at $p > 0.05$

Table 3. continued.

Treatment	CHO (%)	Carbon (%)	Protein (%)	Ash (%)	Fat (%)	Moisture (%)
Compound	8.98±0.002a	80.87±0.001c	0.86±0.007c	0.88±0.016c	0.17±0.007c	90.00±0.129c
Control	8.91±0.002b	85.90±0.001a	0.40±0.007d	0.58±0.016d	0.12±0.007d	90.00±0.129c
Single 1	6.08±0.002d	82.76±0.001b	0.86±0.007c	0.88±0.016c	0.17±0.007c	92.00±0.129a
Single 2	6.41±0.002c	79.84±0.001e	1.16±0.007b	1.20±0.016b	0.23±0.007b	91.00±0.129b
Single 3	4.72±0.002e	80.35±0.001d	1.44±0.007a	1.44±0.016a	0.29±0.007a	92.00±0.129a
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

The moisture content in lettuce, carrot, and sweet pepper ranged from 87.7 - 90.7 %, 84.22 - 86.12 %, and 90.00 - 92.00 % respectively, across the different treatments. In the case of lettuce, the moisture content was significantly ($p < 0.0001$) different among all five treatments, however, in a descending order of Compound, Single 1, Single 3, Control, and Single 2 (Table 1). With the exception of Single 1 and Single 3 which were not significantly different in moisture content, the other treatments were significantly ($p < 0.0001$) different among the carrot treatments. These were, however, in a descending order of Compound, Single 2, Single 3/Single 1, and Control (Table 2). In the case of sweet pepper, indifferences in moisture content occurred between Single 3 and Single 1, and between Control and Compound. There were however, significant ($p < 0.0001$) differences in moisture content among sweet pepper treatments with changes in a descending order of Single 3/Single 1, Control/Compound, and Single 2 (Table 3).

DISCUSSION

Effects of single-based fertilizers and compound fertilizers on the nutritional value of fresh lettuce, carrot, and sweet pepper

Iron (Fe) content of lettuce varied remarkably with differences in fertilizer application with the highest content resulting from Compound fertilizers where Single 3 recorded the least among the Single-based fertilizers. This agrees with affirmation of Patricia et al. (2014) which reported that the addition of nitrogen fertilizer increased Fe content of lettuce grown in either sandy or calcareous soils when compared to the Control (no fertilization). The current results further lends support to Ouda and Mahadeen (2008) who reported a remarkable increase in Fe content in broccoli leaves with organic and inorganic fertilization. This however, contradicts that of Wiesler et al. (2004) who found no variations in the mineral (including Fe) content of lettuce under different fertilizer tests. Similar reports have been shown in *Hibiscus sabdariffa* cultivation on fertilizer trials by Musa and Ogbadoyi (2012). Among the fertilizer treatments, the Fe content of lettuce grown in the Compound fertilizer treated soils was significantly higher when compared to the Single-based fertilizer treatments. This is in line with report by Wiesler et al. (2004) who indicated that Fe content in lettuce seemed to be influenced by a nitrification inhibitor, which could probably explain the differences in Fe content of lettuce grown in Compound fertilized soils and in Single-based N fertilized soils.

Fe content of carrot grown in the Control treatment was significantly lower than those grown in the fertilized soils with Single 2 potassium treatment recording significantly higher Fe content amongst them. This agrees with that of Petzoldt (2008) and Shibairo et al. (2015) who reported that an increase in the supply of nitrogen decreased Fe content in carrot roots.

Single 2 gave a significantly higher Fe content among the sweet pepper treatments following reports that suggest that application of compound fertilizers enhances Fe and Mn accumulation in vegetables (Moreno et al., 2003; Wang et al., 2008). The present results contradict these reports since the Fe content was rather higher in the Single-based fertilizer on comparison with Compound fertilizer. Differences including crop species, cultivar, variety, environment, and cropping practices might explain the discrepancies in the results outcome.

The crude protein content of lettuce, carrot, and sweet pepper was significantly higher in the Single-based fertilizer treatments comparatively to the Compound fertilizer treatments and to the Control. The significant increase in protein content in the leaves, roots, and fruits of lettuce, carrot, and sweet pepper respectively could be attributed to the fundamental principle of ‘’requirements (basic fertilizer-type and quantities required) specific to each type of vegetable crop’’ (Fageria, 2009) which were taken into account and considered as indicated in the various treatments. Hence, the significant increase in the protein content of Single-based fertilizer treatments when compared to the Compound fertilizer treated samples and Control. This supports that of Pathirana (2013) who reported a significant increase in protein content of hot pepper with N application. It does not however, agree with Wiesler et al. (2004) who reported that the protein concentration in lettuce did not show any significant change either with the kind of fertilizer or with the application rate used. In buffalo grass forage, the crude protein content increased with the N rate also increased (Wiesler, 2008).

The CHO content of lettuce, carrot, and sweet pepper was significantly influenced by fertilizer treatment. For lettuce and sweet pepper, the Compound fertilizer gave the highest CHO content. This lends support to Abu (2010) who reported that during the early part of fruit and vegetable crop maturation, CHO which is almost sucrose is the predominant sugar, but in the later stages glucose and fructose predominate almost in the same quantities but with a slight preponderance of the latter. Thus, the low CHO/sucrose content in the later stages (the ideal time for harvesting carrot) of maturation in carrot is probably due to the CHO being used by the carrot root for metabolic activities after all the starch had been hydrolyzed. Hence, the normal characteristic astringent sweetening taste in carrot. Since lettuce and sweet pepper are or can be harvested at an earlier stage of the leaf and fruit development respectively depending on the purpose, CHO which is almost sucrose is the predominant sugar in it, and so at that stage of harvest in lettuce and sweet pepper, CHO/sucrose will predominate in content.

The high moisture content of vegetables corroborated with results of investigated moisture content of vegetables as indicated by FAO (2006). In the current study, the moisture content was significantly higher in the Compound fertilized treatments for all the test crops except for sweet pepper. This is probably why the Compound fertilized vegetables are likely to have short shelf life as speculated elsewhere that vegetables with high moisture content are usually likely to be predisposed to deterioration earlier (Kitinoja & Kader, 2002; Kwenin, 2011). On the other hand, Kader et al. (1985) stated that attack by most organisms follows physical injury or physiological breakdown of the commodity. The authors added that in a few cases, pathogens can infect apparently healthy tissues and become the primary cause of deterioration. According to the authors, in general, harvested fruits and vegetables exhibit considerable resistance to potential pathogens during most of their postharvest life. Thus, since the moisture content of the various test crops seem to tally with those of literature (Sinnadurai, 1992), the moisture magnitudes recorded in the present study no longer pose threat to unusual deterioration provided the crops under study have healthy tissues.

The ash content of the three vegetable crop species was generally higher in samples harvested from the fertilized plots. This agrees with Gichuhi et al. (2014) who reported increased ash content in sweet potato when the sweet potato was tested after being subjected to increased application of nitrogen rich broiler litter during cultivation. Thus, the ash content which represents the total mineral content could enhance the nutritive value in vegetables by either single-based or compound fertilizer application. Alam et al. (2016) reported that the application of fertilizer together with sufficient irrigation can influence the nutrient content, especially the mineral content of vegetables.

Vegetable crop species are generally low in fat content (Ejoh et al., 1996; Patricia et al., 2014). It was therefore not surprising to encounter low fat content in lettuce, carrot, and sweet pepper in the present study. Cardiovascular disorders such as atherosclerosis, cancer, rapid aging, and obesity are said to be associated with excessive fat consumption (Kris-Etherton et al., 2002). Therefore, the consumption of these vegetables in recommended amounts may be a solution to individuals suffering from cardiovascular disorders and obesity.

The Single 3 treatment in each case of lettuce, carrot, and sweet pepper gave a significantly higher Ca content when compared to the other treatments. This suggests that Single-based fertilizers respond to the fundamental principle of "requirements (basic fertilizer-type and quantities required) specific to each type of vegetable crop" (Fageria, 2009), and that where this principle is taken into account and considered, could enhance statistically recommendable quantities of some minerals such as Ca which is the most abundant in the human body (Moss, 1961). According to Moss (1961), almost 99 % of the body's Ca is stored in the structure of the bones and teeth. Thus, builds and maintains strong bones and teeth; enhances proper functioning of the heart, muscles, and nerves; and offers protection against cancer, diabetes, and high blood pressure (Barman, 2015).

It has been proven that high temperature conditions may decrease the Mg content in foods (Barman, 2015). This assertion confirms the situation where for lettuce, the Mg content was significantly ($p < 0.0001$) different among all five treatments except Single 3 and Single 2, however, in a descending order of Compound, Control, Single 1, and Single 2/Single 3; in the case of carrot, the Mg content was significantly ($p < 0.0001$) different among all five treatments, however, in a descending order of Single 3, Single 2, Compound, Single 1, and Control; with sweet pepper, except Single 1 and Compound, there were significant differences in Mg content among the other treatments but in a descending order of Single 3, Single 2, Single 1/Compound, and Control. These results could be due to the fact that the experiment was conducted within the period December 2016 to April 2017 (i.e. within the dry season) with a daily mean sun shine hours of 9.48, daily maximum temperature of 40.6 ^{o}C, daily minimum relative humidity of 18 %, and total rain fall of 33 mm in the five month experimental period (SARI, 2016; SARI, 2017); a situational condition that favored carrot and sweet pepper production by significantly retaining Mg in their highly fertilized treatment harvests since they have a deep rooted system to counteract the prevailing conditions during growth. Lettuce was unable to significantly retain Mg in its highly fertilized treatment harvests, but in the low fertilized treatments probably because its highly fertilized treatments were more vulnerable to the prevailing conditions during growth. Lettuce is a shallow rooted vegetable and probably was unable to stand the heat of the higher temperatures and other adverse weather conditions that occurred during growth (Barman, 2015).

The Ca content of lettuce and sweet pepper was higher in the Single 3 treatment than in the Compound fertilizer and the Control treatments when the two test crops were considered. Benton Jones Jr. (2012) speculated that to increase the Ca concentration in leaves or fruits, more effective measures than simply increasing the Ca supply should be considered; namely the avoidance of high concentrations of competing ions (K^+, NH_4^+, Mg^{+2}) in the soil solution. In the current study, it appeared that the NH_4^+ concentration in the soil was not high enough to cause an antagonistic effect. It, however, shows that to improve the Ca content in lettuce and sweet pepper, the highest application rate of the single-based fertilizers in each case of these two test crops in this study is recommended.

In carrot, a moderate (Single 2) application rate of the Single-based fertilizer gave the highest Ca content. Shibairo (2015) opined that an increase in N supply for carrot production could result in a decline in the concentrations of phosphorous, calcium, magnesium, potassium, iron, sulphur, and boron in the root of carrot. The reason for the decline in the macro and micro nutrients with increased N supply could probably be a dilution effect in plant nutrition (Jarrell, 1981). Generally, however, the concentrations of Ca and Mg in carrot roots increased with increased supply of N.

CONCLUSION

Changes in mineral content of the different categories of vegetables studied in relation to their response to either Single-based fertilizers or Compound fertilizers did not show a similar pattern. Compound fertilizer was in favour of higher Fe content in lettuce whiles Single 2 treatment was in favour of that in carrot and sweet pepper. Single 3 treatments was in favour of higher Ca content in lettuce and sweet pepper whiles Single 2 treatment was in favour of that in carrot. Compound fertilizer was in favour of higher Mg content in lettuce whiles Single 3 treatment was in favour of that in carrot and sweet pepper. Mineral content patterns were strikingly dissimilar in all test crops.

The crude protein content of lettuce, carrot, and sweet pepper was significantly higher in the single-based fertilizer treatments when compared to the compound fertilizer treatments and to the control. For lettuce and sweet pepper, the compound fertilizer gave the highest CHO content following the fact that lettuce and sweet pepper are or can be harvested at an earlier stage of the leaf and fruit development respectively, depending on the purpose. Generally, all treatments of the various test crops recorded higher moisture content but found to be normal provided the crops under study had healthy tissues.

The ash content of the three vegetable crop species was generally higher in samples harvested from the fertilizer applied plots but with a slight preponderance of the Single-based fertilizer treatments. Thus, the ash content which represents the total mineral content could enhance the nutritive value in vegetables by either single-based or compound fertilizer application. All test crops recorded low fat content but with a slight preponderance of the Single-based fertilizer treatments as in the case of ash

Conflict of interest

The authors have no conflict of interest to report.

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