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Quality of Carrot (*Daucus Carota L.*) As Influenced by Green Manure and Plant Spacing On Forest Ochrosols in Ghana

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Abstract

An experiment was carried out to study the influence of different green manures and plant spacing on quality of carrot at Enchi in 2015 and 2016. Four different soil amendments (10 t/ha *Mucuna pruriens, Chromolaena odorata, Gliricidia sepium,* 300Kg/ha NPK (15, 15, 15) and control) along with three different spacing regimes (25 x 10cm, 25 x 15cm and 25 x 20cm) were employed in the investigation in Randomized Complete Block Design (RCBD) experiment. The result revealed that the branching (forking) percentage of carrot root increased with increase in plant population. Plants that received amendments recorded higher percentages of branched roots compared with the control. Percentage cracked roots increased with decreasing plant density. The highest percentage cracked root was produced by plants that received green manures and 300 kg/ha NPK whilst the lowest was found in control plots. Application of green manures improved the nutritional contents and biochemical properties of carrot relative to the NPK. Plant population density also influenced the nutritional content with contents increasing with decreasing plant density. From the results it may be concluded that application of 10/ha *Chromolaena odorata* along with 25 x 20cm better improved the quality of carrot in the study area.

Keywords: ***Mucuna pruriens, Chromolaena odorata, Gliricidia sepium*, green manure, plant spacing.**

Introduction

Carrot (*Daucus carrota L.*) is a highly nutritious root crop with high market demand in Ghana. It contains substantial amount of carotene, thiamin, riboflavin and other minerals and vitamins (Sharfuddin and Siddique, 1985). In recent times market women and consumers in general have raised concerns about quality of vegetables including carrot in Ghanaian market.

The quality of carrot and to a large extent other vegetables can be assessed based technological suitability (suitability for processing), nutritional value (such as protein, vitamins, minerals etc.) and appearance (size, shape etc.). These attributes which can be measured quantitatively form the basis of consumers' preference for these vegetables. The appearance (size and shape) of carrot roots and the levels and magnitude of nutrients they contain depend on the amount of nutrients in the soil (Allemann & Young, 2002). Hence the need to improve on the fertility of the soil.

The common means of improving soil fertility has been the use of mineral fertilizers. The use of mineral fertilizers to improve soil fertility in small holder farms in Ghana is however, associated with myriad of economic problems (Drechesel and Gyiele, 1999). Making use of readily available organic materials in the farmstead is seriously being considered as the best alternative to mineral fertilizers. Various studies have established that vegetables grown on organic amended soils have higher concentrations of vitamins, soluble protein, total sugars (sucrose, glucose and fructose) and mineral compounds (Ca, K, Mg, S and Na) Wong *et al*., 1998; Premuzic *et al.*, 2002; Liu & Li, 2003; Suojala, 2003; Xu *et al.*, 2003). The utilization of most common animal manure (cow dung and poultry droppings) is facing challenges in the forest zones in Ghana because such animals are not fully integrated in the farming system. Besides, they are reared under extensive system making their manures difficult to gather for field application, not to mention the huge transportation cost considering the distance between the farms and human settlements.

To solve the problem of transportation and labour cost there is the need to identify species very close to the location of the farm. Most studies in Ghana on the use of plant materials for soil fertility improvement have been

limited to crop waste and leguminous crops because they are considered to be of high quality especially in terms of decomposition and nutrients (Cadisch and Giller, 1997; Palm *et al*., 1997; Mafongoya *et al*., 1998). In the forest zones of Ghana, *Mucuna pruriens Chromolaena odorata* and *Gliricidia sepium* abound on farmers' field which are often cleared and burnt during land preparation. Green manures of these plants have rarely been utilized in carrot production. Their effects on the nutritional and biochemical attributes of carrot is an area that needs attention. In view of the limited range of effective organic manures presently available, suitable organic sources of nutrients are urgently needed to cater for the growing interest in organic vegetable cultivation in Ghana.

Observations on carrot farms in Ghana have shown variation in inter and intra-row spacing with varied population densities resulting in uneven root sizes. The impact of the spacing regimes on the nutritional and biochemical properties of the roots is another area that has rarely been investigated. Therefore, the present study was undertaken to study the effect of green manure and plant spacing on the quality of carrot.

Materials and Methods

The study was conducted at Enchi located in the tropical rainforest of Ghana (5° 49' 0" N, 2° 49' 0" W, 309 metres above sea level) with two peaks of rainy seasons. The major rainy season starts from April of each year to July. This is followed by a short dry period in August, and then the minor rains begin in September and ends in early part of December of the same year. Soil type at the site was Forest Ochrosol (Acrisol) with good drainage (Dwomo and Asiamah, 1993, Dwomo, 1998). These soils have great agriculture value – they support all forms of arable crops with a considerable layer of organic matter. The site had been subjected to continuous cropping with Okra as the main crop cultivated on the land.

The experiment was a 3x5 factorial with treatment arranged in a Randomized Complete Block Design (RCBD). Spacing and soil amendments constituted the factors.

The treatments were three spacing regimes; S_1 (25 x 10cm), S_2 (25 x 15cm) and S_3 (25 x 20cm) and four amendments; T_1-10t/ha *Mucuna prurien,* T_2- 10t/ha *Chromolaena odorata,* T_3-10t/ha *Gliricidia sepium,* T_4-300kg/ha NPK (15, 15, 15) and T_5-Control (no amendment). Green manure of these plants were chosen based on their availability in the study area and their promising potentials in conserving soil fertility and improving crop yield. These plants have been applied as soil amendment for the cultivation of maize, okro and cowpea with favourable response at rates ranging from 2-30t/ha (Atta Poku *et al.,* 2014; Ogundare *et al*., 2014).
The area of land used was 37m×11m ($407m^2$). The site was cleared of all vegetation using manual labour. The debris was gathered into heaps outside the demarcated areas for controlled burning and to allow for ease of ploughing, harrowing, lining and pegging. Plots measuring 2m x 2m ($4m^2$) were demarcated and prepared manually using hoes and rakes. Manures were incorporated into the soil and allowed to decompose for three weeks before beds were raised on each plot to about 30cm high.

The carrot variety '*new improved kuroda*' were sown at their respective planting distances. The beds were covered with straw to minimize excessive heat and to prevent falling off of the small seeds during watering. The straw was removed six days after planting when the seedlings have emerged from the soil. Watering was done every day except on rainy days using watering can. Thinning out was done 14 days after germination. Fertilizer (NPK-15, 15, 15) was applied on the respective plots after thinning out at a rate of 300kg/ha. Weeds were hand-picked when necessary. The paths between the blocks and plots were weeded with the help of cutlass and hoe when the need arose. Earthening- up was carried out every two weeks to cover the root shoulders that have been exposed as a result of watering. The intra-rows were also stirred to improve aeration for proper growth and development of the crop.
At harvest, roots with cracks and forking characteristics were selected, weighed and their weight expressed as percentage of the total weight of roots on each plot.

Samples of roots were collected after harvesting with respect to treatments and replications. They were packaged in envelopes and stored in the laboratory for the analysis of the nutrient content and biochemical properties at Soil Research Institute-Kwadaso, Kumasi and the Department of Biochemistry, Kwame Nkrumah University of Science and Technology, Kumasi respectively. Total nitrogen was estimated by the Kjeldahl method, total phosphorus by ashing process using gravimetric quinilinium phosphomolybdate method, Potassium by flame photometer AAS (Atomic Absorption Spectrophotometer) method which was taken through the process of dry-

ashing process, Sulphur was through di-acid method through the dry ashing process, calcium and magnesium by the Ethelynediamine pentaacetic acid (EDTA) titration method (FAO/UN, 2008). Reducing sugar, Total Soluble Sugars (TSS) and Vitamin C were analyzed using the procedures described by Kilyobo (2009).
Data were analyzed using Analysis of Variance (ANOVA) with Genstat Version 11 package. Significant means obtained were separated by Least Significant Difference (LSD) method at 5% significance level.

Results and Discussion

Percentage Branched and Cracked Roots as Influence by Green Manure and Plant Spacing

Results on percentage branched (forked) roots of carrot (Table1) showed that significant differences existed amongst the spacing and amendments. The treatment effect of 25cm x 10cm was greatest and that of 25 x15cm was also greater than the 25 x 20cm treatment. For amendments, the *Mucuna pruriens* treatment effect was greatest on all sampling occasions, and the control treatment effect was the lowest.

It was observed that the branching (forking) percentage of root increased with the increase in plant population. The relationship between density and the shape disorders (bent and twisted roots) suggest that competition between carrots may contribute to the regulation of carrot root development. McGarry (1994) stated shape defects can be reduced by more even spacing of plants and by reduced planting densities. It is interesting to note that the percentage of forked roots varied significantly between amendments, suggesting that non-biotic factors may contribute to the development of this disorder. This collaborates with the work of Gutezeit (2001) and Fritz (2007) who reported that forking in carrots is promoted by factors such as poor soil structure (compacted heavy clay soil), application of fresh manure, application of excess nitrogen and improper irrigation management. McGarry (1993) also observed that the bends and twist of roots occur with lower soil moisture levels, or soils with high bulk density. In this study plants that received amendments recorded higher percentages of branched roots compared with the control. The high nitrogen content in the green manure and NPK might have contributed to the high percentage of forked roots. Alice (2008) in studying the influence of organic fertilizers on the yield and quality of cabbage and carrots stated an increase in the organic fertilizer rate promoted the development of hairy and forked carrot.

The percentage cracked roots (Table 1) was affected by spacing in both years. The effect of 25 x 20cm spacing was significantly higher than that of the 25 x 10cm only in both years. For amendments, the NPK treatment effect was greatest in both periods followed by the *Mucuna pruriens* treatment effect, which was also significantly higher than all other treatment effects. In both years the control treatment had significantly lowest percentage cracked roots. Significant variation in the percentage of cracked root was found due to spacing. The increasing trend of cracking percentage of root with the decreasing number of plant per plot might be due to overcrowding that occurred among smaller spacing plants. Such plants facing high inter plant competition for nutrient, water, space, air and light produced thinner roots having minimum diameter and possibly that might have contributed to them resisting cracking. The large spaced roots had enough room to expand reaching the limit of internal turgor pressure resulting in cracking. This collaborates with the report of Bienz, (1964) and McGarry (1994) that carrot split when the cell walls rapture, forming longitudinal fractures in the phloem parenchyma as a result of internal turgor pressure. They stated that carrot susceptibility to cracking increase following maturity of the roots and timing of harvest is critical. The trend in this study also supports that of Philip and Alistair (2001) that over the growing period, there are commonly differences in growth rate between carrots in the outer and inner rows of a bed. Carrot in the inner rows is usually of a greater size/weight early in the life of the crop, but the growth tends to be slower over the final stages due to increased competition. This difference in growth pattern may influence the susceptibility to cracking with outer rows often highly susceptible to cracking.

There was significant variation on percentage of cracked root due to application of different amendments (Table 1). The highest percentage of cracked root was produced by the plants having received green manure and 300 kg/ha NPK whilst the lowest was found in control plots. This collaborates with the report of Obi and Ebo (1995) and Obi and Ofonduru (1997) that organic fertilizer promoted the development of undesirable characteristics such as forked, cracked and hairy carrots. The addition of green manure and NPK to the soil might have reduced soil bulk density and made appreciable difference in the root growth of the plants. The reduction in bulk density created improvement in soil total porosity due to the manure application giving the roots enough room for expansion and cracking having reached their internal turgor pressure.

Table 1: Branched and cracked roots as influenced by spacing and green manure

Treatments	Branched Roots (%)		Cracked Root (%)	
	2015	2016	2015	2016
Spacing				
S_1 25 x 10cm	3.70	4.70	3.38	3.34
S_2 25 x 15cm	3.53	4.54	3.49	3.45
$S_3$25 x 20cm	3.33	4.35	3.58	3.54
LSD(P<0.05)	0.107	0.108	0.138	0.138
Amendments				
T_1 *Mucuna pruriens*	5.66	6.66	4.43	4.39
T_2 *Chromolaena odorata*	4.58	5.58	3.33	3.29
T_3 *Gliricidia sepium*	3.44	4.47	2.55	2.50
T_4 NPK (15, 15, 15)	2.39	3.40	5.45	5.41
T_5 Control	1.53	2.54	1.67	1.63
LSD (P<0.05)	0.138	0.140	0.178	0.178
CV (%)	4.81	3.73	6.22	6.31

Nutritional and Biochemical Properties of Carrot Roots as Influenced by Green Manure and Plant Spacing

Table 2 shows that the nutritional properties were significantly affected by spacing and amendments in both years.

In both years, the treatment effect of the 25 x 20cm spacing was the greatest, whilst that of the 25 x 15cm spacing was also significantly (P<0.05) higher than that of 25 x 10cm spacing at all sampling times except in 2016 where the treatment effect of 25 x 15cm was similar to that of 25 x 20cm with regards to nitrogen, phosphorus and magnesium.

Soil amendments also significantly affected nutritional properties of the carrot roots. For calcium content, the treatment effect of *Gliricidia sepium* was significantly greater than all the other treatments in both years. The control treatment effect was lowest at all sampling periods. Additionally, the NPK treatment effect was significantly lower than all the treatments at all sampling periods. With the other nutrients, the treatment effect of *Chromolaena odorata* was the greatest, followed by *Mucuna pruriens,* and *Gliricidia sepium.* The control treatment effect was lowest at all sampling periods. Additionally, the NPK treatment effect was significantly lower than all the green manure treatments at all sampling periods.

The biochemical properties of the carrot roots were significantly influenced by both spacing and amendments (Table 3). For reducing sugars, the *Chromolaena odorata* treatment effect was significantly higher than all other treatments at all sampling periods. The *Gliricidia sepium* treatment effect was also the lowest at all sampling times, except in 2015 where control recorded the lowest.

The Total Soluble Sugar (TSS) was significantly affected by spacing with the 25 x 20cm treatment resulting in the significantly (P<0.05) greater effect than the other treatments, whilst that of 25 x 15cm spacing was also greater than that of 25 x 10cm in both years. For amendments, the *Mucuna pruriens* treatment effect was

significantly higher than all other treatments in both years. On all sampling occasions the NPK treatment was the lowest for total soluble sugar content.

Spacing differences did not affect vitamin C content during the second year ($P>0.05$). However, at all other sampling periods the effect of the 25 x 10cm spacing was significantly lower ($P<0.05$) than the effect of the other treatments. For amendments, the *Chromolaena odorata* treatment effect was significantly higher than all other treatment effects at all sampling periods. The control treatment effect was also greater than all the amended plots in all sampling days. The NPK treatment effect was the lowest on all sampling days.

The quality of vegetables cannot be defined in terms of any single, measurable characteristic. The assessment is based on three critical criteria namely; technological suitability (specific attributes which determine suitability for processing and storage), nutritional value (content of beneficial nutrients, such as protein, vitamins, and minerals content) and appearance (size, shape, colour, freedom from blemishes and a taste specifically associated with individual products). In many cases, these quality characteristics can be measured quantitatively and thus provide a basis for comparison (Allemann and Young, 2002).

The concentration of the desirable compounds such as vitamin C, total sugars (sucrose, glucose and fructose), reducing sugars and mineral compounds (Ca, N, P, K, Mg, and S) was significantly influenced by spacing (Tables 2 and 3) with contents increasing with decreasing plant density. This observation may be due to less competition among the widely spaced plants which enabled the roots to absorb more of these compounds as compared with the closely spaced roots.

The calcium content in carrot root was significantly lowered where NPK was applied as compared with *Gliricidia sepium* and *Mucuna pruriens* even though slightly higher than the control. Similar observation was made by Lampkin (2000) who found high calcium levels in organic grown products than inorganic grown ones.

The greatest reducing sugar content was obtained in roots treated with the *Chromolaena odorata* which was significantly higher than the NPK and the control. This result indicates that the application of green manure positively influenced sugar contents in carrot. This result collaborates with the findings reported by Yan *et al*. (2004).

The highest Total Soluble Sugars (TSS) were obtained in carrots planted on plots that received *Mucuna pruriens* and *Chromolaena odorata*, while the lowest TSS were obtained in carrots with NPK application. The values obtained in this study were much lower than what Zakir *et al.* (2012) reported (10.51%) when farm yard manure was used. This reduction of TSS in carrots may be caused by the increase of Nitrogen, Phosphorus and potassium in soil which have negative effect on plant sugars (Hochmuth *et al*., 1998). Josiane *et al*., (2014) in studying nutritional quality of carrot as influenced by farm yard manure observed that farm yard manure did not significantly improved total soluble sugar content in carrots.

Green manures increased significantly the vitamin C content in carrots. A significant difference occurred between carrots that did not receive any treatment and those that received NPK (Table 3). The greatest vitamin C content was obtained in carrots that received *Chromolaena odorata* while the lowest vitamin C was obtained in carrots that received NPK. The highest value (8.66mg/100g) recorded for *Chromolaena odorata* in this study was lower than what Sarhad (2007) reported (12%). The slight variation in the data compared to others may be due to difference in experimental conditions, storage conditions of carrots, extraction procedures and materials used. This may also be attributed to the different solvent used, temperature during analytical process because all these have influence on results (Sarhad, 2007).

Green manure treated roots have shown an increase in the concentration of desirable compounds such as vitamin C, total sugars (sucrose, glucose and fructose) and mineral compounds compared to inorganic fertilizer (NPK) similar to the reports of others including Liu and Li (2003), Rembialkowska (2003), Suojala (2003) and Xu *et al.* (2003).

Table 2: Percentage Calcium, Nitrogen, Phosphorus, Potassium, Magnesium and Sulphur as Influenced by Plant Spacing and Green Manure

Treatment	Ca		N		P (%)		K		Mg		S	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Spacing												
S_1 25 x 10cm	0.41	0.43	2.63	2.79	0.46	0.48	0.69	0.73	0.92	0.98	0.12	0.15
S_2 25 x 15cm	0.43	0.45	2.65	2.82	0.47	0.49	0.71	0.75	0.94	1.00	0.13	0.16
S_3 25 x 20cm	0.44	0.46	2.68	2.83	0.48	0.49	0.74	0.78	0.95	1.01	0.14	0.17
LSD(P<0.05)	0.008	0.008	0.012	0.036	0.004	0.008	0.017	0.017	0.013	0.013	0.005	0.005
Amendments												
T_1 *Mucuna pruriens*	0.55	0.57	2.85	2.88	0.51	0.53	0.78	0.82	1.34	1.40	0.14	0.17
T_2 *Chromolaena odorata*	0.14	0.16	2.94	2.94	0.55	0.55	0.94	0.98	0.89	1.95	0.17	0.20
T_3 *Gliricidia sepium*	0.93	0.95	2.66	2.87	0.47	0.47	0.73	0.77	1.17	1.19	0.12	0.15
T_4 NPK (15, 15, 15)	0.45	0.47	2.46	2.74	0.44	0.46	0.60	0.64	1.14	0.23	0.11	0.14
T_5 Control	0.07	0.09	2.36	2.64	0.41	0.42	0.53	0.53	0.13	0.20	0.11	0.14
LSD (P<0.05)	0.010	0.01	0.016	0.046	0.005	0.011	0.022	0.022	0.017	0.017	0.007	0.007
CV (%)	2.93	2.87	0.75	2.08	1.22	2.63	3.77	3.58	2.22	2.08	6.13	5.06

Table 3: Reducing Sugar, Total Soluble Sugar and Vitamin C as Influenced by Plant Spacing and Green Manure

Treatments	Reducing Sugar (g/100g)		Total Soluble Sugar (g/100g)		Vitamin C (mg/100g)	
	2015	2016	2015	2016	2015	2016
Spacing						
S_1 25 x 10cm	1.65	0.11	3.24	3.24	6.14	6.10
S_2 25 x 15cm	1.82	0.11	3.26	3.26	6.18	6.15
S_3 25 x 20cm	2.01	0.12	3.28	3.28	6.19	6.16
LSD(P<0.05)	0.086	0.008	0.011	0.011	0.026	NS
Amendments						
T_1 *Mucuna pruriens*	2.26	0.12	3.76	3.77	5.56	5.52
T_2 *Chromolaena odorata*	3.58	0.16	3.47	3.47	8.65	8.55
T_3 *Gliricidia sepium*	1.25	0.08	3.27	3.27	4.93	4.89
T_4 NPK (15, 15, 15)	1.62	0.08	2.37	2.38	4.32	4.32
T_5 Control	0.42	0.13	3.42	3.42	7.40	7.40
LSD (P<0.05)	0.111	0.010	0.014	0.014	0.034	0.103
CV (%)	7.44	10.73	0.53	0.85	0.77	2.63

Conclusion

The findings of the study have shown that the application of the green manure improved the nutritional contents and biochemical properties of carrot relative to the NPK. Plant population density also influenced the nutritional content with contents increasing with decreasing plant density. From the results it may be concluded that application of 10/ha *Chromolaena odorata* along with 25 x 20cm better improved the quality of carrot in the study area.

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