Effects of different NPK fertilizers and time of harvest on physical quality and root yield of carrot (*Daucus carota* L.) cultivated in the "Bediese soil and Nyankpala soil series" of Ghana

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Abstract
Fertilizer formulations and time of harvest are among the important factors that influences the yield and quality of vegetable crops. The use of NPK (15-15-15) fertilizer and harvesting at 80-90 days after sowing (DAS) are common practices among carrot farmers in Ghana. In this study, we investigated the effects of different NPK fertilizer formulations and time of harvest on physical quality and root yield of carrot cultivated in the "Bediese soil series" and "Nyankpala soil series" of Ghana. A 5 × 3 factorial experiment was conducted with three replications at both locations. The fertilizers [(i) 15-15-15 (ii) 23-10-5 (iii) 20-10-10 (iv) 23-10-10, at 300 kg ha^{-1} each and (v) control (no fertilizer)] were applied to the main plot whiles time of harvest [(i) 80 (ii) 90 and (iii) 100 DAS)] were the sub plot treatments. There was no significant (P>0.05) interaction effect of the treatments on all the parameters measured at both locations. In the "Bediese soil", the application of 300 kg ha^{-1} NPK (20-10-10) fertilizer significantly (P<0.05) improved the physical quality of the roots which resulted in the highest marketable yield. Moreover, harvesting at 100 DAS also increased the physical quality of the roots and gave the highest marketable yield compared with harvesting at 80 and 90 DAS. Generally, the different fertilizers and times of harvest did not affect (P>0.05) the physical quality and yield of carrot cultivated in the "Nyankpala soil". The study has shown that the application of 300 kg ha^{-1} NPK (20-10-10) fertilizer and harvesting at 100 DAS can be used to increase the yield and improve the physical quality of carrot cultivated in the "Bediese soil series" of Ghana.

Keywords: *Daucus carota*, NPK fertilizers, root yield, root quality, time of harvest

Introduction
Carrot (*Daucus carota* L.) is one of the important root vegetable crops cultivated worldwide. It is a herbaceous biennial plant belonging to the family *Apiaceae* but usually cultivated as an annual crop in the tropics (Lorizzo *et al*., 2013). The roots are highly nutritious, containing water, protein, vitamin and mineral, beta-carotene, thiamin, riboflavin and iron. The nutritious root can be eaten raw or cooked alongside other vegetables in delicious soups, stew and curries (Bose and Som, 1990). The consumption of carrot has also been found to be useful in controlling ulcers, eczema and boils and it has been used in the preparation of cosmetics to

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manage wrinkles (Ageless, 2009). Regular consumption of carrot can improve eyesight (da Silva Dias, 2014).

In Ghana, commercial production of carrot is largely practiced in the Ashanti Region, especially in Asante Mampong (Appiah *et al*., 2010). The average yield of carrot in tropical soils can be as high as 21 t ha^{-1}, but poor soil fertility and other constraints can greatly decrease the yield (Kahangi, 2004). For instance, in Asante Mampong, carrot yield was as low as 4 t ha^{-1} has been reported when the crop was grown without any fertilizer application (Asiedu *et al*., 2006). However, in similar studies, Kiran et al. (2016) found that the application of NPK (100:100:125 kg ha^{-1}) significantly improved the growth and increased the yield and yield components of carrot better than manures. The use of NPK (15-15-15) fertilizer to increase the yield of carrot in Asante Mampong, in particular, has been a common practice among farmers. In recent times, there have been influx of different NPK fertilizers formulations in the Ghanaian markets and the farmer's choice of these fertilizers usually depend on the cost. Thus, carrot farmers are more likely to buy the cheaper NPK fertilizer formulations for the crop, regardless of its impact on the crop. However, different NPK fertilizer formulations influence the growth, yield and quality of crops differently (Abalos *et al*., 2014). Selvi *et al*. (2005) reported that, the application of NPK (135:135:170 Kg ha^{-1}) gave the highest carrot yield (21.2 t ha^{-1}) whiles NPK (170:170:170 kg ha^{-1}) gave 18.6 t ha^{-1} yield. Similarly, time of harvest is also known to influence the yield and quality of crops. Moniruzzaman *et al*., (2013) reported that the age at which carrot roots are harvested influences the yield and quality of the edible roots. Al-Sayed *et al*. (2012) found that regardless of cultivar, late harvesting of sugar beet (*Beta vulgaris* L.) increased the yield and sugar content. Depending on cultivar, growing conditions and the size of root expected, carrot can be allowed to grow in the field for short or longer period before harvesting (Silva et al., 2008). In previous studies, the Improved Kuroda carrot variety was harvested at 90 DAS based on farmers practice (Dawuda *et al*., 2011; Asiedu *et al*., 2006). Lana (2012) found that harvesting carrots at 100 DAS resulted in bigger roots and greater total and marketable yields compared with harvesting at 80 or 90 DAS.

Several authors have reported varying effects of different fertilizers and/or fertilizer rates on growth and yield of carrot (Dawuda *et al*., 2011; Boskovic-Rakocevic, 2008; Selvi *et al*., 2005). However, the effects of different NPK fertilizer formulations and time of harvest have rarely been reported in Ghana. The current experiment was conducted with the hypothesis that NPK fertilizer formulation and harvesting time affect the physical quality and root yield of carrot. We, therefore, conducted this experiment to determine the influence of NPK fertilizer formulation and appropriate time of harvest on physical quality and yield of carrot cultivated in the "Bediese soil and Nyankpala soil series" of Ghana.

Materials and Methods

Description of experimental sites

The first experiment was conducted from June to September, 2014 at the College of Agriculture, University of Education Winneba, Asante Mampong, Ashanti Region of Ghana. Asante Mampong is located in the Forest-Savannah Transition zone of Ghana. The area has a bimodal rainfall pattern with the major rainy season occurring from March to July and the minor rainy season from September to November with minimum rainfall of 512.7 mm (Obeng, 2007). The soil, which is locally classified as the "Bediese soil series" (Asiamah, 1998), is sandy-loam, free from stones and well drained, with a thin layer of organic matter (Adu, 1992).

The second experiment was conducted from July to October, 2015, at the University for Development Studies, Nyankpala, Northern Region of Ghana. The area is within the Guinea Savannah agro ecological zone and lies within latitude 09^{o}25'N and longitude 0˚58'W and at altitude 183 above sea level. The annual rainfall is about 1034.4 mm and it usually occurs from July to early November. The average daily temperatures during rainy and dry seasons are 22˚C and 34˚C respectively. The maximum relative humidity of 80 % occurs in the area during the rainy season and this decrease to minimum of 53 % during the dry season. The soil, which is locally classified as "Nyankpala soil series", is brownish in colour, sandy-loam, free from concretion, very shallow with a hardpan under the top soil (SARI, 2007).

The texture and chemical properties of soil samples collected (0-25 cm deep) from the experimental sites were analysed just before the experiments and the results are shown in Table 1.

Table 1: Physical and chemical properties of soil samples (0-20 cm soil depth) of the "Bediese and Nyankpala soil series" tested before experiment.

Soil property	*Bediese soil*	*Nyankpala soil*
pH	5.60	5.8
Total organic carbon (%)	0.83	0.93
Total Nitrogen (%)	0.19	0.1
Total Organic matter (%)	1.42	1.3
Calcium (meq/100g)	3.74	3.0
Magnesium (meq/100g)	1.17	1.7
Sodium (meq/100g)	0.10	0.4
Potassium (meq/100g)	0.27	0.2
Total Cation Exchange Basicity (meq/100g)	5.01	Trace
Exchange Acidity (meq/100g)	0.55	0.3
Effective CEC (meq/100g)	5.56	5.8
Base saturation (%)	90.11	93.3
Available potassium (ppm)	110.34	ND
Available phosphorus (ppm)	54.29	Trace
Iron (ppm)	99.46	ND
Texture	Sandy-loam	Sandy

ND-Not determined

Field preparation, sowing and crop management

The experimental plots at both locations were ploughed and harrowed before the carrot beds were prepared using hoe. Each experimental unit was 2.4 m x 2 m containing 4 beds of 2 m long, 0.6 m wide and 0.3 m high. The beds were separated by 0.3 m spaces whiles the plots and the blocks were separated by 0.5 m spaces. Furadan 3G (active ingredient: Carbofuradan) was applied (15 g per bed) by drilling the granules to a depth of about 5 cm along the planting rows to check soil-borne insect pests. Six shallow drills (0.5 cm deep), were made at 25 cm apart across the length of each bed and the seeds were sown manually by drilling. The carrot seeds (*Daucus carota* L. var. Improved kuroda) were also treated against insect pests by dusting with Insector T45 powder at the rate of 10 g kg^{-1} seed before sowing. The beds were mulched with palm fronds and elephant grass in Asante Mampong and Nyankpala, respectively, before watering. At each location, 80 g of the seeds was used for the experiment. The seeding rate was far in excess of the recommended seeding rate and this was due to the manual drilling of seeds which is associated with the use of more seeds. At 25 days after seedling emergence, thinning was done to allow 5±2 cm spacing between the plants and maintaining 50 plants per bed. Weed control was done regularly with the aid of a hand fork. Earthening up was also done regularly to prevent the root shoulders from being exposed to sunlight. Supplementary irrigation was done as and when necessary to ensure that the soil was moist throughout the growing period. Harvesting was done manually at 80, 90 and 100 DAS, according to the experimental design, by holding the shoot and pulling out the roots gently from the soil.

Experimental design and treatments
A 5×3 factorial experiment was arranged in a split plot design with four replications at both locations. The NPK fertilizer treatments [(i) 15-15-15 (ii) 23-10-05 (iii) 20-10-10 (iv) 23-10-10 each at 300 kg ha^{-1} and (v) control-(fertilizer)] were applied to the main plots and the time of harvest [(i) 80 (ii) 90 and (iii) 100 DAS] were assigned to the subplots. The various fertilizer granules were applied at 30 days after seedling emergence at 36 g per bed (300 kg ha^{-1}) by drilling at about 3 cm along the planting rows.

Data collection
Six plants were randomly selected from each bed and tagged for data measurement and the average per plant was calculated for each treatment. Harvesting was done at 80, 90 and 100 DAS (Lana, 2012) from the designated subplots. Root weight of each treatment was determined using digital balance. The roots sampled for the determination of core and cortex weights of each treatment were kept under shade for 24 h before these parts were gently separated using kitchen knife and weighed with digital balance. Root length was measured using a plastic meter rule whiles root shoulder diameter was measured using vernier callipers and the average per plant recorded. The weight of all marketable roots harvested per bed (1.2 m^2) was used to extrapolate the marketable yield per ha for each treatment. Individual roots that were greater than 40 g, longer than 10 cm, with shoulder diameters greater than 2.4 cm wide and also free from cracks and forks or other deformities constituted the marketable roots.

Data analysis
Data collected were subject to Analysis of Variance (ANOVA) and treatment means were separated by the Least Significant Difference (LSD) test at 5 % level of significance using GenStat Statistical Package (9th edition, Lawes 179 Agricultural Trust, Rothamsted Experimental Station, UK).

Results
Effect of different NPK fertilizers on physical quality and root yield of carrot
The effect of the different NPK fertilizer formulations on the physical quality of the carrot roots cultivated in the “Bediese soil and Nyankpala soil series” is shown in Table 2. In the Bediese soil, the different fertilizers significantly ($P<0.05$) affected the physical quality of the roots. The plants which were treated with 23-10-10, 23-10-5 and 20:10:10 NPK fertilizers produced longer and heavier roots which also had heavier root cores and cortices. These fertilizers also produced roots with wider shoulders compared with the NPK (15:15:15) fertilizer and the control treatments. Even though statistically, the treatments did not show any significant ($P>0.05$)

effect on the physical quality indices of the roots produced in the "Nyankpala soil", the roots produced with the various NPK fertilizers were relatively bigger than those from the control plots (Table 2).

The fertilizer treatments also significantly affected (P<0.05) the marketable yield of the carrot cultivated in the "Bediese soil" but did not affect (P>0.05) the marketable yield in the "Nyankpala soil" (Fig. 1). In the "Bediese soil", the 20-10-10 fertilizer produced the highest yield, which was 32% and 23% more than the control and 15-15-15 fertilizer treatments, respectively. The 23-10-10 also led to 26 % and 17 % more marketable yield than the control and the 15-15-15 fertilizer treatments, respectively. Moreover, the 23-10-5 also resulted in 24% and 14% more yield than the control and the 15-15-15 fertilizer treatments, respectively. Although the fertilizers did not statistically (P>0.05) affect carrot yield in the "Nyankpala soil", commercially, the various NPK fertilizer formulations gave 15.3 - 22.4% more marketable yield than the control (Fig. 1). The 20:10:10 fertilizer formulation gave the highest marketable yield (14.3 t ha^{-1}) in the "Nyankpala soil".

Table 2: Effect of different NPK fertilizers on physical quality of carrot roots cultivated in the "Bediese soil and Nyankpala soil series"

NPK Fertilizer type	RL	RSD	RW	RCW	RCXW
	(cm)		(g)		
Bediese soil series					
20-10-10	13.3	3.6	103.6	20.5	35.8
23-10-10	14.3	3.7	97.2	18.8	35.3
23-10-5	14.7	3.6	89.4	18.2	34.6
15-15-15	13.0	3.3	76.6	15.6	29.8
Control	12.3	3.1	68.0	13.8	24.5
LSD (0.05)	**1.5**	**0.3**	**16.4**	**3.6**	**7.6**
CV (%)	**4.9**	**8.0**	**9.2**	**6.1**	**8.5**
Nyankpala soil series					
20-10-10	13.8	2.9	51.4	16.6	34.7
23-10-10	13.8	2.5	46.9	14.9	32.0
23-10-5	14.3	2.6	48.1	15.5	32.6
15-15-15	13.7	2.5	47.0	14.8	32.2
Control	13.6	2.6	40.0	11.7	28.2
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**23**	**21**	**31**	**28**	**24**

RL *- Root length;* ***RSD*** *- Root shoulder diameter;* ***RW*** *- Root weight;* ***RCW*** *- Fresh root core weight;* ***RCXW*** *- Fresh root cortex weight;* ***NS*** *- No significant difference at P<0.05*

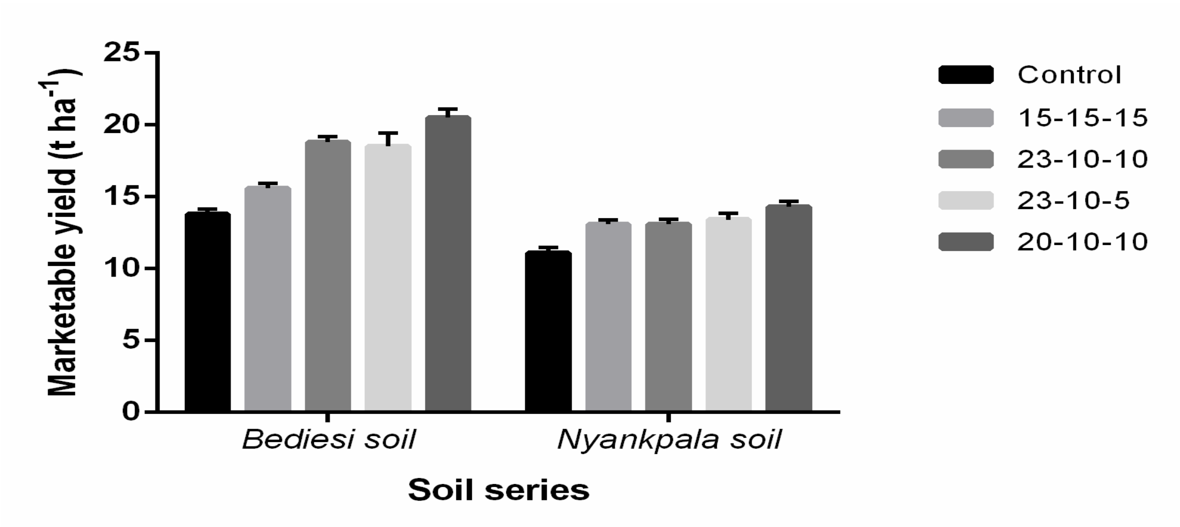

Figure 1: Effect of different NPK fertilizers on marketable yield of carrot cultivated in the "Bediese soil and Nyankpala soil series" of Ghana. The error bars indicated on the treatment means represents the values for the standard deviations.

Effect of time of harvest on physical quality and root yield of carrot

The effect of time of harvest on physical quality indices of carrot root and yield are shown in Table 3. Time of harvest significantly (P<0.05) affected the physical quality indices of carrot root in the "Bediese soil" but in the Nyankpala soil, the effect was only significant (P<0.05) on root shoulder diameter. Generally, the root weight, root core weight and root cortex weight increased with longer time of harvest at both soils. In the "Bediese soil", the roots harvested at 100 DAS were longer and heavier and also had heavier cores and cortices. Time of harvesting also significantly affected marketable yield of carrot cultivated in the Bediese soil (Fig. 2). Harvesting at 100 DAS gave 28.9% and 24.2% more marketable yield than harvesting at 80 and 90 DAS, respectively. Although time of harvest did not statistically (P>0.05) affect root size and marketable yield in the "Nyankpala soil", commercially, harvesting at 100 DAS gave 15% and 7.1% more marketable yield than harvesting at 80 and 90 DAS, respectively (Fig. 2).

Table 3: Effect of time of harvest on physical quality of carrot roots cultivated in the "Bediese soil and Nyankpala series" of Ghana.

Time of harvest	RL	RSD	RW	RCW	RCXW
Bediese soil series	(cm)			(g)	
80 DAS	13.9	3.6	73.8	26.4	62.8
90 DAS	12.8	3.2	78.6	28.7	73.9
100 DAS	14.0	3.6	108.5	40.8	98.4
LSD (0.05)	**1.1**	**0.2**	**21.2**	**9.6**	**13.9**
CV (%)	**4.9**	**8.0**	**9.2**	**6.1**	**5.8**
Nyankpala soil series					
80 DAS	13.6	2.4	43.0	13.9	29.1
90 DAS	13.7	2.8	46.8	13.9	32.9
100 DAS	14.2	2.7	50.2	16.3	33.8
LSD (0.05)	**NS**	**0.02**	**NS**	**NS**	**NS**
CV (%)	**22**	**26**	**29**	**25**	**20**

***RL** - Root length; **RSD** - Root shoulder diameter; **RW** - Root weight; **RCW** - Fresh root core weight; **RCXW** - Fresh root cortex weight; **DAS** - Days after sowing; **NS** - No significant difference at P<0.05.*

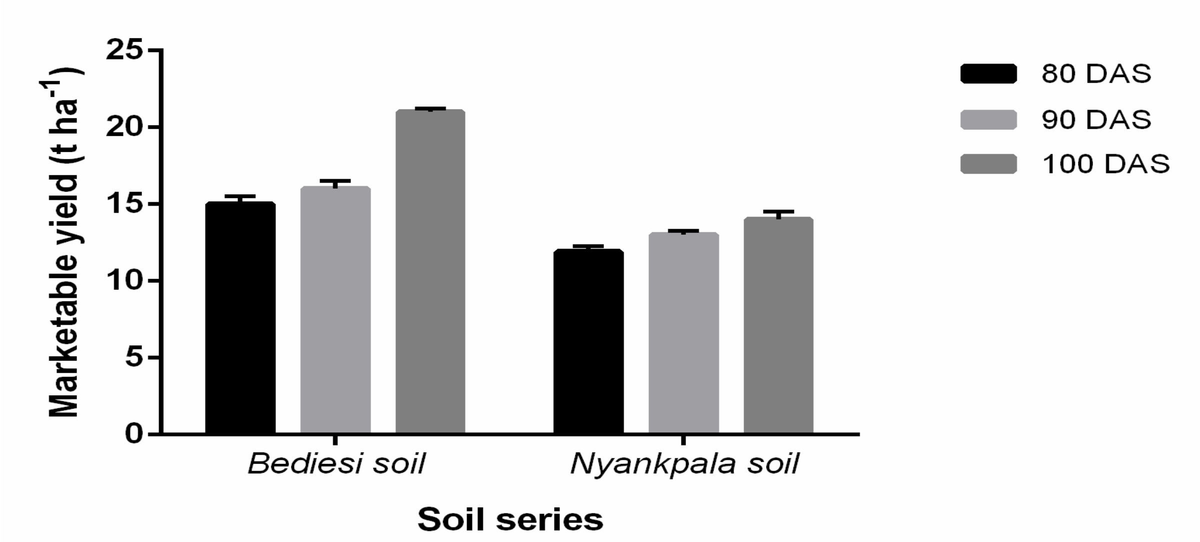

Figure 2: Effect of time of harvest on marketable yield of carrot cultivated in the "Bediese soil and Nyankpala soil series" of Ghana. The error bars indicated on the treatment means represents the values for the standard deviations.

Discussion

The increased yield and improved root quality obtained from the other fertilizers in comparison with the 15-15-15 fertilizer and the control treatments could be attributed to increases in the amount of nitrogen that was supplied to the plants. The application of the NPK (20-10-10), NPK (23-10-10) and NPK (23-10-5) fertilizers at 300 kg ha^{-1} each supplied about 60 kg ha^{-1} N, 69 kg ha^{-1} N and 69 kg ha^{-1} N respectively whiles the 300 kg ha^{-1} NPK (15-15-15) fertilizer supplied about 45 kg ha^{-1} N. Nitrogen which is a component of chlorophyll probably enhanced photosynthesis and contributed to the accumulation of photosynthates in the roots, hence, the increase in root weight and yield. It was also observed that the plants response to the fertilizers was better in the Bediese soil compared with the Nyankpala soil. This could be due to the higher organic matter and total nitrogen contents available in the "Bediese soil", which probably supported the growth of the carrot plants better than the "Nyankpala soil". In an experiment to determine the effect of nitrogen rate on carrot growth and yield, Moniruzzaman *et al*. (2013) found that increasing nitrogen from 70 to 100 kg ha^{-1} significantly increased the root size as well as total and marketable yields. Increasing nitrogen rate to 150-180 kg ha^{-1} also increased the yield and carotene content in the root of different cultivars of carrot (Hochmuth *et al*., 1999).

In root crops, longer growing season can contribute to increases in root size and yield through the accumulation of more carbohydrates in the roots, provided the plants are healthy and the growing conditions are favourable. Thus, the root size and yield of the carrot cultivated in the "Bediese soil" were highest when harvesting was done at 100 DAS. Regardless of planting density, greater root weight and total yield of carrot were obtained when harvesting was done at 100 DAS compared with harvesting at 80 and 90 DAS (Lana, 2012). AL-Sayed *et al*. (2012) also found that harvesting sugar beet (*Beta vulgaris* L.) at 210 days after planting increased the yield and sugar content of the roots compared with harvesting earlier at 180 or 195 days after planting. The physical quality of roots and the marketable yield of the carrots from the "Bediese soil" were markedly higher than those from the "Nyankpala soil". This could be attributed to the higher contents of organic matter, nitrogen, potassium, phosphorus and calcium of the "Bediese soil" (shown earlier in Table 1). Low soil fertility has been a major limitation to increased yield and higher root quality of carrot (Boskovic-Rakocevic, 2008). The non-significant effect of the fertilizer formulations and time of harvest in the experiment conducted in the "Nyankpala soil" might be due to very poor soil condition. These results suggest the need for the study to be conducted again with modifications in the fertilizer and time of harvest treatments.

Conclusion

The study has shown that the interaction effect of different NPK fertilizer formulations and time of harvest was not significant on the parameters measured form the "Bediese soil and the Nyankpala soil series" of Ghana. However, the main effect of fertilizer formulations and time of harvest significantly affected carrot performance in the "Bediese soil". The application of 300 kg ha^{-1} NPK (20-10-10) and harvesting at 100 DAS improved the physical quality of the roots and also gave the highest yield in the "Bediese soil". The various fertilizers did not significantly affect the physical quality and root yield of carrot in the "Nyankpala soil". Moreover, with the exception of root shoulder diameter, time of harvest did not affect the quality and root yield of the crop in the "Nyankpala soil". The application of NPK (20-10-10) at 300 kg ha^{-1} and harvesting at 100 DAS can be recommended for increased yield and improved physical quality of carrot cultivated in the "Bediese soil series" of Ghana.

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