*RESEARCH PAPER*

# GROWTH AND YIELD RESPONSE OF CARROT (*DAUCUS CAROTA L.*) TO DIFFERENT RATES OF SOIL AMENDMENTS AND SPACING.

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**ABSTRACT**
***A 5 x 2 factorial field experiment in a randomised complete block design with four replications was conducted at the College of Agriculture Education, University of Education, Winneba, Mampong Campus to investigate the growth and yield responses of carrot to different rates of soil amendments and spacing. The five rates of soil amendments were: (i) 10 t/ha chicken manure (ii) 15 t/ha chicken manure (iii) 20 t/ha chicken manure (iv) 300 kg/ha NPK (15-15-15) and (v) Control (no soil amendment). The two spacings were: (i) 30 cm x 5 cm and (ii) 20 cm x 5 cm. The application of 15 t/ha and 20 t/ha decomposed chicken manure improved vegetative growth, increased root yield and gave more income. More plants were however, infected by Sclerotium rolfsii by the application of the 20t/ha chicken manure. Soil amendment rates did not suppress nematode populations but the highest root galling index was recorded on the control plants. The wider spacing of 30cm x 5cm promoted vegetative growth and increased root length of carrot but planting at closer spacing of 20cm x 5cm resulted in higher total and marketable yields and also increased income and profit.***

**Keywords**: *Soil amendments, spacing, nematode populations, carrot yield*

## INTRODUCTION

Carrot (*Daucus carota* L.) is an important vegetable which is ranked third among the succulent vegetables in world production (Yamaguchi, 1983). In Ghana, it is one of the exotic vegetables with high value and great demand in urban centres and it is a potential export crop (MoFA, 2002). The edible roots are nutritious and contain water, protein, ash, vitamins and mineral (Norman, 1992). Carotene which is extracted from the roots is used in colouring margarine and for improving the colour of egg yolk when added to layer feed. The leaves and mature roots are used in the preparation of animal feed (Kahangi, 2004).

Carrot which belongs to the family Apiaceae is a biennial and is usually cultivated as an annual crop in the tropics (De Lannoy, 2001). The crop is tolerant to soil pH of 5.5 to 6.5 and it requires a deep and well-drained loamy soil with high amount of organic matter (Yayock *et al*., 1988). Fordham and Biggs (1985) recommended the application of 70-120 kg/ha N, 30-

35 kg/ha P and 0-55 kg/ha K for high yield of carrots. Application of 300 - 450 kg/ha NPK (15:15:15) before planting has been recommended for improved growth and yield of the crop in Ghana (Norman, 1992). Kahangi (2004) has recommended the application of 10-20 t/ha poultry manure for improved growth and yield of carrot in the tropics.

The average yield of carrot estimated at 8-12 t/ha for the tropics is far below the world average estimated at 21 t/ha (Kahangi, 2004). Ofosu-Budu *et al.* (1999) have attributed the low yield of horticultural crops in the tropics to poor soil fertility. Carrot yield is also adversely affected by low planting density (Splittoesser, 1990).

The application of manures improves soil fertility and increases crop yield. It makes both macro and micro nutrients available to plants and also improves soil structure and enhances root growth. Manures also promote the activities of soil micro-organisms which convert organic matter into humus and promote plant growth (Dupriez and De Leener, 1988). Although chicken manure is the most frequently used organic manure in peri-urban vegetable production in Ghana, the quantities applied by farmers are often not based on research recommendations. The study was conducted to determine the effects of different rates of soil amendments and spacing on growth and yield of carrots at Mampong-Ashanti, one of the major carrot growing areas in Ghana.

## MATERIALS AND METHODS

The experiment was conducted from October 2007 to February, 2008 at the Teaching and Research Farm of the College of Agriculture Education, University of Education Winneba-Mampong Campus. Mampong-Ashanti is within the Forest-Savanna Transitional Zone which stretches from about latitude 6˚30'N to 9°45'N, embracing an extensive part of Ashanti Region and extending into some parts of Brong-Ahafo Region (Obeng, 2007). The area has a bimodal rainfall pattern with an annual average of about 1300 mm. The major season starts from April and ends in July whilst the minor season begins from September and ends in November. August is usually characterized by a short dry spell between the two rainy seasons (MoFA, 2001). Percent relative humidity is generally high, ranging from 75 to 97% in the morning and falling to between 73 and 32% in the afternoons depending on the season. The diurnal temperature ranges from 24.4°C to 28.6°C (Obeng, 2007). Results of soil analysis carried out before the application of treatments were as follows: pH 5.4, organic matter, 1.4%, total N, 0.13%, available P, 8.4, available K, 170 and effective CEC, 5.84meq/100g.

The soil is savanna ochrosol derived from the Voltarian Sandstone and falls within the Bediase Soil Series internationally described as Chromic Luvisol (Asiamah, 1998). It is reddish in colour, sandy-loam in texture, deep and free from stones and pebbles and contains some appreciable amount of organic matter (Adu, 1992).

The experimental area was slashed, ploughed and harrowed to a fine tilth. The debris was raked off the field and the area demarcated into 40 plots each measuring 2m x 2m. Three beds, each measuring 2m long, 0.5m wide and about 0.25m high were prepared on each plot. The experiment was a 5 x 2 factorial in RCBD with four replications. The factors considered in the study were: Soil amendments at five levels (10 t/ha, 15 t/ha and 20 t/ha chicken manure, 300 kg/ha NPK (15:15:15) and control). The two levels of spacings were 30 cm x 5 cm and 20 cm x 5cm. The various rates of chicken manure were incorporated into the soil during the preparation of the beds whilst the NPK fertilizer granules were applied thirty days after germination of the carrot seeds by side dressing. The chicken manure was allowed to decompose for three weeks before it was applied at the respective rates. Laboratory analysis of the chicken manure applied showed that it contained 1.47 % N, 1.79 %P, 0.66 %K, 1.79 %Ca and 2.85 %Mg.

Seeds of carrot variety, 'Kuroda Improved', were treated by dusting with Seed Plus (ai. Imidacloprid 5%, Metalaxyl 5%, and Carbendazin 10%) and sown on 1st October, 2007. The seeds were drilled at about 1-2 cm deep and at an inter row spacing of 30 cm or 20 cm. Shading of beds was done by placing palm fronds on the beds before watering. The seeds germinated seven days after sowing. The palm fronds were removed fourteen days after sowing and the seedlings were thinned to about 5cm between plants. Watering was done daily to keep the soil moist throughout the growing period. The spaces between the rows of carrot plants were stirred with a hand fork fortnightly to remove weeds and to loosen the soil to improve infiltration and aeration. The root shoulders were earthed up to prevent them from greening. A chemical compound (Top cop) with fungicidal and bactericidal effect was applied as soil drench at a rate of 20 ml/l fifty days after sowing to check the spread of root rot.

**Data collection and analysis**

Data were collected on number of leaves, plant height, canopy spread, plant survival against *Sclerotium* root rot, root length, root weight and root diameter from twenty plants which were randomly selected. The leaves were counted whilst plant height was measured from soil level to the tip of the longest leaf. Canopy spread was recorded as the mean of the widest spreading leaves on opposite sides of the plant in two directions at right angles to each other with a meter rule. Root diameter was measured at about 1cm from the shoulder of the root with veneer calipers. Total yield, marketable yield and cost-benefit analysis were determined using all the harvest from the central bed ($1m^2$) of each plot. Roots which weighed at least 30 g and were without cracks, forks and galls on the main root, constituted the marketable yield. Soil samples were collected before the application of treatments and after harvest for nematode assessment at the Nematology Laboratory, Crop and Soil Sciences Department, Kwame Nkrumah University of Science and Technology, Kumasi. Nematodes were extracted by Whitehead and Hemming's (1965) technique and counted using Doncaster (1962) tray method. Data on nematode counts were transformed by the square root method. Data collected were analyzed using ANOVA and means were separated by the Lsd at 5 % level of probability.

## RESULTS AND DISCUSSION

**Effect of soil amendments on plant survival against *Sclerotium* root rot**

Percentage plant survival against *Sclerotium* root rot was significantly affected ($P<0.05$) by the different rates of soil amendments (Fig. 1). Significantly more plants from the 20t/ha chicken manure plots were infected by *Sclerotium rolfsii* than the 15 t/ha chicken manure. The 20t/ha chicken manure which was the highest rate, probably increased the soil moisture holding capacity to a level more favourable for the spread of the fungus, *Sclerotium rolfsii*, which caused the root rot disease. Chicken manure at 15 t/ha gave the highest percentage plant survival compared to the other soil amendments rates. This was probably because it supplied adequate amount of nutrients to the plants and did not hold excess soil moisture which could expose more plants to fungal infection (Fig. 1). Crops cultivated in soil with adequate levels of nutrients can better tolerate pathogens and pests (MoFA, 2005). De Lannoy (2001) reported that high soil moisture usually exposes plants to fungal diseases in the tropics.

**Influence of soil amendment rates on vegetative growth**

The influence of different rates of soil amendments on number of leaves and plant height are shown in Table 1. Plants treated with 20t/ha and 15 t/ha chicken manure produced more leaves and were taller at 37 days after sowing (DAS). The 20 t/ha chicken manure resulted in a significantly higher number of leaves compared to the other treatments (Table 1) at 51 DAS. The various chicken manure rates produced plants which were statistically similar in height at 51 DAS but significantly taller compared to the NPK and control treatments (Table 1). At 65 DAS, plants treated with 20 t/ha chic-

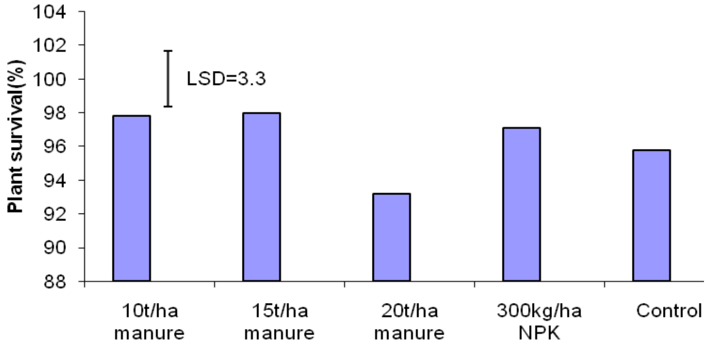


**Fig.1: Effect of soil amendments on plant survival against *Sclerotium* root rot**

ken manure resulted in a significantly more leaves compared to other treatments (Table 1). The 10 t/ha and 15 t/ha chicken manure and NPK treated plants had similar number of leaves which were significantly more than the control. The height of plants from the chicken manure amended plots did not differ significantly but these plants were significantly taller than those from the NPK and control plots at 65 DAS (Table 1). Soil amendments did not significantly (P=0.05) affect canopy spread (Fig. 2). However, the various chicken manure rates and NPK treatments produced plants with wider canopy diameter compared to the control. The increased vegetative growth associated with the chicken manure treatments might be due to improvement in levels of organic matter, nitrogen, available P and also some soil physical properties such as bulk density and infiltration rate. Frempong *et al*. (2006) found that the levels of organic matter, soil nutrients and cation exchange capacity increased with chicken manure and this led to improvement in the vegetative growth of okra.

**Effect of spacing on vegetative growth of carrot**

Plant height was not affected (P=0.05) by spacing. However, plants which were widely spaced produced significantly ($p<0.05$) more leaves and wider canopies at 65 DAS (Table 2). This might be because the wider spacing reduced the competition for soil nutrients, moisture, carbon dioxide and light among the plants. This prob–ably enhanced photosynthesis which resulted in the production of more leaves and wider canopies. This result is in agreement with the results of Koriem and Farag (1990) who found that onions planted at a wider spacing, produced more leaves and higher foliage dry matter.

**Effect of soil amendment rates and spacing on yield and yield components**

Chicken manure significantly ($P<0.05$) increased root diameter and root weight (Table 3). The largest root diameter was observed at 20 t/ha application (2.7 cm) even though this was not significantly different from 15 t/ha application (2.6 cm). Root weight, however, was significantly largest for the 20 t/ha application (55.5g) and least in the control (35.0g). Total and marketable yields were significantly ($P<0.05$) highest in the 20 t/ha application even though this was not significantly different from the 15 t/ha treatment. The chicken manure treatments probably improved the physical soil properties and increased the levels of soil nutrients which improved plant growth and increased the root size. Asiedu *et al*. (2007) also reported increased yield of carrot with the application of poultry manure and cowdung compared to the control.

**Table 1: Effect of soil amendments rates on number of leaves and plant height of carrot**

| Soil amendments | Number of leaves | | | Plant height (cm) | | |
|---|---|---|---|---|---|---|
| | 37 DAS | 51 DAS | 65 DAS | 37 DAS | 51 DAS | 65 DAS |
| 10 t/ha manure | 4.2 | 6.9 | 7.3 | 17.0 | 35.9 | 44.2 |
| 15 t/ha manure | 4.4 | 6.8 | 7.4 | 17.8 | 37.5 | 44.1 |
| 20 t/ha manure | 4.6 | 7.3 | 8.4 | 17.0 | 36.9 | 42.9 |
| 300 kg/ha NPK | 4.0 | 6.4 | 7.4 | 14.0 | 32.9 | 40.3 |
| Control | 4.2 | 6.3 | 6.9 | 14.9 | 32.4 | 38.7 |
| Lsd (0.05) | 0.4 | 0.4 | 0.5 | 1.9 | 3.2 | 4.1 |
| CV (%) | 9.2 | 6.5 | 7.1 | 11.6 | 9.1 | 9.5 |

The widely spaced plants produced longer roots than the closely spaced plants (Table 3). This might be due to reduced competition for essential soil nutrients and sunlight which probably promoted the accumulation of photosynthates in the roots. Norman (1992) observed that higher plant density per unit area or closer spacing increases the competition for essential growth factors among individual plants which do not attain their normal size. Even though longer roots were produced from the wider spacing, total and marketable yields were significantly ($P<0.05$) higher in the closely spaced plants (Table 3) because more roots were produced per unit area. This was similar to the results of Muck (1980) who reported that carrot yield increased when plant density was increased with closer inter-row spacing.

**Effect of different rates of soil amendments on number of nematodes and severity of galling**

The populations of root- knot and non- parasitic nematodes before the application of soil amendments were significantly ($P<0.05$) different among the treatment plots (Table 4). This could be due to the heterogeneous nature of the soil in the field. It has been reported by Hooper

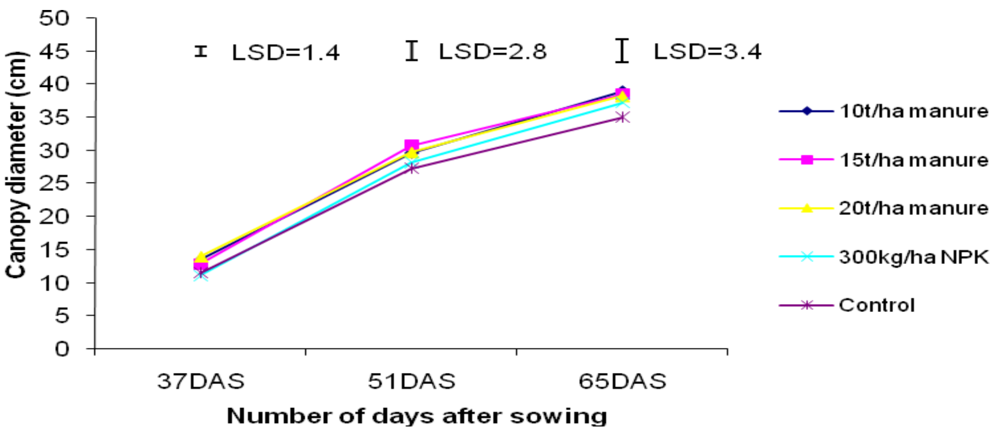


**Fig. 2: Influence of soil amendment rates on canopy spread**

**Table 2: Effect of spacing on some vegetative growth parameters of carrot plants**

| Spacing | Plant height (cm) | | | Number of leaves | | | Canopy diameter (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 37DAS | 51DAS | 65DAS | 37DAS | 51DAS | 65DAS | 37DAS | 51DAS | 65DAS |
| 30cmx 5cm | 16.2 | 35.0 | 42.2 | 4.3 | 6.8 | 7.7 | 12.6 | 30.0 | 38.8 |
| 20cm x 5cm | 16.0 | 35.0 | 42.0 | 4.2 | 6.6 | 7.2 | 12.5 | 28.2 | 36.3 |
| Lsd 0.05) | NS | NS | NS | NS | NS | 0.5 | NS | NS | 3.3 |
| CV (%) | 11.6 | 9.1 | 9.5 | 9.2 | 6.5 | 7.1 | 10.9 | 9.3 | 8.7 |

*NS= Not significant at 5% level of probability*

**Table 3: Effect of different rates of soil amendments and spacing on yield components of carrot**

| Treatments | Root length per plant (cm) | Root diameter per plant (cm) | Root weight per plant (g) | Total yield (t/ha) | Marketable yield (t/ha) |
|---|---|---|---|---|---|
| **Rates of soil amendments** | | | | | |
| 10 t/ha manure | 13.2 | 2.5 | 46.5 | 11.1 | 10.1 |
| 15 t/ha manure | 12.9 | 2.6 | 50.3 | 11.8 | 9.3 |
| 20 t/ha manure | 13.3 | 2.7 | 55.5 | 13.0 | 10.6 |
| 300 kg/ha NPK | 13.0 | 2.4 | 42.3 | 9.9 | 7.9 |
| Control | 12.4 | 2.2 | 35.0 | 8.3 | 6.2 |
| Lsd (0.05) | NS | 0.2 | 6.0 | 1.7 | 1.8 |
| CV (%) | 7.6 | 7.7 | 12.8 | 23 | 24 |
| **Spacing** | | | | | |
| 30 cm x 5 cm | 13.4 | 2.5 | 47.8 | 9.3 | 7.7 |
| 20 cm x 5 cm | 12.5 | 2.5 | 44.1 | 12.4 | 9.5 |
| Lsd (0.05) | 1.0 | NS | NS | 2.9 | 2.1 |
| CV (%) | 7.6 | 7.7 | 12.8 | 18 | 21 |

*NS= Not significant at 5% level of probability* *et al*. (2005) that nematodes are not uniformly distributed in soil. The populations of both the root-knot and non parasitic nematodes increased in all treatment plots but the differences were not significant (P< 0.05). The increase in the population of non parasitic nematodes which are usually saprophytes might be due to increased availability of organic matter which served as food substrates for the non -parasitic nematodes. Akhtar (1999) also found that the population of non-parasitic nematodes increased with the application of organic soil amendments. The population of root- knot nematodes also increased in all plots probably because of the availability of adequate soil moisture and the growing of carrot which is a susceptible host plant. Although there were no marked differences among the soil amendments rates with respect to galling indices (Table 4), the control plants had the highest galling index. This might be due to inadequate soil nutrients in the control plots. Sasser (1989) indicated that plants cultivated on soils with poor fertility are usually more susceptible to root knot nematodes.

**Influence of soil amendment rates and spacing on production cost, income and profit**

Significantly (P<0.05), higher cost of production was incurred in the application of the different chicken manure rates compared to NPK and the control (Table 5). This might be due to the large quantities of the manure applied and the cost of application. The income and profit obtained from the application of 20t/ha and 15t/ha chicken manure were statistically not different but higher than NPK and the control because higher marketable roots were obtained from these treatments. The 15t/ha and 20t/ha chicken manure also gave more profit than the 300kg/ha NPK (15-15-15) and the control.

Although the cost of production was significantly (P<0.05) higher in closer spacing, it gave higher income and more profit than the wider spacing. This could be attributed to the fact that more marketable roots were produced per unit area. None of the parameters studied was influenced by the interaction between soil amendment rates and spacing.

**Table 4: Effect of different rates of soil amendments on number of nematodes and severity of galling in field**

| | Before sowing | | After harvest | | | |
|---|---|---|---|---|---|---|
| **Rates of soil amendments** | **Number of root-knot nematode juveniles** | **Number of non-parasitic nematodes** | **No. of root -knot nematode juveniles** | **Number of non-parasitic nematodes** | **Percentage increase in root-knot nematode juveniles** | **Galling index (0-10)** |
| 10 t/ha manure | 4.5 | 11.4 | 15.6 | 30.0 | 73.1 | 0.8 |
| 15 t/ha manure | 4.2 | 11.3 | 14.8 | 32.2 | 89.4 | 1.0 |
| 20 t/ha manure | 2.7 | 8.1 | 15.9 | 32.7 | 91.0 | 1.3 |
| 300kg/ha NPK | 0.7 | 7.6 | 13.2 | 23.6 | 100 | 1.2 |
| Control | 4.2 | 11.3 | 13.3 | 28.9 | 79.0 | 1.4 |
| Lsd (0.05) | 3.3 | 3.1 | NS | NS | NS | 0.5 |
| CV (%) | 36.2 | 30.5 | 34.7 | 32.7 | 30.0 | 38.1 |

*NS= Not significant at 5% level of probability*

**Table 5: Influence of soil amendment rates and spacing on production cost, income and profit in carrot production**

| Treatments | Cost of production (Gh¢/ha) | Income (Gh¢/ha) | Profit (Gh¢/ha) |
|---|---|---|---|
| **Rate of soil amendments** | | | |
| 10 t/ha chicken manure | 2,672 | 6,356.3 | 3684.3 |
| 15 t/ha chicken manure | 2,809 | 7,009.7 | 4200.7 |
| 20 t/ha chicken manure | 2,986 | 8,084.1 | 4,941.5 |
| 300 kg/ha NPK | 2,594 | 5983.1 | 3,388.9 |
| Control | 2,432 | 4651.9 | 2,450.6 |
| Lsd (0.05) | 160.8 | 1188.4 | 1313.1 |
| CV (%) | 22.0 | 17.9 | 34.2 |
| **Spacing** | 2,324 | 5689.1 | 3,394.3 |
| 30cm **x** 5cm | 3,073 | 7144.9 | 4,972.1 |
| 20cm x 5cm | | | |
| Lsd (0.05) | 747.0 | 1454.8 | 830.4 |
| CV (%) | 22.0 | 17.9 | 34.2 |

## CONCLUSION

The study showed that the application of either 15t/ha or 20t/ha decomposed chicken manure improved vegetative growth, increased root length and yield of carrot. The 20t/ha chicken manure rate, however, had more plants infected with *Sclerotium rolfsii*. The application of these chicken manure rates also resulted in higher income and more profit. The application of 300kg/ha NPK (15:15:15) did not bring about any significant improvement in the vegetative growth, root length, total yield and marketable yield of carrot relative to the control. Soil amendment rates did not suppress nematode populations, but the highest root galling occurred on the control plants. Planting at 30cm x 5cm improved the vegetative growth and root length of the crop. The closer spacing (20cm x 5cm), however, gave more yield, higher income and profit. Carrot growers in Mampong-Ashanti can increase their yield and income with the application of 15t/ha decomposed chicken manure and planting at 20cm x 5cm spacing.

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