

Growth and Yield Response of Carrot (Daucus Carota L) to Different Green Manures and Plant Spacing

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Abstract
A field experiment was carried out to study the growth and yield response of carrot to different green manures and plant spacing at the College of Agriculture Education, University of Education, Winneba-Mampong Campus 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 spacing regimes (25 x 10cm, 25 x 15cm and 25 x 20cm) were employed in the investigation in Randomized Complete Block Design. The result revealed that the application of 10 t/ha *Mucuna pruriens, Chromolaena odorata, Gliricidia sepium* and 300Kg/ha NPK (15, 15, 15) improved the vegetative growth of carrot and translocated the assimilates into the final gross and marketable yield of the root compared to the control. Among the spacing regimes, 25 x 20cm produced the best vegetative growth. Application of 300kg/ha NPK was found suitable for maximum gross and marketable yields (28.73 t/ha and 27.23 t/ha, respectively) in 2015. In 2016, *Mucuna pruriens, Chromolaena odorata,* and *Gliricidia sepium* treatments produced gross and marketable yields similar to 300kg/ha NPK. With the spacing regime, 25 x 10cm produced maximum gross and marketable yield in both years. The combined treatment effect of 300kg /ha NPK and 10 t /ha of *Mucuna pruriens* at 25 x 10cm spacing resulted in the best performance in terms of gross and marketable yields. From the production as well as economic points of view a combination 10t/ha *Mucuna pruriens* at 25 x 10cm spacing may be suggested for maximizing carrot production in the study area.
Keywords: Mucuna pruriens, Chromolaena odorata, Gliricidia sepium, green manure, plant spacing, vegetative growth, gross and marketable yields.

Introduction

Carrot (*Daucus carota* L.*)* is a very important root vegetable mostly used in the diet of many Ghanaians. It is highly valued as food mostly because it is a rich source of Vitamin A (Zeb and Mahmood, 2004). Furthermore, carrot has abundant nutrients and minerals (Handelman, 2001). It is used in salads, stews and soups with other vegetables. Besides being food, different parts of the crop can be utilized for different medicinal purposes. It is useful in curing kidney diseases (Anjum and Amjad, 2002).

Carrot production can be a lucrative enterprise especially for most small scale, resource poor farmers in Ghana, since it is a short duration crop and higher yields can be obtained per unit area (Ahmad *et al*., 2005). In Ghana, it is one of the highly treasured exotic vegetables with great demand in urban centres and a potential export crop (MoFA, 2002). However, yields per unit area still fall below the estimated 8-12 t/ ha for the tropics and the world average of 21 t/ha (Kahangi, 2004).

One of the reasons advanced for such low yields is low soil fertility (Muendo and Tschirley, 2004). In order to obtain high yield, good soil fertility is required to facilitate the production and translocation of carbohydrates from leaves to roots. Essential nutrients (nitrogen, phosphorous and potassium) are key limiting factors relating to growth, development and yield of crops (Glass, 2003; Parry *et al*., 2005). In most cases, carrot farmers use inorganic fertilizers as the main source of nutrients supply to obtain higher growth and yield (Stewart *et al*., 2005; Dauda *et al*., 2008). The use of inorganic fertilizers has, however, been associated with health and environmental problems (Arisha and Bardisi, 1999). Moreover, the increasing costs of inorganic fertilizers have rendered them unaffordable to most resource-poor small scale growers.

Organic manures have over the years been used as substitute to mineral fertilizers. They have proven to supply the required nutrients (nitrogen, phosphorus, potassium), improve soil structure, increase microbial population and maintain the quality of produce (Suresh *et al*., 2004; Sanwal *et al*., 2007; Adeleye *et al*., 2010). In Ghana, the use of farmyard manure and compost are common among small holder farmers as main sources for soil fertility improvement with associated transportation and storage problems. The more readily available green manures therefore constitute a valuable potential source of N (Meelu *et al*., 1994), which benefits have not been extensively exploited. *Mucuna pruriens, Chromolaena odorat*a and *Gliricidia sepium* are among a number of plant species readily available in the forest-savanna transition zones of Ghana (Gyamfi *et al*., 2001), but their green manure has not been widely exploited in carrot production.

Plant spacing is one of the important factors for the increased production of carrot. Carrot yield is also adversely affected by planting density (Splittoesser, 1990). McCollum *et al.* (1986) reported that there is positive correlation between the number of plants and yield of carrot. But many workers have reported that different plant densities have different effect for marketable yield of carrot (Nogueira *et al.*, 1982; Dragland, 1986). Significant interaction between plant spacing and soil amendments have been recorded for many crops (Salter *et al.*, 1979) with scarce information on carrots. Information on optimum spacing for carrot production is varied. For instance, Tindall (1983) recommended inter-row spacing of 30-40cm and intra rows of 8-10cm. Rice *et al.* (1987) stated that seeds are sown with rows 30-40cm apart and seedling thinned to 10-14cm apart within row. Hodder and Stoughton (1990) suggested between rows of 15cm and within rows of 10cm. Observation on farmers' fields in Ghana reveals varied inter and intra-row spacing resulting in small and uneven root sizes which are rejected by most market women. The study was undertaken to determine the influence of spacing and green manure on the growth and yield of carrot in the forest-savanna transition zone of Ghana.

Materials and Methods

The study was conducted at the College of Agriculture Education, University of Education, Winneba, Mampong-Ashanti campus in the Ashanti region. Mampong is situated in the forest-savanna transition zone of Ghana (7^0 8'N, 1^0 24'W, 457.5 metres above sea level). The area has bimodal rainfall pattern with the major season experienced from March to July and minor rainy season from September to November. Between the two seasons is a short dry period in August. The soil at the study site is described locally as of the Bediese series of the savanna Ochrosol. The soil exhibits feature of sandy loam. It is well drained with a thin layer of organic matter. The field was used for garden eggs production in the previous year.

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. Initial soil samples were taken on the field to a depth of 0- 30cm with a soil augur. Plots measuring 2m x 2m (4m²) were demarcated and prepared manually using hoes and rakes. Each block was separated from the next by a distance of one metre. Manures (10t/ha) were applied on each plot, 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.

Twenty plants were randomly selected from the middle rows of each plot and tagged for growth measurement. Plant height was measured from the base of the plant to the tip of the longest leaf using a metre rule. The number of leaves produced was counted for each treatment. The growth measurements were taken at 4, 6, 8, 10, and 12 weeks after planting (WAP).

Immediately after harvest, the total root from each treatment plot within the harvestable area were taken and their fresh weight measured with the help of an electronic scale. The weight was subsequently converted to tonnes per hectare.

Twenty carrot roots were randomly selected from each treatment plot to measure yield components such as root length, root diameter, root weight and shoot weight (fresh and dry weight). Root length was measured using a rule from the crown to the end of the root. The diameter of the roots was taken at harvest with the help of veneer caliper 2cm from the crown. Root weight was measured with an electronic scale. Shoots of ten plants were weighed, oven dried at 78^oC to constant weight at harvest and the weight recorded as dry weight. Roots with no deformities like cracks, nematode infection, forking, disease, malformation or size and those without spots and weighed above 40 grams were selected from each plot and weighed the weight recorded as marketable yield. Roots which showed the above characteristics and with weight below 40g were selected from each plot and their weight recorded as unmarketable yield.

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

Influence of Green Manure On Vegetative Growth of Carrot

Table 1 shows the effects of soil amendments on number of leaves, plant height, fresh and dry shoot weight. *Mucuna pruriens* and NPK amended plots produced similar number of leaves which were significantly higher than *Gliricidia sepium* and control plots in both years. Even though there was an increase in plant height with time, amendments did not significantly affect it in the first year. In the second year, however, application of *Mucuna pruriens* at 10t/ha produced significantly taller plants than the control. Plant fresh weight was also affected by soil amendments in the first year only. Treatment effect of NPK was greatest, but this was significantly higher than the *Gliricidia sepium* and control treatments only.

Treatment differences in the second year with regards to dry shoot weight were not significant (P > 0.05). The dry shoot weight in the first year was greatest in the NPK applied treatment, but this was significantly higher than those of the control, *Gliricidia sepium* and *Chromolaena odorata* treatments only.

The increased vegetative growth associated with the green manure 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. This collaborates with the results of Walker and Bernal (2004*)* that application of organic manure promoted the production of more shoots at a later growth stage of carrots and other vegetables which can be attributed to high nutrient sustainability of organic manure and improved biological properties of the soil. In similar studies, Afari (1999), Nandekar and Sawarka (1990) and Naik *et al*. (1996) reported NPK application significantly increased the number of leaves of eggplant compared with the unfertilized control. Amjad *et al* (2005) studied the effect of different levels of N on the growth and seed yield of carrot in 2002-2003 and reported plant height increased with various combinations. In nutrient depleted soil (sandy) and soil with high percentage of clay, Hu and Barker (2004) reported the application of green manure from non-leguminous plants including Siam weed was found to improve the soil structure and stimulated the growth of carrot which promoted the growth rate.

Table 1: Number of Leaves, Plant Height, Fresh and Dry Shoot Weight as Influence by Green Manure and Plant Spacing

Parameters	Number of Leaves		Plant Height (cm)		Fresh Shoot Weight (g plant -1)		Dry Shoot Weight (g plant-1)	
	2015	2016	2015	2016	2015	2016	2015	2016
Treatments								
T_1 *Mucuna pruriens*	14.62	14.44	43.72	52.99	72.27	39.07	7.20	3.87
T_2 *Chromolaena odorata*	13.99	14.11	44.12	52.70	70.66	36.09	6.90	3.59
T_3 *Gliricidia sepium*	13.44	13.51	43.69	51.22	46.92	32.67	4.67	3.39
T_4 NPK (15, 15, 15)	14.09	14.19	42.82	52.56	74.72	37.79	7.59	3.55
T_5 Control	11.61	13.08	41.86	50.77	35.79	32.16	4.44	3.16
LSD (P<0.05)	0.530	0.630	2.190	1.980	4.131	NS	0.510	NS
CV (%)	4.87	5.56	6.18	4.67	8.30	21.68	10.05	23.35

Vegetative Growth of Carrot as Influenced by Plant Spacing

The number of leaves showed no significant differences amongst the spacing treatments in the first year. However, significant differences existed in the second year with 25 x 20cm plants producing more number of leaves than the other treatments. Plant height was affected by spacing in both years with 25 x 10cm spacing producing the tallest plants compared with 25 x 20cm spaced plants. The fresh shoot weight was significantly influenced by spacing in both years. The 25 x 20cm treatment effect was significantly (P<0.05) higher than the other treatment effects in both years. All other treatment differences were not significant at 5% probability. Shoot dry weight did not significantly vary under the different spacing in 2015. However, in 2016, treatment effect of 25 x 20cm was significantly (P < 0.05) higher than that of 25 x 10cm only.

Generally, the widest spacing plants produced more leaves per plant than the other spacing. This might be because the wider spacing reduced the competition for soil nutrients, moisture, carbon dioxide and light among the plants. This probably 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 greater foliage dry matter. Korem *et al*. (1991) also reported that wider spacing resulted in greater number of leaf blade and larger foliage per plant than closer spacing in bulb yield of onion grown from sett. In a similar trial, Agyekum (1999) also reported that wider spacing produced more leaves and nodes per plant of okra. The significantly higher plant height recorded for the closer spacing treatment shows that there was competition for light and space among the treatments. This collaborates with the findings of Agyekum (1999) who reported closer spacing increases competition among the plants for nutrients, air, and light, which results in taller and weaker plants. The wider spacing plots significantly recorded greatest fresh and dry weight values which might be due to less competition among plants on those plots.

Table 2: Number of Leaves, Plant Height, Fresh and Dry Shoot Weight as Influenced by Plant

Parameters	Number of Leaves		Plant Height (cm)		Fresh Shoot Weight (g plant -1)		Dry Shoot Weight (g plant-1)	
Treatments	2015	2016	2015	2016	2015	2016	2015	2016
S_1 25 x 10cm	13.65	13.15	47.21	54.89	57.93	32.39	6.07	3.20
S_2 25 x 15cm	13.59	13.73	42.73	52.11	59.39	34.60	6.27	3.49
S_3 25 x 20cm	13.42	14.71	39.78	49.14	62.90	39.68	6.14	3.84
LSD(P<0.05)	NS	0.480	1.700	1.530	3.200	4.905	NS	0.520
CV (%)	4.87	5.56	6.18	4.67	8.30	21.68	10.05	23.35

Effect of Green Manure and Spacing on Yield and Yield Components

Both spacing and amendments significantly affected root length in both years (Table 3). In both years 25 x 20cm plants produced significantly longer roots than 25 x 10cm and 25 x 15cm plants. The latter two treatment effects were similar in the 2015. In terms of amendments, *Mucuna pruriens, Gliricidia sepium*, *Chromolaena odorata* and NPK plants produced similar root lengths which were significantly longer than the control in 2016. In the 2015, the control treatment effect was the lowest, and the *Chromolaena odorata* treated plots was also significantly lower than the other treatments.

Both spacing and amendment influenced root diameter. In 2015, the NPK treatment effect was significantly higher ($P < 0.05$) than all other treatment effects, while the control treatment effect was also lower than the other treatments. In 2016, however, *Mucuna pruriens* applied treatment effect was significantly higher than those of the NPK and control treatments. Spacing effect on root diameter was significant in both years. Plants from 25 x 20cm treatment had significantly greater root diameter than the others in both years (Table 3).

Mean root weight was significantly affected by amendment (Table 3) in both years but not spacing. The 300kg/ha NPK (15-15-15) produced greater root weight which was significantly higher than all other treatment. The control treatment effect was significantly lower than all other treatment effect in both years.

Table 4 shows that gross and marketable yields (t/ha) were significantly affected by both spacing and amendments. In both years, root yield of the 25 x 10cm spacing was significantly the highest, while that of 25 x 15cm spacing was also significantly higher than that of 25 x 20cm spacing. Among the amendments, the NPK treatment effect was significantly higher than all other treatments in 2015. The *Mucuna pruriens* treatment effect was also greater than those of *Chromolaena odorata and Gliricidia sepium* treatments. Also the *Chromolaena odorata* treatment effect was greater than the *Gliricidia sepium* treatment. On all these occasions, the control treatment was the lowest. In 2016, all amended treatments effects were similar, and each effect was significantly higher than the control treatment.

The results of the marketable yield were similar to gross yield. In both years, the 25 x 10cm spacing effect was greatest than the other treatments. Also among the amendments the NPK treatment effect was greater than all other treatment effects in 2015. The *Mucuna pruriens* effect was also greater than the other two amendments, whilst the control treatment effect was the lowest on all sampling occasions.

Generally, there were significant differences among the treatments with regards to root length, root diameter and root weight with increasing spacing in the two years. The widely spaced plants produced longer roots than the closely spaced plants. 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. Heavier and longer carrot roots can be produced by reducing planting density. Even though longer roots were produced from the wider spacing, gross and marketable yields were significantly ($P<0.05$) higher in the closely spaced plants 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. He stated that plant population can be asymptotic and explained that yields increased with increase population over the lower range of population.

Planting density and evenness of spacing of the carrot seedlings at establishment influence the distribution of sizes at harvest. Dawuda *et al.* (2011) in studying growth and yield response of carrot to different rates of soil amendments and spacing reported that 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. Carrot yield is also adversely affected by low planting density (Splittoesser, 1990). The root length of the green manure amended plots was significantly higher than the control in both years. The green manure treatments probably improved the physical soil properties and increased the levels of soil nutrients which improved plant growth and increased the root length. Asiedu *et al*. (2007) also reported increased root length of carrot with the application of poultry manure and cowdung compared to the control. The structural superiority of the green manure amended soils enhanced the textural quality of the root by maintaining uniform soil moisture and nutrient levels. This enabled the carrots roots to expand to deeper layers without any inhibition resulting in longer roots compared to the control. This work supports that of Warman and Havard (1996) and Stone (1998) who stated that it is possible to obtain carrots root length of more than 18 cm on green manure treated fields. The root length of NPK amended plots was higher than the control plots. Mallareddy (2007) reported that a recommended dose of NPK fertilizer alone can perform better in terms of root length. The report of Mallareddy (2007) is supported by the present study of NPK contribution to the carrot root length.

Generally, it could be observed that the mean root diameter of green manure and NPK amended plots was higher than the control. The increase in diameter of carrot roots could be due to the phosphorus content in the green manure and NPK confirming the work of Cole (1984) that applied P in adequate quantity increased the medium yield of carrot crown diameter between 2.5-5.0cm.

Spacing and amendments had significant influence on weight of root per plant. In this study, the widest spaced plants produced greater weight of roots per plant but in terms of per hectare, the closest spaced plants had more roots and therefore greater weight. Similar results were obtained by Agyekum (1999) that wider spacing gave greater weight per plant of okro than closer spacing but yield per unit area increased with closer spacing.

Green manure and fertilizer amendments significantly influenced the weight of roots per plant and per hectare. Nitrogen applied together with adequate amount of phosphorus and potassium has beneficial effect on productivity of crops. Generally, N fertilization rates maximized carrot root yield. In a study conducted by Hochmuth *et al.* (1999) on nitrogen fertilization in a sandy soil, it was observed that yield increased with N fertilization. Similarly, the application of nitrogen and potassium to carrot resulted in root yield significantly increased over control (Ali *et al*., 2006)

Spacing, amendments and their interaction had significant effect on both gross and marketable yield. The S_1 plants produced greater gross and marketable roots per hectare than the S_2 and S_3 plants. The yield per hectare for the inorganic fertilizer and soil amended plots was better than the control in both years during the period of the study. The increase in yield of NPK and the amended plots than the control might be due to the adequate supply of phosphorus which is involved in carrot establishment and yield. The NPK and the amendments supplied enough nutrients to the carrot plant which ensured good growth and yield more than the control. This supports Cole (1984) that adequate supply of phosphorus is involved in carrot establishment and good yield. The yield could also be attributed to the nitrogen content supplied in the soil which stimulated root growth and development as stated by Brady (1990). Similarly, Walker and Bernal (2004) stated that microbes in green manure release growth regulators essential for plant growth and photosynthetic activity. This might be the reason why carrots on green manure plots grew better and produced higher yields which could be attributed to high nutrient sustainability of the manure and improved biological properties of the soil.

Table 3 Root Length, Diameter and Weight as Influenced by Green Manure and Plant Spacing

Parameters	Root Length (cm)		Root Diameter(cm)		Root Weight (g)	
Treatments	2015	2016	2015	2016	2015	2016
Spacing						
S_1 25 x 10cm	18.23	16.52	3.32	2.30	49.56	47.48
S_2 25 x 15cm	18.55	17.42	3.56	2.49	51.22	49.14
$S_3$25 x 20cm	19.91	19.29	3.77	3.01	51.94	49.86
LSD(P<0.05)	1.186	0.880	0.180	0.199	NS	NS
CV (%)	9.82	7.74	8.10	12.03	7.91	8.22
Amendments						
T_1 *Mucuna pruriens*	21.25	17.78	3.71	2.82	54.46	52.38
T_2 *Chromolaena odorata*	19.57	18.04	3.72	2.72	52.34	50.26
T_3 *Gliricidia sepium*	20.80	17.73	3.33	2.70	46.86	44.78
T_4 NPK (15, 15, 15)	20.05	18.79	4.67	2.51	58.50	56.42
T_5 Control	12.81	16.37	2.34	2.24	42.37	40.29
LSD (P<0.05)	1.531	1.130	0.240	0.257	3.302	3.302
CV (%)	9.82	7.74	8.10	12.03	7.91	8.22

Table 4: Gross and marketable yield as influenced by green manure and plant spacing

Parameters	Gross Yield (t/ha)		Marketable Yield (t/ha)	
Treatments	2015	2016	2015	2016
Spacing				
S_1 25 x 10cm	21.44	18.55	19.03	16.14
S_2 25 x 15cm	20.42	16.29	18.11	12.74
$S_3$25 x 20cm	19.58	13.59	17.41	10.74
LSD(P<0.05)	0.361	1.866	0.349	1.798
CV (%)	2.84	18.13	3.01	21.31
Amendments				
T_1 *Mucuna pruriens*	23.55	17.52	21.18	15.06
T_2 *Chromolaena odorata*	22.15	18.68	19.43	14.72
T_3 *Gliricidia sepium*	21.22	19.71	18.76	16.47
T_4 NPK (15, 15, 15)	28.73	17.33	27.23	14.66
T_5 Control	6.75	7.48	4.32	5.12
LSD (P<0.05)	0.466	2.409	0.450	2.321
CV (%)	2.84	18.13	3.01	21.31

Conclusion

The study showed that the application of the green manure and 300kg/ha NPK (15:15:15) improved vegetative growth, increased root length and yield of carrot relative to the control. Planting at 25 x 20cm improved the vegetative growth and root length of the crop. The closer spacing (25 x 10cm), however, gave more yield. From the economic point of view, carrot growers in Mampong- Ashanti can increase their yield with the application of 10t/ha *Mucuna pruriens* green manure and planting at 25 x 10cm spacing.

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