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# GROWTH AND YIELD RESPONSE OF CARROT (Daucus carotaL) TO SPACING IN WOLAITA ZONE, SOUTHERN ETHIOPIA

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**ABSTRACT**

Carrot (Daucus carota L) is one of the most important root vegetables grown and consumed in Ethiopia. However, not much work has been done to determine the appropriate spacing for increasing carrot plant growth and yield in Wolaita district. A field experiment was conducted to determine carrot plant growth and yield as affected by three plant row spacing (15, 25 and 35cm) and four within plant row spacing (2.5, 5, 7.5 and 10 cm). Shoot water content and root shelf life at Delbo were not significantly affected by spacing. Other parameters were significantly influenced by effect of inter and intra row spacing. The highest plant height (34.5 cm), leaf length (25.9 cm) and root dry weight per plant (3.7 g) at the spacing of 25x2.5 cm, leaf number pre plant (11.5), shoot fresh weight per plant (10.4 g),root diameter (2.6 cm), root length (20.6 cm), root fresh weight per plant (38.3 cm), core diameter per plant (0.9 cm) and root water content (94.3 %) at the spacing of 35x7.5 cm and root yield and marketable yield of 57,111 kg/ha at the spacing of 15x2.5 cm was obtained at Delbo site. At Soddo site the highest plant height (35.9), leaf length (31.2 cm), root diameter (1.9 cm), root weight (21.8 g) and core diameter per plant (0.7cm) at the spacing of 5x35cm, leaf number (9.0), shoot fresh weight per plant (9.7 g) and root water content (96.3 %) at the spacing of 10x25 cm, shoot water content per plant (94.6 %),dry weight per plant (2.30 g) at the spacing of 15x5 cm, root length (17.2 cm) at the spacing of 15x7.5 cm, root shelf life (21.7 days) at the spacing of 25x5 cm and 35x10cm and root yield (29,333 kg/ha) and marketable yield (29,067 kg/ha) at the spacing of 25x2.5cmwas obtained, respectively. It is recommended that the study should be repeated in different seasons before recommendation.

***Keywords:*** carrot, plant pacing, plant density, carrot growth and carrot yield.

## INTRODUCTION

Carrot (Daucuscarota L.) is a herbaceous biennial plant that belongs to the genus Daucus, species carotamember of the Apiaceous family (Hossain, 2012). Carrot originated from the Mediterranean region (Rubashevskaya, 1931). It is grown in spring, summer and autumn in temperate climate and during winter in tropical and subtropical climate (Bose and Som, 1990). Carrot is the most important carotenoids source in human diet. It also contains a wide spectrum of other antioxidants vitamins, carbohydrates, crude fiber, and minerals like Ca, P, Fe and Mg (Sharma *et al.,* 2011). Carrot intake enhances the immune system and protect against cancer, high blood pressure, osteoporosis, cataracts, heart diseases, and many others (Brandt *et al.,* 2004). Productivity of carrot was about 3.87 and 4.38 t/hain Ethiopia during 2014/15 and 2015/16 growing seasons, respectively (CSA, 2016). 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).The low productivity of carrot in the country is due to poor cultural practices such as inappropriate sowing time, lack of productive variety, inappropriate spacing, poor weed, pest and disease management and poor irrigation (Tadele and Solomon, 2016). An important factor that contributes towards the attainment of good yield of a crop is maintenance of optimum plant population (Endale and Gebremedhin, 2001). This is due to the fact that the quantity of solar radiation, which penetrates a crop canopy greatly, depends on planting patterns or spacing and individual plant morphology (Frezgi, 2007). Optimum population density is determined by optimum plant spacing that provides the plant with the best environment for the capture and efficient use of available resources(Salter *et al.,* 1999).

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Although25 cm x 5 cm spacing was recommended in Eastern Ethiopia (Wassu *et al.,* 2014), systematic work has not been carried out so far to find out the best spacing for potential carrot root yield at Wolaita zone. There is also a need to understand the relationship between inter row spacing and intra row spacing to identify the most befitting spacing for carrot production in this zone. Therefore, the objective of this study was to determine the appropriate plant row spacing and within plant spacing for carrot production in the area.

## MATERIALS AND METHODS

### Description of the Study Area

The experiments was conducted under rain-fed conditions within farm in Damot Galee and Soddo Zuria districts of Wolaita zone in Ethiopia during the cropping years of 2018. The experimental site is located at latitude 6° 49'N, longitude 37° 45'E and altitude of 1,886 meter above sea level. The area experiences bimodal type of rainfall. The shortest rainy season stretches from March to April, and the main rainy season from June to September when carrot is mainly grown in the region. Based on data from the last 12 years (i.e. 2003-2015), the average annual rainfall is about 1,580 mm while the average annual maximum and minimum temperature is 23.7°C and 17.7 $^0$C, respectively. The relative humidity of the area is 75.2% in the month of August and drops as low as 56.0% in February (NMA, 2015). The dominant soil of the Wolaita area is well drained sandy loam with low organic matter content (Gebru *et al*., 2017a).

### Treatments and Experimental Designs

The experiment was consisted of three inter row spacing of(15, 25 and 35cm) and four within plant spacing of (2.5, 5, 7.5 and 10cm) arranged in randomized complete block design with three replications. The plot size was 1.8 m$^2$ (i.e. 1.75 m × 1.2 m). The

blocks were separated by 1 m wide space and each plot was separated by 0.5 m space. All treatments were arranged randomly with in all blocks. Uniform dose of nitrogen in the form of urea and (NPS) pre-mixed compound fertilizer obtained from Wolaita Soddo ATVET collage was applied at the rate of 89 and 121 kg $ha^{-1}$respectively.

**Field management and Cultural Practice**

Field soil was thoroughly ploughed to a depth of 30 cm to get a fine tilth. The field was leveled off and divided into plots as per the layout of the experiment. The carrot seeds of Nantes variety obtained from Debrezeyt agricultural research center were sown by drilling to a depth of 1.5 cm in rows. Half the dose of N and full dose of the NPS was applied as basal application at sowing. The remaining half dose of N fertilizer was applied as top dressing at 30 days after sowing. Two thinning was done by hand pulling the seedlings to maintain optimum plant population per individual within plant spacing treatment. The first thinning was done at 20 days after sowing and the second thinning was done 10 days after the first thinning. Earthing-up of the plants was done twice at 30 and 60 days after sowing to cover exposed roots. Watering and other required cultural practices were performed similarly for all the treatment plots.

**Data Collection**

Root yield was taken from the entire net plot. Ten plants were randomly selected and tagged from the middle raw for the collection of the other agronomic parameters. The collected agronomic data include plant height, leaf length, root length, root diameter and core diameter were measured in centimeter at plant maturity. Number of leaves per plant were counted at harvest and the average number of leaves per plant was calculated. Plant shoot fresh weight and root weight per plant were measured using sensitive balance and expressed in terms of grams. Shoot and root dry weights were determined after drying in an oven held at $60^{O}C$ until a constant weights were attained. The mean dry weight were expressed in grams per plant. Total mature root yields was weighed and expressed in terms of kg hectare. Marketable root yield was weighed after observing and recording oversized, under sized, branched, cracked and damaged carrot and expressed as kg per hectare. Shoot and root water content were determined as percentage using the following equation suggested by Keshavarzpour (2011):

$$\text{Water content } (\%) = 100 \text{ x } \frac{M_1 - M_2}{M_1}$$

Where, $M_1$= weight measured before drying,
$M_2$= weight measured after drying

Harvested root shelf life (days)was measured as a period (in days) between harvest of the roots and end of edible life of the root at room temperature. End of shelf life was considered to be at a stage where 50 percent of the stored roots become unfit for consumption. Finally Total soluble solids was obtained by using the following linear regression model described by Keshavarzpour (2011)

TSS = 34.9 – 0.30 WC
*Where, TSS = Total soluble solid;*
*WC = Water content*

**Data Analysis**

All the data collected were analyzed using the Generalized Linear Model(GLM) procedures of the Statistical Analysis System (SAS) software (SAS institute of North Carolina, American, 2002). Fisher's Least Significant Difference (LSD) test at α= 0.05 was used to separate significant differences between treatments means when analysis of variance indicated P≤0.05.

## RESULTS AND DISCUSSION

The effect of different row spacing and plant spacing on plant height, leaf length, leaf number and shoot fresh weight per plant was found to be significant (P < 0.05) both in Delbo and Soddo sites. However, shoot water content per plant was no significant at Delbo. The highest plant height (34.5 cm)and leaf length (25.9 cm)was recorded from spacing of 25x2.5 cm, the highest leaf number pre plant (11.5) and shoot fresh weight per plant (10.4 g) was obtained from the spacing of 7.5x35 cm at Delbo site. In Soddo site the highest plant height (35.9) was recorded from the spacing of 35x5 cm. The highest leaf length (31.2 cm) from 35x5 cm and the highest leaf number (9.0) and shoot fresh weight per plant (9.7 g) was recorded by the spacing of 25x10 cm and the highest shoot water content per plant (94.6 %) was recorded at the spacing of 15x5 cm (Table 1). The lowest plant height (25.5 cm), leaf length (18.1 cm) and shoot fresh weight per plant (4.1 g) was recorded with the spacing of 15x5 cm, the lowest leaf number (8.3) was obtained by the spacing of 15x7.5 cm and the lowest a shoot water content per plant (82.0 %) was recorded at the spacing of 15x7.5cmat Delbo. At Soddo the lowest plant height (28.9 cm) and leaf length (23.3) was recorded by the spacing of 25x10 cm and the lowest leaf number (5.7) and shoot fresh weight per plant (2.2 g) was achieved by the spacing of 15x2.5 cm (Table 1). This finding were agreed with Kabir et al. (2013) result as they found significant difference between different spacing and they reported that as spacing increases significant decrease in plant height was obtained and leaf number. In this case in narrow spacing plants length could increase for computing the available light. Similarly, the significantly higher plant height and leaf number was recorded by Appiah et al. (2017) for the closer spacing treatment.

The data on yield parameters revealed significant differences (P < 0.05) between and among spacing. The combination of spacing 35x7.5cm recorded significantly highest root diameter (2.6 cm), root length (20.6 cm) and root fresh weight per plant (38.3 cm) at Delbo. However, the highest root yield (57,111 kg/ha) was obtained at the spacing of 15x2.5 cm. At Soddo the highest root diameter (1.9 cm) and root weight (21.8 g) was obtained at the spacing of 35x5 cm, the longest root length (17.2 cm) at the spacing of 15x7.5 cm and the highest root yield (29,333 kg/ha) at the spacing of 25x2.5 cm(Table 2). The lowest root diameter (2.0 cm) at the spacing of 15x7.5 cm, root length (16.7 cm) at the spacing of 35x5 cm, root fresh weight per plant (17.1 cm) at the spacing of 15x2.5 cm and root yield (9,238 kg/ha) at the spacing of 35x10 cm was obtained Delbo. At Soddo the lowest root diameter (1.4 cm) at the spacing of 15x10 cm, root weight (8.6 g) at the spacing of 35x5 cm, root length (13.5 cm) at the spacing of 15x2.5 cm and root yield (7,429 kg/ha) at the spacing of 35x10 was obtained (Table 2). Even though it is not constant, root weight per plant and root yield increases with increasing of spacing.

This is due to that plant spacing is one of the important factor affecting productions of carrot (Pavlek, 1977).McCollum et al. (1986) reported that there is a positive correlation between the number of plants and yield of carrot. Dawuda et al. (2011) observed that total and marketable yields were significantly higher in the closely spaced plants because more roots were produced per unit area. Appiah et al. (2017) also stated that plant population can be asymptotic and explained that yields increased with increase population over the lower range of population. Similarly, Muck (1980) reported that carrot yield increased when plant density was increased with closer spacing.

**Table 1. Effect of spacing (cm) on aerial growth parameters of carrot**

| | Delbo | | | | | Soddo | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Plant spacing** | **Row spacing** | **PH** | **LL** | **LN** | **SFWPP** | **PH** | **LL** | **LN** | **SFWPP** | **SWC** |
| 15 | 2.5 | 29.2ab | 21.6ab | 8.5b | 4. 7de | 32.9ab | 27.7abc | 5.7c | 2.2h | 87.3abc |
| | 5 | 25.5b | 18.1b | 8.5b | 4.1e | 30.9ab | 24.4bc | 6.4bc | 3.0h | 82.0c |
| | 7.5 | 29.9ab | 23.9ab | 8.3b | 5. 7cd | 32.2ab | 27.1abc | 7.3abc | 8.4c | 94.6a |
| | 10 | 29.5ab | 21.8ab | 9.3ab | 6.5bc | 29.1b | 24.7abc | 6.0bc | 4.9fg | 93.2ab |
| 25 | 2.5 | 34.5a | 25.9a | 8.9b | 7.0b | 31.9ab | 25.8abc | 7.5ab | 4.7g | 91.2ab |
| | 5 | 26.3b | 22.0ab | 9.1ab | 6.4bc | 35.9a | 30.3ab | 6.5bc | 7.9c | 90.5abc |
| | 7.5 | 27.5ab | 20.3ab | 9.4ab | 6.0bc | 29.4b | 24.2bc | 8.6a | 6.1e | 86.3abc |
| | 10 | 31.7ab | 24.5a | 9.8ab | 6.7bc | 28.9b | 23.3c | 9.0a | 9.7b | 88.8abc |
| 35 | 2.5 | 31.3ab | 24.2a | 9.5ab | 5.7cd | 35.8a | 30.4ab | 6.3bc | 6.7de | 93.0b |
| | 5 | 31.6ab | 24.4a | 9.2ab | 7.1b | 34.9ab | 31.2a | 8.6a | 7.7cd | 91.3ab |
| | 7.5 | 30.6ab | 23.9ab | 11.5a | 10.4a | 32.5ab | 26.8abc | 8.5a | 5.9ef | 84.9bc |
| | 10 | 30.9ab | 23.3ab | 10.7ab | 9.2a | 33.6ab | 28.1abc | 8.8a | 11.3a | 87.1abc |
| LSD(0.05) | | 7.4 | 5.9 | 2.5 | 1.3 | 6.0 | 6.8 | 1.8 | 1.2 | 8.68 |
| CV (%) | | 14.3 | 15.5 | 15.0 | 18.6 | 10.8 | 14.6 | 15.5 | 28.2 | 5.75 |

Means followed by the same letter with in the column are not different from each other at P=0.05 level of significance. Where, PH = plant height (cm), LL = leaf length (cm), SFWPP = shoot fresh weight per plant, LN = leaf number and SWC = shoot water content (%).

**Table 2. Effect of spacing (cm) yield and yield attributes of carrot**

| | | Delbo | | | | Soddo | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Plant spacing** | **Row spacing** | **RD** | **RL** | **RWPP** | **RY** | **RD** | **RL** | **RWPP** | **RY** |
| 15 | 2.5 | 2.3abc | 18.3ab | 17.1g | 57111a | 1.5bc | 13.5b | 8.7e | 29111a |
| | 5 | 2.1bc | 17.2ab | 17.3g | 28889c | 1.8abc | 15.3ab | 8.6e | 14194de |
| | 7.5 | 2.0c | 17.5ab | 20.5fg | 22815cde | 1.7abc | 17.2a | 20.7a | 22963b |
| | 10 | 2.4ab | 19.0ab | 28.8b | 24000cd | 1.4c | 16.7a | 16.3cd | 13611de |
| 25 | 2.5 | 2.4ab | 18.1ab | 21.7ef | 43333b | 1.6abc | 16.3ab | 14.7d | 29333a |
| | 5 | 2.3abc | 19.5ab | 27.8bc | 27800c | 1.6abc | 14.7ab | 17.2bcd | 17533c |
| | 7.5 | 2.3abc | 17.5ab | 23.1def | 15422f | 1.8abc | 17.0a | 17.7bc | 11778ef |
| | 10 | 2.3abc | 19.1ab | 26.0bcd | 13000fg | 1.9a | 15.7ab | 19.8ab | 9900fg |
| 35 | 2.5 | 2.3abc | 17.1ab | 23.3def | 43048b | 1.5abc | 15.6ab | 10.9e | 15524cd |
| | 5 | 2.3abc | 16.7b | 23.8cdef | 17000ef | 1.9a | 15.8ab | 21.8a | 15571cd |
| | 7.5 | 2.6a | 20.6a | 38.3a | 18222def | 1.8abc | 16.5a | 19.5ab | 9302fg |
| | 10 | 2.3abc | 20.5a | 25.9bcde | 9238g | 1.8ab | 17.1a | 20.9a | 7429g |
| LSD(0.05) | | 0.4 | 3.7 | 4.3 | 6095.7 | 0.4 | 3.0 | 2.8 | 2843.2 |
| CV (%) | | 10.6 | 12.1 | 19.8 | 16.5 | 14.2 | 10.9 | 19.5 | 24.1 |

Means followed by the same letter with in the column are not different from each other at P=0.05 level of significance. Where, RD = root diameter (cm), RL = root length (cm), RWPP (g) = root weight per plant and RY = root yield (kg/ha).

**Table 3. Effect of spacing (cm) on quality parameters of carrot**

| | Delbo | | | | | Soddo | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Plant spacing** | **Row spacing** | **CDPP** | **MY** | **RDWPP** | **RWC** | **CDPP** | **MY** | **RDWPP** | **RWC** | **RSL** |
| 15 | 2.5 | 0.8ab | 57111a | 0.9f | 94.1ab | 0.5bc | 23333b | 1.4b | 83.8bc | 17.7abc |
| | 5 | 0.7ab | 28889cd | 2.1cde | 88.3abc | 0.6abc | 18861c | 2.3a | 81.0c | 15.3bc |
| | 7.5 | 0.7b | 22222def | 1.3ef | 93.7ab | 0.6abc | 19481c | 1.6b | 91.2ab | 17.0abc |
| | 10 | 0.8ab | 24000cde | 3.6ab | 86. 6bc | 0.5c | 13056ef | 1.2bc | 90.0ab | 13.7c |
| 25 | 2.5 | 0.8ab | 38800b | 3.7a | 88.2abc | 0.5abc | 29067a | 1.6b | 89.0abc | 18.3abc |
| | 5 | 0.8ab | 27800cd | 2.5cd | 89.6abc | 0.5abc | 15667d | 1.7b | 88.2abc | 21.7a |
| | 7.5 | 0.8ab | 11778gh | 3.5ab | 85.9c | 0.6abc | 11600fg | 1.6b | 90.7ab | 20.7ab |
| | 10 | 0.8ab | 13000gh | 1.8de | 92.4abc | 0.6ab | 9900gh | 0.8c | 96.3a | 16.7abc |
| 35 | 2.5 | 0.8ab | 30381c | 2.3cd | 90.9abc | 0.5bc | 15524de | 2.2a | 81.1c | 15.3bc |
| | 5 | 0.8ab | 16762fg | 2.8bc | 87.5abc | 0.7a | 15476de | 1.2bc | 93.5a | 20.7ab |
| | 7.5 | 0.9a | 18063efg | 2.1cd | 94.3a | 0.6abc | 9238gh | 1.7b | 92.3a | 17.7abc |
| | 10 | 0.6b | 6238h | 2.0cde | 90.9abc | 0.6abc | 7333h | 1.3b | 91.2ab | 21.7a |
| LSD(0.05) | | 0.2 | 6890.8 | 0.8 | 7.7 | 0.2 | 2605.4 | 0.5 | 8.2 | 5.7 |
| CV (%) | | 16.9 | 23.9 | 20.3 | 5.4 | 15.8 | 20.3 | 26.8 | 6.0 | 18.6 |

Means followed by the same letter with in the column are not different from each other at P=0.05 level of significance. Where, CDPP = core diameter per plant (cm), MY = marketable yield (kg/ha), RDWPP = root dry weight per plant (g), RWC = root water content (%) and RSL = root shelf life (days).

Effect of different row spacing and plant spacing on core diameter per plant, marketable yield, root dry weight per plant and root water content was found to be significant ($P < 0.05$) both in Delbo and Sodoo sites. However, shelf life was not significant at Delbo. The highest core diameter per plant (0.9 cm)at the spacing of 35x7.5 cm, marketable yield (57,111 kg/ha) at the spacing of 15x2.5cm, root dry weight per plant (3.7 g) at the spacing of 25x2.5 cm and root water content (94.3 %) at the spacing of 35x7.5 cm was obtained at Delbo. At Soddo the highest core diameter per plant (0.7cm)at the spacing of 35x5 cm, marketable yield (29,067 kg/ha) at the spacing of 25x2.5cm, root dry weight per plant (2.30 g) at the spacing of 15x5 cm, root water content (96.3 %) at the spacing of 25x10 cm and root shelf life (21.7 days) at the spacing of 25x5 cm and 35x10 cm (table 3) was obtained. The lowest core diameter per plant (0.6 cm)at the spacing of 35x10 cm, marketable yield (6,238 kg/ha) at the spacing of 35x10cm, root dry weight per plant (0.9 g) at the spacing of 15x2.5 cm and root water content (85.9) at the spacing of 25x7.5 cm was obtained at Delbo. At Soddo the lowest core diameter per plant (0.5cm)at the spacing of 15x10 cm, marketable yield (7,333 kg/ha) at the spacing of 35x10cm, root dry weight per plant(0.8 g) at the spacing of 25x10 cm, root water content (81.0) at the spacing of 15x5 cm and shelf life (13.7 days) at the spacing of 15x10 cm (table 3) was recorded. Other researchers reported that different plant densities of spacing have different effect for the marketable yield of carrot and

anther quality parameters (Nogueira, *et al.,* 1982) and Drag land, 1986). Similar result of marketable yield was obtained by Kabir *et al.* (2013). They reported that the highest marketable yield was obtained in narrowest spacing(10 cm x 10 cm). As spacing increases amount of marketable yield was decreased. Appiah *et al.* (2017) also indicated that as spacing increases marketable yield decreases. Even though longer root length per plant was produced from the wider spacing, gross and marketable yields were significantly higher in the closely spaced plants because more roots were produced per unit area.

## CONCLUSTION

In conclusion, the present study revealed the above water content and shelf life at Delbo were not significantly affected by spacing. Other growth parameters, yield parameter and quality parameters were significantly influenced by the interaction effect of inter and intra spacing. This study has clearly indicated that row and plant spacing showed significant effect on growth and productivity of carrot. Growing of the carrot by using the spacing of 15 cm x 2.5cm at Delbo and spacing of 25 cm x 2.5cm at Soddohad the potential for better productivity of carrot in the experiment area and areas having similar environmental condition. However, further research is needed in different season to confirm this result.

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