

Effect of Row spacing on growth and yield components of Carrot (*Dacusa carrot L*)

Abebe Misganaw*, Yonas Yeshambel

Department of Plant science, Mekdela Amba University, Germame, Ethiopia

ABSTRACT

Carrot is the most important root vegetable of Apeaceae families and it is cultivated in many parts of the world. Its production is increasing from time to time mainly due to its ease of production, and the increases in small-scale rain fed and irrigation areas. However, the production level is too low according to its potential. This is due to the case of poor Agricultural practice including spacing. Plant spacing is one of the important factors for the increased production of carrot. The objective of this review articles was to review the growth and yield response of carrot to intra row spacing. Different researchers reported that different plant spacing, have different effects for the growth and marketable yield of carrot concerning the ecology of area. So based on different scholars reports carrot plants have different response for different plant spacing ranging from 5 cm up to 7.5 cm intra row. Therefor investigation of the effect of plant spacing on carrot yield and yield component on different agro ecology is mandatory.

Keywords: Carrot; Growth; Intra row; Spacing; Yield

INTRODUCTION

Background and Justification

Carrot [1] is the most important root vegetable of Apeaceae families and it is cultivated in many parts of the world [2], [3-5]. It originates from the wild forms growing in Europe and southwestern Asia [6]. Carrot is high content of carotene (a precursor of vitamin A) which prevents night blindness. They also contain appreciable quantities of vitamin B (thiamine and riboflavin) carrot contains also abundant quantities of nutrients and minerals [7]. Carrot has therapeutic importance as it enhances resistance against blood and eye diseases. Carrot roots are consumed uncooked in salads steamed or boiled in vegetables and may be prepared with other vegetables in the preparation of soups and stews. Carrot is cool season crop. It is an important vegetable, which ranked third among the succulent vegetables in world production and China is the leading country in production.

Root crops covered more than 1.42% of the area under all crops and contributed 6.15% to the production of all crops total in Ethiopia. Carrots introduce since the early 1960's through the research system in Ethiopia. It is one of the important vegetable crops Produced on small scale in Ethiopia and widely grown in the mid and highlands of the country [8]. Carrot production has been expanding since then and the total production reached 173,334.90 in quintals on 4,902.90 hectares of land. The area coverage of carrot is increasing from time to time mainly due to

its ease of production, and the increases in small scale rain fed and irrigation areas (Table 1).

Table 1. Production of carrots (and turnips) in 2016

COUNTRY	PRODUCTION (MILLIONS OF TONES)
CHINA	20.5
EUROPEAN UNION	5.9
UZBEKISTAN	2.3
RUSSIA	1.8
UNITED STATES	1.4
UKRAINE	0.9
WORLD	42.7
SOURCE: (FAOSTAT. 2017).	product

Carrot is the most important horticultural root vegetable crops and highly perishable crop due to high water content. It requires a special skill and specific technique of production and handling. Despite areas increase, the productivity of carrot production reduced by several factors. The low productivity could be attributed to poor cultural practices including plant-to-plant spacing. Gernew A Reported that yield and quality of dry carrot root can be influenced by cultural practices and growing environments [9].

Correspondence to: Abebe Misganaw, Department of Plant science, Mekdela Amba University, Germame, Ethiopia, Email: abebemisganaw1423@gmail.com

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The quality and size of the roots depends on the spacing of plant to plant and row to row [10]. Optimum spacing between plants play crucial role in the growth and yield quality of carrot [10]. Planting pattern significantly influences the encompassing condition of the seed crop field, which alters the harvest phenology, eventually influencing the growth and yield of carrot. Optimized plant spacing is of prime importance to proliferate the biomass production and nutritional availability to plants and ultimately affect the growth and yield.

Table 2. Carrot production in ethiopia from 2014/15 to 2017/18 in ethiopia

YEAR	NO OF HOLDERS	AREA (HA)	PRODUCTION (QT)	PRODUCTIVITY (QT/HA)
2017/18	204,439.00	4,902.90	173,334.27	35.35
2016/17	168,252.00	2,578.13	90,339.27	35.04
2015/16	177,774.00	3,823.41	167,513.76	43.81
2014 / 15	159,136.00	3,697.27	142,970.14	38.67

SOURCE: (CSA, 2014/15 TO 2017/18).

The higher yield and better control of over or under root size can be obtained if plants are grown at optimum density. Root diameter; mean root weight and plant height decreased as population density increased. Total root yield can be increased as population density increases. Many reviews have also shown that spacing altered the plant architecture, photosynthetic efficiency of leaves, root size and root production pattern. According to [12], both too narrow and too wide spacing do affect crops yield through competition and shading effect.

In other hand, producers complain narrow intra row spacing produces large root size which is not preferred by consumer for home consumption. The control of plant spacing is one of the cultural practices to control root size, shape and yield. Therefore, it is imperative to review intra row-spacing recommendation that may help the carrot plant to utilize resources more effectively and efficiently towards increased production, productivity and root quality [13]. Systematic review of different spacing combination is very important for base line of any study and help to growers to increase the yield and quality of carrot plant. So that the goal of this review paper was to understand the finding of different scholars regarding to carrot response to intra row spacing and shear the information to growers.

Objective

To review the growth and yield response of carrot to intra row spacing

Significance of the review

This review is to shear information about the optimum spacing of carrot for better growth and yield. It would be the base for future researchers. To shear information about carrot production for farmers, researchers and NGOs and Governmental organizations

LITERATURE REVIEW

Carrot origin and botanical description

Carrots were thought to be domesticated in Afghanistan as the primary center of diversity and they were spread over Europe, Asia and the Mediterranean area, however, the origin of western cultivated carrots were thought to be in the Asia Minor Centre,

Appropriate plant spacing is essential for maximum seed yield of carrot because it minimizes competition for nutrition, light and water [11]. Optimal row spacing in forage turnip significantly influenced growth and yield component. In other side, attack of diseases (*Alternaria* sp.) and the crop lodging was observed in narrow spaced seed crops. Various review indicated that narrow plant spacing intra-row spacing, gives us in highest growth and yield of carrot (Table 2).

primarily Turkey [6]. Carrot is one of the major vegetable crops cultivated worldwide. The domesticated types are divided into two groups:

(1) the Eastern or Asian carrots (var. *atrurubens*, Alef), with mainly purple and yellow roots; and (2) the Western carrots (var. *sativus*, Hoffm.) with mainly orange roots.

Daucus carota is a biennial plant. In the first year, its rosette of leaves produces large amounts of sugars, which are stored in the taproot to provide energy for the plant to flower in the second year. Seedlings shortly after germination soon after germination, carrot seedlings show a distinct demarcation between taproots and stem.

The stem is thick and lacks lateral roots. At the upper end of the stem is the seed leaf. The first true leaf appears about 10–15 days after germination. Subsequent leaves are alternate (with a single leaf attached to a node), spirally arranged, and pinnately compound, with leaf bases sheathing the stem. As the plant grows, the bases of the seed leaves, near the taproot, are pushed apart. The stem, located just above the ground, is compressed and the internodes are not distinct. When the seed stalk elongates for flowering, the tip of the stem narrows and becomes pointed, and the stem extends upward to become a highly branched inflorescence up to 60–200 cm (20–80 in) tall [14].

The roots were long and thin, and either purple or yellow in color. These colors, as well as white and orange, still exist, with the orange or orange-red colors being by far the most popular today. Many shapes of roots also exist, from rather long and thin roots to shorter and thick. Roots may be cylindrical, conical, or even spherical in shape. Most of the taproot consists of a pulpy outer cortex (phloem) and an inner core (xylem). High-quality carrots have a large proportion of cortex compared to core. Although a completely xylem-free carrot is not possible, some cultivars have small and deeply pigmented cores; the taproot can appear to lack a core when the color of the cortex and core are similar in intensity. Taproots are typically long and conical, although cylindrical and nearly spherical cultivars are available. The root diameter can range from 1 cm (0.4 in) to as much as 10 cm (4 in) at the widest part. The root length ranges from five to 50 cm (2 to 20 in),

although most are between 10 and 25 cm (4 and 10 in) [14].

Carrot production, productivity and distribution

The world production of carrot is increase from year to year, in the year 2012 the production of the crop is 36.9 million Mg, cropped in an area of 1.19 million hectares, with average yield of 31.0 Mg ha⁻¹. Carrots can be grown all the year round in Brazil.

Carrots are not a traditional crop in Ethiopia, but are now grown throughout the country, albeit sparsely in most areas. They are predominantly cultivated as a cash crop for sale to urban markets, hotels and restaurants. Some carrots are consumed by farmers and their families, but the high levels of vitamin deficiency recorded throughout Ethiopia indicate that many people even in rural areas are not eating enough carrots or other vitamin A rich vegetables [15].

Currently, about 12345.8 t of carrot is produced in Ethiopia on 2,215 ha of land although the production trend is not consistent from year to year the production of carrots has doubled between 2004/5 and 2010/11 due to increasing urbanization and the recognition of carrots as an income and nutrition source mainly. Moreover, foreign currency income obtained from exporting fresh or chilled carrots and turnips increased from time to time, because an increase demands of the population. In addition, a significant number of individuals get their income from brokering, trading (wholesale or retail), and transporting carrots. Carrots are produced in a wide range of agro-ecologies from the lowlands to the highlands of Ethiopia.

Carrot is frost tolerant and has become one of a few alternative crops that can be grown in the frost prone highlands around 3000 m.a.s.l. It grows in well drained alluvial and sandy loam soils but not in heavy clay and water-logged soils. Carrots are usually grown on small plots in the backyards of town and per urban dwellers for family consumption; however, some farmers grow carrots on up to 0.25 t/ha as a means of income. Carrots can be grown throughout the year if rain and irrigation water is available in highlands that get bimodal rainfall, two cycles. Carrots can be produced based solely on rain. These are the short rainy season (Belg March to May) and the long rainy season (Meher, June to September). The third cycle is also possible between October and March with irrigation water.

Agro-ecological requirements of carrot

Carrot requires an optimum air temperature of 16-24°C and the crop is fairly sensitive to high soil temperature which results in low germination, short root and pale colour when the temperature is over 25°C and burning of carrot seedlings. The crop is tolerant to a wide range of rainfall but must not be excessive to cause change in colour of root. This assertion is supported by [16] that the soil for carrot must be moist and not waterlogged. Water requirement for carrot is more during the vegetative period. Carrot thrives well on a deep moist, well drained, friable, sandy loam soil rich in organic matter. Carrots perform best in sandy soils with plenty of compost. In dry soils, the roots of carrots crack but in favorable soil conditions, it produces long roots [17].

The crop is believed to tolerate moderately acidic to alkaline soils. According to [17,18] the optimum soil pH for carrots ranges from 5.8-6.6. Sinnadurai S also recommends an optimum pH of 5.8-7.0 for carrot growth and yield. Mulching is recommended on seed bed for good germination [19,17]. Weed management in carrot production is very critical in the crop cycle if yield losses are

to be avoided.

For optimum growth of carrots, it is good for the crop to be spaced well after establishment. The seeds are sown in drills 1 cm deep, and intra rows of 8-10 cm [18]. Hodder and Stoughton reported that between rows of 15 cm and within rows of 10 cm for carrot is ideal. [17], state that seeds be sown 1-2 cm deep, rows 30-40 cm apart and seedling thinned to 10-14 cm apart within row.

Carrot is normally classified as a biennial species that requires vernalization to induce flowering. During the first year it produces a basal rosette of leaves and stores carbohydrates in its hypertrophic root. The stage of growth when carrot seedlings are not responsive to low-temperature vernalization is known as juvenility. This condition usually ends when carrot plants have initiated 8 to 12 leaves, and storage roots are larger than 4 to 8 mm in diameter. After a vernalization period, with temperatures between 0 and 10 °C, and long days, floral stem elongation and flowering are induced. Carrot roots quickly become very lignified after vernalization, even before the floral stalk elongates, so that the initiation of flowering results in a complete loss of commercial value. The level of response to cold treatments is cultivar dependent. Late-flowering cultivars require 11 to 12 weeks at 5 °C to be permanently vernalized.

The carrot plant consists of a stem, leaves, roots and flowers. The stem of the plant, as with many vegetable umbelifers is just above the ground during its vegetative state and is compressed so that the internodes are not clearly discernible. The apical meristem is slightly convex. The leaves of carrots develop alternative from the apical meristem forming a rosette at the base. Petioles bases are expanded and sheath-like at their basal attachment. New leaves develop centripetally in a spiral within the basal clasping of preceding petioles. Carrots have compound leaves, each leaf consisting of several finely divided leaflets. Leaf blades are two to three pinnate, the leaflets being repeatedly divided (pinnatifid) with small highly lobed segments that are oblong or linear and acute.

Agronomic and morphological characteristics of carrot

Carrot can be grown medium to high altitudes in Ethiopia (1600-2400 meters above sea level) and similar areas of the country either under rain-fed or irrigation (CSA, 2018). It has a deep orange root color. It has attractive root size and shape, long roots with small cores. It is released mainly for its total root yield advantage of 11.41 and 16.23% over the commercial and the farmers' open pollinated cultivar, respectively. It has also 5.82 and 6.48% marketable root yield advantage. The yield and some agronomic and morphological characteristics of the carrot.

Effect of spacing and plant population on plant

Row spacing alters structure of plant, photosynthetic rate and distribution of dry matter in several agronomic and horticultural. Total umbels per plant were increased through widest plant spacing. The difference in spacing brought significant variation in growth and yield components. Number of harvested umbels per plant can be higher in wider spacing than the closer spacing, which seems to be mainly due to less competition for nutrition and light. This less competition might have augmented more branching, ultimately producing more umbels per plant. Wider spacing gives higher umbels per plant, good growth and yield of carrot crop.

Optimum spacing between plants play crucial role in the growth and yield quality of carrot [10]. Planting pattern significantly

influences the encompassing condition of the seed crop field, which alters the harvest phenology, eventually influencing the growth and yield of carrot.

Optimized plant spacing is of prime importance to proliferate the biomass production and nutritional availability to plants and ultimately affect the growth and yield quality. Optimal row spacing among the crop plants helps to avoid shading effect on plants as well as competition for soil moisture and nutrient elements among the plants. Appropriate plant spacing is essential for maximum seed yield of carrot because it minimizes competition for nutrition, light and water [11].

Optimal row spacing in forage turnip significantly influenced growth and yield component. Both too narrow and too wide spacing do affect yields through competition (for nutrients, moisture, air, radiation, etc.) and due to the effect of shading. In the latter case (too wide spacing), yield reduction can occur due to inefficient utilization of the growth factors [20]. Normally, as population increases yield also increases proportionally; after it reaches a certain level, the yield declines. Population density is also dependent on the moisture availability and nutrient status of the soil. Hence, optimum planting density should be determined through conducting experiments. The spacing between stands is largely determined by the extent of the root and shoots systems of the crop plant in question. The spacing between stands in turn determines the number of stands per hectare. A number of factors also influence spacing: fertility status of the soil, growth pattern of the crop and cultural practices. Likewise, attack of diseases (*Alternaria* sp.) and the crop lodging was observed in narrow spaced seed crops. Various review indicated that narrow plant spacing intra-row spacing, gives us in highest growth and yield of carrot.

Effects of intra row spacing on growth parameters of carrot

Effects of intra row spacing on plant height: Plants, which are widely spaced, produced more leaves and wider canopies. 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.

Plant height is affected due to the use of different spacing [21] says that closer spacing increases the competition for essential growth factors among individual plants which do not attain their normal size, but when there is wider spacing plant height also increase due to free availability of space, nutrient, air, water, and others. The maximum plant height is found in wider intra spacing followed by narrow intra spacing in open condition and minimum plant height is in the minimum intra spacing. Maximum plant height under agro forestry system is occur in wide intra spacing and the minimum plant height is exist in closest intra spacing. Plant height decrease as the intra row spacing increase. This is because when the space between plants is narrow there is a completion for sunlight, water, and nutrients. It is in line with Shamsi and Kobraee who reported that the height of carrot plant increase as the spacing between plants decreases.

Effects of intra row spacing on number of leaves per plant: Number of leaves per plant is affected due to different intra row spacing. When spacing increase number of leaves per plant also at the same increase, however when spacing decrease, it also decreases [22].

Effects of intra row spacing on canopy spread: The spacing re-

vealed the maximum canopy spread per plant and the minimum spacing is found from closest spacing. This indicate that if there is optimum space for plant growth, plants grow both horizontally and vertically to explore the available resources like light and nutrients. As the plant increases in their canopy, they have the chance to intercept more light and convert that to dry matter for better growth and yield than those grown in too closer spacing. Canopy width is important to determine plant spacing for its contribution to total amount of light that plant intercepts for photosynthesis efficiency of crops.

Effects of intra row spacing on root length: 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 photosynthetic in the roots. States 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 are produced from the wider spacing, total and marketable yields are higher in the closely spaced plants because more roots are produced per unit area. This is similar to this scholar [23] who reported that carrot yield increased when plant density is increased with closer inter-row spacing.

The length of root of carrot is affected by spacing. The length of root is to be gradually increasing row to row spacing. The highest length of root per plant is produced at wider spacing and the lowest length of root per plant is produced at closer spacing. The root length of some carrot plants can be measured with the ruler during harvesting period. In matter, when the intra row spacing increased the length of root is increased. This is revealed that the root length gradually increased or decreased when increasing or decreasing to the optimum intra row spacing of carrot.

Effects of intra row spacing on root diameter: The diameter of root of carrot is affected by spacing. The diameter of root is to be increased with increasing spacing. When closer spacing minimum diameter of root is obtained. The tallest average root diameter is found, when plants have sufficient space to develop their root in soil, and the minimum diameter is also obtain when, it is caused by competition of nutrients, air, and water [24].

Effects of intra row spacing on fresh weight: Rajasekaran L and Alves s reported that higher population densities result in lower fresh weight of roots [25,26]. Lana also reported that the use of wider spacing between plants, in general, provides larger and not uniform roots, with high frequency of various strains, with consequent reduction in quality and productivity. Wider spacing has substantial effects on weight of carrot, but did not affect the germination percentage [27].

Spacing significantly influences the fresh weight of root per plant due to spacing. Plants, which are widely spaced, produced more leaves and wider canopies. 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. In other hand, Fordham, Biggs and Ashrafal 2013 reported that crops planted at a wider spacing, produced more leaves and higher foliage dry matter on different agro ecological conditions and edaphic factor.

Effect of intra row spacing on dry weight of root of carrot: Dry weight of root is also varied with different plant spacing's. When

spacing increase dry weight of root is increased, but when it is decreased, the dry weight of root is also decreased at the same way.

Effects of intra row spacing on primary and secondary branches of carrot: Increasing planting density resulted in a decreased number of branches. Growing carrot seed crops at high density reduced the number of lateral branches [28]. Increased number of branches per plant in widely spaced plants than in closely spaced ones. This may be due to competition for space, nutrients, light and air between the plants. The effect of sowing date and its interaction with planting density was found to be non-significance in affecting the number of branches per plant.

Effects of intra row spacing on flowering characters of carrot: Plants at lower population density, this means that there is wider intra row spacing can give the highest number of secondary and tertiary umbels and their number decreased with increasing planting density. This could likely be related with the number of branches extending from the main stalk and the primary branches, at the terminus of which umbels of the respective orders may be formed [29]. Number of umbels per plant decreased with increasing plant density, this indicates that there is response of plant to closest or narrow intra row spacing.

Effect of intra row spacing on phonological parameters of carrot

Effect of intra row spacing on days to 50% emergence of carrot: When there is appropriate intra row spacing, enough emergences takes place. However, when intra row spacing decrease emergence takes loge time. Therefore, to get the needed emergence, intra row spacing should be increased properly [30]. In other hand, it has been reported that spacing did not affect germination but improved vigor in radish because of adequate photosynthesis availability to be accumulated in seeds under wider spacing conditions.

Effect of intra row spacing on days to 50% flowering of carrot: To get this there must be the right intra row spacing. Unless it is not possible. When intra row spacing decreased days to fifty percent flowering takes loge time.

Effect of intra row spacing on days to 90% physiological maturity of carrot: When there are appropriate intra row spacing, days to ninth percent physiological maturity performed properly. However, when intra row spacing decreased, it also takes longer time to mature.

Effects of intra row spacing on yield and yield components of carrot

Wider spacing between plants provided lower root yields due to the lower number of plants per hectare. These results suggest that an ideal plant population is needed for proper distribution of photosynthetic radiation in the leaves, increasing the net photosynthetic rate, with consequent increase in root yield.

According to [31], commercial yield of carrot increases with an increase in population density. Carrot yield is also adversely affected by low planting density, in another words wider spacing reduce yield of carrot. In contrast, root yield per plot is higher for closely spaced plants because plants population is high that eventually enhanced yield production. Previously, increased yield of carrot due to closely spaced plants this is reported by some researchers. Higher yield in closely spaced plots than at wider spacing had also been reported in forage turnip. Similarly, yield of

fodder radish is enhanced with increase in plant population due to close plant spacing. Muck H who reported that carrot yield increased when plant density is increased with closer row-to-row spacing [23].

CONCLUSION

According to various scholars' reports the production of carrot is constrained by different factors, among these, spacing is one of the major. Spacing is significantly interacted in all growth parameters as expressed by plant length or height, leaf number per plant, leaf area per plant, leaf chlorophyll content, and plant fresh and dry weights. Additionally, intra row spacing was affects the phonological parameters such as days to flowering and days to maturity of carrots. Intra row spacing also influence the yield and yield components of carrot. Some scholar's reports indicated that spacing increases the total tuber number, marketable total number, total tuber yield, marketable tuber yield decreased. As spacing increase, the root length, weight of fresh leaves, and total weight of carrot increase; however, when spacing decrease these parameters also decrease. In contrast, some scholars reported that when spacing is decreases growth, phonological and yield and yield component parameters of carrot are increases. The study result of one scholar to other scholars is vas verse. Therefore, spacing has an effect on growth and yield of carrot.

Future prospects

According to different scholar research results plant spacing have significantly influence the growth, phonological, yield and yield component of carrot. So that it is recommended that important to do research in different soil type and location and know there optimum spacing to increase carrot productivity. When optimum spacing applies, increase production and quality of carrot.

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