Effect of Planting Spacing on the Growth and Estimated Root Yield of Carrot (*Daucus Carota* L.) Intercropped in A Young Oil Palm (*Elaeis Guineensis* Jacq.) Plantation in Ghana During the Rainy Season

Dickson Osei Darkwah, Kusan Jochebed, Bright Fiawona, Samuel Addo Banafo, Samuel Adu Osei, Enoch Sapey

Council For Scientific and Industrial Research-Oil Palm Research Institute. P.O. Box 74, Kusi-Kade, Ghana.

DOI: https://doi.org/10.51244/IJRSI.2026.1311000022

Received: 01 November 2026; Accepted: 06 November 2026; Published: 20 November 2026

ABSTRACT

Intercropping short-duration crops within the inter-row spaces of young oil palm plantations may provide an opportunity to utilise land before the palms develop a closed canopy. However, the productivity of an intercrop may depend on the planting arrangement adopted. This study evaluated the effects of four planting spacings on the growth and estimated root yield of carrot (*Daucus carota* L.) cultivated within a young oil palm plantation at the Oil Palm Research Institute, Kusi, in Ghana's Eastern Region. The experiment was conducted during the rainy season from May to September 2026. Four spacing treatments, comprising 15 × 15, 15 × 20, 15 × 25 and 15 × 30 cm, were arranged in a randomized complete block design with four replications, giving 16 experimental beds. The carrot cultivar Bahia was used, and the beds received decomposed poultry manure before planting. Data were collected on leaf number, leaf area, total leaf area, plant height, chlorophyll content, root length and fresh root weight. Estimated root yield was derived from mean root weight and plant population. Data were analysed using analysis of variance, and treatment means were separated using the least significant difference test at the 5% probability level. Plant spacing significantly affected leaf area, total leaf area, plant height and estimated root yield. The 15 × 30 cm spacing recorded the highest leaf area (1,118.00 cm²), total leaf area (10,712.00 cm²) and plant height (56.70 cm). In contrast, the 15 × 15 cm spacing produced the highest estimated root yield (23.85 t ha^{-1}), followed by 15 × 20 cm (18.02 t ha^{-1}), 15 × 25 cm (14.85 t ha^{-1}) and 15 × 30 cm (12.82 t ha^{-1}). Spacing did not significantly affect leaf number, chlorophyll content, root length or individual root weight. Within the conditions and treatments evaluated, 15 × 15 cm was the most productive spacing in terms of estimated root yield per unit area, whereas wider spacing favoured vegetative development. The findings provide preliminary agronomic information for carrot cultivation in the inter-row spaces of young oil palm plantations in the study environment.

Keywords: Carrot; intercropping; oil palm; planting spacing; plant population; root yield.

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is an important perennial oil crop cultivated throughout the humid tropics. Its high oil yield per unit area has made it a major source of vegetable oil for food, cosmetics, oleochemicals and other industrial applications. The crop also supports agricultural employment and processing activities in producing countries, including those in West Africa (Murphy et al., 2021).

In Ghana, oil palm production is undertaken by both smallholder and commercial producers. The crop contributes to the supply of raw materials for edible oil production and other processing activities. However, the establishment of a perennial plantation involves a period during which the young palms have not yet developed their full productive canopy. During this immature phase, portions of the inter-row spaces may remain available for the cultivation of compatible short-duration crops. The use of these spaces for intercrops is one possible approach to improving the utilisation of land during the early years of plantation establishment.

Oil palm intercropping has been investigated in different production environments, particularly as a means of making use of available space during the juvenile phase of plantation development. The suitability of an intercrop depends on factors such as the age and arrangement of the palms, the amount of available light, soil conditions, water availability and the management requirements of the component crops. Consequently, the performance of an intercrop under oil palm should be evaluated under the particular conditions in which it is intended to be cultivated (Nchanji et al., 2016; Murphy et al., 2021).

Carrot (*Daucus carota* L.) is an economically important root vegetable valued for its nutritional composition, particularly its provitamin A carotenoids, dietary fibre and other bioactive compounds (Arscott & Tanumihardjo, 2019). Its relatively short production cycle makes it a potential candidate for cultivation in available spaces within young perennial crop plantations. Nevertheless, successful carrot production requires appropriate management of plant population, soil fertility and growing conditions.

Plant spacing is an important agronomic factor in carrot production because it determines the number of plants established per unit area and influences the degree of competition among neighbouring plants. At relatively close spacing, a larger plant population may increase total root production per unit area, although competition may influence individual plant development and root characteristics. Wider spacing may provide individual plants with more growing space, potentially favouring canopy development and individual root growth. The relationship between plant population and crop yield therefore involves a balance between individual plant performance and the number of plants contributing to production (Donald, 1963; Willey & Heath, 1969).

Previous studies have examined the influence of spacing and plant population on carrot growth and yield under different production conditions. Dawuda et al. (2011), McCollum et al. (1986), and Muhie and Yimer (2023) reported that planting arrangement and population density are relevant considerations in carrot production. However, results from sole-crop production environments cannot automatically be assumed to apply to carrot cultivated within young oil palm plantations. The presence of the perennial crop may alter the growing environment and the resources available to the intercrop.

Although oil palm intercropping has received research attention, information on the response of carrot to different planting spacings within young oil palm plantations under Ghanaian rainy-season conditions remains limited in the material reviewed for this study. This represents a contextual research need rather than evidence that no previous work has been conducted. Evaluating different carrot spacings within a young oil palm plantation can provide initial information on the planting arrangement associated with improved carrot growth and estimated root yield under the conditions of the study.

The present study therefore evaluated the growth and estimated root yield of carrot under four planting spacings in a young oil palm plantation at the Oil Palm Research Institute, Kusi, Ghana, during the rainy season. Specifically, the study assessed the effects of spacing on vegetative growth, chlorophyll content, root characteristics and estimated root yield. The findings are intended to identify the most productive of the four spacings evaluated under the experimental conditions.

MATERIALS AND METHODS

2.1 Study location

The experiment was conducted at the Oil Palm Research Institute (OPRI) of the Council for Scientific and Industrial Research (CSIR), Kusi, in the Eastern Region of Ghana. The study area lies between latitudes 06°02′ and 06°05′ North and longitudes 00°52′ and 00°54′ West, at an elevation of approximately 164 m above sea level. The area falls within the humid semi-deciduous forest agroecological zone and experiences a bimodal rainfall pattern. The major rainy season generally occurs from March to July, while the minor rainy season occurs from September to November. The site is reported to receive an annual rainfall of approximately 1,400–1,600 mm, with average temperatures ranging from 24 to 30 °C. The predominant soil type is Ferric Acrisol (Danso et al., 2019).

2.2 Experimental site and design

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue X October 2026

The experiment was established within a 2 years young oil palm plantation planted in 2024 at a nominal spacing of 9 m × 9 m in a triangular arrangement. The available inter-row spaces were used for establishing the carrot beds. The beds were 2m from the established palms.

The experiment was arranged in a randomized complete block design (RCBD), comprising four planting-spacing treatments replicated four times. Each block contained all four treatments, which were randomly assigned to the experimental beds. The experiment therefore consisted of 16 experimental units.

2.3 Carrot cultivar and experimental materials

The Kuroda-type carrot cultivar Bahia (Technisem) was used. Sixteen experimental beds, each measuring 1.7 m × 1.0 m, were prepared. About 15 kg decomposed poultry manure was incorporated into each bed two weeks before planting.

2.4 Treatments and planting arrangement

Four planting-spacing treatments were evaluated. The inter-row spacing was maintained at 15 cm, while the intra-row spacing varied as follows:

- T_1: 15 × 15 cm
- T_2: 15 × 20 cm
- T_3: 15 × 25 cm
- T_4: 15 × 30 cm

The treatments represented progressively wider intra-row spacing and corresponding reductions in theoretical plant population density.

2.5 Land preparation and crop establishment

The inter-row spaces between the young oil palms were manually cleared of weeds before the establishment of the carrot beds. The beds were prepared to dimensions of 1.7 m × 1.0 m and planted directly with certified carrot seeds according to the assigned spacing treatments.

Two to three seeds were sown per planting hole at an approximate depth of 2 cm. Seedlings were subsequently thinned to one healthy plant per station after emergence to establish the required planting arrangement.

All experimental plots received the same general crop-management practices. Weeds were controlled manually when necessary, and supplementary irrigation was applied during periods of inadequate rainfall to maintain soil moisture. The experiment was conducted from May to July 2026, corresponding to the rainy-season production period.

2.6 Data collection

Data were collected from 10 randomly selected carrot plants within each experimental plot. Measurements were conducted on these same selected plants until the completion of the study. The growth and yield-related traits assessed included plant height, number of leaves, leaf area, total leaf area, chlorophyll content, root length and fresh root weight. Measurements were taken during crop development and at harvest, with the final reported treatment means corresponding to 12 weeks after planting.

2.6.1 Plant height

Plant height was measured in centimetres from the base of the plant to the tip of the longest leaf using a metre rule.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue X October 2026

2.6.2 Number of leaves

The number of fully emerged leaves on each sampled plant was counted and recorded.

2.6.3 Leaf area

Three leaves were selected from each sampled plant. Leaf length (L) was measured from the base to the tip, while maximum leaf width (W) was measured across the widest portion of each leaf. Leaf area was estimated using:

LA = 0.785 L*W

where LA is leaf area (cm²), L is leaf length (cm), W is maximum leaf width (cm), and and 0.785 is the correction factor for the elliptical leaf shape (Montgomery, 1911).

2.6.4 Total leaf area

The mean leaf area of the three sampled leaves was calculated for each plant. Total leaf area per plant was estimated by multiplying the mean leaf area by the total number of leaves on that plant.

2.6.5 Chlorophyll content

Chlorophyll content was measured using a SPAD-502 chlorophyll meter. Measurements were taken from the middle portion of fully expanded mature leaves, avoiding the midrib. Three leaves were measured per sampled plant, and the readings were used to obtain the plant-level value. The approach was consistent with the use of chlorophyll meters in field-grown carrot described by Westerveld et al. (2004).

2.6.6 Root length

Root length was measured in centimeters from the crown to the tip of the harvested root using a ruler.

2.6.7 Fresh root weight

Individual fresh root weight was determined in grams using an electronic balance after removal of the leaves.

2.6.8 Estimated root yield

Estimated root yield was derived from mean fresh root weight and plant population density. The general conversion used was:

$$\text{Carrot yield (t/ha)} = \frac{\text{Total root weight (kg)}}{\text{Net plot area (m}^2\text{)}} \times 10$$

2.7 Statistical analysis

Data were analysed using analysis of variance (ANOVA) appropriate for a randomized complete block design. Planting spacing was treated as the treatment factor, while blocks accounted for field variation among

replications. The statistical model was:

$Y_{ij} = \mu + T_i + B_j + \varepsilon_{ij}$

where (Y_{ij}) is the observed value for the (i)th treatment in the (j)th block, (μ) is the overall mean, (T_i) is the effect of the (i)th spacing treatment, (B_j) is the effect of the (j)th block, and {ij}) is the experimental error.

Where treatment effects were significant, means were separated using the least significant difference (LSD) test at the 5% probability level. The Shapiro–Wilk test and Levene's test were used to examine normality and

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue X October 2026

homogeneity of variance, respectively. Statistical analyses were performed using GenStat Release 12.1 (VSN International Ltd., Hemel Hempstead, UK).

RESULTS

3.1 Tests of homogeneity of variance and normality

Levene's test results indicated no strong evidence of unequal variances among the treatments for the measured traits. The reported probability values were greater than or equal to 0.05 (Table 1). For the traits assessed using the reported normality plots, the Shapiro–Wilk results were not statistically significant at the 5% level.

Table 1. Levene's test of homogeneity of variances for carrot growth and yield traits

Trait	Levene's statistic	P-value
Number of leaves	1.161	0.365
Leaf area (cm^2)	0.719	0.560
Total leaf area (cm^2)	0.244	0.864
Plant height (cm)	0.861	0.487
Chlorophyll content	0.719	0.560
Root length (cm)	3.574	0.050
Root weight (g)	0.536	0.666
Estimated root yield (t ha^{-1})	0.142	0.933

3.2 Normal distribution curves

Figures 1 to 4 show the histogram observations (four treatments × four replicates) with a fitted normal curve overlaid, for leaf area, total leaf area, plant height, and total yield, confirming that these data met the normality assumption before proceeding to the analysis of variance.

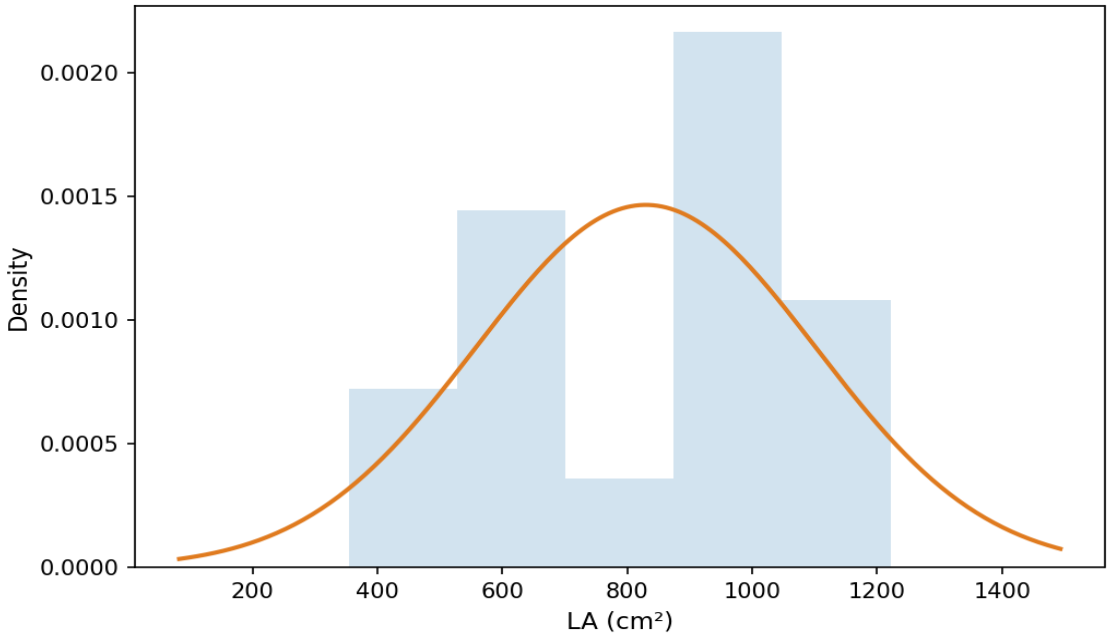

Figure 1. Distribution of leaf area (cm^2) observations with fitted normal curve. Shapiro-Wilk: W= 0.945, P = 0.411 normally distributed.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue X October 2026

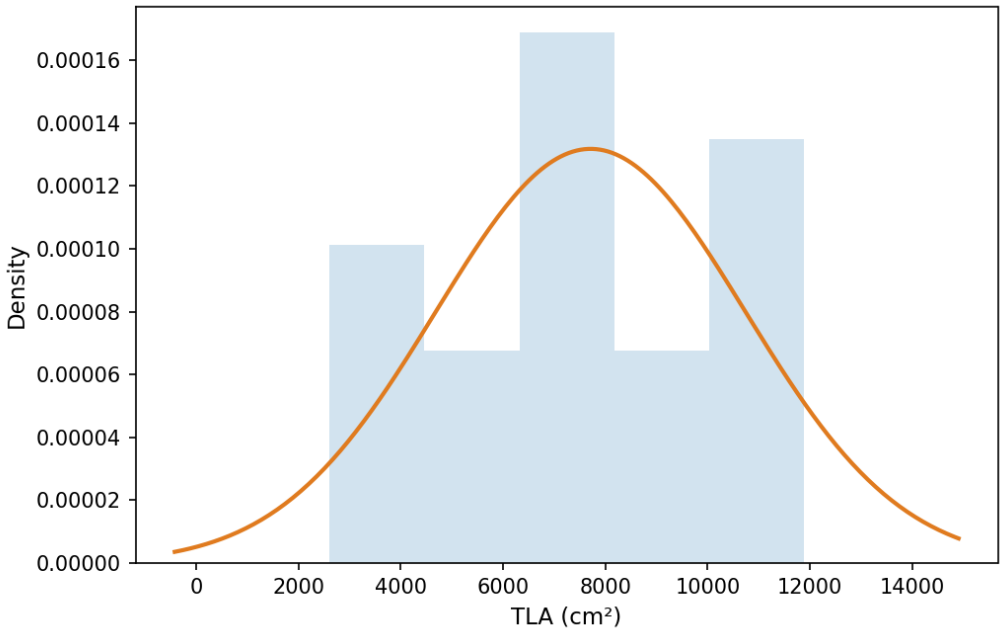

Figure 2. Distribution of total leaf area (cm²) observations at 12 WAP with fitted normal curve. Shapiro-Wilk: W = 0.947, P = 0.437 normally distributed.

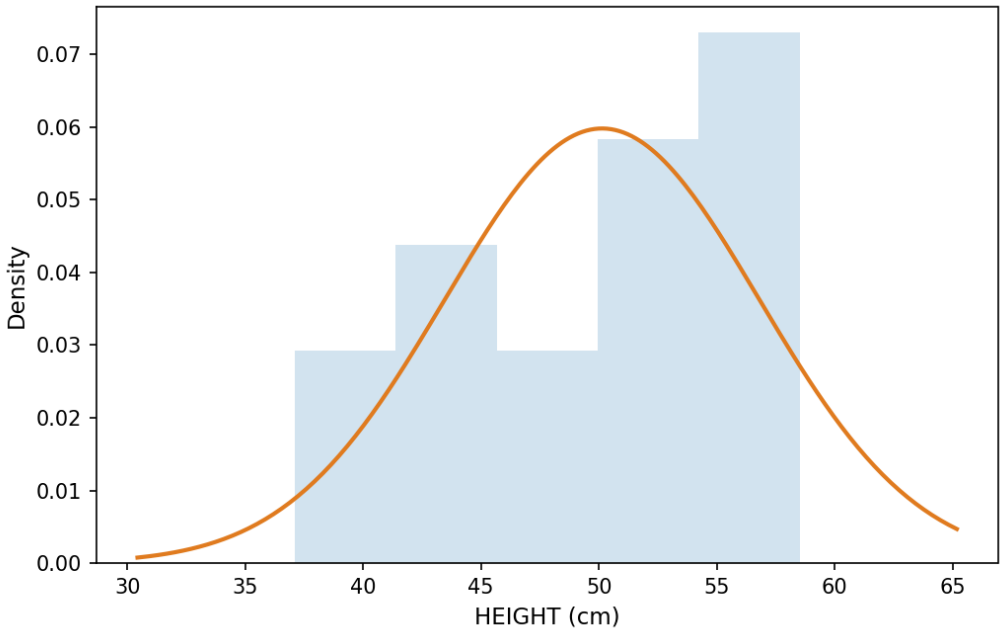

Figure 3. Distribution of raw plant height (cm) observations at 12 WAP with fitted normal curve. Shapiro-Wilk: W = 0.936, P = 0.305 normally distributed.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue X October 2026

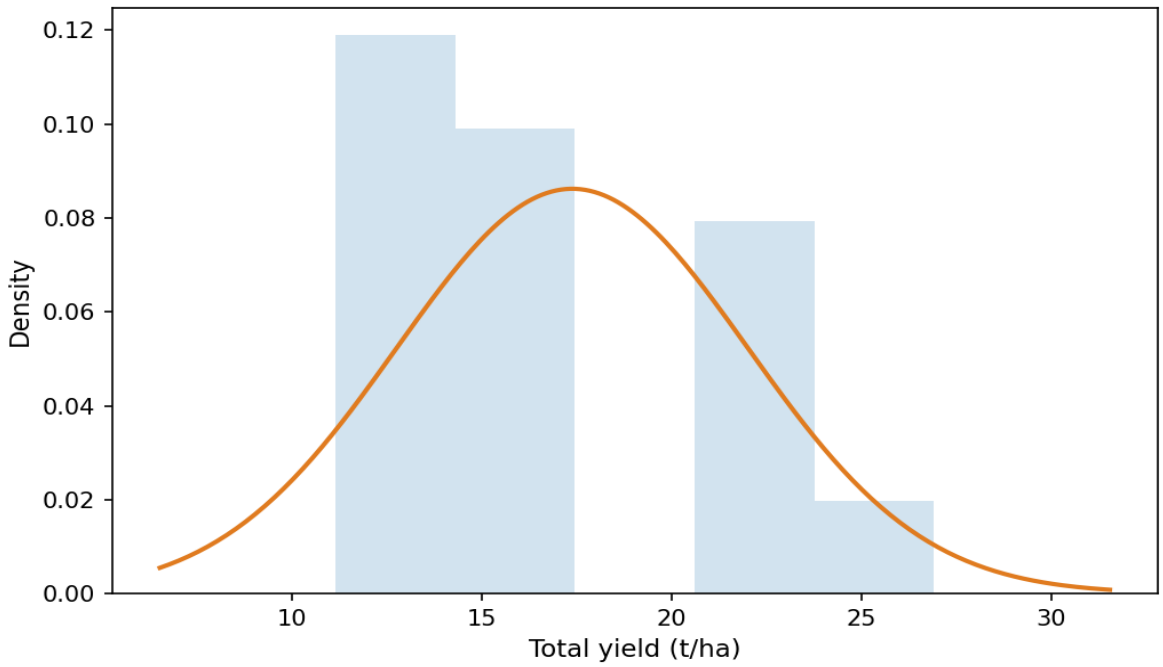

Figure 4. Distribution of raw total yield (t/ha) observations at 12 WAP with fitted normal curve. Shapiro-Wilk: W = 0.900, P = 0.080 normally distributed.

3.3 Analysis of variance for growth and yield traits

Plant spacing significantly affected leaf area, total leaf area, plant height and estimated root yield. In contrast, the treatment effects on number of leaves, chlorophyll content, root length and individual fresh root weight were not statistically significant at the 5% probability level (Table 2).

Estimated root yield showed a highly significant treatment effect ($P < 0.001$), indicating differences among the four spacing treatments.

Table 2. Mean squares from the analysis of variance for carrot growth and yield traits

Trait	Unit	Blocks mean square	MeanTreatment square	Residual square
Number of leaves	—	4.65	0.55 ns	0.17
Leaf area	cm^2	124,470.00	156,196.00 *	29,935.00
Total leaf area	cm^2	20,194,820.00	16,950,647.00 *	2,898,403.00
Plant height	cm	82.91	87.07 *	17.49
Chlorophyll content	SPAD units	6.53	6.53 ns	13.62
Root length	cm	0.30	3.49 ns	6.47
Root weight	g	27.00	13.73 ns	59.16
Estimated root yield	$t\ ha^{-1}$	0.24	92.63 **	4.75

Note: ns = not significant; * = $P < 0.05$; ** = $P < 0.001$.

3.4 Mean performance of carrot under the different spacing treatments

The widest spacing, 15 × 30 cm, recorded the highest leaf area (1,118.00 cm^2), total leaf area (10,712.00 cm^2) and plant height (56.70 cm). These values were significantly greater than those recorded under the other spacing treatments according to the reported LSD groupings.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue X October 2026

The 15 × 20 cm treatment recorded the lowest leaf area (674.00 cm²), total leaf area (6,037.00 cm²) and plant height (46.10 cm). The 15 × 15 cm and 15 × 25 cm treatments recorded intermediate values for these vegetative traits.

Number of leaves, chlorophyll content, root length and individual root weight did not differ significantly among treatments. Although the highest numerical values for number of leaves, chlorophyll content and root length occurred under 15 × 30 cm, these differences were not statistically significant. The highest numerical root weight was recorded under 15 × 15 cm.

Estimated root yield was highest under 15 × 15 cm (23.85 t ha^{-1}), followed by 15 × 20 cm (18.02 t ha^{-1}), 15 × 25 cm (14.85 t ha^{-1}) and 15 × 30 cm (12.82 t ha^{-1}).

Table 3. Growth and estimated root yield of carrot under different planting spacings at 12 weeks after planting

Trait	15 × 15 cm	15 × 20 cm	15 × 25 cm	15 × 30 cm	LSD (5%)
Number of leaves	8.87	8.67	8.77	9.50	—
Leaf area (cm²)	740.00 b	674.00 b	786.00 b	1,118.00 a	276.80
Total leaf area (cm²)	6,926.00 b	6,037.00 b	7,171.00 b	10,712.00 a	2,723.20
Plant height (cm)	47.70 b	46.10 b	50.00 b	56.70 a	6.69
Chlorophyll content (SPAD units)	26.73	25.95	25.52	28.42	—
Root length (cm)	16.88	17.01	18.24	18.79	—
Root weight (g)	58.00	54.10	55.70	57.70	—
Estimated root yield (t ha^{-1})	23.85 a	18.02 b	14.85 bc	12.82 c	3.50

Note: Means followed by different letters within a row differ significantly according to the reported LSD test at the 5% probability level. ns = not significant.

3.5 Correlation among carrot traits

Pearson correlation analysis indicated positive associations among several vegetative traits. Leaf number was positively correlated with leaf area ($r = 0.72$, $P = 0.002$), total leaf area ($r = 0.83$, $P < 0.001$) and plant height ($r = 0.71$, $P = 0.002$). Leaf area was strongly correlated with total leaf area ($r = 0.98$, $P < 0.001$) and plant height ($r = 0.98$, $P < 0.001$). Total leaf area was also strongly correlated with plant height ($r = 0.97$, $P < 0.001$).

Chlorophyll content was positively correlated with leaf area ($r = 0.61$, $P = 0.01$), plant height ($r = 0.60$, $P = 0.02$) and total leaf area ($r = 0.59$, $P = 0.02$). Root length was positively correlated with root weight ($r = 0.59$, $P = 0.02$).

The association between root weight and plant height was positive but did not reach statistical significance ($r = 0.49$, $P = 0.054$). Chlorophyll content was weakly correlated with root weight ($r = 0.43$, $P = 0.10$) and root length ($r = 0.24$, $P = 0.36$). Leaf number showed no significant association with root length ($r = 0.12$, $P = 0.65$) or root weight ($r = 0.02$, $P = 0.94$).

Estimated yield showed no significant correlation with the measured vegetative and root traits. Its correlation with root weight was positive but not significant ($r = 0.31$, $P = 0.24$). The reported correlation between estimated yield and chlorophyll content was close to zero ($r = 0.02$, $P = 0.94$).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue X October 2026

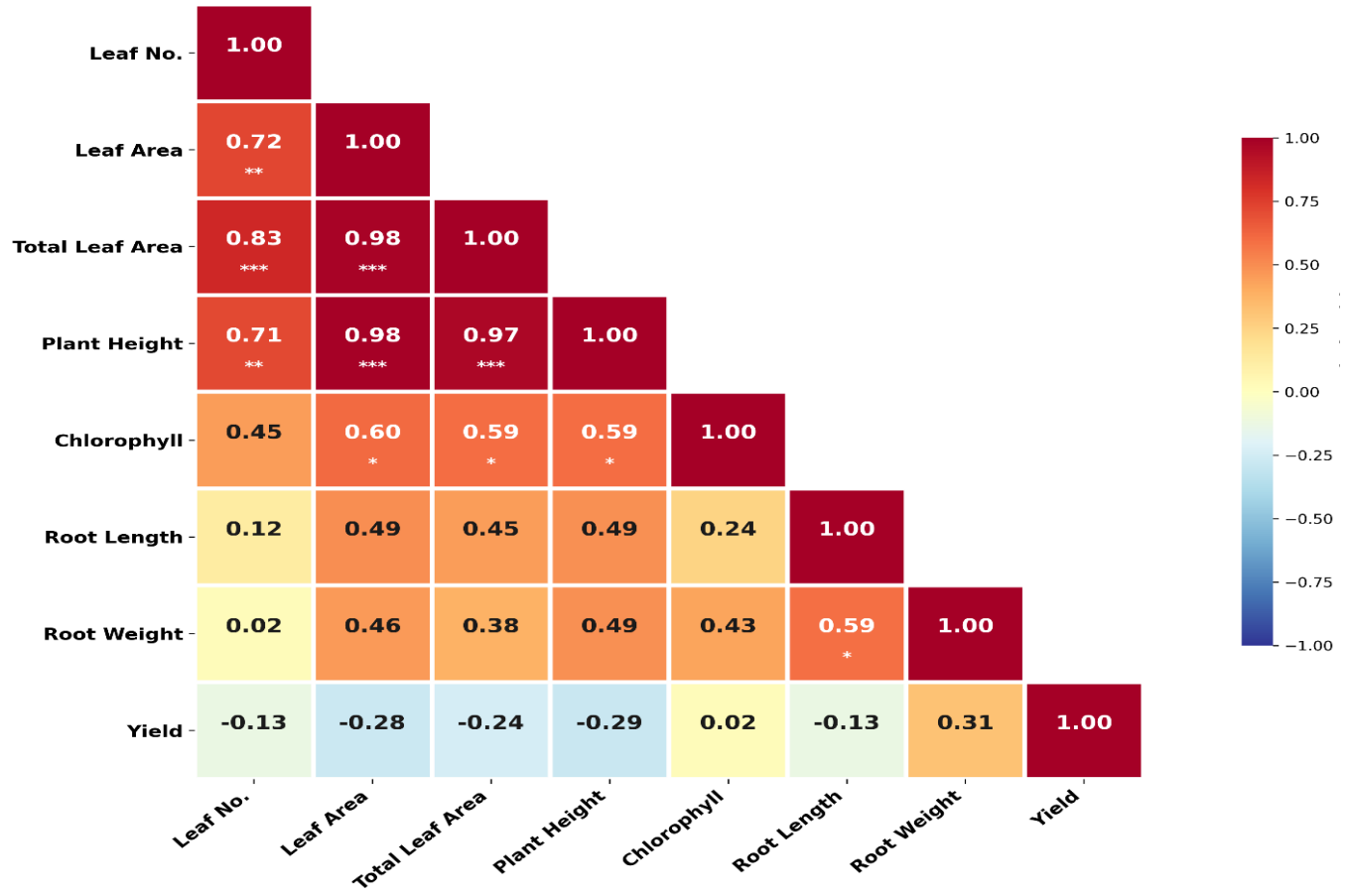

Figure 5. Heatmap Showing Pearson' correlation coefficient among eight traits

DISCUSSION

4.1 Effects of spacing on vegetative growth

Spacing significantly affected leaf area, total leaf area, plant height, and total yield, but had no significant effect on number of leaves, chlorophyll content, root length, or root weight at 12 weeks after planting. The responses indicate that spacing influenced vegetative development and yield differently. The 15 × 30 cm spacing promoted greater vegetative development, whereas 15 × 15 cm produced the highest yield per unit area. These responses may be attributed to differences in plant population and inter-plant competition. Wider spacing likely reduced competition for light, water, nutrients and growing space, thereby promoting individual plant growth, whereas closer spacing increased plant population and consequently yield per unit area. Similar contrasting responses have been reported in carrot, where wider spacing promotes vegetative growth and root development, while closer spacing increased yield per unit area (Dawuda et al., 2011; McCollum et al., 1986). The greater leaf area and plant height observed at 15 × 30 cm suggest that wider spacing provided greater opportunity for individual plants to expand their canopy. This response is consistent with the general effects of plant competition, whereby lower plant density can reduce competition for light, moisture, nutrients, and physical growing space and promote individual plant growth (Donald, 1963; Willey & Heath, 1969). However, the greater vegetative development at wider spacing did not result in greater yield per unit area. Dawuda et al. (2011) similarly reported greater vegetative growth under wider carrot spacing, whereas closer spacing produced higher total and marketable yields.

Number of leaves, chlorophyll content, root length, and root weight were not significantly affected by spacing. The absence of a significant response in these traits indicates that the effects of spacing were more pronounced for canopy expansion than for number of leaves, chlorophyll content, or the measured root traits. Although root length was numerically greater under 15 × 30 cm spacing, the variation among treatments was not statistically significant. Previous studies have demonstrated that carrot root characteristics depended on plant density, with lower densities generally favoring larger individual plant roots (McCollum et al., 1986; Muhie & Yimer, 2023).

The 15 × 15 cm spacing produced the highest estimated carrot root yield (23.85 t ha^{-1}), significantly exceeding all other treatments. Yield declined as spacing widened, reaching 12.82 t ha^{-1} at 15 × 30 cm. The difference of 11.03 t ha^{-1} represents an approximately 86% yield advantage for the closest spacing. Although the widest spacing produced greater leaf area and taller plants, mean root weight did not differ significantly among treatments. The yield advantage at 15 × 15 cm therefore primarily reflects the greater plant density used to extrapolate yield per hectare. This pattern is consistent with previous studies showing that higher plant populations can increase carrot yield per unit area, while wider spacing can favour individual plant growth (Alam et al., 2020; Tegen & Jembere, 2021; Muhie & Yimer, 2023).

At the same spacing, Alam et al. (2020) reported a marketable yield of 39.97 t ha^{-1} for carrots sown on 30 November in a dryland trial in Bangladesh, while Muhie and Yimer (2023) reported a total root yield of 12.27 t ha^{-1}, including 10.47 t ha^{-1} of marketable roots, under irrigation in Ethiopia. Differences in production systems, planting dates, and yield measurement limit direct comparison. Excessive rainfall may have contributed to the lower yield relative to the Bangladesh trial if it caused prolonged soil saturation, which can suppress root thickening and promote rot (Kusakawa & Inoue, 2010). Heavy rainfall late in the growing season can also increase cracking and rot without a detectable change in total harvested yield (Thomsen & Asalf, 2024). The contribution of rainfall could not be isolated from other differences among the trials. Under the conditions of the present study, 15 × 15 cm was the most productive spacing tested for carrots intercropped with young oil palms.

4.2 Relationships among growth and root traits

The correlation analysis showed strong positive relationships among the main vegetative traits. Leaf area, total leaf area, and plant height were closely associated, indicating that taller plants generally developed larger leaves and greater total canopy area. Similar relationships among carrot vegetative traits have been reported under different growing conditions (Turner et al., 2018; Ratul et al., 2025). Chlorophyll content was moderately and positively associated with leaf area, total leaf area, and plant height also indicating that greater canopy development tended to occur alongside higher chlorophyll content. However, these correlations indicate association and should not be interpreted as evidence of causation. Root length and root weight were positively correlated ($r = 0.59$), indicating that plants with longer roots tended to have greater root biomass. Similar relationships among carrot root traits have been reported under different growing conditions (Benjamin & Sutherland, 1989; Priya & Santhi, 2026). Yield showed weak and non-significant correlations with the measured vegetative and root traits. Thus, greater vegetative growth or root development at the individual plant level did not necessarily result in higher yield per unit area. This may reflect the influence of treatment on the number of plants contributing to total yield. Previous studies have similarly reported that wider spacing can promote individual-plant growth without necessarily producing the highest yield per hectare (Dawuda et al., 2011; Muhie & Yimer, 2023).

4.3 Implications for carrot cultivation within young oil palm plantations

The findings demonstrate the agronomic potential of carrot cultivation within the inter-row spaces of young oil palm plantations. Among the spacings evaluated, 15 × 15 cm produced the highest carrot yield per unit area, making it the most productive treatment under the conditions of the study. This spacing therefore offers a practical option for farmers seeking to utilize the available inter-row space during the juvenile phase of oil palm establishment. Intercropping during this period may improve land-use efficiency and provide an additional source of income before the developing oil palm canopy limits the space available for intercrops (Nchanji et al., 2015).

Therefore, 15 × 15 cm should be regarded as the most productive spacing for optimum carrot–oil palm intercropping since it produced 23.85t/ha significantly exceeding the yields of the other treatments.

CONCLUSION AND RECOMMENDATIONS

Planting spacing influenced the vegetative growth and estimated root yield of carrot cultivated within the inter-row spaces of a young oil palm plantation at Kusi, Ghana. The widest spacing, 15 × 30 cm, produced the highest leaf area, total leaf area and plant height. However, the closest spacing, 15 × 15 cm, produced the highest

estimated root yield at 23.85 t ha^{-1}. Spacing did not significantly affect leaf number, chlorophyll content, root length or individual fresh root weight.

Among the four spacing treatments evaluated, 15 × 15 cm was the most productive in terms of estimated root yield per unit area under the conditions of this rainy-season experiment. It may be considered a preliminary spacing recommendation for the Bahia carrot cultivar in comparable young oil palm environments.

REFERENCES

1. Alam, M. S., Islam, M. R., Kamruzzaman, M., Arefin, K. S., & Mehedi, M. N. H. (2020). Effects of planting time and spacing on the growth and yield of carrot under dry land condition at BINA, Mymensingh. Research in Agriculture, Livestock and Fisheries, 7(3), 373–382. https://doi.org/10.3329/ralf.v7i3.51356
2. Arscott, S. A., & Tanumihardjo, S. A. (2019). Carrots of many colors provide basic nutrition and bioavailable phytochemicals acting as a functional food. Comprehensive Reviews in Food Science and Food Safety, 18(4), 1020–1035. https://doi.org/10.1111/1541-4337.12455
3. Benjamin, L. R., & Sutherland, R. A. (1989). Storage-root weight, diameter and length relationships in carrot (Daucus carota) and red beet (Beta vulgaris). The Journal of Agricultural Science, 113(1), 73–80. https://doi.org/10.1017/S002185960008463X
4. Bonneau, X., & Impens, R. (2022). Experimental determination of the optimum oil palm planting density in Western Africa. OCL, 29, Article 30. https://doi.org/10.1051/ocl/2022019
5. Coulibaly, L. F., Touré, A., Siéné, L. A. C., Coulibaly, N. A., & Soro, Y. R. (2018). Physicochemical and nutritional properties of varieties of carrot (Daucus carota) grown in region of Korhogo, north of Côte d'Ivoire. International Journal of Environment, Agriculture and Biotechnology, 3(3), 792–798. https://doi.org/10.22161/ijeab/3.3.11
6. Danso, I., Okyere, S. A., Larbi, E., Danso, F., & Nuertey, B. N. (2019). Assessment of nutrients status of areas supporting optimum oil palm (Elaeis guineensis Jacq.) cultivation in Ghana. Ghana Journal of Agricultural Science, 54(2), 1–14.
7. Dawuda, M. M., Boateng, P. Y., Hemeng, O. B., & Nyarko, G. (2011). Growth and yield response of carrot (Daucus carota L.) to different rates of soil amendments and spacing. Journal of Science and Technology (Ghana), 31(2), 11–20. https://doi.org/10.4314/just.v31i2.462
8. Donald, C. M. (1963). Competition among crop and pasture plants. Advances in Agronomy, 15, 1–118. https://doi.org/10.1016/S0065-2113(08)60397-1
9. Kusakawa, T., & Inoue, M. (2010). Damage to pot-cultured carrot growth due to a temporarily raised groundwater level and flooding period. Horticultural Research (Japan), 9(4), 495–500. https://doi.org/10.2503/hrj.9.495
10. McCollum, T. G., Locascio, S. J., & White, J. M. (1986). Plant density and row arrangement effects on carrot yields. Journal of the American Society for Horticultural Science, 111(5), 648–651.
11. Muhie, S. H., & Yimer, H. S. (2023). Growth and yield performance of carrot (Daucus carota L.) as influenced by plant population density under irrigation condition. Advances in Horticultural Science, 37(3), 307–315.
12. Murphy, D. J., Goggin, K., & Paterson, R. R. M. (2021). Oil palm in the 2020s and beyond: Challenges and solutions. CABI Agriculture and Bioscience, 2, Article 39. https://doi.org/10.1186/s43170-021-00058-3
13. Nchanji, Y. K., Nkongho, R. N., Mala, W. A., & Levang, P. (2016). Efficacy of oil palm intercropping by smallholders: Case study in South-West Cameroon. Agroforestry Systems, 90(3), 509–519. https://doi.org/10.1007/s10457-015-9873-z
14. Tegen, H., & Jembere, M. (2021). Influences of spacing on yield and root size of carrot (Daucus carota L.) under ridge-furrow production. Open Agriculture, 6(1), 826–835.
15. Thomsen, M. G., & Asalf, B. (2024). Precipitation, drought, and soil factors affecting carrot quality. Acta Horticulturae, 1393, 1–6. https://doi.org/10.17660/ActaHortic.2024.1393.1
16. Westerveld, S. M., McKeown, A. W., Scott-Dupree, C. D., & McDonald, M. R. (2004). Assessment of chlorophyll and nitrate meters as field tissue nitrogen tests for cabbage, onions, and carrots. HortTechnology, 14(2), 179–188. https://doi.org/10.21273/HORTTECH.14.2.0179

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue X October 2026

17. Willey, R. W., & Heath, S. B. (1969). The quantitative relationships between plant population and crop yield. Advances in Agronomy, 21, 281–321.
18. Woittiez, L. S., van Wijk, M. T., Slingerland, M., van Noordwijk, M., & Giller, K. E. (2017). Yield gaps in oil palm: A quantitative review of contributing factors. European Journal of Agronomy, 83, 57–77.