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Impact of Tillage Depth and Planting Spacing on Growth and Root Yield of Carrot (*Daucus carota* L.)

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Abstract

This study aimed to explore the impact of tillage depth and plant spacing on carrot growth and yield. The experiment followed a two-factor design using a randomized complete block approach, with three replications. Factor A comprised of three tillage depths: 10 cm (D1), 15 cm (D2), and 20 cm (D3), while Factor B included three planting spacings: 25 cm x 5 cm (S1), 25 cm x 10 cm (S2), and 25 cm x 20 cm (S3). Plant height, leaf fresh weight, root length, fresh weight, diameter, and dry weight exhibited significant variations across different tillage depths and plant spacings. The most noteworthy results, including a maximum root length (17.97 cm), diameter (4.07 cm), fresh weight (99.33 g per plant), and dry weight (3.87 g.50 g^{-1}), were observed in the D3S3 combination. Conversely the D1S1 combination yielded the least favorable outcomes in terms of these parameters. The incidence of root cracking, rot, and branching in carrots was lowest in the D3S3 combination, followed by other combinations. These issues became progressively more prominent with lower plant spacing and shallower tillage depth. In terms of yields, the highest gross yield (35.67 $t.ha^{-1}$) was achieved in the D3S1 combination, while the lowest (20.17 $t.ha^{-1}$) was recorded in D1S3. Similarly, the D3S1 combination demonstrated the highest marketable yield (32.67 $t.ha^{-1}$), whereas the lowest (17.00 $t.ha^{-1}$) was observed in D1S3. The most favourable benefit-cost ratio was associated with D3S1, while the least favourable ratio was linked to D1S3. Notably, yield and yield components saw improvement with narrower spacing, while growth parameters exhibited enhancement with wider spacing. The findings of this study suggested that the highest tillage depth combined with reduced spacing led to increased gross and marketable yields, whereas lower tillage depth combined with greater spacing resulted in decreased yields. Among the various treatment combinations, the D3S1 combination consistently yielded the highest overall results in terms of yield and marketability.

Keywords: branched root, cracking root, gross yield, marketable yield, rotten root.

Introduction

The Apiaceae family includes the cool-season crop carrot (*Daucus carota* L.), previously classified as Umbelliferae family. Carrots are one of the most important vegetable crops grown worldwide for its tasty roots. In terms of production areas and market value, it is one of the top ten most economically significant vegetable crops in the world for a short-duration crop (Adon et al., 2010). In Bangladesh, carrots are effectively produced during the Rabi season, or during October to March. For its satisfactory yield, mid-November to early December is the best time to sowing. Carotene (10 mg.100 g^{-1}), thiamin (0.04 mg.100 g^{-1}), and riboflavin are present in high concentrations (0.05 mg.100 g^{-1}) in carrots. As a source of calories, carbohydrate, protein, fat, minerals, vitamin C, and other nutrients as well (Simon et al., 2008), carrots can help avoid night blindness in children, a problem of public health in developing nations caused by severe vitamin A deficiency.

The consumption of carrots has expanded throughout time due to these several uses (Chandy, 2010; FAO, 2016). It is used to make pickles, preserves, and desserts and is consumed fresh (as a salad), shredded, boiled, or cooked as stews, soups, curries, etc. Due to a variety of reported pharmacological effects, carrots can be utilized for a variety of medical purposes in addition to their nutritional value (Pant and Manandhar, 2007; Rossi et al., 2007; Tavares et al., 2008). The mature roots and leaves are used to

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make animal feed (Kahangi, 2004). In the world's top carrot-growing nations, yields of carrots can range from 30 to 100 t .ha^{-1} (Muendo et al., 2004). Carrot yields per unit area in the majority of developing nations continue to be below average globally. Carrot gardening is becoming more and more popular as a result of the tasty nature and vitamin content. Tillage is essential for making the fine seedbed required for excellent stand establishment for small seeded crops like carrots (Brainard and Noyes, 2012). Expanding root growth and development is mostly dependent on the depth of the tillage. Tillage affects the soil environment and the pace of organic matter decomposition, changing the soil's moisture content, density, and aeration as well as the nutrients that are available to plants (Blazewicz-Wozniak and Wach, 2012).

Farmers are cultivating carrots on a large scale to meet the demand, but they lack sufficient knowledge on planting depth or tillage depth. Since carrots are a root crop that prefers the lowest part of the soil, tillage depth is crucial to their growth. It is presumable that if tillage depth is increased, carrot plants will be able to develop its economic section or roots freely, leading to increases in length and diameter. The overall yield per area will eventually rise. On the other hand, plant spacing is a crucial element in the growth of carrots. A high plant density may improve carrot quality and productivity. The most significant aspect influencing plant development and carrot root yield is maintaining an adequate plant population per unit area. Finding the ideal spacing is therefore crucial if you want to increase crop output while maintaining quality (Kumar et al., 2017).

Optimal tillage and appropriate plant spacing are essential factors that can contribute to maximizing carrot yields. The strategy of densely planting carrots doesn't necessarily lead to higher yields due to the inherent competition among plants for essential resources such as nutrients, water, and sunlight. In contrast, when plants are spaced optimally, there is minimal competition for these vital resources. The ideal plant spacing plays an important role in determining carrot production. This study aimed to explore the effects of tillage depth and plant spacing on carrot growth and yield. The results of this study would be useful for carrot producers to enhance their production outcomes.

Materials and methods

Experimental Site

The study was carried out from November 2017 to January 2018 at the Horticulture Farm, Department of Horticulture, Bangladesh Agricultural University, Mymensingh and the analytical works were done at the postgraduate laboratory of the same university. The experimental site's soil type was sandy loam, which is a part of the Old Brahmaputra Flood Plain Alluvial Tract (FAO, 1988). The experimental area is situated in the sub-tropical zone, characterized by heavy rainfall during the month of April to October and scanty rainfall during the rest period of the year.

Experimental Treatments and Design

The experiment consisted of 9 treatment combinations and was laid out in randomized complete block design with 3 replications. Factor A consisted of three tillage depths viz., D1: 10 cm, D2: 15 cm, D3: 20 cm and Factor B having three plant spacing viz., S1: 25 cm × 5 cm, S2: 25 cm × 10 cm, S3: 25 cm ×15 cm. The total area of the experimental plot was divided into three equal blocks and each block was divided into 9-unit plots. The size of each plot was 1.0 m x 1.0 m. Thus, there were 27 (9 x 3) unit plots in the experiment. The distance between blocks were 0.5 m and 0.5 m wide drain was made between the plot.

Land Preparation, Manures and Fertilizers Application

The experimental field's ground was tilled multiple times to achieve good tilth. The recommended doses of manures and fertilizers were used, i.e., 10 t.ha^{-1} of cow dung, 165 kg.ha^{-1} urea, 105 kg.ha^{-1} TSP (Triple Super Phosphate), 175 kg.ha^{-1} MoP (Muriate of Potash) Rashid (1999). Cow dung was applied during land preparation. Half of the recommended dose of urea, total amount of TSP and half of MoP were applied as top dressing after 30 days and the remaining of urea and MoP were applied after 45 days of seed sowing. Beds were ploughed and then spading was done for getting good tilth. The size of the bed was 1 m × 1 m. The height of beds was 10 cm, 15 cm and 20 cm.

Seed Sowing and Crop Culture

The seeds were soaked in water for 24 hours and spread over polythene sheet for 2 hours to dry surface water. Then seeds were sown uniformly in the finally prepared land in rows and covered with loose soil to help the quick germination of seed. Sevin 85 WP @2 kg.ha^{-1} was applied around each plots as precautionary measures against ants and

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worm infestation, followed by banana leaf covering. Seedlings were thinned out twice, the first was at 15 days of sowing to have three seedlings in each site at requisite distance as per treatment. The second thinning was done after 30 days of sowing keeping only one seedling in each hole. Irrigation, weeding, fertilizer top dressing, etc. were done as and when required.

Data Collection

Ten plants per plot were selected randomly for data collection and the mean value for growth parameters including plant height, root length and diameter; root fresh and dry weight, number of branched, cracked and rotten roots and yield parameters like gross and marketable yield were considered for analysis. The carrot was harvested at 30, 45 and 60 days after seedling stage and measured the root diameter and length, and leaf weight. Sample for determination of moisture content was prepared from 50 g of fresh root then chopped and oven dried at 70 ˚C for 72 hours. Dry root weight was measured for calculated moisture content by the following formula.

$$Moisture\ content\ (\%) = \frac{Fresh\ weight\ of\ root - Dry\ weight\ of\ root}{Fresh\ weight\ of\ root} \times 100$$

$$Dry\ matter\ content\ (\%) = \frac{Dry\ weight\ of\ root}{Fresh\ weight\ of\ root} \times 100$$

Percent branched roots was calculated by the following formula.
% Branched roots= $\frac{No.\ of\ branched\ roots}{Total\ no.\ of\ roots} \times 100$

Percent cracked roots was calculated by the following formula.
% Cracked roots= $\frac{No.\ of\ cracked\ roots}{Total\ no.\ of\ roots} \times 100$

Percent rotten roots was calculated by the following formula:
% Rotten roots= $\frac{No.\ of\ rotten\ roots}{Total\ no.\ of\ roots} \times 100$

Carrot roots were detached from the foliage by a sharp knife and the gross yield calculated from conversion of total fresh plant weight per plot (total fresh plant weight are sum of fresh leaves weight) to per hectare. The marketable yield was calculated from the subtract of total fresh root weight per plot and rotten and cracked roots.

Statistical Analysis

The data were statistically analyzed using MSTAT computer program. The analysis of variances at α = 5% and 1% levels of significance. The mean difference between treatments was further tested by the Least Significant Difference (LSD) test.

Results and Discussion

Growth Parameters

Different tillage depths and plant spacing significantly influenced the plant height of carrot. It was observed that the treatment with a planting hole depth of 20 cm produced the tallest carrot compared to other treatments at 30, 45 and 60 days after planting (Figure 1). The loosening of subsurface soil, which promoted soil aeration and encouraged the nitrification process, activities of beneficial bacteria, and chemical processes of soil, may have contributed to the increase in plant height with increasing tillage depth. Additionally, loose soil reduces evaporative loss. The plants grew taller as a result of all these favorable conditions, which made it easier for them to absorb more nutrients and use enough moisture for growth and development. The tallest (55.73 cm) plant was observed from the spacing of S1 (25 cm x 5 cm) at 60 days after showing (DAS) while the shortest (30.64 cm) from the spacing of S3 (25 cm x 15 cm) at 30 DAS (Figure 1). As the spacing was increased, the plant height proportionately decreased. The treatment with a spacing of 25 cm x 5 cm from the start had the best effect on plant height until the end of the observation. Due to higher competition for air and light at tighter spacing, plants grew taller. This is consistent with the findings of Amjad and Anjum (2001), who noticed that plant spacing had significant effects on 1000-seed weight, root length and fresh weight of seedlings. Wider spacing (45 cm) proved better compared with close spacing, they obtained taller plants from closer spacing. But this is contradictory with the findings of Kharsan et al. (2019). He observed that plants grow taller at wider spacing and revealed that closer spacing or higher plant densities per unit area enhance competition for vital growth elements among individual plants that do not reach their normal size. The interaction of tillage depth and plant spacing, the tallest (37.00 cm) plant was observed from treatment combination of D3S1 (tillage depth 20 cm and spacing 25 cm x 5 cm) while the shortest plant (29.73 cm) from treatment combination of D1S3 (tillage depth 10 cm and spacing 25 cm x 20 cm) at 30 DAS (Table 1 and Figure 1).

The maximum root length (17.68 cm) was obtained from 20 cm tillage depth treatment followed by 15 cm depth (16.67 cm) treatment. The minimum root length (15.19 cm) from the 10 cm spading depth treatment (Figure 2). It might be because the plough pan broke, which encouraged roots to encroach. The largest root (16.97 cm) was recorded from the plants grown at the spacing of 30 cm × 15 cm (S3). The smallest root was 16.27 cm from the plants grown at the spacing of 20 cm × 5 cm (S1), which was statistically significant

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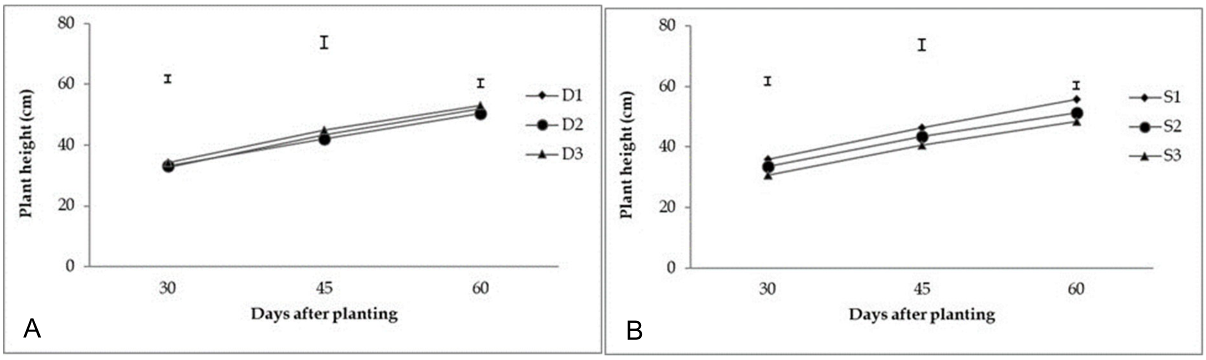

Figure 1. Effect of tillage depth (A) and plant density (B) on carrot plant height (cm) at different days after planting. Vertical bars represent LSD at 1% level of probability.

Table 1. Effects of tillage depth and plant spacing on carrot plant height at different days after planting.

Treatment combinations	Plant height (cm) at different days after planting (DAP)		
	30	45	60
D1S1	37.00	46.80	57.40
D1S2	31.53	43.07	51.93
D1S3	29.73	40.53	46.93
D2S1	33.93	43.27	52.87
D2S2	33.47	41.80	49.27
D2S3	32.00	41.47	48.87
D3S1	36.60	49.00	56.93
D3S2	35.73	45.87	52.73
D3S3	30.20	40.00	49.80
$LSD_{0.05}$	1.22	1.79	1.14
$LSD_{0.01}$	1.68	2.47	1.57
Level of signi	**	**	**

** = Significant at 1% level of probability; D1= 10 cm, D2= 15 cm, D3= 20 cm and S1=25 cm × 5 cm, S2= 25 cm × 10 cm, S3= 25 cm ×15 cm

compared to others (Figure 2). The interaction of tillage depth and plant spacing, the longest root (17.97 cm) was recorded from the treatment D3S3, whereas the shortest root (13.84 cm) was from the treatment D1S1 (Table 2).

The maximum diameter of root (3.97 cm) was found in the plant raised at that availed 20 cm tillage depth and the minimum (3.68 cm) in this regard from the plant raised at 10 cm tillage depth (Figure 3). The existence of ideal soil aeration and nitrification, which aid in the expansion of root diameter, may have contributed to the higher tillage depth that resulted in larger root diameter. According to Wozniak et al. (2015), deep soil can support the growth of well-developed roots. The maximum root diameter (3.93 cm) was found from the plants sown at the spacing of 25 cm × 15 cm (S3). While the minimum root diameter (3.62 cm) at the spacing of 25 cm ×5 cm (S1) (Figure 3). The plants under the treatment S3 (25 cm × 15 cm) had to have sufficient space to develop their root in soil so that the root diameter was increased enough than others. The findings agreed with Muhammad and Muhammad (2002). This may be due to competition for space, nutrients, light and air between the plants. The treatment interaction, the highest root diameter (4.07) was observed from the treatment combination of D3S3 where plants were grown at the tillage depth 20 cm (D3) and plant spacing of 25 cm × 15 cm (S3) (Table 2).

Tillage depth and plant spacing interacted in affecting root fresh weight (Table 2). The maximum fresh weight (116.60 g) was recorded from the plants grown at the spacing of 25 cm × 15 cm and tillage depth 20 cm while the minimum (67.07 g) at the tillage depth 10 cm and plant spacing of 25 cm × 5 cm (Table 2). The plants, which were grown under the spacing 25

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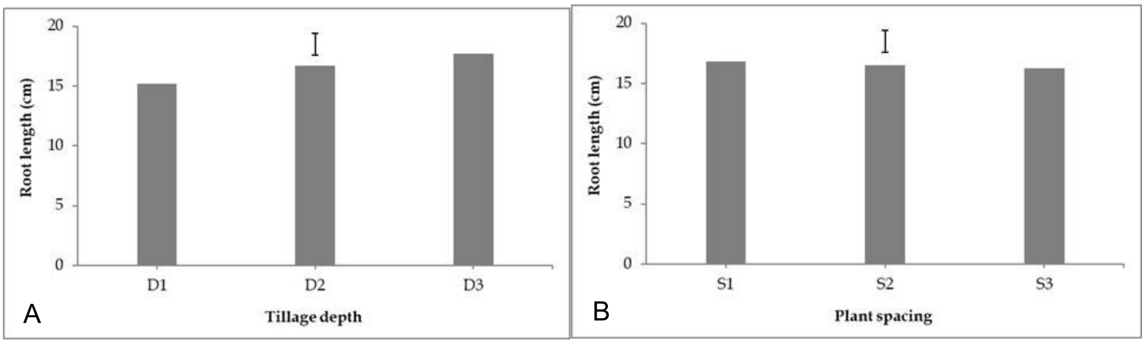

Figure 2. Effect of tillage depth (A) and plant density (B) on carrot root length (cm) at different days after planting. Vertical bar represents LSD at 1% level of probability.

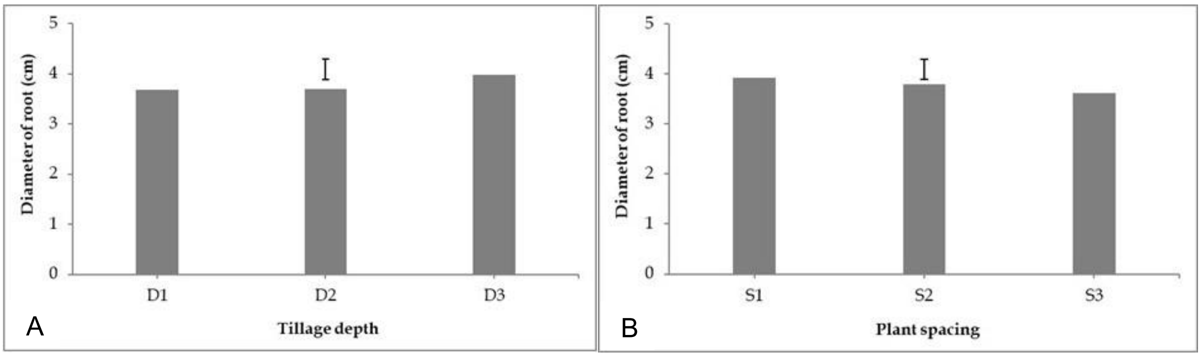

Figure 3. Effect of tillage depth (A) and plant spacing (B) on carrot root diameter (cm) at different days after planting. Vertical bar represents LSD at 1% level of probability.

cm × 15 cm (S3), had more space to develop their roots and had lesser nutrient competition. The result was agreed with the work of Ashraful et al. (2013). The maximum fresh weight (99.33 g) of leaves was recorded from the plants grown at the spacing of 25 cm × 15 cm and tillage depth 20 cm while the minimum (67.07 g) at the tillage depth 10 cm and plant spacing of 25 cm × 5 cm (Table 2).

For moisture content of root, plants grown at 10 cm (D_1) tillage depth produced the highest (3.48%) root dry weight. Plants of 15 cm (D2) depth produced the lowest (3.21%) dry weight of roots (Figure 4). In case of plant spacing, the maximum root dry weight 3.54% was found at the spacing of 25 cm x 10 cm (S2) and the minimum 3.14% was found at the spacing of 25 cm x 15 cm (S3) (Figure 4). This results indicated that the wider spacing (S3) gave more consumption of moisture content of root than densely grown of carrot. The result was agreed by Amjad and Anjum (2001). During combination treatment, the maximum weight of dry matter of root from 3.87% was recorded from the plants grown at the spacing of 25 cm × 10 cm and tillage depth 15 cm while the minimum (2.77%) at the tillage depth 20 cm and plant spacing of 25 cm × 10 cm i.e. combined treatment D2S3 (Table 3). The plants grown at the tillage depth 20 cm and plant spacing of 25 cm ×15 cm (S3) uptake more nutrients, sunlight, nitrogenous fertilizers and rate of photosynthesis was higher than other plants, resulting in increased vegetative development and roots that were rich in carbohydrates. They got more space to develop than other plants.

The percent cracked root was ranged from 1.67% to 2.33%. The maximum percent cracked root (2.33%) was recorded from the plants grown at the spacing of 25 cm × 5 cm and tillage depth 10 cm i.e. combined treatment D1S1 while the minimum (1.67%) at the tillage depth 20 cm and plant spacing of 25 cm × 15 cm i.e. combined treatment D3S3 (Table 3). The maximum percent rotten root (1.33%) was recorded from the plants grown at the spacing of 25 cm × 5 cm and tillage depth 10 cm i.e. combined treatment D1S1 while the minimum (0.23%) at the tillage depth 20 cm and plant spacing of 25 cm × 15 cm i.e. combined treatment D3S3 (Table 3). The maximum percent branched root (1.67%) was recorded from the plants grown at the spacing of 25 cm × 5 cm and tillage depth 10 cm while the minimum (0.67%) at the tillage depth 20 cm and plant spacing of 25 cm × 15 cm i.e. combined treatment D3S3 (Table 3). Plants with greater tillage depth and broader spacing absorbed more of the essential plant nutrients. Thus, the plant was healthy and had fewer cracked roots in this condition.

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Table 2. Effects of tillage depth and plant spacing on carrot root length, root diameter, fresh weight of roots and leaves.

Treatment combinations	Root length (cm)	Diameter of root (cm)	Fresh wt. of root (g. per plant)	Fresh wt. of leaves (g. per plant)
D1S1	13.84	3.33	67.07	75.27
D1S2	15.33	3.68	88.87	80.93
D1S3	16.40	4.03	94.40	91.27
D2S1	16.13	3.57	93.00	78.20
D2S2	16.77	3.68	95.20	81.47
D2S3	17.10	3.86	99.47	88.33
D3S1	17.20	3.86	99.33	87.60
D3S2	17.87	3.97	116.13	98.93
D3S3	17.97	4.07	116.60	99.33
$LSD_{0.05}$	0.64	0.15	3.37	2.10
$LSD_{0.01}$	0.88	0.21	4.64	2.89
Level of sign.	**	**	**	**

** = Significant at 1% level of probability; D1= 10 cm, D2= 15 cm, D3= 20 cm and S1=25 cm × 5 cm, S2= 25 cm × 10 cm, S3=25 cm ×15 cm

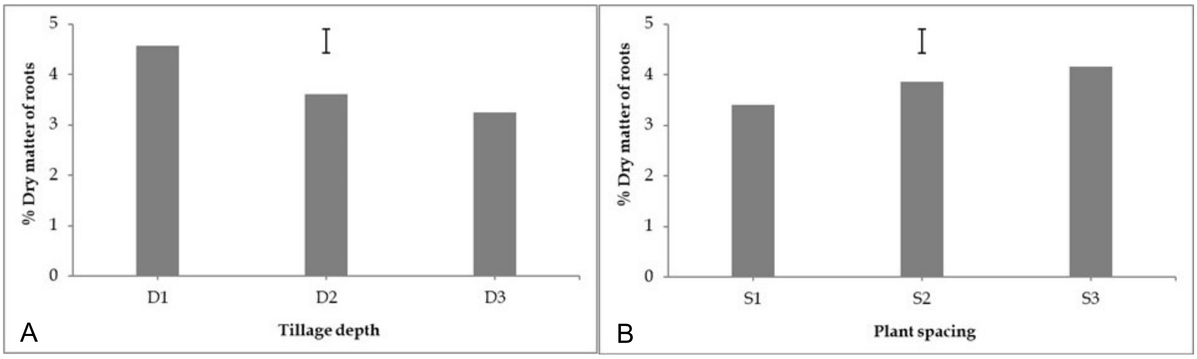

Figure 4. Effect of tillage depth (A) and plant spacing (B) on carrot root moisture content (%) at different days after planting. Vertical bar represents LSD at 1% level of probability.

Yield Parameters

Photographs showing the effect of tillage depth and planting spacing on plant growth and root yield of carrot are in Figure 7. The highest gross yield of carrot (32.76 $t.ha^{-1}$ and 3.28 kg per plot) was recorded from the treatment of 20 cm depth and the lowest (27.78 $t.ha^{-1}$ and 2.78 kg.plot-1) from the treatment of 10 cm tillage depth (Figure 5). The maximum yield (38.01 $t.ha^{-1}$ and 3.80 kg. per plot) was found from the treatment of S1 (25 cm x 5 cm) while the minimum gross yield (19.11 $t.ha^{-1}$ and 1.91 kg per plot) from the treatment of S3 (25 cm x 15 cm) (Figure 5). The highest yield was found as a result of having more plants spaced apart than in the other two plot sizes of the same size. Anjum and Amjad (2002) results agreed with the outcomes of this research in that the highest yield was with the tightest spacing. The maximum yield (42.83 $t.ha^{-1}$ or 4.28 kg per plot) and the minimum yield (19.76 $t.ha^{-1}$ or 1.97 kg per plot) were obtained from the treatment combination of D3S1 and D1S3, respectively (Table 4).

The highest marketable yield (29.89 $t.ha^{-1}$ and 3.0 kg per plot) was obtained from 20 cm depth of tillage and the lowest (25.11 $t.ha^{-1}$ and 2.51 kg per plot) was from 10 cm depth treatment (Figure 6). Higher gross yields are the result of deeper tillage because longer roots and heavier individual roots are produced. Poorer spading depth led to lower yield, which can be explained by the prevention of root penetration that occurred as a result of the presence of hard plough pans. As a result, root length, fresh weight of roots, and yield all decreased.

The maximum marketable yield (3.49 kg per plot and 34.89 $t.ha^{-1}$) was obtained from the treatment of S1 (25 cm x 5 cm) while the minimum (16.11 $t.ha^{-1}$ or

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Table 3. Effect of tillage depth and plant spacing on root branches, cracked roots, rotten roots and root dry matter

Treatment combinations	Root branching (%)	Root cracking (%)	Root rotting (%)	% Dry matter of roots (from 50 g fresh weight)
D1S1	1.67	2.33	1.33	3.63
D1S2	1.33	2.33	1.00	3.65
D1S3	1.00	2.33	0.33	3.17
D2S1	1.33	2.33	1.33	2.98
D2S2	1.00	2.33	0.67	3.87
D2S3	1.00	2.00	0.33	2.77
D3S1	1.00	2.33	1.00	3.13
D3S2	1.00	2.00	0.33	3.11
D3S3	0.67	1.67	0.23	3.46
$LSD_{0.05}$	0.16	0.22	0.16	0.15
$LSD_{0.01}$	0.23	0.30	0.23	0.21
Level of significance	**	**	**	**

** = Significant at 1% level of probability; D1= 10 cm, D2= 15 cm, D3= 20 cm and S1=25 cm × 5 cm, S2=25 cm × 10 cm, S3=25 cm ×15 cm.

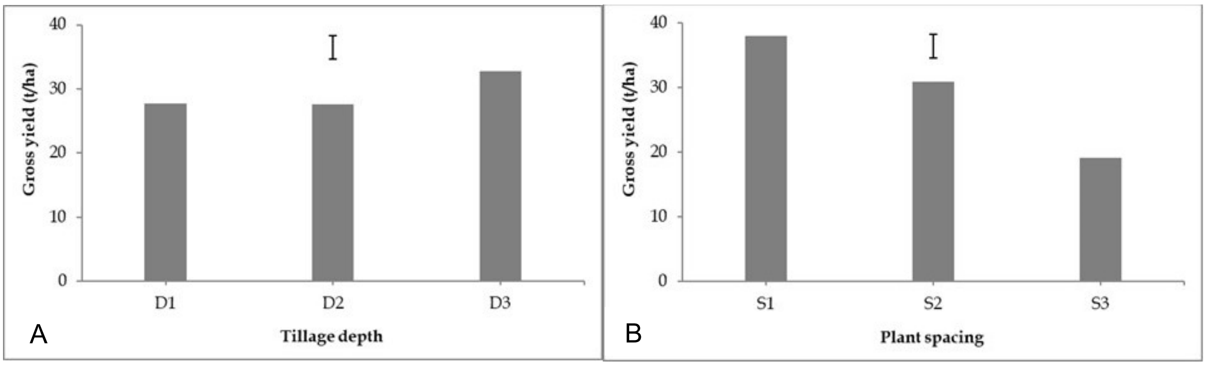

Figure 5. Effect of tillage depth (A) and plant spacing (B) on carrot gross yield ($t.ha^{-1}$) at different days after planting. Vertical bar represents LSD at 1% level of probability.

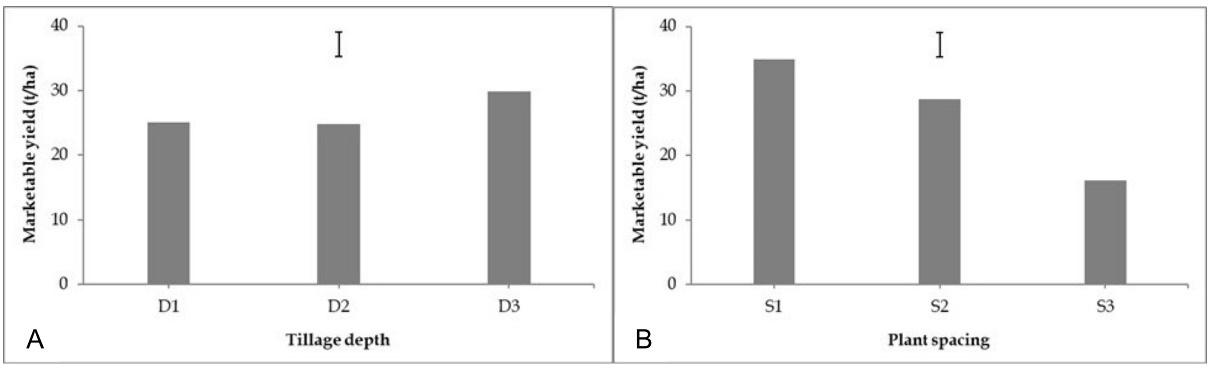

Figure 6. Effect of tillage depth (A) and plant spacing (B) on carrot marketable yields ($t.ha^{-1}$) at different days after planting. Vertical bar represents LSD at 1% level of probability.

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Table 4. Effect of tillage depth and plant spacing on yield contributing characters of carrot.

Treatment combinations	Gross yield (kg.plot^{-1})	Gross yield (t.ha^{-1})	Marketable yield (kg.plot^{-1})	Marketable yield (t.ha^{-1})
D1S1	3.57	35.67	3.27	32.67
D1S2	2.80	28.00	2.60	26.00
D1S3	1.97	19.67	1.67	16.67
D2S1	3.55	35.53	3.23	32.33
D2S2	2.97	29.67	2.73	27.33
D2S3	1.75	17.50	1.47	14.67
D3S1	4.28	42.83	3.97	39.67
D3S2	3.53	35.27	3.30	33.00
D3S3	2.02	20.17	1.70	17.00
$LSD_{0.05}$	0.27	2.68	0.27	2.73
$LSD_{0.01}$	0.37	3.70	0.38	3.76
Level of sign.	**	**	**	**

** = Significant at 1% level of probability; D1= 10cm, D2= 15cm, D3= 20cm and S1=25cm × 5 cm, S2=25cm × 10 cm, S3=25cm ×15 cm

Figure 7. Photographs showing the effect of tillage depth and planting spacing on plant growth and root yield of carrot (D1= 10 cm, D2= 15 cm, D3= 20 cm tillage depth and S1= 25 cm × 5 cm, S2= 25 cm × 10 cm, S3= 25 cm ×15 cm plant spacing).

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1.61 kg per plot) in S3 (25 cm x 15 cm) (Figure 6). The highest marketable yield was observed under the treatment S1 due to the highest amount of seedlings to be set up than other two treatments. This result was agreed with Barbedo et al. (2004) in carrot, Warade et al. (2004) in radish, Bilekudari et al. (2005) in radish, Kumar et al. (2007) in radish, etc. They reported that increasing plant density enhanced the marketable yield. The maximum (39.67 $t.ha^{-1}$ or 3.97 kg per plot) and the minimum yield (16.67 $t.ha^{-1}$ or 1.67 kg per plot) were obtained from the treatment combination of D3S1 and D1S3 respectively (Table 4). The highest yield was found under the spacing of S1 (25 cm x 5 cm) tillage depth 20 due to be set up more number of plants than other two spacing and more space under soil surface to enlarge in the same size of plot which is similar to Kharsan et al. (2019).

The wider spacing promoted vegetative growth and increased root length of carrot but planting at closer spacing of 20 cm x 5 cm resulted in higher total and marketable yields and also increased income and profit.

Conclusions

Maintaining a sufficient tillage depth and plant spacing is necessary for the efficient production of carrot roots. All the characteristics (plant height, length of root, diameter of root, fresh weight of root, fresh weight leaves, moisture content of root, percent cracked root, percent rotten root and percent branched root) under the study were strongly impacted by different tillage depths and plant spacing. The ideal tillage depth and plant spacing depend on the type of land usage, as well as the ecological, social, and economic circumstances. The findings of the research indicated that the performance of carrot in terms of highest gross and marketable yield of carrot (35.67 $t.ha^{-1}$ and 32.67 $t.ha^{-1}$) was better at plant spacing 25 cm x 5 cm and 20 cm tillage depth. On the other hand, the lowest marketable yield (17.00 $t.ha^{-1}$) was found from plant spacing 25 cm × 15 cm and tillage depth 10 cm.

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