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HORTICULTURE | ORIGINAL ARTICLE

Effects of Plastic Mulches on Growth, Yield and Quality of Baby Carrot Germplasm

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ABSTRACT

Carrot (*Daucus carota* L.) is an important biennial root vegetable crop in Bangladesh. But baby carrot having the higher nutritional status is a new crop of Bangladesh. Different germplasm of baby carrot have strong interaction with plastic mulches for growth, yield and quality. The experiment was conducted at the Horticulture Farm of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh from the period of October 2023 to February 2024 to study the effects of plastic mulches on growth, yield and quality of baby carrot germplasm. The experiment consisted of five-baby carrot germplasm namely G1 (PI L1408), G2 (Nantes 5), G3 (261650), G4 (PI 1408) and G5 (Upper cut) and five plastic mulches viz., T0 (control), T1 (black), T2 (silver), T3 (blue) and T4 (red). The two-factor experiment was laid out in Randomized Complete Block Design with three replications. Significant variations were observed due to interaction between germplasm and plastic mulches on all the growth, yield and quality parameters studied. At harvest, maximum root length (29.07 cm) was obtained from PI L1408 with black plastic mulch, maximum root diameter (4.19 cm), root weight (174.45 g), yield (27.06 t/ha) and marketable yield (26.81 t/ha) were obtained from Nantes 5 with black plastic mulch, maximum branched root (11.60%) was recorded from PI 262650 with control and maximum leaf weight (65.63 g) was found from Nantes 5 with blue plastic mulch. On the contrary, minimum root length (15.74 cm) was recorded from Upper cut with red plastic mulch, minimum root diameter (2.06 cm), root weight (40.43 g), yield (12.36 t/ha) and marketable yield (12.25 t/ha) were obtained from PI 1408 with control and maximum leaf weight (24.07 g) from PI 1408 with blue plastic mulch treatment. Therefore, interaction between Nantes 5 with black plastic mulch was found to be better in respect of growth, yield and quality of baby carrot.

1. Introduction

Carrots (*Daucus carota* L.) belong to the family Apiaceae, are one of the most widely grown and enjoyed root vegetables in the world (Ellison et al., 2017; Peirce, 1987). It is thought to be a native of the Mediterranean area (Shinohara, 1984) and grown during winter season in tropical and subtropical countries of the world (Bose and Som, 1990). More than 24 million tons carrots are produced worldwide and they can be consumed as raw or processed into baby food, instant soups, grated carrots, and little carrots (Pongener et al., 2018).

Baby carrots are a popular addition to lunch boxes and are regular addition to vegetable trays or incorporated into smoothies. A California carrot farmer, Mike Yurosek in the early 1980s, invented baby carrots. While the name may lead to believe that this vegetable is a less mature version of regular carrots, they are not (Dole, 2009). Baby carrots are grown to be slightly smaller and sweeter than a large whole carrot as they picked up early. A baby carrot's core is much smaller than a standard carrot and customers found it more straightforward to chew and more convenient than peeled and chopped carrots. Like regular carrots, baby carrots are highly nutritious and are an excellent source of thiamin, riboflavin (Sharfuddin and Siddique, 1985), vitamin A, B, C, K, minerals (Yawalkar, 1985) and carotenoids (beta-carotene, a precursor to vitamin A) an antioxidant that can help immune system work well and reduce risk of cancer (Simon et al., 2020). The potassium and dietary fiber in baby carrots can help to lower blood pressure and cholesterol levels, reducing risk for heart disease. Vitamin C in carrots helps in absorption and utilization of iron to fight against infections. Yellow carrots are rich in lutein, which is beneficial to our eyes.

Carrot is an important winter vegetable of Bangladesh with increasing popularity for consumers and high market value for farmers. Moreover, vitamin A deficiency is a public health concern for young children and pregnant women in Bangladesh, which is the main cause of

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preventable night blindness, childhood stunting and mortality. In Bangladesh about 1 million children under 6 years of age, which constitute 2% of that population and more than 2.7% pregnant and 2.4% lactating women, are becoming victims of night blindness (Shahidullah, 2015). Baby carrots could be a popular second alternative to conventional carrots to ensure nutritional food security in the country.

Production of carrot in Bangladesh is very poor compared to global production. In the year 2022-2023, while 42 million tons of carrots are produced globally, only 35270.61 tons were recorded from 2626.95 hectares of land in Bangladesh (BBS, 2023). This may be due to lack of rainfall during winter season, improper irrigation practices, poor soil status, infestation of weeds, insects and other pests etc (Akand et al., 2023). Baby carrots production can be enriched through various mulching by conserving soil moisture from 2.1-2.8% more than non-mulched one (Mahajan et al., 2007).

Plastic mulches modify microclimates and improve crop quality by aiding crop growth by reflecting, absorbing, or transmitting the sunshine (Spengler, 2021). Plastic mulch warms the soil (Lamont, 2005), minimizes evaporation thus reduces irrigation requirements (Bandyopadhyay et al., 2009), increasing root development, promoting faster crop growth, reducing weed attack (Rathinasabapathi et al., 2005), reduce the infestation of insects and diseases (Ngouajio et al., 2008), limits leaching of nutrients from soil (Gordon et al., 2010), and ready to harvest earlier. Plastic mulch is now available in an array of colours, which determine its impact on a crop. Black is perhaps the most prevalent and the least expensive and suppresses weeds better than any other plastic mulches and also keeps soil warm during the growing season, raising the soil temperature by up to five degrees at a 2-inch (5 cm.) depth which earlier and a quicker carrot harvest. Silver mulch is good for initial seed germination and great at keeping aphids and whiteflies away from crops and also reduces the population of cucumber beetles. Moreover, silver plastic mulches are efficient in reflecting PAR than black and thus reduces root zone temperature and loss of water (Rylander et al., 2020). Blue plastic mulches are better than black for big harvests and improving quality. On the other hand, red plastic mulch is better for absorbing global radiation than black, silver and blue plastic mulch (Al-Karaghouli et al., 1990). Various impacts of plastic mulches on plant growth, development, yield and quality differs for variations in soil type, climatic condition and nature of the crop (Amare and Desta, 2021).

Given the high nutritional value of baby carrots in providing vitamin A to consumers, and reduced carrot availability in Bangladesh markets and above factors keep in mind, the present study will be undertaken to study the effects of various plastic mulches on growth, yield and quality of baby carrot germplasm.

2. Materials and Methods

2.1. Experimental site, soil and climate

The field experiment was conducted at the Horticulture Farm of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from October 2023 to February 2024 in order to study the interaction between germplasm and plastic mulches for growth, yield and quality of baby carrot. The experimental area is situated in the sub-tropical climate zone and characterized by three different seasons, the monsoon or rainy seasons (May to October), the winter or dry season (November to February) and pre-monsoon or hot season (March to April). The experimental site was medium high land belonging to the Old Brahmaputra Floodplain under the Agro-Ecological Zone 9 having non-calcareous dark gray floodplain soil (UNDP, 1988). The soil of the experimental plot was silty loam in texture and about neutral (pH 6.5-7.0) in reaction, which is suitable for baby carrot production.

2.2. Design and treatments of the experiment

The experiment consisted of two factors viz. Factor 1: five baby carrot germplasm namely G1 (PI L1408), G2 (Nantes 5), G3 (PI 261650), G4 (PI 1408) and G5 (Upper cut) and Factor 2: five plastic mulches viz., control (without mulch), black, silver, blue and red. The experiment was laid out in Randomized Complete Block Design with 3 replications. Thus, there were 75 units plot (5 x 5 x 3) in total. The seeds of various baby carrot germplasm were sown in line and the size of each unit plot was 1 m x 1 m = 1 m^2, where spacing was 25 cm x 10 cm. A distance of 0.5 m between blocks and between unit plots were kept to facilitate different intercultural operations.

2.3. Land preparation

The land of the experimental field was prepared well for planting carrot seeds during the month of 25th October 2023. The experimental plot was thoroughly prepared by ploughing for several times with a power tiller. The clods were broken into friable soil and the surface was levelled until the desired tilth was obtained. Then it was exposed to the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Finally, the experimental plot was partitioned into unit plots in accordance with the experimental design. Irrigation and drainage channels were prepared around the plots.

2.4. Application of manures and fertilizers

The experimental plots were treated with recommended doses of NPKS fertilizers i.e. urea @250 kg/ha, TSP @200 kg/ha, MoP @200 kg/ha, gypsum @100 kg/ha (Ahmmed et al., 2018). Whole dose of P and S fertilizers and half dose of K fertilizer were applied during final land preparation whereas N fertilizer was applied in three instalments at 30, 45 and 60 days after sowing of baby carrot seeds. The remaining dose of K fertilizer was applied at 45 days of seed sowing.

2.5. Seed sowing

The seeds of baby carrot germplasm were soaked in water for overnight and then sown in the line under field conditions at a depth of 1.5 cm by maintaining a distance of 25 cm between the lines and plant to plant distance 10 cm. Seeds were sown on 1 November, 2023 and just after

sowing seeds were covered with loose soil immediately. After completion of sowing, the experimental plots were subjected to light irrigation and covered by banana leaves for seven days to provide optimum moisture and dark condition to facilitate seed germination.

2.6. Application of plastic mulches

At 40 days after sowing, the mulches were applied according to treatment on standing carrot plant keeping the root collar zone open.

2.7. Intercultural operations

All the required intercultural operations for plant growth and development including thinning, manuring and fertilizer application, weeding, irrigation, pesticide application were done as and when necessary. Thinning was done at 20 days after sowing of seeds to maintain a distance of 10 cm between the plants. Weeding was done when necessary to keep the soil loose and well aerated and to avoid the crop-weed competition. Irrigation was applied at 15, 30, 45, 60 and 75 days after sowing. To protect the seedlings at early growing stage from cutworm and mole cricket Pyriphos @ 0.1 ppm was applied at 14, 21 and 28 DAS.

2.8. Parameters measured

Data on various parameters were recorded at 10 days intervals starting from 40 days of seed sowing up to harvesting from five random plants under each treatment and replications on growth and yield contributing characters like plant height (cm), number of leaves per plant, root length (cm), root diameter (cm), root weight (g), leaf weight (g), branched root (%). crack root (%), yield (ton/ha), marketable yield (ha), dry matter of root (%).

Vegetative growth of plants was recorded at 40, 50, 60, 70 and 80 DAS (days after sowing). Plant height of each five-sample plant was measured in cm by using meter scale and mean was calculated. Number of leaves was recorded by counting all leaves and mean was calculated.

At harvest, root length and diameter were measured using meter scale (cm) and slide callipers (cm) respectively and mean was calculated for each treatment. For individual root weight five uniform roots were taken and measured by a Table Top Electric Balance and expressed in gram (g) and then mean was calculated. For leaf weight, a sharp knife detached leaves after harvest from the selected plants and its fresh weight was taken by a Table Top Electric Balance (g) and then its average value was recorded.

For percentage of branched and crack roots, number of branched and crack roots were counted at the time of harvest and branching and cracking percentage of roots per plot was calculated by the following formula:

Branched roots (%) = (Number of branched roots)/ (Number of total roots) ×100

Crack roots (%) = (Number of crack roots)/ (Number of total roots) ×100

For yield (ton/ha), yield of individual plot (kg/plot) were measured by Table Top Electric Balance and then it was converted into tons per hectare. For marketable yield of root (ha), weight of carrot roots after discarding the roots damaged by cracking, rotting and branching taken from the total yield of roots in kilograms (kg), then it was converted into tons per hectare.

For determining the dry matter percentage of root, roots under each treatment and replication were cut into small pieces and 20 g of them were taken for oven dry at 78^0 C for 72 hours. Then weight of oven dried roots was taken by a precision electric balance and calculated as following formula:

% dry matter of root= (Constant dry weight of roots (g))/ (Fresh weight of roots (g)) ×100

2.9. Statistical analysis

The data obtained from experiment on various parameters were statistically analysed using MSTAT computer program. The mean values for all the parameters were calculated and the analysis of variance for the characters was accomplished by F variance test. The significance of difference between pair of means was tested by the Least Significant Difference (LSD) test at 5 and 1 % levels of probability (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Plant height

The plant height was recorded at different stages of growth i.e. at 40, 50, 60, 70 and 80 DAS (days after sowing). Different germplasm significantly influenced the plant height of baby carrot. It was evaluated from Figure 1 that the plant height of the baby carrot increased with the advancement of time and the highest plant height attained from Nantes 5 were 18.60 cm, 28.50 cm, 38.45 cm, 49.29 cm and 57.16 cm at 40, 50, 60, 70 and 80 DAS (days after sowing), respectively whereas the lowest plant height 18.35 cm, 27.11 cm, 33.68 cm, 45.20 cm and 52.21 cm for 40, 50, 60, 70 and 80 DAS (days after sowing) respectively was recorded from the PI L1408. The application of different plastic mulches significantly influenced the plant height of baby carrot. The highest plant height 19.50 cm, 28.96 cm, 36.99 cm, 47.30 cm and 55.28 cm were found at 40, 50, 60, 70 and 80 DAS (days after sowing) respectively from silver plastic mulch and the lowest plant height 18.43 cm, 27.31 cm, 34.53 cm and 45.87 cm and 53.93 cm were found at 40, 50, 60, 70 and 80 DAS (days after sowing), respectively from control (no mulch) treatment (Figure 2). The result obtained is in similarity with the findings of Torres-Olivar et al. (2016). This might be due to the silver plastic mulch suppresses weed growth, reduces soil erosion and increases uptake of nutrients compared to the others.

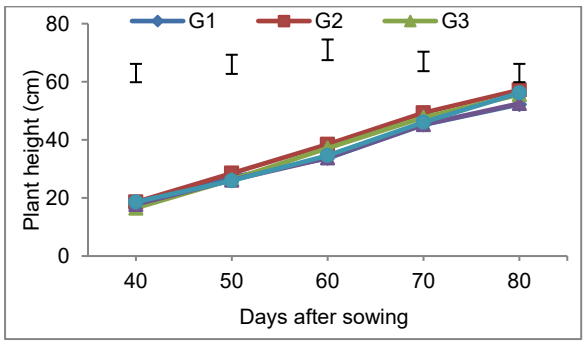

Figure 1. Effect of germplasm on plant height of baby carrots at different days after sowing. Vertical bars indicate LSD at 1% level of probability. G1= PI L1408, G2= Nantes 5, G3= PI 261650, G4= PI 1408, G5= Upper cut

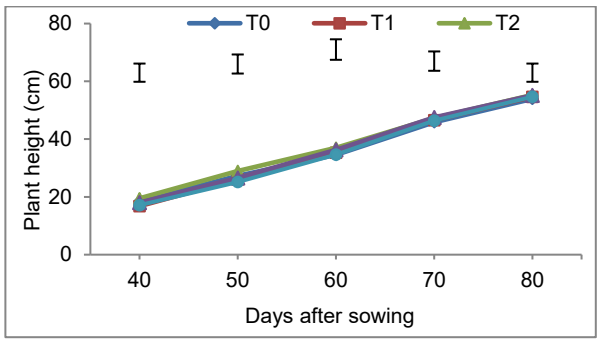

Figure 2. Effect of plastic mulches on plant height of baby carrot germplasm at different days after sowing. Vertical bars indicate LSD at 1% level of probability. T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

Table 1. Interaction between germplasm and plastic mulches on plant height at different days after sowing (DAS) of baby carrots

Treatment combination	Plant height (cm) at different days after sowing (DAS)				
	40	50	60	70	80
T_0G_1	19.20	27.15	32.43	44.47	53.58
T_0G_2	18.51	29.95	37.47	49.49	56.75
T_0G_3	15.85	24.89	35.89	48.55	56.00
T_0G_4	16.52	25.54	32.94	42.98	50.69
T_0G_5	22.06	29.02	33.92	43.88	52.64
T_1G_1	18.01	27.77	32.47	42.74	50.70
T_1G_2	19.34	26.75	37.14	49.35	56.82
T_1G_3	14.09	23.86	35.03	46.84	54.96
T_1G_4	15.52	24.79	32.04	43.44	52.00
T_1G_5	17.06	27.13	39.73	50.33	58.67
T_2G_1	18.37	27.48	32.73	43.85	50.73
T_2G_2	20.73	31.38	43.22	49.63	58.00
T_2G_3	17.68	28.80	36.52	45.69	56.63
T_2G_4	20.05	28.47	36.80	48.41	54.40
T_2G_5	20.67	28.67	35.70	48.93	56.64
T_3G_1	17.89	26.60	34.60	47.00	52.03
T_3G_2	18.31	30.01	39.52	52.02	58.42
T_3G_3	19.06	29.04	39.85	49.03	55.81
T_3G_4	18.76	26.27	33.25	44.78	51.88
T_3G_5	16.07	20.79	34.16	44.56	57.56
T_4G_1	18.30	26.53	36.18	47.94	54.00
T_4G_2	16.09	24.39	34.91	45.98	55.83
T_4G_3	16.01	24.90	38.57	48.50	54.61
T_4G_4	18.03	25.77	33.92	46.76	53.65
T_4G_5	17.16	24.08	29.66	42.76	55.30
$LSD_{0.05}$	1.05	1.11	1.18	1.11	1.06
$LSD_{0.01}$	1.40	1.48	1.58	1.49	1.41
Level of significance	**	**	**	**	**

** = Significant at 1% level of probability; G1= PI L1408, G2= Nantes 5, G3= PI 261650, G4= PI 1408, G5= Upper cut; T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

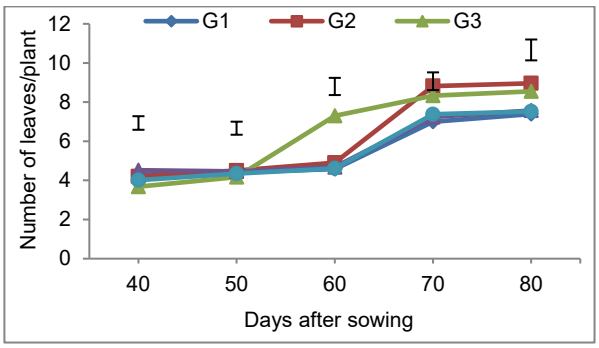

Figure 3. Effect of germplasm on number of leaves per plant of baby carrot at different days after sowing. Vertical bars indicate LSD at 1% level of probability. G1= PI L1408, G2= Nantes 5, G3= PI 261650, G4= PI 1408, G5= PI Upper cut

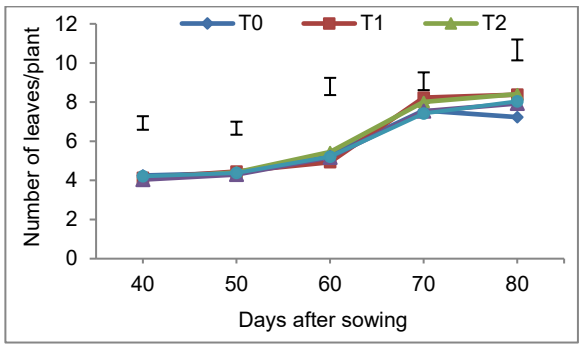

Figure 4. Effect of plastic mulches on number of leaves of baby carrot at different days after sowing. Vertical bars indicate LSD at 1% level of probability. T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

Table 2. Interaction between germplasm and plastic mulches on number of leaves per plant at different days after sowing (DAS) of baby carrots

Treatment combination	Number of leaves per plant at different days after sowing (DAS)				
	40	50	60	70	80
T_0G_1	19.20	27.15	32.43	44.47	53.58
T_0G_2	18.51	29.95	37.47	49.49	56.75
T_0G_3	15.85	24.89	35.89	48.55	56.00
T_0G_4	16.52	25.54	32.94	42.98	50.69
T_0G_5	22.06	29.02	33.92	43.88	52.64
T_1G_1	18.01	27.77	32.47	42.74	50.70
T_1G_2	19.34	26.75	37.14	49.35	56.82
T_1G_3	14.09	23.86	35.03	46.84	54.96
T_1G_4	15.52	24.79	32.04	43.44	52.00
T_1G_5	17.06	27.13	39.73	50.33	58.67
T_2G_1	18.37	27.48	32.73	43.85	50.73
T_2G_2	20.73	31.38	43.22	49.63	58.00
T_2G_3	17.68	28.80	36.52	45.69	56.63
T_2G_4	20.05	28.47	36.80	48.41	54.40
T_2G_5	20.67	28.67	35.70	48.93	56.64
T_3G_1	17.89	26.60	34.60	47.00	52.03
T_3G_2	18.31	30.01	39.52	52.02	58.42
T_3G_3	19.06	29.04	39.85	49.03	55.81
T_3G_4	18.76	26.27	33.25	44.78	51.88
T_3G_5	16.07	20.79	34.16	44.56	57.56
T_4G_1	18.30	26.53	36.18	47.94	54.00
T_4G_2	16.09	24.39	34.91	45.98	55.83
T_4G_3	16.01	24.90	38.57	48.50	54.61
T_4G_4	18.03	25.77	33.92	46.76	53.65
T_4G_5	17.16	24.08	29.66	42.76	55.30
$LSD_{0.05}$	1.05	1.11	1.18	1.11	1.06
$LSD_{0.01}$	1.40	1.48	1.58	1.49	1.41
Level of significance	**	**	**	**	**

** = Significant at 1% level of probability; G1= PI L1408, G2= Nantes 5, G3= PI 261650, G4= PI 1408, G5= Upper cut; T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

Table 3. Main effects of germplasm on yield and yield contributing traits of baby carrots

Germplasm	Root length (cm)	Root diameter (cm)	% of branched root	% of crack roots	Root weight (g)	Leaf weight (g)	Yield (ton/ha)	Marketable yield (t/ha)	% Dry matter content
G_1	26.12	2.47	10.12	2.47	65.33	28.83	16.74	16.56	12.72
G_2	22.26	4.02	9.25	0.68	154.87	60.77	26.29	26.04	7.57
G_3	19.99	2.52	8.09	0.00	47.38	37.58	15.86	15.74	11.21
G_4	23.83	2.40	9.62	0.28	55.95	31.21	14.11	13.98	9.64
G_5	19.85	2.68	8.19	0.30	114.48	46.04	16.75	16.63	8.75
$LSD_{0.05}$	0.51	0.09	1.05	1.02	1.40	1.22	0.61	0.60	0.06
Sig. level	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability; G1= PI L1408, G2= Nantes 5, G3= PI 261650, G4= PI 1408, G5= Upper cut; T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

The plant height was significantly influenced by the interaction effect of germplasm and plastic mulches. At 80 DAS (days after sowing), the maximum plant height (58.67 cm) was obtained from the treatment combination of Upper cut with black plastic mulch (T1G5) and the minimum (50.69 cm) were recorded from PI 1408 with no mulch (T0G4) (Table 1). Black plastic mulch is responsible for increasing soil temperature by absorbing high amount of radiation retain soil moisture and also participate in increasing water use efficiency (Amare and Desta, 2021) that causes highest plant height in Upper cut.

3.2. Number of leaves per plant

Number of leaves of varied significantly with different germplasm of baby carrot. Maximum number of leaves per plant was recorded from Nantes 5. These were 4.20, 4.50, 4.90, 8.82 and 8.96 for 40, 50, 60, 70 and 80 DAS (days after sowing) respectively. On the other hand, Upper cut exhibited the lowest number of leaves per plant and were 4.01, 4.35, 4.61, 7.38 and 7.52 for 40, 50, 60, 70 and 80 DAS, respectively (Figure 3). The plant's increased vegetative growth is mostly responsible for the increase in leaves per plant. Number of leaves per plant showed significant variations due to the application of different plastic mulches. The highest number of leaves per plant was recorded from silver plastic mulch. From silver plastic mulch treatment, number of leaves per plant was 4.08, 4.41, 5.45. 8.01 and 8.41 at 40, 40, 60, 70 and 80 DAS (days after sowing) respectively and the lowest number of leaves were 4.25, 4.37, 5.31, 7.57 and 7.23 at 40, 50, 60, 70 and 80 DAS (days after sowing) respectively recorded from control (no mulch) treatment (Figure 4). The result is in accordance with the findings of Sarkar et al. (2019). The number of leaves per plant was significantly influenced by the interaction effect of baby carrot germplasm and different plastic mulches. The maximum number of leaves per plant (11.33) was obtained from Nantes 5 treated with silver plastic mulch (T2G2) and the minimum number of leaves per plant (6.57) was found in Nantes 5 with control (no mulch) treatment (T0G2) (Table 2). This might be due to silver plastic mulch provide suitable condition for producing higher number of leaves than bare land (Ashrafuzzaman et al., 2011).

3.3. Root length

The length of baby carrot root was found to be statistically significant due to the effects of baby carrot germplasm. The longest root (26.12 cm) was produced by PI L1408 whereas the shortest one (19.85 cm) was found from Upper cut (Table 3). The length of baby carrot root was also found to be statistically significant due to the effects of different plastic mulches. The longest root (23.55 cm) was produced by black plastic mulch whereas the shortest one (21.11 cm) found from the red plastic mulch (Table 4). This result is in accordance with the findings of Akand et al. (2023), Rahman et al. (2018) and Biswas et al. (2019). The root length was significantly influenced by the interaction between germplasm and plastic mulches of baby carrots. The maximum root length (29.07 cm) was obtained from PI L1408 treated with black plastic mulch (T1G1) while the minimum root length (15.74 cm) was observed from Upper cut treated with red plastic mulch (T4G5) (Table 5). Black plastic mulch provides optimum root zone temperature that encourages the development of baby carrot roots (Amare and Desta, 2021).

3.4. Root diameter

Significant variation was observed in root diameter among the different baby carrot germplasm. The maximum root diameter (4.02 cm) was recorded from Nantes 5 whereas the minimum diameter (2.40 cm) was obtained from PI 1408 (Table 3). The diameter of baby carrot root was found to be statistically significant due to the effects of different plastic mulches. The maximum root diameter (2.88 cm) was recorded by black plastic mulch whereas the minimum (2.76 cm) was found from control (no mulch) treatment (Table 4). This result is in accordance with the findings of Biswas et al. (2019). The interaction effect of baby carrot germplasm and plastic mulches was significant for root diameter. The maximum root diameter (4.19 cm) was found in the treatment combination of Nantes 5 with black plastic mulch (T1G2). The minimum root diameter (2.06 cm) was found in the treatment combination of PI 1408 with control treatment (T0G4) (Table 5). Positive relationship between black plastic mulch with soil mean temperature might be a cause to produce maximum root diameter than the control one (Mahajan et al., 2007).

3.5. Percent branched root

Different germplasm had significant variations on percentages of branched roots. The highest percentage of branch root (10.12%) was found from PI L1408 and that of lowest (8.09%) was recorded from PI 261650 (Table 3). The percentage of branched root production was significantly influenced by the application of different plastic mulches. The maximum branch root (10.04%) was obtained from control treatment and lowest one (8.35%) was obtained from red plastic mulch (Table 4). A significant variation was found in the production of branch root of carrot due to interaction baby carrot germplasm and different plastic mulches. The combined effect of PI 261650 with no mulch (T0G3) gave maximum-branched root (11.60%) and minimum (5.46%) was obtained from Upper cut with red plastic mulch (Table 5).

3.6. Percent cracked root

Different baby carrot germplasm had significant variation on cracked root percentage. The highest percentage of cracked root (2.47%) was found from PI L1408 whereas no cracked root (0.00%) was found in PI 261650 (Table 3). Percentage of cracked root production was significantly influenced by the application of different plastic mulches. The maximum cracked roots (1.09%) were obtained from silver plastic mulch and the lowest percentage of cracked roots (0.35%) was obtained black plastic mulch (Table 4). A significant variation was found in the production of cracked root of carrot due to interaction of baby carrot germplasm and different plastic

mulches. Maximum cracked root (4.26%) was recorded from PI L1408 with control (no mulch) treatment (Table 5).

3.7. Fresh weight of roots

Baby carrot germplasm exhibited a significant variation in fresh weight of individual root. The highest significant fresh weight of root (154.87 g) was found from Nantes 5 and the minimum one (47.38 g) was observed from PI 261650 (Table 3). Application of different plastic mulches exhibited a significant variation in fresh weight of root. The highest fresh weight of root (91.88 g) found in black plastic mulch and the lowest fresh weight of individual root (78.69 g) produced by the red plastic mulch (Table 4). The fresh weight of root per plant was significantly influenced by the interaction between germplasm and different plastic mulches. The maximum fresh weight of root per plant (174.45 g) was observed from Nantes 5 with black plastic mulch (T1G2). And the lowest fresh weight of root per plant (40.43 g) was obtained from PI 1408 with no mulch (T0G4) (Table 5). Black plastic mulch was reported for reducing weed and pest infestation resulting in higher weight of root (Farias-Larios et al., 1997).

3.8. Fresh weight of leaves

The influence of baby carrot germplasm in relation to fresh weight of leaf was found to be statistically significant. The maximum fresh weight of leaves (60.77 g) was found from Nantes 5 and minimum (28.83 g) of leaves was recorded from PI L1408 (Table 3). The influence of different plastic mulch treatments in relation to fresh weight of per plant was found to be statistically significant. The highest fresh weight of leaves (45.98 g) was found from red plastic mulch and the lowest fresh weight of leaves (36.97 g) was found from control treatment (Table 4). Red plastic mulches are efficient in controlling aphids that suck cell sap resulting in increasing leaf weight (Brown et al., 1993). Interaction between baby carrot germplasm and plastic mulches was found significant in relation to fresh weight of leaves per plant. The maximum weight of leaves per plant (65.63 g) was obtained from Nantes 5 with blue plastic mulch treatment combination (T3G2), whereas the lowest fresh weight of leaves (24.07 g) was resulted from PI 1408 with blue plastic mulch treatment combination (T3G4) (Table 5).

3.9. Gross yield

The variation due to the effect of germplasm in respect of yield of roots ton per hectare was highly significant. Maximum yield of carrot was obtained from Nantes 5 (26.29 ton) while the minimum (14.11 t) yield was recorded from PI 1408 (Table 3). The application of different plastic mulches increased the yield of root significantly. Black plastic mulch treatment produced maximum yield per hectare (18.65 t) and the lowest yield per hectare (17.01 t) was recorded in no mulch treatment (Table 4). Similar result was also observed by Mazed et al. (2015) and Jaysawal et al. (2018). The interaction between baby carrot germplasm and plastic mulches were also found to be significant for yield of root per hectare. It was found that Nantes 5 treated with black plastic mulch produced highest yield of per hectare (27.06 t) (T1G2) while the minimum yield of root per hectare (12.36 t) was found from PI 1408 with control treatment (T0G4) (Table 5). Dale (2000) reported that black plastic mulches are effective in increasing yield by maintaining soil temperature and restricting weed growth compared to no mulching.

3.10. Marketable yield

The variation due to the effect of baby carrot germplasm in respect of marketable yield of roots (t/ha) was highly significant. The highest marketable yield of roots (26.04 t/ha) was obtained from Nantes 5 and the lowest (13.98 t/ha) was recorded from PI 1408 (Figure 5) (Table 3). The variation due to the effect of application of different plastic mulches in respect of marketable yield of roots per hectare was significant. The highest marketable yield of roots (18.50 t/ha) was obtained from the application of black plastic mulch treatment and the lowest marketable yield (16.84 ton/ha) was obtained from control treatment (Figure 6) (Table 4). A Significant variation was found in marketable yields of carrot root per hectare due to interaction between baby carrot germplasm and plastic mulches. The highest marketable yield (26.81 t/ha) was produced by the treatment combination of Nantes with black plastic mulch (T1G2). The lowest marketable yield (12.25 t/ha) was produced by the treatment combination of PI 1408 with no mulch (T0G4) (Figure 7) (Table 5).

3.11. Dry matter content of root

In case of percent dry matter of root, there was a significant difference among baby carrot germplasm. PI L1408 produced the highest root dry matter (12.72%) whereas the Nantes 5 produced the lowest root dry matter (7.57%) (Table 3). In case of percent dry matter of root there was a significant difference among different plastic mulch treatments. Silver mulch treatment produced the highest root dry matter (11.92%) and the lowest percent dry matter of root (8.04%) was produced by control treatment (Table 4). The percent dry matter of roots was significantly influenced by the interaction of baby carrot germplasm and plastic mulches. The highest root dry matter (16.00%) was found in the treatment combination of PI 261650 with silver plastic mulch treatment (T2G3). The lowest root dry matter (6.23%) was found in the treatment combination of Nantes 5 with red plastic mulch treatment (T4G2) (Table 5). Rahman and Khan (2001) reported that, silver plastic mulch is involved in increasing soil temperature or reducing soil moisture that helps in distributing the photosynthates from leaves to underground root. This might be a cause to be increased dry matter percentage in silver plastic mulch than other treatments.

Table 4. Main effects of plastic mulches on yield and yield contributing traits of baby carrot

Plastic mulches	Root length (cm)	Root diameter (cm)	Branched root (%)	Cracked roots (%)	Root weight (g)	Leaf weight (g)	Yield (t/ha)	Marketable yield (t/ha)	% Dry matter content
T_0	22.65	2.76	10.04	0.85	87.26	36.97	17.01	16.84	8.04
T_1	23.55	2.88	8.42	0.35	91.88	41.19	18.65	18.50	10.20
T_2	22.84	2.86	8.90	1.09	91.38	40.56	18.53	18.37	11.92
T_3	21.91	2.79	9.56	0.52	88.80	39.74	17.81	17.64	9.03
T_4	21.11	2.80	8.35	0.92	78.69	45.98	17.76	17.60	10.70
$LSD_{0.05}$	0.51	0.09	1.05	1.02	1.40	1.22	0.61	0.60	0.06
$LSD_{0.01}$	0.69	0.12	1.40	1.36	1.87	1.63	0.82	0.81	0.07
Sig. level	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability; G1= PI L1408, G2= Nantes 5, G3= PI 261650, G4= PI 1408, G5= Upper cut; T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

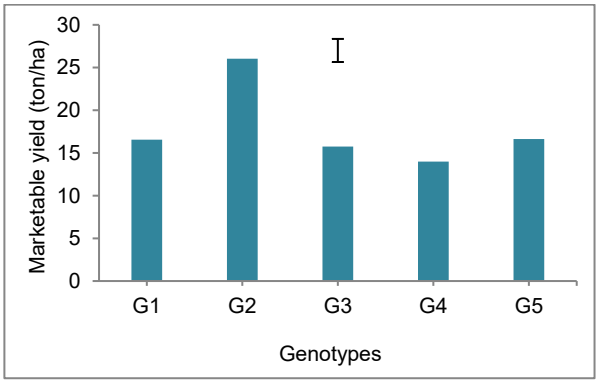

Figure 5. Effect of germplasm on marketable yield of baby carrots at different days after sowing. Vertical bars indicate LSD at 1% level of probability. G1= PI L1408, G2= Nantes 5, G3= PI 261650, G4= PI 1408, G5= Upper cut

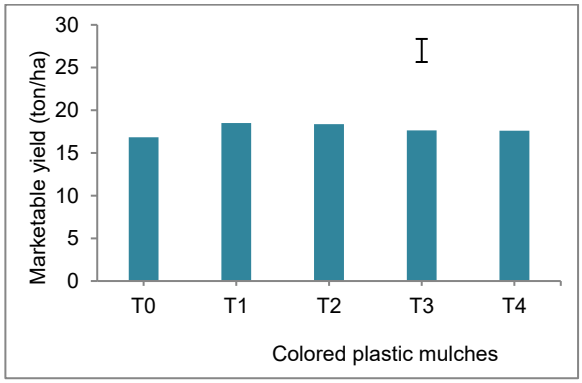

Figure 6. Effect of plastic mulches on marketable yield of baby carrot germplasm at different days after sowing. Vertical bars indicate LSD at 1% level of probability. T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

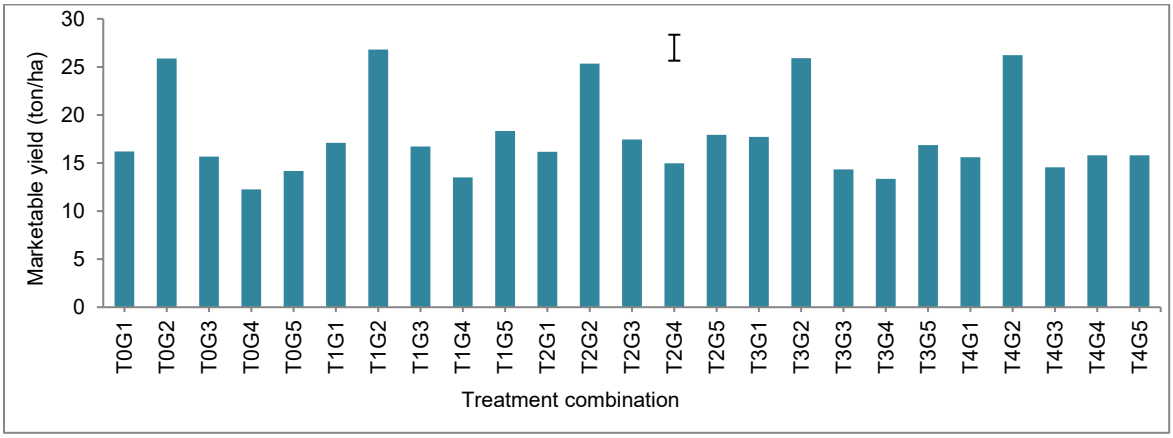

Figure 7. Interaction between germplasm and plastic mulches on marketable yield (t/ha) of baby carrots. Vertical bar indicates LSD at 1% level of probability. G1= PI L1408, G2= PI Nantes 5, G3= PI 261650, G4= PI 1408, G5= PI Upper cut; T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

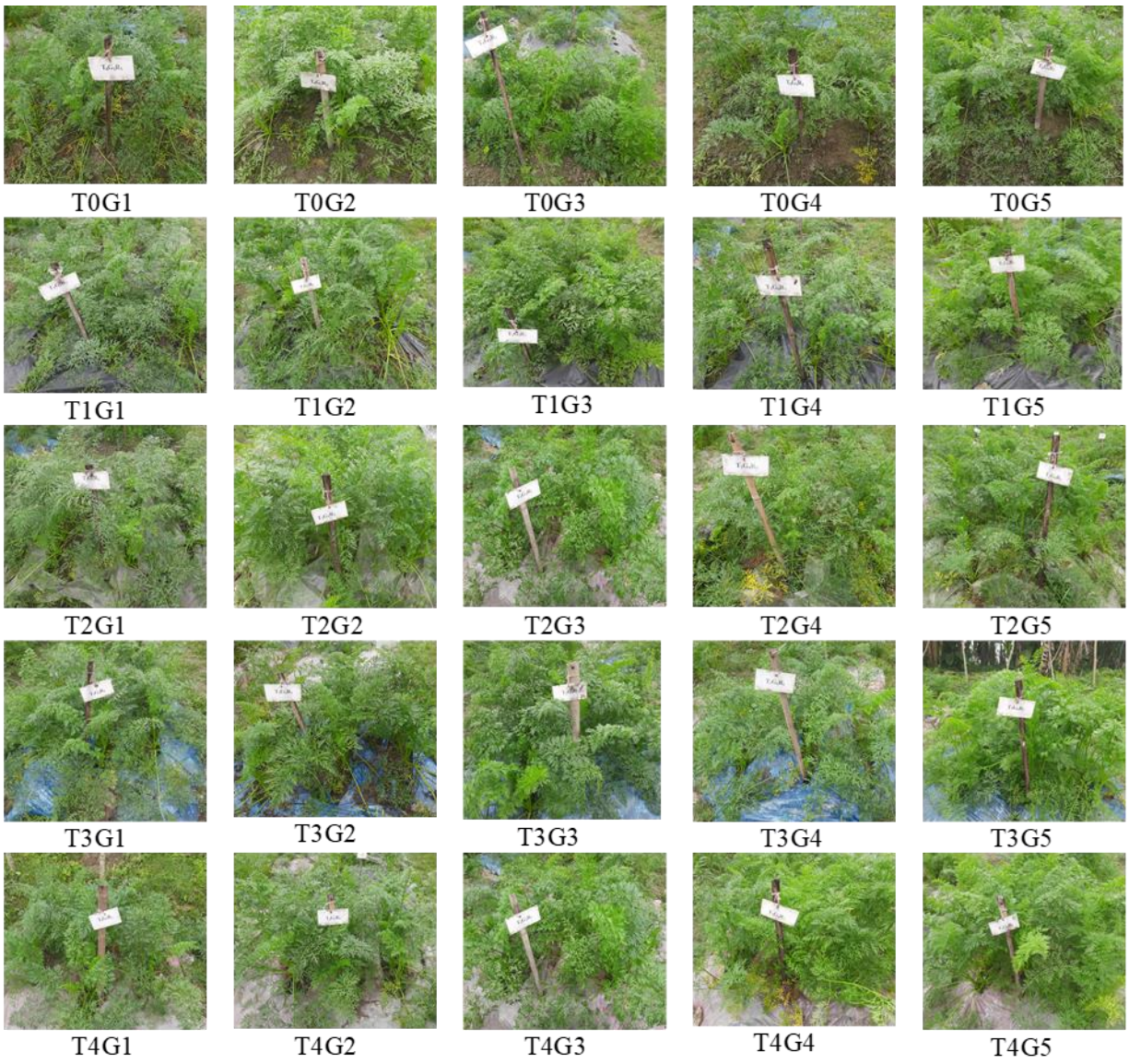

Plate 1. Vegetative growth of baby carrot at 80 DAS (days after sowing) from the interaction between germplasm and plastic mulches where G1= PI L1408, G2= Nantes 5, G3= PI 261650, G4= PI 1408, G5= Upper cut; T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

Table 5. Interaction between germplasm and plastic mulches on yield and yield contributing traits of baby carrots

Treatment combination	Root length (cm)	Root diameter (cm)	Branched root (%)	Cracked roots (%)	Root weight (g)	Leaf weight (g)	Yield (t/ha)	Marketable yield (t/ha)	% Dry matter content
T_0G_1	26.43	2.45	10.30	4.26	66.80	24.27	16.39	16.20	9.25
T_0G_2	21.65	4.08	7.74	0.00	170.45	62.67	26.14	25.88	7.12
T_0G_3	19.40	2.49	11.60	0.00	45.67	37.58	15.83	15.67	9.90
T_0G_4	23.03	2.06	10.53	0.00	40.43	24.27	12.36	12.25	7.66
T_0G_5	22.73	2.74	10.02	0.00	112.94	36.05	14.31	14.18	6.26
T_1G_1	29.07	2.46	9.58	0.00	65.96	26.53	17.26	17.10	14.34
T_1G_2	22.07	4.19	10.07	1.75	174.45	60.57	27.06	26.81	7.68
T_1G_3	21.73	2.65	5.69	0.00	46.57	36.03	16.83	16.72	10.00
T_1G_4	23.25	2.40	8.71	0.00	58.12	37.38	13.62	13.51	11.20
T_1G_5	21.63	2.67	8.06	0.00	114.32	45.41	18.48	18.34	7.75
T_2G_1	24.85	2.46	10.60	2.57	68.65	34.67	16.36	16.17	13.26
T_2G_2	23.30	4.08	9.52	0.00	163.17	52.45	25.58	25.35	9.06
T_2G_3	20.38	2.49	5.69	0.00	49.21	33.92	17.54	17.45	16.00
T_2G_4	23.25	2.58	10.67	1.39	62.58	32.97	15.13	14.97	10.84
T_2G_5	22.40	2.69	8.02	1.52	113.29	48.78	18.07	17.93	10.44
T_3G_1	25.67	2.54	10.45	2.58	64.27	26.20	17.93	17.72	13.02
T_3G_2	21.47	4.08	8.71	0.00	156.27	65.63	26.15	25.91	7.75
T_3G_3	21.09	2.56	10.76	0.00	48.71	34.56	14.48	14.34	6.51
T_3G_4	24.53	2.21	8.49	0.00	57.72	24.07	13.47	13.36	10.04
T_3G_5	16.77	2.58	9.38	0.00	117.02	48.27	17.01	16.87	7.84
T_4G_1	24.60	2.44	9.68	2.92	61.00	32.47	15.75	15.60	13.72
T_4G_2	22.80	3.70	10.23	1.67	110.02	62.55	26.54	26.23	6.23
T_4G_3	17.33	2.40	6.69	0.00	46.73	45.83	14.64	14.55	13.63
T_4G_4	25.07	2.76	9.71	0.00	60.88	37.35	15.95	15.81	8.46
T_4G_5	15.74	2.70	5.46	0.00	114.83	51.69	15.89	15.81	11.44
$LSD_{0.05}$	1.15	0.19	2.35	2.28	3.13	2.73	1.37	1.35	0.12
Sig. level	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability; G1= PI L1408, G2= Nantes 5, G3= PI 261650, G4= PI 1408, G5= Upper cut; T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

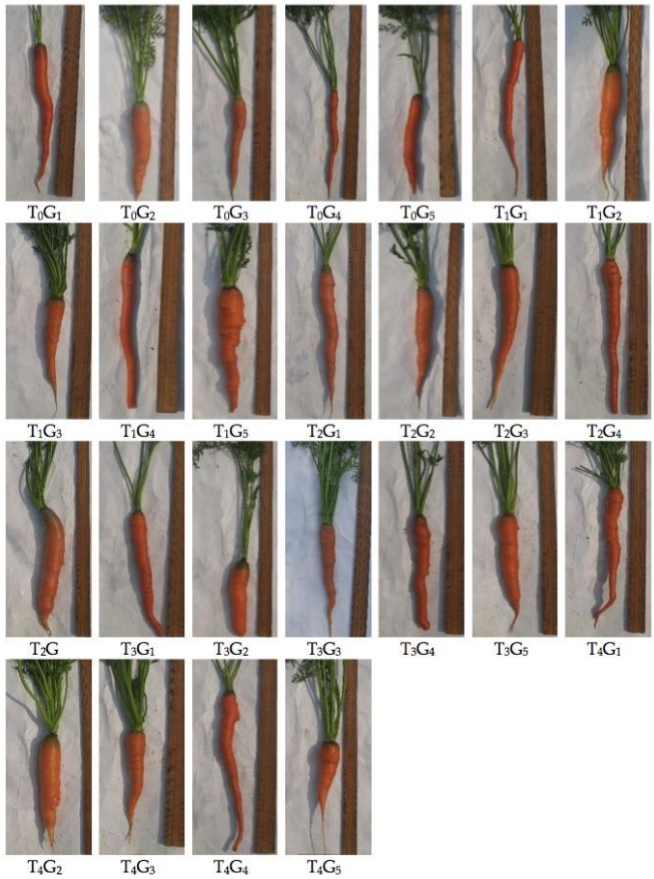

Plate 2. Interaction between germplasm and plastic mulches on roots of baby carrots where G1= PI L1408, G2= Nantes 5, G3= PI 261650, G4= PI 1408, G5= Upper cut; T0= Control, T1= Black, T2= Silver, T3= Blue, T4= Red

4. Conclusion

The study was conducted to know the interaction between germplasm and plastic mulches on the growth, yield and quality of baby carrot. In the experiment, significant variations were observed due to interaction between baby carrot germplasm and plastic mulches on all the parameters studied. Highest yield per hectare (27.06 t) was observed at Nantes 5 with black plastic mulch treatment while the lowest yield per hectare (12.36 t) was recorded at PI 1408 with control (no mulch) treatment. Therefore, it can be concluded that combined treatment of Nantes 5 along with black plastic mulch was found to be better for higher growth, yield and quality of baby carrots.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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