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# Effects of Mulching and Micronutrients on Growth, Yield and Quality of Carrot (*Daucus carota* L.)

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**ABSTRACT**

Carrot (*Daucus carota* L.) is one of the most important root vegetables of Bangladesh. Mulching and micronutrients have strong effect on growth, yield and quality of carrot. An experiment was conducted at the Horticulture Farm of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from November 2021 to February 2022 to examine the effect of mulching and micronutrients on growth, yield and quality of carrot. The two-factor experiment consisted of four mulching treatments viz. control (no mulch), water hyacinth, rice straw and black polythene, and four types of micronutrients viz. control (no micronutrient), boron (3 kg/ha), zinc (2 kg/ha), boron+ zinc (3+2 kg/ha). The experiment was laid out in split plot design with three replications. Result of the experiment revealed that application of mulching materials and different levels of micronutrients alone or in combination significantly influenced all the parameters studied. The highest gross yield of root (29.4 t/ha) was obtained from black polythene mulch. The lowest gross yield of root (14.9 t/ha) was obtained from control (no mulch) treatment. The highest gross yield of root (31.7 t/ha) was obtained from (boron+ zinc) micronutrient treatment. On the contrary, the lowest gross yield of root (13.3 t/ha) was obtained from control treatment. Among the treatment combinations, the highest gross yield of root (39.8 t/ha) was obtained from Black polythene with (boron+ zinc) micronutrient treatment. On the contrary, the lowest gross yield of root (10.6 t/ha) was obtained from control treatment. The highest gross was obtained from black polythene mulch with (boron+ zinc) micronutrient treatment. Therefore, application of black polythene mulch along with combined treatment (boron+ zinc) was found to be better in respect of growth, yield and quality of carrot.



## 1. Introduction

Carrot (*Daucus carota* L.) is a dicotyledonous, herbaceous, biennial cool season root vegetable crop grown all over the world belonging to the family Apiaceae (Umbelliferae). Carrot is a highly nutritious cool season root crop and is grown in the spring, summer and autumn in temperate countries (Bose and Som, 1990). Carrot is one of the most important and enjoyed root vegetable cultivated worldwide. Just one large carrot (one cup) can provide 100% of the daily target for vitamin A. This important nutrient (which acts as a cell-protective antioxidant) may even help protect against cancer, age-related macular degeneration, and measles. A deficiency of vitamin A can lead to a condition called xerophthalmia, which can damage normal vision and result in night blindness (NIH, 2022). In Bangladesh carrot is grown during the winter season when the rainfall is scanty. So, irrigation is essential for cultivation. In the year 2018-20, the area under carrot production was 2321.508 hectares and total production was 30387.416 tons in Bangladesh (BBS, 2020). However, carrot yield per unit area still stays below the demand. In Bangladesh, the average yield of carrot is (13.09 t /ha) which is very low compared to other carrot-producing countries in the world like Belgium (67.25 t/ ha), Netherlands (57.02 t /ha), and Sweden (64.16 t /ha) (FAO, 2017).

Production of carrot in Bangladesh could be increased significantly through increase of per hectare yield with the judicious application of mulching and micronutrient. Mulch will reduce the amount of water that evaporates from our soil, greatly reducing our need to water our plants by breaking up clay and allowing better water and air movement through the soil. Mulch provides nutrients to sandy soil and improves its ability to hold water. To

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achieve the highest possible carrot yield during a relatively short vegetation period, different types of mulch treatment are used. Mulching is highly effective in checking evaporation loss of soil moisture. Mulching protects against the loss of soil moisture by soil evaporation induced by wind and reduces the irrigation requirement (Islam and Rashid, 2022). It increases the efficiency of applied N-fertilizer and irrigation. Different mulches regulate soil moisture and temperature, suppress weeds, and improve germination and emergence (Frazier, 1957). Higher yield and better quality, less infestation of insect's diseases, earliness, prolong growing season, higher nutritive value of the produced, improved storability are the advantages of mulching (Bhardwaj, 2013). In some extent, mulches reduce the invasion of insects and diseases.

Carrot productivity in the developing world and different micronutrients like Zn, Mn, Cu, B, and Mo are becoming deficient in soil with increasing cropping intensity. Zinc also plays an important role in chlorophyll formation. Application of Zinc increased the growth of carrot. Boron is also an essential micronutrient required for normal plant growth and development. It is necessary for normal cell division, nitrogen metabolism and protein formation. It is essential for proper cell wall formation. With this view in mind, the current experiment was conducted to study the effect of mulching and micronutrients on growth, yield and quality of carrot

## 2. Materials and Methods

### 2.1. Experimental site, soil and climate

The research work was conducted at the Horticulture Farm of the Bangladesh Agricultural University (BAU), Mymensingh during the period from November 2021 to February 2022 in order to study the effects of mulching and micronutrients on the growth and yield of carrot. The site of the experiment is located between 24 °75" N latitude and 90° 50" E longitude. The elevation of the experimental area is approximately 18 meters from sea level. The experiment was carried out in a high land belonging to Old Brahmaputra Floodplain Alluvial Tract (UNDP, 1988) and under the Agro-ecological Zone 9. The soil texture was silty loam with pH 6.85 having low organic matter). It was well drained with good irrigation facilities. The experimental area is situated in the sub-tropical climatic zone and is characterized by heavy rainfall during May to October and scanty rainfall during the rest period of the year. The Rabi season is characterized by comparatively low temperatures and plenty of sunshine from November to February. The experimental area is under the sub-tropical climate, which is characterized by heavy rainfall during the month of May to September and sparse rainfall during the month from October to April. Plenty of sunshine and moderately low temperature prevails during rabi season from October to March which are suitable for growing carrot in Bangladesh.

### 2.2. Experiment treatments

New Kuroda variety of carrot was used as a planting material. This carrot variety is well recognized and mostly cultivated in different areas of Bangladesh. The experiment consisted of two factors, Factor A: Four methods of mulching application *viz.,* $M_0$= control and $M_1$== Water hyacinth, $M_2$ = Rice straw $M_3$= Black polythene Factor B: Four levels of micronutrients viz., $T_0$= control treatment, $T_1$= Boron (B) @ 3 kg/ha, $T_2$= Zinc (Zn) @ 2 kg/ha, $T_3$= B @ 3 kg/ha + Zn @ 2kg/ha. The two-factor experiment was laid out in split plot design with three replications. An area of 108 $m^2$ was divided into three equal blocks, representing the replications, each containing 16 plots. The size of each unit plot was 1 m x 1 m. A distance of 0.3 m between two plots and 0.5 m between the blocks were kept to facilitate different intercultural operations.

### 2.3. Land preparation

The experimental plot was thoroughly prepared by ploughing for several times with a power tiller followed by laddering. All the weeds and stubbles were collected and removed from the land. The clods were broken into friable soil and the surface was leveled until the desired tilth was obtained. 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 plot was treated with recommended dose of nitrogen, phosphorus, potassium and sulphur. The control plot was treated with only recommended dose of NPKS fertilizer and the other plots were treated micronutrients with recommended dose of NPKS fertilizer as per treatment. The entire number of micronutrients was applied immediately after opening the land, applied as a basal dose during final land preparation. Recommended doses of urea were applied in three instalments at 30, 45 and 60 days after sowing of carrot seed. Fertilizer (except B and Zn fertilizers) were applied according to the recommendation of Fertilizer Recommendation Guide (Ahmmed et al., 2018), such as urea @100 kg/ha, TSP@ 30 kg/ha, MoP @ 15kg/ha. Micronutrients were applied at B @ 3 kg/ha Zn @ 2 kg/ha and B+Zn (3+2) kg/ha.

### 2.5. Application of mulches

Mulching with water hyacinth and rice straw was done after seed sowing while black polythene before seed sowing. Fresh water hyacinth plants were chopped into small pieces (5-7 cm) dried in the sun for three days and then placed over the plots with a thickness of 10 cm approximately and dried rice straws were chopped into small pieces and placed over the plots. A black polythene sheet with a small hole at proper spacing was spread over the plot so that the seedlings could emerge easily through the hole

### 2.6. Seed soaking and seed sowing

Before sowing the seeds, the seeds were soaked in water for 24 hours and then wrapped with a piece of thin cloth. To dry out the surface water, the moistened seeds were spread over polythene sheets for two hours. This operation is practiced to facilitate quick germination of seeds. The soaked seeds were sown in line in the field at a depth of 1.5 cm. Each plot contained four lines by maintaining a distance of 25 cm between the lines and plant to plant distance 10 cm. The date was sowing was 8 November 2021 and covered with loose soil immediately after sowing.

### 2.7. Intercultural operations

Emergence of seedling was completed within 10 days after sowing. Thinning of the seedlings was done after 15 days of sowing to maintain a spacing of 10 cm between the plants. Thus, the plant spacing was 25 cm x 10 cm between row to row and plant to plant. Weeding was done regularly to keep the plots free from weeds and to keep the soil loose and well aerated. The field was irrigated five times. Just after sowing light irrigation was applied (1st irrigation), the second, third, fourth and fifth irrigations were done at 15, 30, 45, 55 and 75 days after sowing (DAS). The experimental crop was not infected by any diseases and no fungicide was used. Mole cricket and cutworm attacked the crop during the early growing stages of seedlings. Those insects were controlled by spraying of Pyriphos @ 0.1 ppm at 14, 21, and 28 DAS.

### 2.8. Parameters measured

Data on various parameters before harvesting such as plant height (cm), number of leaves per plant, were recorded from the sample plants during experimentation at 30, 45, 60 and 85 DAS. All the leaves of each sample plants were counted separately. The plant height was measured from the point of attachment of the leaves to the root (ground level) to the tip of the longest leaf at harvest by using a meter scale. Mean value of the ten randomized plants was calculated for each unit plot and expressed in centimetre (cm). During harvest the parameters such as carrot root length and diameter, gross yield (kg/plot), gross yield (t/ha), marketable yield of root (kg/ha), percentage of the cracked root, percentage of branched root, fresh weight of leaves per plant, percent dry matter of leaves, fresh weight of root per plant, percent dry matter of root were measured.

The length of the root was measured in centimetre by a scale and the diameter of the roots was measured using a slide calliper. The diameters of the roots were measured at harvest at the thickest portion of the root. The fresh weight of all roots harvested from a plot was weighed and recorded in kilogram. The yield of $ha^{-1}$ was calculated in ton by the converting the total yield of roots per plot. The marketable yield of carrot /plot was the weight of carrot roots after discarding the roots damaged by cracking, rotting and branching taken from the total yield of roots. This was recorded in kilogram (kg).

Marketable Yield = Gross yield – Non-marketable yield (Yield of cracked, branched and rotten roots).

Fresh leaves of 100 g as per treatment were weighted and cut into small pieces. Then it was dried under the sun and after drying for three days the samples were oven dried at 72 hours. Then the weight of dry leaves was evaluated by using the following formula-

$$\% \text{ Dry matter of leaves} = \frac{\text{Constant dry weight of leaves (g)}}{\text{Fresh weight of leaves (g)}} \times 100$$

The fresh weight of carrot roots was recorded at harvest from the average of ten plants in grams. A sample of 100 g was taken from several roots and cut into small pieces. Then the pieces were dried under sun for three days and then oven dried for 72 hours at 70-80° C temperature. After drying in oven, the samples were weighted by an electrical balance and dry matter content was recorded by using the following formula-

$$\% \text{ Dry matter of root} = \frac{\text{Constant dry weight of roots (g)}}{\text{Fresh weight of roots (g)}} \times 100$$

The number of branched roots were counted at the time of harvest and branching percentage of roots per plot was calculated by the following formula-

$$\text{Branched roots (\%)} = \frac{\text{Number of branched roots}}{\text{Number of total roots}} \times 100$$

### 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 30, 45, 60, and 85 days after sowing (DAS). The highest plant height attained with black polythene mulch were 11.18 cm, 20.13 cm, 26.44 cm and 32.21cm for 30, 45, 60, and 85 DAS, respectively. The lowest plant height 9.41 cm 14.98 cm, 22.45 cm and 27.21cm for 30, 45, 60, and 85 DAS, respectively was recorded from the control treatment (Figure 1). The present findings are similar to the results as replied Jaysawal *et al*. (2018) and Biswas *et al.* (2019). This might be caused that mulching suppressed weeds, protect the deterioration of soil structure also influences the nutrient retention of soil and the influence of organic mulch on production of carrot under the climate-ecological conditions. The application of different micronutrients significantly influenced the plant height of the carrot. The highest plant height 12.58cm, 21.25 cm, 26.87 cm, 32.96 cm were found at 30,45, 60, 85 after sowing (DAS) respectively in the (boron + zinc) treatment and the shortest plant height 8.08 cm, 14.58 cm, 21.49 cm and 26.35cm were found at 30,45, 60, and 85 days after sowing (DAS), respectively in the control treatment (Figure 2). The results obtained are in similarity with the findings of Mohanta *et al*., (2013). The plant height was significantly influenced by the interaction effect of different micronutrients and mulches. At harvest (85 DAS), the maximum plant height (35.08cm) was obtained from the treatment combination of black polythene with (boron+ zinc) treatment ($M_3T_3$) and the minimum (25.17 cm) was recorded from no mulch and control treatment ($M_0T_0$) (Table 1). It is occurred due to suitable environmental condition, minimize the requirement of water and helps in retaining moisture, soil porosity and suppresses weed growth, to protect the soil surface from the influence of adverse factors (Muttaleb *et al.* 2018).

### 3.2. Number of leaves

The maximum number of leaves per plant was recorded 4.07, 5.66, 7.30 and 8.34 with black polyethene treatment for 30, 45, 60 and 85 DAS respectively. The present findings are similar to the results as replied by Muttaleb *et al.* (2018) and Biswas et al. (2019). The control plant exhibited the lowest number of leaves per plant and was 3.89, 4.67, 5.70 and 6.58 for 30, 45, 60 and 85 DAS respectively (Figure 3). In the mulching effect, it minimizes the requirement of water and helps in retaining moisture, soil porosity and suppresses weed growth, to protect the soil surface from the influence of adverse factors. Main effect of different micronutrient on leaf number per plant at 30, 45, 60, and 85 DAS, the highest number of leaves per plant (8.42) was recorded from (boron+ zinc) micronutrient treatment followed by (7.69) and the control treatment produced the lowest number of leaves per plant (6.40) (Figure 4). Naher *et al.* (2013) found that application of micronutrient increases the plant height, number of leaves than the control treatment. Application of Zinc increased the growth of carrot. Boron is also an essential micronutrient required for normal plant growth and development. It is necessary for normal cell division, nitrogen metabolism and protein formation. The number of leaves per plant was significantly influenced by the interaction effect of different micronutrients and mulches. The maximum number of leaves per plant (9.68) was obtained from the treatment combination of black polythene with (boron+ zinc) ($M_3T_3$) at 85 DAS and the minimum number of leaves per plant (5.87) was found in the combination of no mulch and control treatment ($M_0T_0$) (Table 1)**.**

### 3.3. Root length

The longest root was produced by black polythene treatment (13.50 cm) whereas the shortest one was found from the no mulch treatment (10.21 cm) (Table 2). This result is in accordance with the findings of Rahman et al (2018) and Biswas et al. (2019). Mulching with synthetic materials provided some benefit for root development, yield and total soluble solids content and its use is recommended to promote the carrot root development. Root length differed significantly due to the effects of different micronutrients. Maximum root length (14.25 cm) was recorded by (boron+ zinc) treatment. Whereas the minimum one found from the control treatment (9.58 cm) (Table 3). The length of root per plant was significantly influenced by the interaction effect of micronutrients and mulch treatments. The maximum length of root per plant (15.86 cm) was obtained from the treatment combination of black polythene with (boron+ zinc) ($M_3T_3$) combination while the minimum length of root per plant (8.94 cm) was observed from no mulch and control treatment ($M_0T_0$) (Table 6). Most similar findings have also obtained from Olfati *et al.* (2008). Mulching with synthetic materials provided some benefit for root development, yield, and total soluble solids content and its use is recommended to promote the carrot root development.

### 3.4. Root diameter

Significant variation was observed in root diameter among the different mulches. The maximum root diameter (3.039 cm) was recorded from the treatment of black polythene and minimum diameter (2.10 cm) was obtained from the no mulch treatment (Table 3). This result is in accordance with the findings of Biswas et al. (2019). Root diameter was also significantly varied due to the use of different micronutrient in carrot. The treatment (boron+ zinc) produced the maximum root diameter (3.2 cm). Whereas, the minimum diameter of root produced by control (1.84 cm) (Table 3). At the combined interactions, the maximum root diameter (3.5 cm) was found in black polythene with (boron+ zinc) combination ($M_3T_3$) and the minimum root diameter (1.51cm) was found in no mulch with control treatment ($M_0T_0$) (Table 6).

### 3.5. Cracked root

The highest percentage of cracked root (11.89%) was found with no mulch treatment and the next highest (7.90%) was obtained from rice straw treatment. The lowest percentage of cracked root (5.19%) was produced by the black polythene treatment (Table 2). The maximum cracked roots (12.55%) were obtained from control treatment followed by $T_1$ (8.96%). The lowest percentage of cracked roots (3.29%) was obtained from the (boron+ zinc) treatment (Table 3). The combined effect of no mulch and control treatment ($M_0T_0$) gave maximum cracked root (14.15%) and that minimum (0.02%) was obtained from black polythene and (boron+ zinc) ($M_3$ $T_3$) treatment combination (Table 6).

### 3.6. Branched root

The highest percentage of branched root (22.89%) was found with no mulch treatment and the lowest percentage of branched root (11.95%) was produced by the black polythene treatment (Table 2). The maximum branch root (25.23%) was obtained from control treatment, followed by Boron treatment (15.99%). The lowest percentage of branch roots (10.91%) was obtained from the (Boron+ Zinc) treatment (Table 3). And in the interaction effect, no mulch and control treatment ($M_0T_0$) gave maximum-branched root (28.24%) and minimum (7.883) was obtained from black polythene and (boron+ zinc) treatment (Table 6).

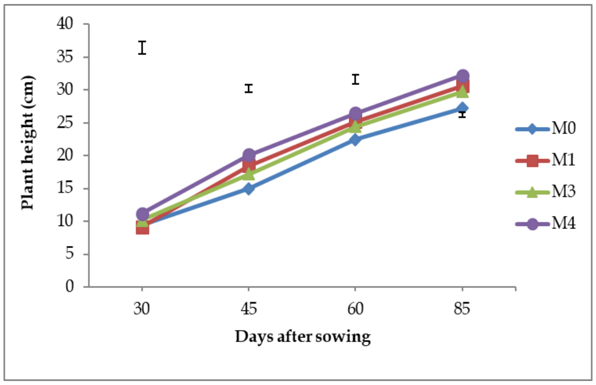


Figure 1. Effect of mulching on plant height of carrot. Vertical bars indicate LSD at 1% level of probability. M0 = No mulch, M1= Water hyacinth, M2 = Rice straw, M3= Black polythene

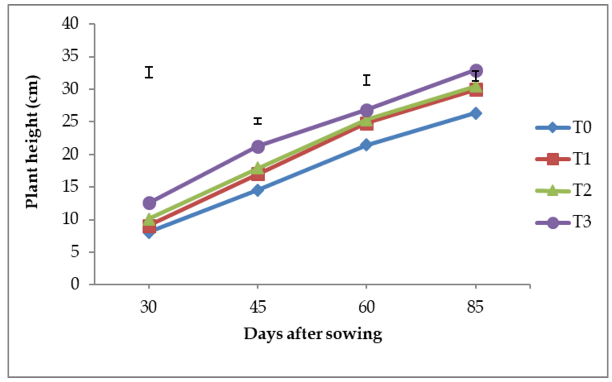


Figure 2. Effect of micronutrients on plant height of carrot. Vertical bars indicate LSD at 1% level of probability. T0 = Control, T1 = Boron (3 kg/ha), T2= Zinc (2 kg/ha), T3= Boron +Zinc (3+2) kg/ha

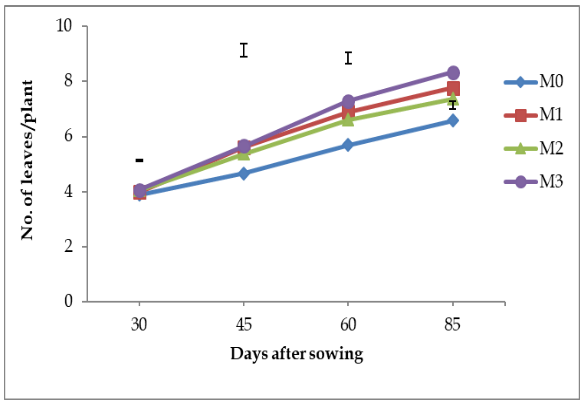


Figure 3. Effect of mulching on number of leaves per plant of carrot. Vertical bars indicate LSD at 1% level of probability. M0 = No mulch, M1= Water hyacinth, M2 = Rice straw, M3= Black polythene

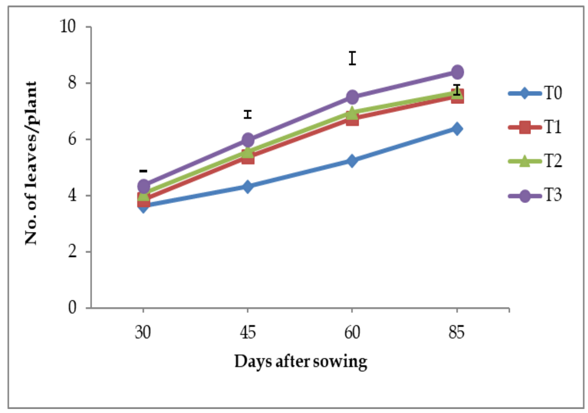


Figure 4. Effect of micronutrients on number of leaves per plant of carrot. Vertical bars indicate LSD at 1% level of probability. T0 =Control, T1 = Boron (3 kg/ha), T2= Zinc (2 kg/ha), T3= Boron +Zinc (3+2) kg/ha

Table 1. Combined effect of mulches and micronutrients on plant height and number of leaves/plants in different days after sowing (DAS) of carrot

| Treatment (mulch× micronutrient) | Plant height (cm) | | | | Number of leaves /plants | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 45 DAS | 60 DAS | 85 DAS | 30 DAS | 45 DAS | 60 DAS | 85 DAS |
| $M_0T_0$ | 7.87 | 13.97 | 20.07 | 25.17 | 3.61 | 3.84 | 4.52 | 5.87 |
| $M_0T_1$ | 8.27 | 14.93 | 22.60 | 27.04 | 3.75 | 4.67 | 5.83 | 6.51 |
| $M_0T_2$ | 10.30 | 15.29 | 23.07 | 27.64 | 3.98 | 4.87 | 5.99 | 6.80 |
| $M_0T_3$ | 11.20 | 15.73 | 24.08 | 29.00 | 4.23 | 5.30 | 6.45 | 7.14 |
| $M_1T_0$ | 8.10 | 14.57 | 21.53 | 26.30 | 3.62 | 4.35 | 5.37 | 6.39 |
| $M_1T_1$ | 8.87 | 17.53 | 25.50 | 30.80 | 3.91 | 5.92 | 7.19 | 7.94 |
| $M_1T_2$ | 8.40 | 18.70 | 26.14 | 31.16 | 4.05 | 6.04 | 7.21 | 8.12 |
| $M_1T_3$ | 11.23 | 23.07 | 27.61 | 34.13 | 4.33 | 6.15 | 7.82 | 8.61 |
| $M_2T_0$ | 8.17 | 14.26 | 20.76 | 25.75 | 3.67 | 4.11 | 4.87 | 6.23 |
| $M_2T_1$ | 9.20 | 16.27 | 24.47 | 29.65 | 3.92 | 5.64 | 6.82 | 7.33 |
| $M_2T_2$ | 10.80 | 16.80 | 25.07 | 30.03 | 4.16 | 5.70 | 7.12 | 7.65 |
| $M_2T_3$ | 12.60 | 21.57 | 27.43 | 33.61 | 4.46 | 6.05 | 7.67 | 8.26 |
| $M_3T_0$ | 8.17 | 15.53 | 23.62 | 28.17 | 3.68 | 5.03 | 6.23 | 7.10 |
| $M_3T_1$ | 10.20 | 19.37 | 26.74 | 32.50 | 3.95 | 5.37 | 7.18 | 8.41 |
| $M_3T_2$ | 11.03 | 21.00 | 27.07 | 33.10 | 4.19 | 5.75 | 7.57 | 8.18 |
| $M_3T_3$ | 15.30 | 24.63 | 28.36 | 35.08 | 4.48 | 6.51 | 8.20 | 9.68 |
| LSD (5%) | 0.55 | 0.30 | 0.53 | 0.54 | 0.05 | 0.23 | 0.40 | 0.30 |
| LSD (1%) | 0.75 | 0.40 | 0.71 | 0.73 | 0.06 | 0.31 | 0.54 | 0.41 |
| Level of significance | ** | ** | ** | ** | ** | ** | * | ** |

** = Significant at 1% level of probability. $M_0$ = No mulch, $M_1$= Water hyacinth, $M_2$ = Rice straw, $M_3$= Black polythene, $T_0$ = Control, $T_1$ = Boron (3 kg/ha), $T_2$= Zinc (2 kg/ha), $T_3$= Boron +Zinc (3+2) kg/ha

Table 2. Effects of mulching on growth yield and quality contributing characters of carrot

| Treatment | Root length (cm) | Root diameter (cm) | Cracked root (%) | Branched root (%) |
|---|---|---|---|---|
| $M_0$ | 10.217 | 2.1075 | 11.89 | 22.896 |
| $M_1$ | 12.569 | 2.7858 | 7.44 | 14.164 |
| $M_2$ | 11.959 | 2.6083 | 7.90 | 17.328 |
| $M_3$ | 13.503 | 3.0392 | 5.19 | 11.95 |
| LSD (5%) | 0.251 | 0.148 | 0.197 | 0.218 |
| LSD (1%) | 0.3808 | 0.2243 | .2294 | 0.3142 |
| Level of significance | ** | ** | ** | ** |

** = Significant at 1% level of probability. $M_0$ = No mulch, $M_1$= Water hyacinth, $M_2$ = Rice straw, $M_3$= Black polythene

Table 3. Effects of micronutrients on growth yield and quality contributing characters of carrot

| Treatment | Root length (cm) | Root diameter (cm) | Cracked root (%) | Branched root % |
|---|---|---|---|---|
| $T_0$ | 9.586 | 1.8425 | 12.55 | 25.238 |
| $T_1$ | 12.006 | 2.6775 | 8.96 | 15.994 |
| $T_2$ | 12.401 | 2.8208 | 7.62 | 14.194 |
| $T_3$ | 14.257 | 3.2 | 3.29 | 10.912 |
| LSD (5%) | 0.1947 | 0.1087 | 0.1503 | 0.1374 |
| LSD (1%) | 0.2638 | 0.1473 | 0.1832 | 0.1724 |
| Level of significance | ** | ** | ** | ** |

** = Significant at 1% level of probability. To =Control, $T_1$ = Boron (3 kg/ha), $T_2$= Zinc (2 kg/ha), $T_3$= Boron +Zinc (3+2) Kg/ha

Table 4. Effects of mulching on growth yield and quality contributing characters of carrot

| Treatment | Fresh weight of leaf (g) | Dry matter of leaf (%( | Fresh weight of root(g) | Dry matter of root (%) |
|---|---|---|---|---|
| $M_0$ | 127.83 | 8.998 | 183.25 | 14.384 |
| $M_1$ | 146.92 | 11.222 | 208.42 | 18.508 |
| $M_2$ | 140.75 | 10.643 | 201.08 | 17.452 |
| $M_3$ | 153.67 | 12.259 | 220.17 | 19.611 |
| LSD (5%) | 1.8099 | 0.071 | 0.7014 | 0.1184 |
| LSD (1%) | 2.6031 | 0.1021 | 1.0628 | 0.1703 |
| Level of significance | ** | ** | ** | ** |

** = Significant at 1% level of probability. $M_0$ = No mulch, $M_1$= Water hyacinth, $M_2$ = Rice straw, $M_3$= Black polythene

Table 5. Effects of micronutrients on growth yield and quality contributing characters of carrot

| Treatment | Fresh weight of leaf (g) | Dry weight of leaf (%) | Fresh weight of root (g) | Dry weight of root (%) |
|---|---|---|---|---|
| $T_0$ | 123.25 | 8.46 | 177.92 | 13.578 |
| $T_1$ | 142.33 | 10.797 | 202 | 17.698 |
| $T_2$ | 146 | 11.255 | 207.08 | 18.437 |
| $T_3$ | 157.58 | 12.611 | 225.92 | 20.242 |
| LSD (5%) | 1.3732 | 0.073 | 0.6951 | 0.0572 |
| LSD (1%) | 1.7227 | 0.0916 | 0.942 | 0.0718 |
| Level of significance | ** | ** | ** | ** |

** = Significant at 1% level of probability. $T_0$ = Control, $T_1$ = Boron (3 kg/ha), $T_2$= Zinc (2 kg/ha), $T_3$= Boron +Zinc (3+2) kg/ha

Table 6. Combined effect of different mulches and micronutrients on growth yield and quality contributing characters of carrot at different days after sowing (DAS)

| Treatment (mulch × micronutrient) | RL (cm) | RD (cm) | CR (%) | BR (%) | GY (kg/plot) | MY (kg/plot) | FLW (g) | DLW (%) | FWR (g) | DWR (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| $M_0T_0$ | 8.94 | 1.51 | 14.15 | 28.24 | 1.06 | 1.02 | 116.00 | 7.873 | 170.33 | 12.19 |
| $M_0T_1$ | 10.06 | 1.97 | 12.24 | 23.11 | 1.42 | 1.33 | 119.00 | 8.78 | 182.33 | 14.2 |
| $M_0T_2$ | 10.5 | 2.27 | 11.32 | 21.12 | 1.603 | 1.48 | 123.33 | 9.12 | 185.33 | 14.91 |
| $M_0T_3$ | 11.36 | 2.66 | 9.85 | 19.103 | 1.88 | 1.723 | 126.67 | 10.21 | 195 | 16.22 |
| $M_1T_0$ | 9.497 | 1.82 | 12.51 | 25.02 | 1.3133 | 1.21 | 130.33 | 8.217 | 177.67 | 13.53 |
| $M_1T_1$ | 12.6 | 2.92 | 9.11 | 12.2 | 2.46 | 2.2 | 134.67 | 11.44 | 208 | 19.27 |
| $M_1T_2$ | 12.97 | 3.01 | 7.07 | 11.27 | 2.73 | 2.55 | 138.33 | 12.01 | 212.67 | 19.7 |
| $M_1T_3$ | 15.20 | 3.39 | 1.09 | 8.16 | 3.55 | 3.28 | 139.67 | 13.22 | 235.33 | 21.52 |
| $M_2T_0$ | 9.187 | 1.62 | 13.14 | 27.08 | 1.22 | 1.10 | 143.33 | 7.99 | 172.33 | 12.98 |
| $M_2T_1$ | 11.83 | 2.72 | 8.26 | 18.51 | 2.05 | 2.0 | 148.33 | 10.55 | 198 | 17.20 |
| $M_2T_2$ | 12.22 | 2.84 | 7.99 | 15.21 | 2.22 | 2.09 | 152.00 | 11.01 | 202 | 18.51 |
| $M_2T_3$ | 14.59 | 3.24 | 2.2 | 8.5 | 3.27 | 3.14 | 154.67 | 13.01 | 232 | 21.11 |
| $M_3T_0$ | 10.72 | 2.42 | 10.4 | 20.60 | 1.75 | 1.54 | 158.33 | 9.76 | 191.33 | 15.6 |
| $M_3T_1$ | 13.53 | 3.08 | 6.23 | 10.15 | 2.95 | 2.7067 | 161.00 | 12.41 | 219.67 | 20.12 |
| $M_3T_2$ | 13.9 | 3.15 | 4.11 | 9.163 | 3.11 | 2.99 | 164.00 | 12.86 | 228.33 | 20.61 |
| $M_3T_3$ | 15.86 | 3.5 | 0.02 | 7.88 | 3.98 | 3.84 | 167.00 | 13.99 | 241.33 | 22.10 |
| LSD (5%) | 0.389 | 0.38 | 0.31 | 0.37 | 0.13 | 0.081 | 3.78 | 0.20 | 1.39 | 0.08 |
| LSD (1%) | 0.52 | 0.29 | 0.41 | 0.44 | 0.18 | 1.51 | 4.48 | 0.23 | 1.88 | 0.18 |
| Level of significance | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |

RL: root length, RD: root diameter, CR: cracked root, BR: branched root, GY: gross yield, MY: marketable yield, FLW: Fresh leaf weight, DLW: dry weight of leaf, FWR: fresh weight of root, DWR: dry weight of leaf; ** = Significant at 1% level of probability. $M_0$ = No mulch, $M_1$= Water hyacinth, $M_2$ = Rice straw, $M_3$= Black polythene, $T_0$ = Control, $T_1$ = Boron (3 kg/ha), $T_2$= Zinc (2 kg/ha), $T_3$= Boron +Zinc (3+2) kg/ha

### 3.7. Fresh weight of leaves

The maximum fresh weight of leaves (153.67 g) was found from black polythene followed by the treatment water hyacinth (146.92 g) and the minimum significant fresh weight (127.83 g) of leaves was recorded with the no mulch treatment (Table 4). The results obtained are in similarity with the findings of Jaysawal *et al*., (2018). The highest fresh weight of leaves (157.58 g) was found from $T_3$ (boron+ zinc) treatment followed by the $T_2$ treatment (146 g) and the lowest fresh weight of leaves (123.25 g) was found from control (Table 5). A significant interaction effect on different micronutrients and mulching was found on fresh weight of leaves per plant. The maximum weight of leaves per plant (167g) was obtained from black polythene with (boron+ zinc) combination, whereas the minimum (116g) fresh weight of leaves was resulted from no mulch and control treatment combination (Table 6).

### 3.8. Dry matter of leaves

The black polythene treatment gave the highest (12.259%) the percentage of dry matter in leaves and lowest dry matter percentage of leaves (8.99%) was obtained from the no mulch treatment (Table 4). The results obtained are in similarity with the findings of Jaysawal *et al*., (2018). The (boron+ zinc) treatment gave the highest (12.61%) percentage of dry matter in leaves followed by $T_2$ treatment (11.255%) and lowest dry matter percentage of leaves (8.46%) was obtained from control treatment (Table 5). The interaction effects of different micronutrients and mulches were not significant. The highest dry matter percentage of leaves per plant (13.99%) was obtained from the treatment combination of black polythene with (boron+ zinc) ($M_3T_3$). Whereas, the lowest dry matter percentage of leaves per plant (7.87%) was obtained from the no mulch and control ($M_0T_0$) treatment (Table 6).

### 3.9. Fresh weight of root

The highest significant fresh weight of root (220.17 g) was found with black polythene treatment followed by water hyacinth (208.42 g). The results obtained are in similarity with the findings of Jaysawal *et al*., (2018). The lowest fresh weight of individual root (183.25g) was produced by the control treatment (Table 4). On the other hand, micronutrients exhibited a significant variation in fresh weight of root. The highest significant fresh weight of root (225.92g) found in $T_3$ treatment followed by $T_2$ (207.08 g) and the lowest fresh weight of individual root (177.92g) produced by the control treatment (Table 5). The combined effect on fresh weight of root per plant was also significant due to different micronutrients and mulch treatments. The maximum fresh weight of root per plant (241.33g) was observed in the treatment combination of black polythene and (boron+ zinc) treatment ($M_3T_3$). The lowest fresh weight of root per plant (170.33 g) was obtained from no mulch and control ($M_0T_0$) treatment (Table 6). This might be caused that mulching suppressed weeds, protect the deterioration of soil structure also influences the nutrient retention of soil and the influence of organic mulch on production of carrot under the climate-ecological conditions. The main role of organic mulches in vegetable crops cultivation is to protect the soil surface from the influence of adverse condition and to improve the growing conditions for the crop plants.

### 3.10. Dry matter of root

Black polythene treatment showed superiority over the control treatment in respect of percent dry matter of root. Black polythene treatment produced the highest root dry matter (19.61%) followed by water hyacinth (18.508%). The results obtained are in similarity with the findings of Jaysawal *et al*., (2018). Whereas the no mulch treatment produced the lowest root dry matter (14.38%) (Table 4). (boron+ zinc) treatment produced the highest root dry matter (20.24%) followed by (18.43%) and the lowest percent dry matter of root (13.57%) was produced by control treatment (Table 5). The combined effect of different fertilizers and mulches was significant. The highest root dry matter (22.107%) and the lowest root dry matter (12.193%) were found in the treatment combination of black polythene with (boron+ zinc) ($M_3T_3$) and treatment combination of no mulch and control treatment ($M_0T_0$) respectively (Table 6).

### 3.11. Gross yield of root

Black polythene treatment produced maximum gross yield per plot (2.94 kg) followed by water hyacinth (2.51 kg) and rice straw (2.19 kg) and the lowest gross yield per plot (1.49 kg) was recorded in no mulch treatment (**Figure 5**). Mazed *et al.* (2015) and Jaysawal *et al*., (2018) also found that highest gross yield (39.12 t/ha) were obtained from black polythene mulch while the lowest obtained from control treatment. Black polythene gives the highest result and control treatment gives the lowest result on growth and yield of carrot and it is occurred due to better moisture utilization by checking evaporation loss and fall of soil temperature during winter and lesser competition of weeds. The variation due to the effect of different micronutrients in respect of marketable yield of roots kg/plot and per hectare was highly significant. The maximum gross yield of carrot was obtained from the (boron+ zinc) treatment (3.17kg) while the minimum (1.33 kg) gross yield was recorded from Control treatment (Figure 6). Mohanta *et al.* (2013) found that integrated effect of boron and zinc produced huge gross yield. In combination effect, it was found that black polythene and (boron+ zinc) ($M_3T_3$) treatment produced highest gross yield of root per plot (3.98 kg) while the minimum gross yield of root per plot (1.06 kg) from the no mulch with control treatment ($M_0T_0$) (Table 6). The highest yield with combined effect of mulching and micronutrients also reported by Islam *et al.* (2014). Most similar findings have also obtained from Olfati *et al.* (2008).

### 3.12. Marketable yield of root

There were significant variations due to the effect of different mulches in respect of marketable yield of roots kg/plot and per hectare. The highest marketable yield of roots (2.77 kg/plot) was obtained from the application of Black polythene treatment followed by the application of water hyacinth (2.33 kg/plot) and the lowest marketable yield (1.39 kg/plot) was obtained from control treatment (Figure 7). The present findings are similar to the results as replied by Biswas et al. (2019). The variation due to the effect of different micronutrient in respect of marketable yield of roots kg/plot was highly significant. The highest marketable yield of roots (3.008 kg/plot) was obtained from the application of (boron+zinc) micronutrient treatment followed by the application of $T_2$ (2.28kg/plot) and the lowest yield from Control treatment (1.22kg/plot) (Figure 8). A Significant variation was found in marketable yields of carrot root per plot and per hectare due to interaction and combined effects of different mulching and micronutrients treatment. The highest marketable yield (3.84 kg/ha) were produced by the treatment combination of black polythene with (boron+ zinc) treatment ($M_3T_3$). The lowest marketable yield (1.02 kg/ha) were produced by the treatment combination no mulch with control treatment (Table 6).

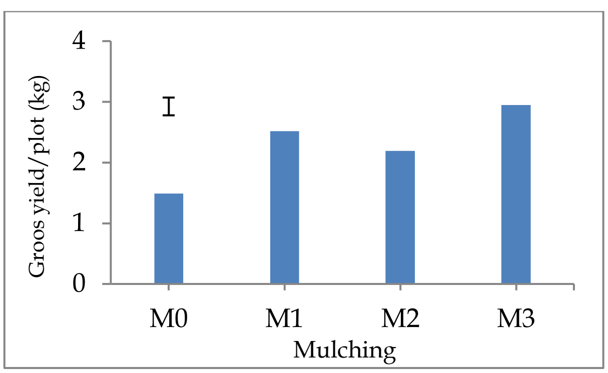


Figure 5. Effect of different mulching on number of gross yield of carrot. Vertical bars indicate LSD at 1% level of probability. M0 = No mulch, M1= Water hyacinth, M2 = Rice straw, M3= Black polythene

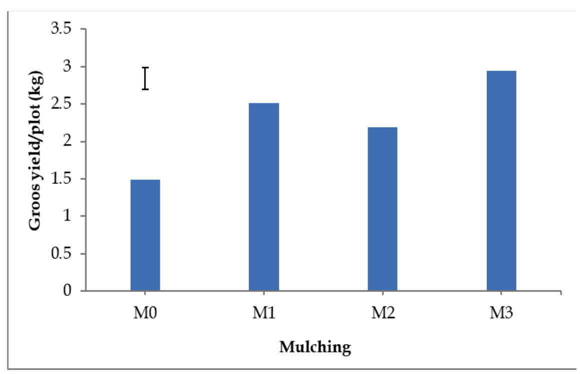


Figure 6. Effect of micronutrients on gross yield of carrot. The vertical bars indicate LSD at 1% level of probability. Here, T0 = Control T1 = Boron (3 kg/ha), T2= Zinc (2 kg/ha), T3= Boron +Zinc (3+2) kg/ha

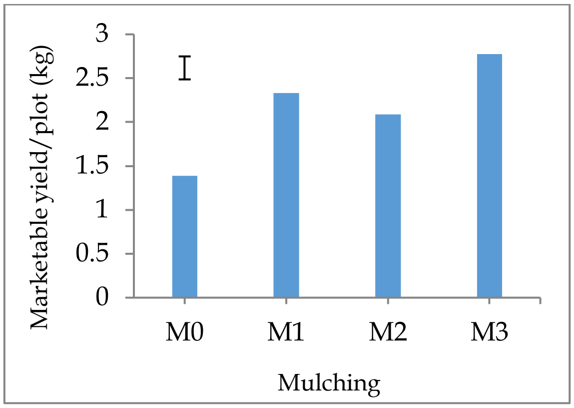


Figure 7. Effect of different mulching on number of marketable yield of carrot. Vertical bars indicate LSD at 1% level of probability. M0 = No mulch, M1= Water hyacinth, M2 = Rice straw, M3= Black polythene

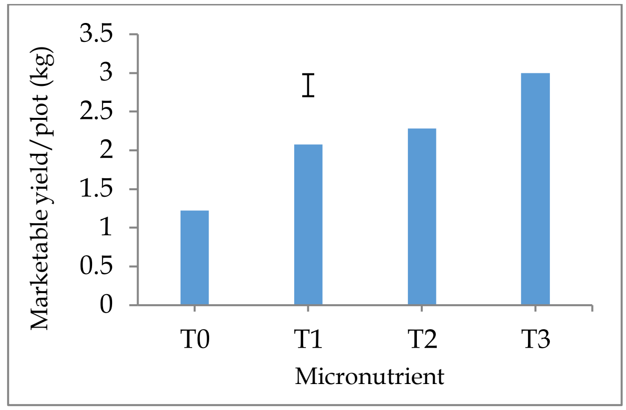


Figure 8, Effect of micronutrients on marketable yield of carrot. Vertical bars indicate LSD at 1% level of probability. T0 =Control, T1 = Boron (3 kg/ha), T2= Zinc (2 kg/ha), T3= Boron +Zinc (3+2) kg/ha

## 4. Conclusion

Different mulching significantly influenced all the parameters studied. Different level of micronutrients played an important role on yield contributing characters and yield of carrot. Due to water absorbance efficiency and weed control purposes, the appropriate combination of mulching and micronutrients varies according to the system of land use, ecological, social and economic conditions. Growth parameter such as plant height, number of leaves, root length and root diameter of leaves were responsive to mulching application and micronutrients effects. Yield was highly responded to boron as well as zinc, hence judicial application of boron and zinc may provide higher yield. In this experiment, the highest yield (44.92 t/ha) was obtained from the treatment combination of black polythene and (boron+ zinc) micronutrient ($M_3T_3$). On the other hand, the lowest yield (37.56 t/ha) was found from the treatment combination of $M_0T_0$ (control treatment) because it is very useful for soil moisture conservation, temperature moderation, soil health maintenance, and weed management. Therefore, it enhances growth and yield of fruit. The overall work concluded that an effective combination strategy of using mulching and micronutrients might be salutary of increasing the yield of carrot.

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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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