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Effects of cultivation method and fertilizer management on the growth and yield of carrot

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ABSTRACT

An experiment was conducted at the Horticulture Farm of the Bangladesh Agricultural University, Mymensingh during winter season to study the effects of different cultivation methods and fertilizer management practices on the growth and yield of carrot. The experiment consisted of three cultivation methods, viz. flat, ridge and deep spading and six fertilizer doses, viz., (i) cowdung @ 9 t/ha, (ii) poultry manure @ 5.63 t/ha, (iii) Urea-TSP-MP @ 195-132-120 kg/ha, (iv) Urea-TSP-MP-Gypsum @ 195-132-120-89 kg/ha, (v) Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha, (vi) Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha. The experiment was laid out in split plot design with 18 treatment combinations and three replications. The results revealed that plant height, fresh weight of roots and leaves, root length, percent dry matter of roots and leaves, cracked roots and branched roots and gross and marketable yields were influenced significantly by different cultivation methods. Similarly, fertilizer doses had significant influence on all of the aforesaid characters along with number of leaves and root diameter. The ridge cultivation method produced the maximum gross (34.29 t/ha) and marketable (30.69 t/ha) yields of carrot. The minimum gross (29.18 t/ha) and marketable (26.24 t/ha) yields were obtained from deep spading method. The use of Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha fertilizers produced maximum gross (36.41 t/ha) and marketable (33.20 t/ha) yields of carrot whereas the minimum gross (26.09 t/ha) and marketable yields (23.45 t/ha) were found from the treatment of cowdung @ 9 t/ha. A significant interaction effect between different cultivation methods and fertilizer management were observed for all the parameters studied except for number of leaves, root length, diameter of roots, dry matter content of root and marketable yield but their combined effects were significant on all parameters. Regarding the combined effects, the maximum gross (38.53 t/ha) and marketable (35.80 t/ha) yields of carrot were obtained from the ridge method of cultivation and application of Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha fertilizers with a maximum net return of Tk. 154516.00 per hectare and benefit cost ratio of 4.64.

Key words: *Daucus carota* L., branched root, rotten root, cracked root, dry matter, gross yield, benefit cost ratio.

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INTRODUCTION

Carrot *(Daucus carota* L.) ranks among the top-ten most economically important vegetable crops in the world, in terms of both area of production and market value (FAOSTAT, 2012; Fontes and Vilela, 2003). It contains higher amount of carotenoids, thiamin and riboflavin (Sharfuddin and Siddique, 1985). It is also an excellent source of iron, vitamin-B, vitamin-C and sugar (Yawalkar, 1985). In Bangladesh carrot cultivation area is 846 ha and production is 6350 t with an average yield of 7.5 t/ha (BBS, 2005). The production is lower compared to other carrot growing countries such as Switzerland, Denmark, Sweden, United Kingdom, Australia and Israel, where the average yield per hectare are 40.9-42.7, 51.9, 54.9, 56.7 and 64.2 t, respectively (FAO, 2000). There are several factors limiting this lower carrot yield in Bangladesh such as high yielding variety, ideal soil type, and improved cultural and management practices. Among the cultivation practices planting methods and fertilizer doses greatly affect both growth and yield of carrot. But

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in Bangladesh farmers usually grow carrot following indigenous methods and improper fertilizer doses, which lead to poor yield.

There are several methods of carrot cultivation generally practiced by the farmers such as ridge and furrow, flat, spaded etc. It was found that cultivation of carrot in ridge method resulted in greater weight of individual root as well as total yield compared to that of flat method (Abdel, 1973). Ridge method favors more root spreading and formation of big tuberous roots with increased diameter. It was also reported an increase of 15% of total yield and 19% marketable yield in ridge method than that of flat one (Nikolov and Savov, 1973). Spading is another important practice for carrot production in Bangladesh, while deep spading improves the physical, chemical and biological properties of soil. It decreases the weed infestation and helps in absorbing plant nutrients and encourages the movement of air in the soil. Deep spading is an important consideration for quality carrot production.

On the other hand, vegetative growth and root yield of carrot require an optimum supply of manures and chemical fertilizers. Fertilization has a potential role on growth and yield of carrot, but indiscriminate use of fertilizers changes the physical, chemical and biological properties of soil which in turn creates problem to the environment and health hazard due to toxic residual effects. Therefore, judicious uses of manures and fertilizers help improving soil texture, structure, aeration, humus content, moisture holding capacity and microbial activities of soil. Organic matter content of Bangladesh soil is below 1% in about 60% cultivable land as compared to an ideal minimum value of 4%. In the area of continues cropping, organic matter supply to soil through cowdung, compost, green manure etc. are provided only to a minimum extent (Islam and Hossain, 1992). Therefore, present study was undertaken to study the growth and yield of carrot under different cultivation methods and fertilizers doses. The experimental results will also be compared to find out the best combination of cultivation method and fertilizer management which lead to increased yield and economic return of carrot.

MATERIALS AND METHODS

Study area

The experiment was carried out at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh, Bangladesh. The site of the experiment is situated between 24°75" N latitude and 90°50" E longitude at the elevation of 18 m above the sea level. The soil of the experimental plot was silty loam in texture belonging to the Old Brahmaputra Brahmaputra Flood plain under the Agro-Ecological Zone 9 having non calcareous dark grey flood plain soil (FAO and UNDP, 1988). The land was medium high and had adequate irrigation facilities and good drainage system having a soil pH of 6.6 which is suitable for carrot cultivation (Gupta and Chipman, 1976). The characteristics of the soil under the experimental plot at a depth of 0-30 cm were analyzed in the Humboldt Soil testing Laboratory, Department of Soil Science, Bangladesh Agricultural University, Mymensingh. The morphological characteristics of the soil of the experimental land as indicated by FAO (1988) are as AEZ - Old Brahmaputra Flood Plain, Soil series - Sonatola Series, General soil - Non calcareous dark grey, and Parent material - Old Brahmaputra River-borne Deposits. The geographic position of the experimental site is in the sub-tropical zone, characterized by heavy rainfall during kharif season (April to September), and scanty rainfall during the rest period of the year i.e. during Rabi season (October to March). Rabi season is characterized by comparatively low temperature and plenty of sunshine.

Planting materials

A Japanese carrot variety (*Daucus carota* L. cv. SB Kuroda) was used in this experiment. It is an improved variety having deep orange red color inside. Storage roots become 18-20 cm long, smooth and uniform. It is a well adapted carrot variety to warm growing areas. The seeds were collected from Takii & Co. Ltd., Kyoto, Japan.

Cultivation procedures

The selected land for the experiment was first opened by disc plough with the help of a tractor and then it was kept open to sun for seven days prior to next ploughing. After discing the land was ploughed and cross ploughed six times with the

help of a power tiller. Deep ploughing was done to have good tilth which was necessary to get better yield of the crop (Ahmed, 1969). Each ploughing was followed by laddering to break up the soil clods into pieces and to level the soil surface. All weeds and stubbles were removed from the plot before sowing seeds and Darsban 20 EC at the rate of 1.235 L/ha were mixed with soil of plots as protective measure against ants and caterpillar.

A two factorial experiment was laid out following split plot design with three replications. Each block was first divided into three main plots which were then splited into six sub-plots. Cultivation methods were assigned to the main plots and fertilizer was assigned to sub-plots. The cultivation methods and fertilizer doses were randomly assigned to the main plots and sub-plots, respectively. Thus, there were 18 main plots and 54 (6 × 3 × 3) unit plots in total. The size of each unit plot was 1.0 m × 1.0 m = 1.0 m^2. The space between two plots was 0.5 m and between blocks was 1.0 m. The total area of the experimental plot was 142.5 (15 m × 9.5 m) m^2.

The seeds were soaked in water for 24 hours and then wrapped with a piece of the cloth for 4 hours prior to sowing. Then they were spread over a polythene sheet for 2 hours to dry the surface water. This treatment was given for quick germination of seeds. Carrot seeds was sown at the rate 3 kg/ha (Rikabdar, 2000). Small holes of about 1.5 cm depth were made at a distance of 10 cm along the rows spaced at a distance of 25 cm. There were 40 holes in each plot and 3-4 seeds were placed in each hole. After sowing, the seeds were covered with loose soil.

The experiment consisted of three cultivation methods, viz., flat method, ridge method and deep spading method; and six combinations of fertilizers viz., cowdung @ 9 t/ha, poultry manure @ 5.63 t/ha, Urea-TSP-MP @ 195-132-120 kg/ha, Urea-TSP-MP-Gypsum @ 195-132-120-89 kg/ha, Urea-TSP-MP-Gypsum-Borax@ 195-132-120-89-10kg/ha, and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10- 20 kg/ha. A general application of cowdung @ 3 t/ha was applied during initial land preparation. The entire quantity of cowdung, poultry manure, TSP, half amount of urea, MP and other fertilizer as per treatment were applied at time of final land preparation. One fourth of urea was applied at 10-12 days of seedling emergence and the remaining one fourth of urea and rest MP were applied at 35-40 days of seedling emergence. In selected plot as per layout of the experiment, ridges were made after fertilizer application and before sowing of seeds with the help of a spade. Height of each ridge was kept 12-15 cm.

Emergence of seedling started after 7 days after sowing (DAS). Seedlings were thinned out two times. First thinning was done at 20 DAS leaving two seedlings in each hill. The second thinning was done after another 10 days keeping only one healthy seedling in each hill. Weeding was done as and when necessary with the help of *khurpi*. Generally weeding was done four times in plots to keep the plots free from weeds. The experimental crop was attacked by mole cricket, field cricket and cutworm during the early growing stages of seedling. As a preventive measure against the insect pests Darsban 20 EC was applied at the rate of 1.235 L/ha at 15 days interval for two months. The crop was disease free and no fungicide was used. The irrigation was given in the experimental plots as per treatment started from 40 DAS. All other subsequent irrigations in these plots were made at an interval of 15 days and continued until 15 days before harvest. Irrigation was made in such a way that sufficient water reached the root zone. Irrigation was given by watering cane. Loosening (natural mulch) of soil was done with the help of a *khurpi* after irrigation when upper layer of the soil started to form crust.

Measurement of growth and yield parameter of carrot

Ten plants were selected at random and uprooted very carefully from each plot and mean data on plant height (cm), number of leaves per plant, root length per plant (cm), diameter of root per plant (cm), root fresh weight per plant (g), leaves fresh weight per plant (g), dry matter of root (%), dry matter of leaves (%), cracked root (%), rotten root (%), branched root (%), gross yield of root per plot (kg), gross yield of root per hectare (ton), and marketable yield of root per hectare (ton).
Immediately after harvest, the roots were cleaned thoroughly by washing with water. Then from

several roots, a sample of 100 g was taken and made into small pieces. The small pieces were sun dried for 3 days, and then oven dried for 72 hours at 72-80 °C. Immediately after oven drying the dried root pieces were weighed, and the dry matter content of the root was calculated by the following formula:

$$\% \text{ Dry weight of root} = \frac{\text{Dry weight of root}}{\text{Fresh weight of root}} \times 100$$

Similarly, leaves sample weighing 100 g were taken and cut into small pieces at harvest. After sun drying for 3 days, the samples were oven dried at 72-80 °C for 72 hours. Then with an electrical balance leaves were weighed. The dry matter content of leaves was calculated on percentage basis by using the following formula.

$$\% \text{ Dry matter of leaf} = \frac{\text{Dry weight of leaf}}{\text{Fresh weight of leaf}} \times 100$$

At harvest the number of cracked carrot roots was counted. The result was calculated on percentage basis according to the following formula:

$$\% \text{ Cracked root} = \frac{\text{Number of cracked roots}}{\text{Number of total roots}} \times 100$$

At harvest the number of rotten roots was counted and the result was calculated on percentage basis as per the following formula:

$$\% \text{ Rotten root} = \frac{\text{Number of rotten roots}}{\text{Number of total roots}} \times 100$$

At harvest, number of branched roots was counted and percent branched roots were calculated by the following formula:

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

Statistical analysis

The calculated data on various parameters under study were statistically analyzed using MSTATC statistical package program. The means for all the treatments were calculated and analyses of variance for all the characters under consideration were performed by 'F' variance test. The mean differences were adjusted with Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Cost and return analysis

The cost and return analysis in the details was done according to the procedure of Alam *et al.* (1989). The material, non-material and overhead costs were recorded for all the treatments and calculated per hectare basis. The farm gate price of carrot root (marketable yield) was taken into consideration for cost return analysis.

RESULTS AND DISCUSSION

Effect of cultivation methods and fertilizer management on the growth of carrot

Plant height of carrot

The plant height at different stages of growth was recorded after 45, 60, 75 and 90 DAS had significant influence on carrot plant growth in different cultivation methods (Fig. 1). At 90 DAS the highest plant height (63.8 cm) was found when grown on ridge method, while flat method produced lowest plant height (62.4 cm). This was possibly due to proper growth of the root system under loosened soil provided by ridge method of cultivation, which might encourage more vegetative foliage growth of carrot. Results revealed that there was significant difference between different fertilizers management practices at different stages of plant growth (Fig. 2). The tallest plant height was (66.9 cm) and the shortest was (60.0 cm) at 90 DAS when the treatment Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha and cowdung @ 9 t/ha were applied, respectively. The interaction effects of cultivation method and fertilizer management practices were from significant at different stages of plant growth (Table 1). The highest plant height (68.7 cm) was recorded from the combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha while the shortest plant height (59.6 cm) was found from combination of deep spading and cowdung @ 9 t/ha at 90 DAS. This might be due to the balanced supply of plant nutrients which provided better soil condition as well as more vegetative growth and development.

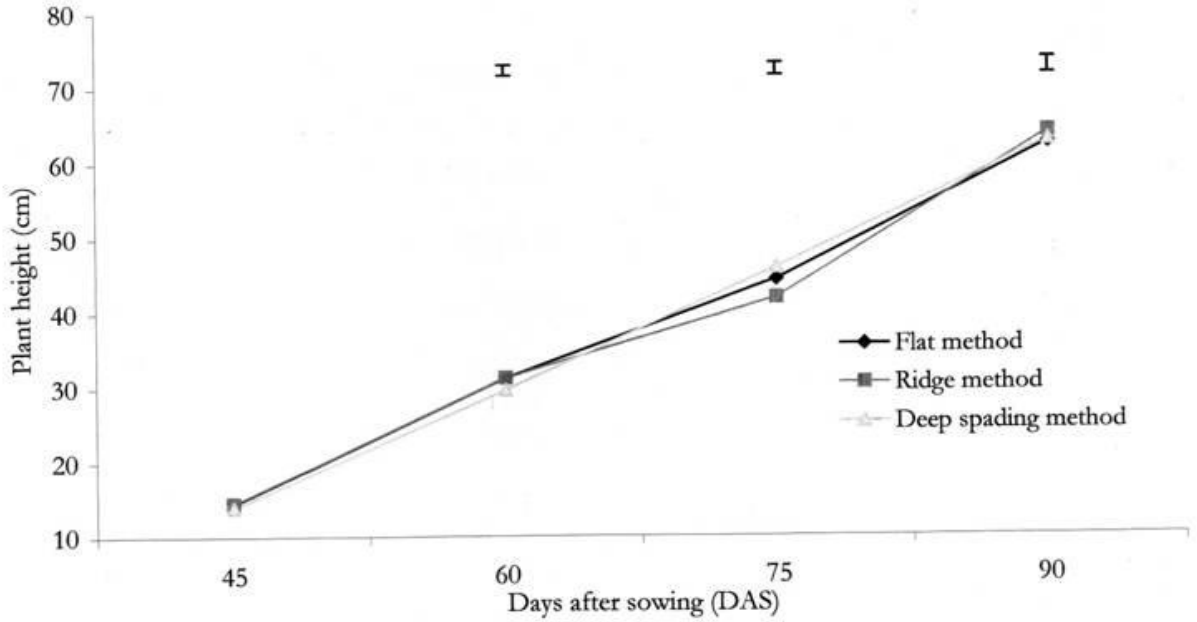

Fig.1 Effect of cultivation method on plant height of carrot at different days after sowing. Vertical bars represent the LSD values at 5% level of probability;

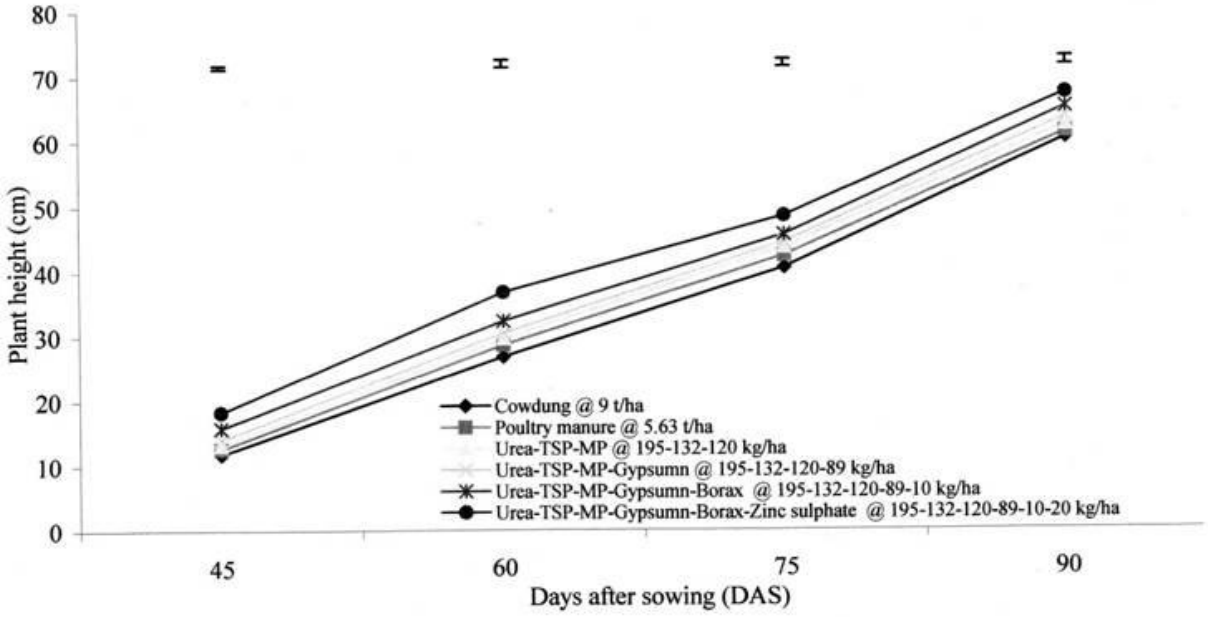

Fig.2 Effect of fertilizer management on plant height of carrot at different days after sowing. Vertical bars represent the LSD values at 5% level of probability.

Table 1
Interaction effect of different cultivation methods and fertilizer management on plant height and number of leaves per plant in carrot at different days after sowing.

Interaction[z]	Plant height (cm) at				Number of leaves per plant at			
	45 DAS[y]	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P_1T_1	11.96ij	26.90jk	39.41j	60.08gh	4.03	7.61defg	8.97d	12.19c
P_1T_2	12.73gh	29.19h	41.76h	60.82fgh	4.40	8.34bc	9.60cd	13.47bc
P_1T_3	13.06fg	30.70fg	43.72g	61.44efg	4.63	8.20bc	10.31bc	12.82c
P_1T4	13.50f	31.40ef	44.41efg	62.36ef	4.73	8.39bc	10.66bc	13.40bc
$P1T_5$	17.13c	32.93d	45.34def	62.86de	4.90	8.48b	11.37b	14.80b
P_1T_6	17.90b	35.78b	50.61a	66.59b	5.20	8.59b	12.24ab	14.83b
P_2T_1	11.80ij	27.4lij	37.39k	60.41gh	4.34	7.61defg	10.31be	12.60c
P_2T_2	12.73gh	28.81hi	39.88ij	61.43efg	5.06	8.38bc	10.62be	12.95c
P_2T_3	13.43f	29.31gh	41.12hi	62.37ef	4.76	8.14bcde	10.84be	13.14bc
P_2T_4	14.46e	29.75gh	42.29h	62.87e	5.39	8.32bc	11.57b	13.52bc
P_2T_5	15.13d	32.21de	43.79g	66.85b	4.86	8.57bc	12.24ab	15.63ab
P_2T_6	19.23a	39.53a	46.17cd	68.65a	5.46	9.29a	13.20a	16.47a
P_3T_1	11.56J	25.63k	44.07fg	59.56h	4.30	7.28fg	8.48d	11.10cd
P_3T_2	12.30hi	27.47ij	44.78defg	60.37gh	4.43	7.08g	10.14bc	12.90c
P_3T_3	12.96fgh	28.54hi	45.50cde	62.20ef	4.53	7.55efg	11.04d	12.96c
P_3T_4	14.20e	29.98fgh	45.92cd	64.37cd	4.40	7.78cdef	11.44d	13.38bc
P_3T_5	15.13d	31.41ef	46.84bc	64.50ce	5.23	8.48b	12.19ab	13.68bc
P_3T_6	17.56bc	34.42c	47.88b	65.46bc	5.22	8.8 lab	12.27ab	14.35a

[z]Cultivation methods include - PI : Flat method, P_2 : Ridge method, and P_3 : Deep spading method; and Fertilizer management include - TI : Cowdung @ 9 t/ha, T_2 : Poultry manure @ 5.63 t/ha, T_3: Urea-TSP-MP @ 195-132-120 kg/ha, T_4 : Urea-TSP-MP-Gypsum @ 195-132-120-89 kg/ha, T_5: Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha, and T_6 : Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha.
[y]Days after sowing
[x]Means followed by different letter(s) differ significantly following Duncan's Multiple Range Test at 5% level.

Number of leaves per plant

Number of leaves showed significant variation due to the different cultivation methods only at 90 DAS (Fig. 3). Ridge method provided maximum number of leaves per plant (14.1) while deep spading produced minimum number of leaves per plant (13.1) at 90 DAS. The increased number of leaves in ridge method was probably due to the fact that crop of this system got more loose and friable soil around root system for their luxuriant growth resulting production of more number of leaves. Similar result was found in sweet potato following ridge method of cultivation (Bhuiyan and Chowdhury, 1984). Different fertilizer treatments exhibited significant variation in respect of number of leaves per plant at different growth stages of crops (Fig. 4). It was found that the number of leaves gradually increased with the advancement of time but started decreasing towards harvesting time when ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha was applied. The ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha produced the maximum number of leaves per plant (15.2), while cowdung @ 9 t/ha produced the minimum number of leaves per plant (12.0) at 90 DAS. Combined effects of cultivation method and fertilizer management practices was significant at 60, 75 and 90 DAS while interaction effect between the same was found significant only at 60 DAS (Table 1). The combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha produced maximum (16.5) number of leaves per plant which was statistically similar (15.6) was found from ridge method and Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha. The minimum number of leaves per plant (11.1) was found from the treatment combination of deep spading and cowdung @ 9 t/ha at 90 DAS.

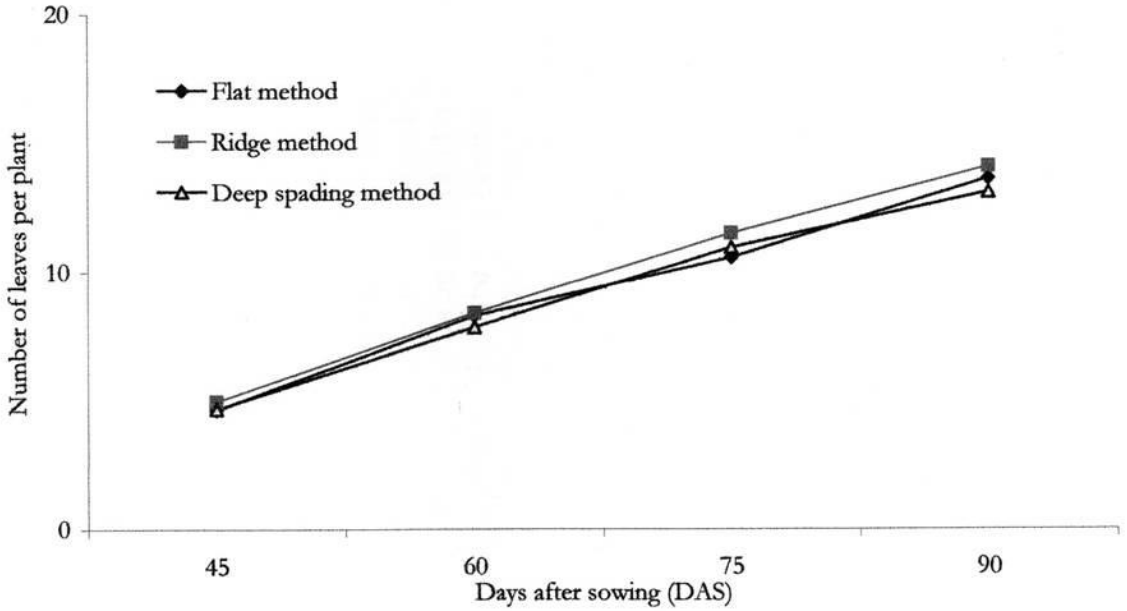

Fig.3 Effect of cultivation method on number of leaves per plant at different days after sowing (DAS). Vertical bars represent the LSD values at 5% level of probability.

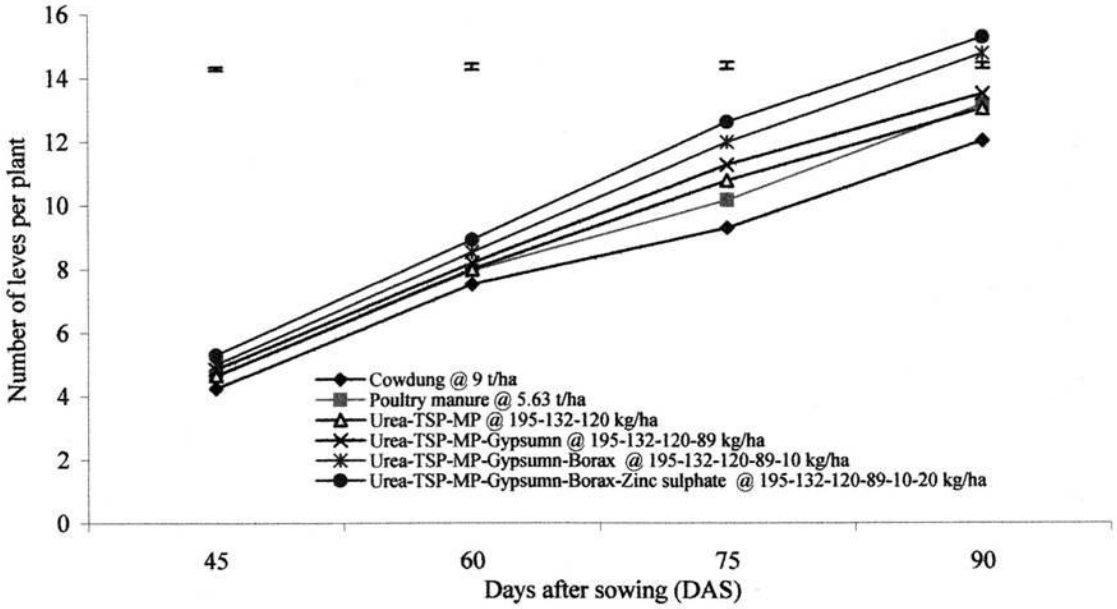

Fig.4. Effect of fertilizer management on number of leaves per plant of carrot at different days after sowing (DAS). Vertical bars represent the LSD values at 5% level of probability.

Table 2
Effects of cultivation methods and fertilizer management on the yield and yield components of carrot

Factors[z]	Dry matter of leave (%)	Root fresh weight/ plant (g)	Leaves fresh weight/ plant (g)	Root length/ plant (cm)	Diameter of root/plant (cm)	Dry matter of root (%)	Branched root (%)	Cracked root (%)	Gross yield of root/plot (kg)	Rotten root (%)	Gross yield of root (t/ha)	Marketable yield of root (t/ha)
Factor A: Cultivation method												
P_1	11.77b[y]	93.94b	80.42b	15.88ab	3.87b	7.75c	5.33a	5.71a	3.00b	6.76a	29.95b	27.55b
P_2	12.63a	101.36a	89.33a	17.24a	4.13a	9.18a	3.42c	3.81b	3.43a	5.95b	34.29a	30.69a
P_3	11.75b	85.28c	73.56c	14.4b	3.65c	8.20b	3.96b	3.86b	2.92c	5.97b	29.18c	26.24c
Factor B: Fertilizer												
T_1	9.41f	75.39f	63.43f	13.84f	323c	6.43e	6.00a	6.57a	2.61f	7.69a	26.01f	23.43f
T_2	10.10e	85.88e	71.23e	14.68e	3.67bc	7.18d	3.33e	3. 11e	2.82e	5.36e	28.21e	25.53e
T_3	11.51d	94.22d	74.33d	15.38d	3.90b	7.67d	3.82d	4.00d	3.03d	5.92d	30.31d	27.22d
T_4	12.14c	98.67c	82.73c	16.18c	3.96b	8.46c	4.31c	4.83c	3.17c	6.60c	31.71c	29.09c
T_5	13.66b	101.33b	93 *22*b	17.02b	4.06ab	9.26b	4.97b	5.27b	3.41b	7.23b	34.11b	30.49b
T_6	15.47a	105.68a	101.67a	17.98a	4.49 a	11.28a	3.00f	2.98e	3.64a	4.54f	36.41a	33.20a

[z]Cultivation methods include - PI : Flat method, P_2 : Ridge method, and P_3 : Deep spading method; and Fertilizer management include - TI : Cowdung @ 9 t/ha, T_2 : Poultry manure @ 5.63 t/ha, T_3: Urea-TSP-MP @ 195-132-120 kg/ha, T_4 : Urea-TSP-MP-Gypsum @ 195-132-120-89 kg/ha, T_5: Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha, and T_6 : Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha.
[y]Means followed by different letter(s) differ significantly following Duncan's Multiple Range Test at 5% level.

Effect of cultivation methods and fertilizer management on the yield and yield components of carrot

Root length per plant

The length of carrot root was found to be statistically significant due to the effect of cultivation method (Table 2). Ridge method of cultivation produced the longest root (17.2 cm) followed by flat method (15.9 cm). The shortest (14.4 cm) length of carrot produced from deep spading method of cultivation. In the ridge method, soil was in loosened condition up to more depth which might increased the root length. A remarkable difference in respect of root length of carrot plant was found significant due to the effect of different fertilizers treatments (Table 2). The maximum root length (18.0 cm) was produced by the plants grown following treatment Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha whereas, the minimum root length (13.8 cm) was found from that of cowdung @ 9 t/ha. Combined effects of cultivation method and fertilizer management practices were found significant, but interaction effect between the same was not significant (Table 3). The longest root (19.9 cm) was obtained from the treatment combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha and shortest (12.5 cm) root was obtained from the combination of deep spading and cowdung @ 9 t/ha.

Diameter of root per plant

Root diameter per plant was found significant due to different fertilizers treatments (Table 2). The maximum root diameter (4.49 cm) was produced by the treatment Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha which was statistically similar (4.06 cm) that of the treatment Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha. The minimum root diameter (4.23 cm) was found from the treatment cowdung @ 9 t/ha. It is evident that interaction effects of cultivation method and fertilizer management practices were not significant but their combined effects were found significant (Table 3). The maximum root diameter (4.99 cm) was recorded from the combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc

Table 3
Interaction effect of different cultivation methods and fertilizer management on the yield and yield components of carrot.

Interaction[z]	Dry matter of leaves (%)	Root fresh weight/ plant (g)	Leaves fresh weight/ plant (g)	Root length/ plant (cm)	Diameter of root/plant (cm)	Dry matter of root (%)	Branched root (%)	Cracked root (%)	Gross yield of root/ plot (kg)	Rotten root (%)	Gross yield of root (t/ha)	Market-able yield of root (t/ha)
P_1T_1	9.07g	75.33 g	66.96gh	14.13d	3.47b	5.83c	7.97a	8.50a	2.54ij	7.83a	25.46ij	22.40h
P_1T_2	10.26f	87.30ef	71.66fg	15.03cd	3.76b	6.83d	2.66h	2.66gh	2.65hi	7.60a	26.56hi	25.73f
P_1T_3	11.55e	93.66d	72.33fg	15.57cd	3.77b	7.10cd	3.10g	2.80gh	2.79gh	5.76fg	27.90gh	26.63ef
P_1T4	11.95dc	98.00 c	82.53d	16.13c	3.92b	7.93cd	3.70f	4.46d	3.03ef	6.10def	30.30ef	28.63de
$P1T_5$	13.41bc	101.00bc	92.33c	16.98c	4.02b	8.63c	3.80ef	4.50cd	3.35d	6.43cde	33.53d	26.56d
P_1T_6	14.35 b	108.33a	96.66c	17.43bc	4.26b	10.16b	4.66d	6.00b	3.59bc	5.30gh	35.96bc	32.33bc
P_2T_1	9.87 fg	87.50 ef	66.66gh	14.91d	3. 20bc	7.06cd	3.66f	2.93fgh	2.83g	5.46fg	28.36g	25.43f
P_2T_2	9.93 fg	92.00 d	78.00de	15.77cd	3.80b	7.53cd	4.06e	3.66ef	3.15e	6.06ef	31.50e	27.56e
P_2T_3	11.46e	102.33 b	80.66 d	16.73c	4.36ab	8.36c	4.50d	6.16b	3.45cd	6.46cde	34.56cd	29.76d
P_2T_4	12.38cd	107.00 a	92.33 c	17.63bc	4.19b	9.16be	5.16c	6.33b	3.56bc	6.96bc	35.60bc	32.00bc
P_2T_5	14.51b	109.33a	105.00b	18.48b	4.25b	10.10b	6.63b	6.66b	3.72ab	7.73a	37.16ab	33.60b
P_2T_6	17.63a	110.00a	113.33a	19.92a	4.99a	12.87a	2.60h	2.40h	3.86a	3.67J	38.53a	35.80a
P_3T_1	9.30fg	63.33h	56.66i	12.47def	3.00c	6.40d	2.73h	3.33efg	2.44 j	7.63a	24.43j	22.46h
P_3T_2	10.10fg	78.33g	64.03h	13.23de	3.43b	7.16cd	3.26g	3.26efg	2.65hi	4.73hi	26.56hi	23.30g
P_3T_3	11.50e	86.66f	70.00fg	13.85de	3.56b	7.53cd	3.86ef	3.03efgh	2.84 g	5.53fg	28.46g	25.26f
P_3T_4	12.09de	91.00de	73.33ef	14.78d	3.75b	8.26c	4.06c	3.70e	2.92fg	6.73cd	29.23fg	26.63ef
P_3T_5	13.06cd	93.66d	82.33d	15.60cd	3.90b	9.03bc	4.46d	4.63cd	3.16e	7.53ab	31.63e	28.30de
P_3T_6	14.41b	98.70be	95.00c	16.59c	4.21b	10.80b	5.36c	5.20c	3.47cd	4.50i	34.73cd	31.46c

[z]Cultivation methods include - PI : Flat method, P_2 : Ridge method, and P_3 : Deep spading method; and Fertilizer management include - TI : Cowdung @ 9 t/ha, T_2 : Poultry manure @ 5.63 t/ha, T_3: Urea-TSP-MP @ 195-132-120 kg/ha, T_4 : Urea-TSP-MP-Gypsum @ 195-132-120-89 kg/ha, T_5: Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha, and T_6 : Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha.
[y]Means followed by different letter(s) differ significantly following Duncan's Multiple Range Test at 5% level.

sulphate @ 195-132-120-89-10-20 kg/ha, which was statistically similar (4.36 cm) was found from combination of ridge method and Urea-TSP-MP @ 195-132-120 k/ha. The minimum root diameter (3.00 cm) was recorded from the treatment combination of deep spading and cowdung @ 9 t/ha.

Root fresh weight per plant

The fresh weight of root per plant differed significantly due to different cultivation methods (Table 2). The highest fresh weight of root per plant (101.36 g) was recorded when grown on ridge cultivation method, while the lowest fresh weight of root per plant (85.28 g) was obtained from deep spading method. Significant variation in respect of fresh weight of individual root was observed due to different fertilizers management practices (Table 2). The fresh weight of individual root (105.68 g) given by Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha was found to be maximum and the minimum individual fresh weight of root (75.39 g) was recorded in the treatment cowdung @ 9 t/ha. Both the combined and interaction effects of cultivation method and fertilizer management practices were found statistically significant (Table 3). The maximum fresh weight of root (110.00 g) was measured in the treatment combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha which was statistically similar to those of the combinations of ridge method and Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha, ridge method and Urea-TSP-MP-Gypsum @ 195-132-120-89 kg/ha, flat and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20

kg/ha, while the minimum (63.33 g) was found in the treatment combination of deep spading and cowdung @ 9 t/ha.

Leaves fresh weight per plant

Different cultivation methods exhibited highly significant variations in respect of fresh weight of leaves per plant (Table 2). The maximum fresh weight of leaves per plant (89.3 g) was found from the ridge cultivation method and the minimum (73.6 g) was found from the deep spading method. The fresh weight of leaves per plant was significantly affected by different fertilizer treatments (Table 2). Application of Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha produced the maximum fresh weight of leaves per plant (101.7 g) while the minimum one (63.4 g) was observed in plants treated with cowdung @ 9 t/ha. The combined and interaction effects of cultivation method and fertilizer management practices were statistically significant in respect of same parameter (Table 3). The combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha produced the maximum fresh weight of leaves per plant (113.3 g) and the minimum (56.7 g) was found in the treatment combination of deep spading and cowdung @ 9 t/ha.

Dry matter content of carrot root

Percent dry matter of carrot root was significantly influenced by different cultivation methods (Table 2). The ridge cultivation method was contained the maximum percent dry matter of root (9.18) while the minimum (7.75) was obtained from flat method. Percent dry mater of root was found to be significantly influenced by fertilizer management practices (Table 2). The highest dry matter of root (11.28%) was obtained from the plants grown under treatment Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha and the minimum (6.43%) was recorded from the plants grown under treatment cowdung @ 9 t/ha. This might be due to the balanced application of fertilizer which increased plant height, number of leaves and chlorophyll production of the plant. The combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha produced the highest percent dry matter of root (12.87%) and the lowest (5.83%) was produced by the combination of flat method and cowdung @ 9 t/ha (Table 3).

Dry matter content of leaves of carrot

Significant effect of cultivation method was found on the production of percent dry matter of leaves (Table 2). The maximum percentages of leaves dry matter (12.63) was recorded from ridge method while the minimum (11.75%) in deep spading method. Ridge method produced higher vegetative growth which possibly helped in maximum photosynthesis and thereby maximum accumulation of dry matter in plant. The different fertilizers management practices significantly influenced the production of dry matter of leaves (Table 2). The maximum dry matter content of leaves (15.47%) was obtained from the treatment of Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha and minimum (9.41%) was obtained from the treatment cowdung @ 9 t/ha. There were significant combined and interaction effects among different cultivation methods and fertilizer management in respect of leaves dry matter production (Table 3). Combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha produced the maximum dry matter of leaves (17.63%) while the minimum (9.07%) dry matter of leaves was produced by the combination of flat and cowdung @ 9 t/ha.

Percent cracked root in carrot

The percent cracked root was varied significantly due to influence of different cultivation methods (Table 2). The highest percent of cracked root (5.71) was obtained from the flat method. On the other hand ridge method produced minimum percentage of cracked root (3.81) which was statistically similar (3.86%) deep spading method. The percent cracked root production was also significant in respect of the same parameter by the different fertilizers management practices (Table 2). The highest cracked root percent (6.57) was found from the treatment cowdung @ 9 t/ha and the lowest cracked root percent (2.98) was obtained from the treatment Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-

10-20 kg/ha which was statistically similar (3.11%) at poultry manure @ 5.63 t/ha (Table 2). This may be due to the vigorous growth of carrot encouraged by the balanced fertilizer application. There were found both significant combined and interaction effects in respect of percent cracked root production of carrot (Table 3). Higher percentage of cracking (8.5) was found in the treatment combination of flat method and cowdung @ 9 t/ha but lower (2.4%) was found in the treatment combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20kg/ha.

Percent rotten root in carrot

Due to the effect of different cultivation methods a significant variation was found on the percent rotten root (Table 2). The maximum rotten root (6.76%) was recorded from flat method, whereas the minimum rotten root (5.95%) was obtained from the ridge method which was statistically similar (5.97%) to the deep spading method. The percent rotten roots differed significantly with different fertilizer management practices (Table 2). The highest rotten root (7.69%) was observed from the treatment cowdung @ 9 t/ha while minimum (4.54%) was recorded from the treatment Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha. The combined and interaction effects of cultivation method and fertilizer management practices in respect of percent of rotten root were statistically significant (Table 3). The highest percentage of rotten roots (7.83) was recorded in the treatment combination of flat method and cowdung @ 9 t/ha which was statistically similar to the combination of deep spading and cowdung @ 9 t/ha, flat and poultry manure @ 5.63 t/ha, ridge and Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha, deep spading and Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha combination. The lowest percent of rotten roots (3.67%) was obtained from the combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha.

Percent branched root in carrot

There was a significant influence of different cultivation method on production of branched root in carrot (Table 2). Maximum percent branched root (5.33) was found in carrot grown under flat method of cultivation. Ridge method produced the minimum branched root (3.42%). The percent branched root also varied significantly due to different fertilizers management practices (Table 2) the highest branched root percentage (6.00) was recorded in the treatment cowdung @ 9 t/ha while Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha noticed lowest (3.00%) percent of branched root. The combined and interaction effects of cultivation method and fertilizer management practices had a significant influence on the branched root of carrot (Table 3). The highest branched root (7.97%) was recorded from the combination of flat method and cowdung @ 9 t/ha whereas minimum (2.60%) branched root was obtained from the combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20kg/ha.

Gross yield of carrot root per plot

Gross yield of carrot root per plot was increased significantly by different cultivation methods (Table 2). The maximum gross yield of root per plot (3.43 kg) was recorded from ridge method of cultivation and the minimum (2.92 kg) was from deep spading method. There was also a significant effect on this regard by the fertilizer management practices (Table 2). The highest gross yield of root per plot (3.60 kg) was produced by the Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha while cowdung @ 9 t/ha resulted the minimum (2.61 kg/ha). The combined and interaction effects of cultivation method and fertilizer management practices were found statistically significant (Table 3). The maximum gross yield of root per plot (3.86 kg) was obtained from the combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha which was statistically similar (3.72 kg) to the combination of ridge method and Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha whereas, the combination of deep spading method and cowdung @ 9 t/ha was resulted the minimum (2.44 kg) gross yield of carrot per plot.

Table 4
Cost and return analysis of carrot as influenced by cultivation method and fertilizer management

Interaction[z]	Marketable yield (t/ha)	Total cost (Tk/ha)[y]	Gross return (Tk/ha)	Net return (Tk/ha)	BCR[x]
P_1T_1	22.40	43068.50	123200	80131.50	2.86
P_1T_2	25.73	46079.00	141515	95436.00	3.07
P_1T_3	26.63	41801.86	146465	104663.14	3.50
P_1T_4	28.63	42495.49	157465	144969.51	3.70
P_1T_5	29.56	43164.10	162580	119415.90	3.76
P_1T_6	32.33	44056.49	177815	133758.51	4.03
P_2T_1	25.43	41396.00	139865	98469.00	3.37
P_2T_2	27.56	44406.50	151580	107173.50	3.41
P_2T_3	29.76	40129.46	163680	123550.54	4.04
P_2T_4	32.00	40822.99	176000	135177.01	4.31
P_2T_5	33.60	41491.99	184800	143308.01	4.45
P_2T_6	35.80	42383.99	196900	154516.01	4.64
P_3T_1	22.46	43068.50	123530	80461.50	2.87
P_3T_2	23.30	46079.00	128150	82071.00	2.78
P_3T_3	25.26	41801.86	138930	97128.14	3.32
P_3T_4	26.63	42497.49	146465	103967.51	3.45
P_3T_5	28.30	43164.10	155650	112485.90	3.60
P_3T_6	31.46	44056.49	173030	128973.51	3.93

[z]Cultivation methods include - P_1 : Flat method, P_2 : Ridge method, and P_3 : Deep spading method; and Fertilizer management include - T_1 : Cowdung @ 9 t/ha, T_2 : Poultry manure @ 5.63 t/ha, T_3: Urea-TSP-MP @ 195-132-120 kg/ha, T_4 : Urea-TSP-MP-Gypsum @ 195-132-120-89 kg/ha, T_5: Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha, and T_6 : Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha.
[y]Selling price of carrot @ Tk 5500/t,
[x]Benefit cost ratio (BCR) = Gross return/total cost of production

Gross yield of carrot root per hectare

Cultivation method produced a significant variation in respect of gross yield of root per ha (Table 2). Ridge cultivation method produced the highest gross yield of root (34.24 t/ha) while deep spading method gave the minimum gross yield of root (29.18 t/ha). It was evident from the experiment that, different fertilizer management practices had also significant influence on gross yield of root per ha. Application of Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha resulted the maximum gross yield of carrot root (36.41 t/ha) and cowdung @ 9 t/ha produced minimum gross yield of root (26.09 t/ha). Ridge may be due to the cumulative increase root length, root diameter and individual root weight. There were statistically significant combined and interaction effects in respect of gross yield of root per ha (Table 3). The maximum gross yield of root per ha (38.53 ton) was measured from the combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha which was statistically identical (37.17 t) to the combination of ridge method and Urea-TSP-MP-Gypsum-Borax @ 195-132-120-89-10 kg/ha. Moreover, deep spading and cowdung @ 9 t/ha combination resulted minimum (24.43 t) gross yield of root per ha.

Marketable yield of carrot root per hectare

Statistically significant variation due to different cultivation methods was found in respect of marketable yield of root per ha (Table 2). Growing with ridge method resulted the highest marketable yield of root per ha (30.69 t). Whereas, deep spading method gave lowest (26.24 t) marketable yield of root per ha. The marketable yield of carrot per ha was also significantly influenced by this regard (Table 2). It is reveled that Urea-TSP-MP-

Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha produced the highest marketable yield of carrot root per ha (33.20 t) and cowdung @ 9 t/ha gave lowest (23.43 t) marketable yield of root per ha. Combined effects was remarkable significant but interaction effect was not significant in this regard (Table 3). It was recorded that, the combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha resulted maximum (35.80 t) marketable yield of root per ha. On the other hand combination of flat method and cowdung @ 9 t/ha produced the minimum (22.40 t) marketable yield of root per ha.

Cost and return analysis

The total cost of production ranged between Tk. 40129.46 to Tk. 46079.00 among the combination of cultivation method and fertilizer application (Table 4). There was no big variation due to the cost of different cultivation methods and fertilizer management. However, the highest cost of production (Tk. 46079.00/ha) was recorded from the treatment combination of deep spading method and poultry manure @ 5.63 t/ha. The lowest cost of production (Tk. 40129.46/ha) was involved in the treatment combination of ridge method and Urea-TSP-MP @ 195-132-120 kg/ha. The gross return from different combinations ranged between Tk. 123200.00 to 196900.00/ha showing minimum in the combination of flat method and cowdung @ 9 t/ha and maximum in the combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha. The ridge method with Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha gave the highest net return (Tk. 154516.01). But the lowest net return (Tk. 80131.50) was obtained from the combination of flat method and cowdung @ 9 t/ha. The benefit cost ratio (BCR) was found to be highest (4.64) in the treatment combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha. The lowest BCR (2.78) was recorded from deep spading method and poultry manure @ 5.63 t/ha combination. It was apparent that Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha irrespective of different cultivation methods gave the highest net return and BCR.

CONCLUSION

Among the cultivation method, ridge method produced the highest gross yield (34.29 t/ha) but the lowest in deep spading method (29.18 t/ha) while the maximum gross yield (36.41 t/ha) was obtained in Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha, and the minimum gross yield (26.09 t/ha) in cowdung @ 9 t/ha. The interaction and combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha, was produced the maximum gross yield (38.53 t/ha) while the minimum (24.33 t/ha) gross yield was obtained from the treatment combination of deep spading and cowdung @ 9 t/ha. The maximum marketable yield (30.69 t/ha) was produced by the ridge method while the minimum marketable yield (26.24 t/ha) was found from deep spading method. Among the fertilizer management Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha, produced significantly the highest marketable yield (33.20 t/ha) while the lowest (23.43 t/ha) was found cowdung @ 9 t/ha treatment. The interaction effects of cultivation method and fertilizer management was not significant for marketable yield but their combined effect was significant for marketable yield per hectare. The combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha, fertilizer gave the maximum yield (35.80 t/ha) and the lowest yield (22.40 t/ha) was found from the combination of flat and cowdung @ 9 t/ha.

From the economic point of view, it was evident that the highest net return of Tk. 154516.01/ha was obtained from the combination of ridge method and Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha. The benefit cost ratio was also maximum (4.64) in the same treatment and the lowest (2.78) was in the deep spading method and poultry manure @ 5.63 t/ha. Therefore, it can be recommended that ridge method is suitable for production of carrot cultivation and use of Urea-TSP-MP-Gypsum-Borax-Zinc sulphate @ 195-132-120-89-10-20 kg/ha, may lead to higher production of carrot.

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