EFFECT OF BARI IMO SOLUTION WITH INORGANIC FERTILIZERS ON GROWTH, YIELD AND QUALITY OF CARROT

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Dedicated to

My

Beloved Parents

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CERTIFICATE

*This is to certify that thesis entitled, "**EFFECT OF BARRI IMO SOLUTION WITH INORGANIG FERTILIZERS ON GROWTH, YIELD AND QUALITY OF CARROT**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of bonafide research work carried out by **MD. NAZMUL HAQUE JAMIL**, Registration No. 13-05296, Email. nazmulsau95@gmail.com, Cell. +8801521213465 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: December, 2021
Place: Dhaka, Bangladesh

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Associate Professor
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LIST OFABBREVIATIONS

FULL WORD		ABBREVIATION
Agro Ecological Zone	=	AEZ
Analysis of variance	=	ANOVA
Association of Official Agricultural Chemists	=	AOAC
Bangladesh Agricultural Research Institute	=	BARI
Bangladesh Bureau of Statistics	=	BBS
Bangladesh	=	BD
Centimeter	=	cm
Cultivar variety	=	cv.
Percentage of coefficient of variation	=	CV%
Degree Celsius	=	^{0}C
Degrees of freedom	=	df
Duncan's Multiple Range Test	=	DMRT
Date After Sowing	=	DAS
Dry Flowables	=	DF
And others (at elli)	=	*et al.*
Effective micro-organism	=	EM
Emulsifiable concentrate	=	EC
Fertilizer	=	F
Food and Agriculture Organization	=	FAO
The Food and Agriculture Organization Corporate Statistical Database	=	FAOSTAT
Gram	=	g
Hectare	=	ha
Indigenous micro-organism		
Indole 3-acetic acid	=	IMO
Kilogram	=	IAA
Liter		
Least Significant Difference	=	Kg
Milligram	=	L
Mean sum of square	=	LSD
Meter	=	Mg
Milliliter	=	M.S.
Micro-organism	=	m
Murate of Potash	=	ml
Ministry of Agriculture	=	MO
Nitrogen	=	MoP
Non-Significant	=	MoA
Percentage	=	N
Phosphorus	=	NS
Potassium	=	%
Parts per million	=	P
Solution	=	K
Randomized Complete Block Design	=	ppm
Recommended dose of fertilizer	=	S
Sher-e-Bnagla Agricultural University	=	RCBD
Total soluble solid	=	TSS
Wettable powder	=	WP

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The Author

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ABSTRACT

The experiment was conducted at the Olericulture Research Field-2, Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the November, 2019 to February, 2020 to evaluate the effect of BARI IMO solution with inorganic fertilizers on growth, yield and quality of carrot. The experiment consisted of two following factors as Factor A: Four levels of IMO (Indigenous micro-organisms) solution, viz., S_0= Control (No IMO solution), S_1= 150 ml/L IMO solution, S_2= 250 ml/L IMO solution, S_3= 350 ml/L IMO solution and Factor B: Four levels of inorganic fertilizer, viz., F_1= 25% RDF (Recommended Dose of Fertilizer), F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF. The experiment was laid out in RCBD design with three replications. Various data and parameters were recorded during the experiment. In case of IMO solution, the highest yield (24.52 t/ha) was found in S_3 and the lowest was observed in S_0. In combined application of IMO solution and inorganic fertilizers, the highest root length (18.67 cm), root diameter (4.87 cm), root pith flesh ratio (2.14), root dry matter content (17.78%), marketable yield (25.24 t/ha), TSS (9.07%), β carotene content (36.85%), total sugar content (11.09%) and reducing sugar content (3.03%) were found from the treatment combination of S_3F_3 whereas, S_0F_1 showed the lowest results. Likewise, the maximum yield (26.49 t/ha) was also recorded from S_3F_3 whereas, the minimum yield (15.20 t/ha) was found in S_0F_1. The highest BCR (2.58) was obtained from the treatment combination in S_3F_3 whereas, the lowest result was observed from S_0F_1. Therefore, S_3F_3 is considered to be the most effective treatment combination (350 ml/L and 75% RDF) for increasing growth, yield and quality of carrot.

CHAPTER I

INTRODUCTION

Among the root crops, carrots (*Daucus carota* L.) are an important one. The carrot gets its name from the French word "Carrotte", which comes from the Latin word "Carota" (Singh and Bahadur, 2015). Carrot (*Daucus carota* L.) is a cool season crop grown all over the world and belongs to the family Apiaceae (Alam *et al.,* 2010). The carrot is annual (for root production) and biennial (for seed production). The stem is a small plate-like structure with rosette-like leaves. The edible part of a carrot is the modified root (conical form). The fruit type of carrot is schizocarp, and the seeds are spiny (Singh and Bahadur, 2015).

The orange colored root of carrot contain more β-carotene (Vanangamudi *et al*., 2006), a precursor of vitamin A and the Asiatic type of carrot is rich in thiamin and riboflavin (Chandha, 2003) and acts as an excellent source of vitamin B, sugar, folic acid and minerals (Arscott and Tanumihardio, 2010). Carrot contains sucrose 10 times higher than that of glucose or fructose. (Ahmad *et al*., 2014). Besides, it gives medicinal benefits as the root has therapeutic action against different blood and eye diseases (Pant and Manandhar, 2007) while the leaf is used for its excellent pharmacological effects (Rossi *et al*., 2007). Nutrient composition of carrot root is moisture 86 g, protein 0.9 g, carbohydrate 10.6 g, fat 0.2 g, fiber 1.2 g, energy 48 kcal, mineral 1.1 g, iron 2.2 mg, carotene 1890 mg, thiamine 0.04 mg, Vitamin C 3 mg, vitamin A 3150 IU and folic acid 15 mg per 100 g of edible portion (Bose *et al*., 2000). Carrot has gained worldwide acceptance because of its high vitamin A content, good taste, ease of production (Rossi *et al*., 2007), and relatively long storage life at low temperature (Ali *et al*., 2006). Thus, the world carrot production is continuously increasing (FAO, 2015) whereby China, the European Union, Russia and Ukraine are the major carrot producing countries in the world (FAOSTAT, 2018). In 2018, global production of carrots (combined with turnips) was 39.99 million tons from 1131049 ha of land with Chinese 45% share in the world total 17.90 million tons (FAOSTAT, 2018). In 2020-2021, the area under carrot cultivation was 5736.57 acres with the total production of 27567.35 tons in Bangladesh (BBS, 2021). Owing to their modest needs for cultivation and storage, they can be produced fresh throughout the year and sold fresh carrot cultivation is now gaining popularity among farmers in Bangladesh but the yield is low due to lack of high yielding varieties as well as use of a low standard of agro-technologies (Kabir *et al*., 2002).

In carrot cultivation, fertilizer is the one of the most important factors that plays a crucial role in increasing growth and yield attributes. Nitrogen increases the vegetative growth and promotes carbohydrates synthesis. Phosphorus stimulates the diameter of root and increase the rate of growth. The deficiency of phosphorus causes reduction in yield. Potassium helps in the root development and increase the efficiency of leaf in the manufacture of sugar and starch. Excessive or under dose of N, P and K can affect the growth, yield and quality of carrot. Excess of nitrogen increases root splitting, which reduces marketable yield. It is considered that doses of nitrogen, phosphorus and potassium are important fertilizer variables for quality production of carrot (Pal, 2019). Carrot is a heavy feeder of nutrients, which removes 100 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 180 kg K_2O ha^{-1} and is very sensitive to nutrients and soil moisture (Sunanadarani and Mallareddy, 2007).

The available nutrients from chemical fertilizers give the initial boost of crop growth required by the young plants. But the continuous high input of nutrients from the inorganic fertilizers under intensive cropping system poses environmental burden and enhance the toxic bioavailability of nutrients to living beings. The balanced fertilization by managing soil organic matter and reducing the indiscriminate use of chemical fertilizers has now become a vital issue. For sustainable agriculture, a soil management strategy must be based on maintaining soil quality. Bangladesh Agricultural Research Institute (BARI) has developed a new package of microorganism solution named BARI IMO-1 and BARI IMO-2. IMO is short abbreviated form of Indigenous Micro Organisms.

The long-term manorial studies conducted at many places have revealed the superiority of integrated nutrient supply system is sustaining crop productivity in comparison of chemical fertilizers. Several attempts have been made to increase the yield potential of root crops, but farmers are concerned with the use of inorganic fertilizers which results in decrease fertility of soil, soil health, contents of organic matter and decreases the microbial activity of soil (Chen *et al*., 2014). Indigenous micro-organism maintains soil fertility and water holding capacity which encourages better plant growth. It also improves soil structure. Soil productivity could be maintained by using combination of mineral fertilizers and indigenous micro-organism solution. Modern day intensive crop cultivation results in huge application of chemical fertilizers which are not only in short supply but also expensive and pollute the environment, soil and water too. Therefore, current emphasis is being given to explore the possibilities the supplementing the chemical fertilizers with indigenous micro-organism which are locally available cheap and eco-friendly. A lot of microorganisms, for example *Bacillus* and *Pseudomonas* have a direct effect on the plant growth (Kloepper *et al*., 1986). Effective microorganisms (EM), concept developed by Professor Teruo Higa, (Higa, 1991), consist of mixed cultures of beneficial and naturally occurring microorganisms that can be applied as inoculants to increase the microbial diversity of soil and plant. In the IMO solution(s), the beneficiary microorganisms are densely present. Inoculation of EM cultures to the soil plant ecosystem can improve soil quality, soil health and the growth, yield and quality of soil crops (Kengo and Hui Lian, 2000). IMO consist of small naturally occurring soil microbes that are collected from the local area to be cultivated and then used to breakdown the complex organic molecules into the simple organic molecules and inorganic nutrients such as amino acids, vitamins and antioxidants. Indigenous microorganisms are a group of innate microbial consortium which have the potentiality in biodegradation, nitrogen fixation, improving soil fertility, phosphate solubilisers and plant growth promoters (Umi Kalsom and Sariah, 2008).

Indigenous microorganisms play an important role by protecting the normal host from invasion by microorganisms with a greater potential for causing disease. They compete with the pathogens for essential nutrients and for receptors on host cells by producing bacteriocins. They are the important component of world biodiversity (Sadi *et al*., 2006). These microorganisms increase the availability of nutrients to host plants (Vessey, 2003) and increase the water-holding capacity. It improves the aeration to the plant roots and prevents soil erosion. The potential microorganisms were selected for development of bio fertilizer. (Phua *et al*., 2011) particularly studied on the isolated indigenous microorganisms which may enhance plant growth through N_2 fixation using the 15 N isotopic tracer technique and stimulate plant growth through hormonal actions such as IAA production. Combination of microbial strains could be a good multifunctional bio fertilizer for sustainable agriculture. Agro-waste management and enhancement of biodiversity are the approaches towards sustainability (Shukor, 2009).

The inherent abilities of microorganisms are suitable for the removal of metals from solutions (Langley and Beveridge, 1999). These abilities have been identified as passive or active for accumulation and biosorption, respectively, (Brandl and Faramarzi, 2006). *Bacillus* strains have been widely used in the removal of metals from waste waters (Kim *et al*., 2007). IMOs create the optimum and favorable environment to improve and maintain soil flora and soil fauna as well as the other microorganisms. Better quality carrots are assured due to the absence of synthetic chemical fertilizers and pesticides as inputs. It can reduce the unnecessary use of chemical fertilizers which can help the farmers to get high benefit cost ratio and conserve soil health and be the sustainable agricultural practice. With all of this in mind, an experiment was done with the following aims to examine the applicability of various BARI IMO solution with inorganic fertilizers on the growth, yield and quality of carrot

- To reduce the unnecessary use of inorganic fertilizers and ensure plant growth
- To assess the optimum level of BARI IMO solution and inorganic fertilizer for higher yield of carrot
- To find out the suitable combination of new BARI IMO solution and inorganic fertilizer on quality carrot production.

CHAPTER II

REVIEW OF LITERATURE

Carrot (*Daucus carota* L.) is one of the most important vegetable crops of the world. From the nutritional point of view, it received much attention to the researches throughout the world to develop its production technology. Many research works have been carried out in relation to the effect of different inorganic fertilizers and organic fertilizers for the production of marketable size, maximizing the yield and quality of carrot in different countries. Yet, a few studies were found to have made in the effect of BARI IMO solution with inorganic fertilizers on carrot in Bangladesh. However, literatures available in this respect at home and abroad are presented here.

Ballooch *et al*. (1993) studied the effect of P_2O_5 (70 or 100 Kg ha^{-1}) K_2O (75, 100 or 125 kg ha^{-1}) and N at 100 kg ha^{-1} the highest yield carrot 29.79 t ha^{-1} were recorded by the application of the highest NPK. This was due to increased root size and weight.

Tomar *et al*. (1998) reported that the highest yields were recorded when brinjal plants were grown in pots containing soil with the addition of vermicompost followed by FYM, vermicompost + FYM compared to soil alone. They further reported that the highest yield was recorded when carrots were grown in pots containing soil amended with vermicompost and FYM compared to un-amended soil.

Ahmed (2000) revealed that the nitrogen along with phosphorus applied at different rates had significantly influenced the growth and yield parameters of carrot ($P>0.01$). Nitrogen when applied in combination with P at the rate of 75-50 kg ha^{-1} produced maximum length of leaves (44.70 cm), length of root (23.71 cm), length of leaves + roots (68.41 cm), weight of leaves (58.58 gm), single root (61.84 gm), root yield per plot (7.89 kg) and yield ha^{-1} (13.157 mt). Minimum values for all the growth and yields components were recorded in case of control.

Gupta and Sanger (2000) found that the application of nitrogen resulted in appreciable improvement in plant height, weight of fruit and fresh yield of tomato. Increasing levels of nitrogen application also increased the yield and yield components significantly up to 120 kg.

Polat and Onus (2000) reported that the carrot (*Daucus carota* L.) cultivars Monanta, Delphi F_1, Museon F_1, Frantes, Cyrano and parade were evaluated in Antalya (Turkey) in terms of yield, soluble content, mean root weight, root length and amount of first and second-class roots. Delhi F_1 exhibited the best performance under Antalya condition.

Schulz *et al*. (2000) reported that in hybrid varieties of carrot (*Daucus carota* L.) and 3 seed cultivars were evaluated under organic cultivation at Giessen in 1997-98. Most hybrids had high yields and good quality trails, while more medium yielding true seed varieties showed insufficient external quality and composition.

Sharma (2000) revealed that integration of organic and inorganic fertilizers application on broccoli significantly increased the head yield over inorganic fertilizers alone and also over control. The treatment N (175 kg), P (75 kg), K (60 kg) + FYM 12.5 t ha^{-1} recorded the maximum yield 63.12 q ha^{-1} which was at par with 150:75:60 kg NPK+FYM 12.5 t ha^{-1} (57.59 q ha^{-1}) but significantly superior over rest of the treatments in terms of yield and net profit.

Singh and Singh (2000) reported that the linear increase in plant height of broccoli was observed with increase in the level of N & K. Days of maturity were also influenced by different fertility levels. There was no significant difference up to the level of N 150, K 50 kg ha^{-1}. The highest net head weight and yield was recorded with the application of N 150 and K 50 kg ha^{-1}.

Netra Pal (2001) reported that the splitting of carrot root it is major problem in many carrots growing area. Although the tendency of splitting seems to be controlled by genetic factors, a number of other factors may be involved. The splitting is reduced by low N and increasing as the amount of N in the soil increase. High soil concentration of ammonium compounds causes more serious splitting than by other terms of N. Wider the spacing, the greater is the amount of splitting and large roots are more likely to split than small ones.

Shanmugasundaram and Savithri (2002) reported that the N at 240 kg ha^{-1} resulted in the highest root yield 57. 7 t ha^{-1} and root ascorbic acid 6.4 mg/100 gm and nitrate N (283%) contents. The highest carotene contents were obtained with 240 (16.7 mg/100 g) and 180 (13.6 mg/100 g) kg N ha^{-1}.

Sharma *et al*. (2003) were investigated effect of integrated use of FYM and NPK on carrot cv. Nantes. Three levels of NPK (50%, 100% and 150% of the recommended dose of 50:40:35 kg ha^{-1}) and three levels of FYM (0, 10, and 20 t ha^{-1}) were used and concluded that the application of 100% NPK + FYM @ 10 t ha^{-1} were gave the maximum yield of root.

Uddin *et al*. (2004) reported that the different combinations of NPKS and cowdung showed significantly influence on the yield of carrot. The combination of fertilizer 120-45-120-30 kg ha^{-1} of NPKS and 5 t ha^{-1} cowdung produced the highest yield 27.22 t ha^{-1} which was 30.3% higher over control treatments. The highest marginal rate of return (76.33%) also obtained from the same treatment.

Anjaiah *et al*. (2005) assessed the response of carrot to different levels of potassium (K) and farmyard manure (FYM) to determine the optimum levels of K and FYM which enhance nutrient uptake and root yield. The root yield was the highest at K_3 (17.59 t ha^{-1}), followed by K_2 (12.19 t ha^{-1}). There was significant increase in root yield (13.0 t ha^{-1}) with FYM application up to F_3. Interaction effect of K and FYM revealed that K_2F_3 was the best combination to obtain the highest carrot yield.

Bilekudari *et al.* (2005) observed that the higher fertilizer level (130:55:55 NPK ha^{-1}) significantly increased the plant height (124 cm), number of branches per plant (9.47), seed yield per plant (12.3 g), per hectare (5.13 q) and test weight (9.9 g) compared to recommended dose of fertilizer in radish.

Selvi *et al*. (2005) studies the highest yield (21.21 t ha^{-1}) was obtained under NPK rate of 135:135:170, followed by 20.25 and 20.21 t ha^{-1} obtained from treatments with 170:100:170 and 170:135:170 kg ha^{-1}, respectively. A rate of 170:170:170 kg ha^{-1} did not significantly increase the yield, which was low at 18.67 t ha^{-1}.

Anjaiah and Padmaja (2006) evaluated the effects of potassium (0, 40, 80 and 100 kg K_2O ha^{-1}) and FYM (0, 5, 10 and 15 t ha^{-1}) on the root yield and quality (total carotenes, total soluble solids and total sugars) of carrot. Root yield and quality parameters increased with increasing levels of both potassium and FYM. Potassium at 120 kg ha^{-1} and FYM at 15 t ha^{-1} recorded the best yield and quality, but potassium at 80 kg ha^{-1} and FYM at 15 t ha^{-1} was the most cost-effective.

Rajput *et al*. (2006) observed that the superimposition of 25% nitrogen (equivalent to 30 kg N) through vermicompost over recommended dose i.e.120-60-40 kg NPK ha^{-1} (100% IN+25% N) in addition to 20 kg S ha^{-1} resulted in significantly higher values of yield. Harvest index, BC ratio, protein content, and nutrient content and nutrient harvest index. Moreover, the interaction between the 100% IN + 25% N on fertility level with biofertilizer + Zn + Fe gave significantly higher grain yield.

Rani *et al*. (2006) opined that among the different integrated nutrient management practices, application of neem cake and castor cake in combination with half the recommended dose of NPK recorded higher yield (14.7 and 15.86 t ha^{-1}, respectively) and quality compared to other organic manures, namely vermicompost and farmyard manure. The gross monetary returns in general were higher when carrot was intercropped in ber (Rs. 61761 ha^{-1}) and under planted carrot (Rs. 56872 ha^{-1}).

Meena *et al*. (2007) observed that the application of 150% recommended dose of N as poultry manure, produced significantly higher values of green pod yield, grain protein content (%) and % carbohydrate content. All the sources of organic N nutrition at different rates recorded significantly higher green pod yield (24.8-91.0%) compared to 100% RND through urea (control). Total nutrient uptake also increased significantly in organic treatments compared to control and was the highest with application of 150% RND as poultry manure. The highest net returns (Rs.49758 ha^{-1}) while the lowest net return (Rs. 10109 ha^{-1}) obtained with the control. The benefit cost ratio was the highest with 150% RND as poultry.

Singh *et al*. (2007) reported that application of 1/2 NPK + green leaf manure 2.5 t ha^{-1} + *Azotobacter* + PSB 5 kg ha^{-1} each resulted in significant improvement in plant height (61.39 cm), length of leaves (45 cm), number of leaves per plant (12.08), fresh weight of leave per plant (25.92 gm), root length (16.37 cm), diameter of root (2.85 cm) and yield (242.85 q ha^{-1}). The cost-benefit ratio (1:1.95) was maximum in this treatment.

Sunandarani and Mallareddy (2007) revealed that castor cake + 50% RDNPK and 100% RDNPK resulted in the greatest plant height (30.23 and 30.90 cm, respectively). Vermicompost, neem cake and FYM combined with 50% RD of NPK, as well as 100% RD of NPK were superior in terms of root length (15.28, 15.93, 15.33 and 15.18 cm). Castor cake + 50% RD of NPK also registered the greatest root girth (9.18 cm), fresh root weight (52.50 g $plant^{-1}$), dry root weight (6.80 g per plant), and net income (38,672 rupee's ha^{-1}). Neem cake + 50% RD of NPK gave the highest TSS (total soluble solids) (13.280 Brix) and recorded the highest carotene content (4.60 mg/100 g), total sugars (8.41%) in carrot.

Hailu *et al*. (2008) investigated the effect of combined application of organic P and inorganic N fertilizers on yield and yield components of carrot. Yield and yield components of carrot were significantly influenced by the preharvest combined application of "orga" and urea treatments. The result showed that the combined application of 309 kg ha^{-1} "orga" and 274 kg ha^{-1} urea resulted in the maximum yield of carrot.

Gajewski *et al*. (2009) reported that nitrogen fertilizers should be applied in such a way to prevent the excessive supply of this nutrient without limiting the yield potential of different carrot genotypes. The minimum nitrate accumulation in vegetables is affected by choice of low nitrate-accumulating genotypes and proper nitrogen fertilization rates.

Bhullar *et al.* (2010) the effects of planting density and nitrogen on sugar beet. A basal dose of 60 kg ha^{-1} each of P and K was applied to all the treatments. On an average, planting density of 100,000 plants ha^{-1} produced the highest beet root and sugar yield. Among nitrogen levels, the response was significant up to 150 Kg N ha^{-1}. Addition of 20 t FYM ha^{-1} along with 90 kg N ha^{-1} produced similar root and sugar yield to 120 kg N ha^{-1} alone. The yields were also similar with 150 kg N ha^{-1} alone and, 120 kg N ha^{-1} + 20 t FYM ha^{-1}.

Kirad *et al*. (2010) concluded that the cumulative effect of treatment (½ RDF + ½ FYM + rhizosphere bacteria) associated with higher vegetative growth, maximum photosynthates production and better establishment of source sink relationship resulting higher root yield and could result in lowered levels of chemical fertilizers and enhanced quality traits.

Dawuda *et al*. (2011) investigated the growth and yield responses of carrot to different rates of soil amendments and spacing. The application of 15 t ha^{-1} and 20 t ha^{-1} decomposed chicken manure improved vegetative growth, increased root yield and gave more income.

Jatav *et al*. (2011) studied the role of FYM on phosphorus and potassium economy in potato-radish crop sequence under rain fed conditions. The application of recommended dose of N along with 50% PK from inorganic fertilizers and rest from FYM in potato resulted in the highest concentration of nitrogen, phosphorus and potassium in leaves which consequently enhanced yields of potato (319 q ha^{-1}). This treatment also gave the highest yield of following crop radish (192.9 q ha^{-1}). Therefore, for the higher productivity and better return of the potato-radish system, 25 to 50% of the recommended dose of P and K fertilizers can be replaced with FYM.

Hamma *et al*. (2012) reported that irrigation scheduling at 5 day's interval (I_1) and NPK fertilizer at 250 kg ha^{-1} significantly enhanced the production of the highest values of characters measured compared to the other treatments and control (I_0) and 0 kg ha^{-1} of NPK fertilizer.

Kumar *et al*. (2012) conducted field experiment to study the effect of integrated nutrient management on productivity of potato under rain fed condition. Three years pooled result revealed that integrated application of 50 % of recommended NPK through inorganic and 50 % RDN through PM recorded significantly highest tuber yield (22.73 t ha^{-1}) which was 228 %, higher than control.

Mehedi *et al*. (2012) reported that the application of 150 kg N ha^{-1} as urea was found suitable for maximum gross and marketable yield (47.35 t ha^{-1} and 39.0 t ha^{-1}, respectively), while 15 t cowdung ha^{-1} showed better gross and marketable yield (38.13 t ha^{-1} and 30.42 t ha^{-1}, respectively). Regarding the combined effect, the combination of 150 kg N ha^{-1} and 15 t cowdung ha^{-1} resulted in the best performance in gross and marketable yields (51.22 t ha^{-1} and 43.41 t ha^{-1}, respectively). The net return (TK. 211142 ha^{-1}) and benefit cost ratio (4.61) were maximum in the treatment combination of 150 kg N ha^{-1} in the form of urea and 15 t cowdung ha^{-1}.

Sarker *et al*. (2012) investigated the influence of city finished compost (CFC) and NPK fertilizer on the yield, nutrient uptake and nutrient use efficiency of radish. Among the treatments, growth performance of radish was better with the highest rate of 40 t ha^{-1} CFC treatments. Uptake of N and K by plant showed very strong and positive correlation ($P<0.001$) with total dry matter yield. Agronomic and physiological use efficiency of N and K of radish decreased with increasing the rates of CFC and NPK fertilizer treatments. Results of the present study indicated that 10 t ha^{-1} CFC could be used instead of 100% NPK fertilizer to obtain similar yield and nutrient use efficiency.

Vijayakumari *et al*. (2012) conducted an experiment to analyze the effect of farm yard manure (FYM), phosphobacteria, Azospirillum, vermicompost, humic acid and NPK on growth and yield of radish. The best germination percentage was observed in NPK treatment. The tuber weight and tuber length were maximum in vermicompost treated plants. Tuber diameter was maximum in NPK treated plants. From this investigation it is inferred that the potting mixture containing, farmyard manure, vermicompost, humic acid and NPK could be ideal and suitable for better production of radish.

Zakir *et al.* (2012) obtained the maximum gross yield (29.27 t ha^{-1}) of carrot from T_4 treatment while the second lowest gross yield (18.73 t ha^{-1}) was recorded in alone RDB (6 t ha^{-1}) treatment. Carrot plants treated with RDIF showed the highest values for fresh weight of individual root (67.13 g), marketable yield (18.74 t ha^{-1}), shoot length (47.87 cm), individual root diameter (10.91 mm) and nitrogen content in carrot (2.48%). Among the biochemical properties, the maximum amount of reducing sugar and total sugar (5.15 and 10.51%, respectively) were obtained from T_7 treatment

(RDIF + RDB). In context of carotene, the highest amount (4.92%) was found in T_4 treatment (RDIF + ½ RDB).

Amara and Mourad (2013) investigated the effects of natural organic manure on the growth and productivity of potato. The treatment by mixed manure showed significant increase in the tubers weight and the quantity of production and the percent of standard tubers in comparison with control. The treatments with poultry manure gave the highest yield in comparison to other treatments. Thus the combination of natural organic manures and low rates of inorganic fertilizers is a promising low cost option in the production of high yields of potatoes.

Bhattarai and Maharjan (2013) reported that application of vermicompost @ 1.2 t ha^{-1} and FYM @ 3 t ha^{-1} was found effective in improving the growth and yield. The available phosphorus and potassium content was observed higher in application of poultry manure @ 1 t ha^{-1} and compost @ 2 t ha^{-1} combination.

Jeptoo *et al*. (2013a) compared the four levels of decomposed tithonia manure (0, 1.5, 3.0 and 4.5 t ha^{-1}) in carrot. Application of tithonia divers' folia manure resulted in increase in total fresh root weight, dry root and shoots biomass and root volume compared to the control. Total yield of carrots subjected to 3.0 t ha^{-1} increased by 33% and 18% in season 1 and 2, respectively compared to control. The sweetness of carrot was influenced at the highest level of tithonia.

Jeptoo *et al.* (2013b) observed that application of 7.8 t ha^{-1} of bio-slurry manure increased leaf numbers, plant height, dry weight of shoot and root, root volume, root yield and quality in carrot.

Kumar *et al.* (2013) conducted a field experiment was conducted at Research Farm, Department of Vegetable Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.), India; during rabi season of 2009-10 to see the effect of integrated nutrient management on seed yield and economics in radish cv. Chinese Pink. Fifteen combinations of different treatments comprising of organic sources (vermicompost, biovita liquid and granules), biofertilizers (*Azotobacter* and PSB) and inorganic fertilizers (NPK) were choosen for the study. These treatments were replicated thrice in RBD. Treatment T_{14} [vermicompost + biovita (L) + 75%

recommended dose of NPK] produces maximum seed yield but net returns and B : C ratio was the highest in T_4 [*Azotobacter* (2.5kg/ha) + PSB (2.5kg/ha) + 75% R D of N, P, K (112.5:45:40.5 kg/ha)].

Vithwel and Kanaujia (2013) concluded that integrated application of 50% NPK + 50% FYM + Biofertilizers was found optimum for getting maximum productivity of carrot without reducing fertility status of soil. This treatment reduced 50% chemical fertilizers without any compromise on yield of carrot and fertility of soil.

Ahmad *et al.* (2014) reported that 14 treatment combinations of FYM, LF, PM and urea based on the total nitrogen requirement was tested for two carrot cultivars (T_{29} and Oranza). Results indicated that T_{29} was significantly better for all the growth and yield attributes as well as nutrient uptake in leaves except root firmness and root to shoot ratio where Oranza showed its superiority. Among different fertilizer treatment combinations of FYM, LM, PM and urea, both carrot cultivars performed better when half PM + half FYM was applied.

Ahmed *et al*. (2014) concluded that application of FYM at 20 t ha^{-1} significantly increased most yield characters and marketable yield at harvesting in carrot.

Baloch *et al*. (2014) conducted a field experiment to find out the effect of nitrogen along with constant doses of phosphorus and potassium on *Raphanus sativus* L. cv. Early Long White. After compiling the results, it was that an increase in nitrogen levels from 100 to 150 Kg ha^{-1} positively affected all growth and yield parameters of radish. Control plots where no fertilizers were applied remained inferior for all characteristics. The root yield kg $plot^{-1}$ and root yield (t ha^{-1}) were 73.37, 86.81, 98.45 and 45.64, 64.00, 72.60 obtained at 100, 100 and 150 Kg ha^{-1} of nitrogen, respectively.

Banjare *et al*. (2014) investigated the effect of different nitrogen levels on growth and yield parameters in potato. The highest values for number of tubers per plant and per plot as well as tuber yield per plot and per hectare were recorded on application of 225 kg N ha^{-1}. The highest net returns (Rs. 117323) and maximum B: C ratio (1.42) was recorded on application of 225 kg N ha^{-1}.

Barman *et al*. (2014) observed that the application of 150:100:120 kg NPK, 20 tons FYM, 5 tons vermicompost and 3 ton's neem cake ha^{-1} brought paramount of improvement in growth and tuber yield of potato.

Kumar *et al*. (2014) observed that the plant height was significantly increased by the application of organic manures and it was maximum under treatment T_9 i.e. vermicompost + poultry manure (50% each). Similarly, vermicompost + poultry manure 50% each (T_9) recorded the highest number of leaves. The highest root length (18.91 cm) was recorded with vermicompost (50%) + poultry manure (50%). The treatment was also proved to be better for fresh and dry weight of plant as well as roots and recorded the highest in vermicompost (50%) + poultry manure (50%) treatment.

Kumar *et al*. (2014) studied the effect of organic and inorganic nutrient sources on carrot growth under irrigated conditions and revealed that the application of 25% NPK through fertilizer + 25% N through VC or compost enhanced productivity of carrot as well as improving in carrot quality attributes significantly.

Mbatha *et al*. (2014) reported that chicken manure-treated plants produced more leaves than compost (2005) and longer leaves than kraal manure (2006) treated plants. The TSS of roots treated with chicken manure or compost was lower than that of roots not receiving fertilizer (2005). As organic fertilizer rate increased leaf number, length, root fresh mass and shoulder diameter increased. Root TSS and dry mass decreased as organic fertilizer rate increased and roots were of a lower grade. Organic fertilizer can be beneficial to carrot yield and quality within specific application levels.

Mbouobda *et al*. (2014) reported that the number of leaves from plants treated with EM and IMO manures increased significantly over time. This number varied from 5.042 ± 0.55 to 11.292 ± 1.488 in plants treated with EM manure while in plants treated with IMO manure, it varied from 4.875 ± 0.797 in week 2 to 10.458 ± 1.215 in week 12. The number of leaves from treated plants was higher compared to control and also reported that the average weight of carrot was significantly high ($p \leq 0.05$) in plants treated with EM manures (78 kg.) relative to plants treated with IMO manure (5.95 kg.) and control plants (5.68 kg).

Narayan *et al*. (2014) found that application of 75% of full recommended dose of fertilizers (RDF) (120:75:75 NPK ha^{-1}) + 8 t ha^{-1} vermicompost + pre-sowing tuber treatment with *Azotobacter* and phosphorus solubilizing bacteria proved significantly superior in terms of number of tubers hill, harvest index, tuber yield (32.7 t ha^{-1}) and benefit: cost ratio (1.75) of potato.

Sumagaysay (2014) revealed the recommended rate T_3 (31.5-48-42) of NPK fertilizer produced the highest yield of radish tubers. Although T_2 (recommended rate 21-32-28) obtained the highest tuber weight and tuber length but it did not significantly differ from the plant applied with T_3 of NPK fertilizer.

Sylvestre *et al*. (2014) reported that to determine the effect of chicken manure and NPK fertilizer on growth and yield of carrot. Results revealed that the significantly ($P<0.005$) the highest plant height (45.59 cm) and leaf length (45.29 cm) were obtained in the combination of chicken manure and NPK fertilizer and the lowest were 34.12 and 34.69 cm, respectively, in the absolute control. The sole application of chicken manure and NPK fertilizer recorded plant heights of 43.70 and 39.89 cm and leaf lengths of 43.46 and 39.61 cm, respectively. Results also indicated that marketable root yield was statistically similar between control (5.6 t ha^{-1}) and chicken manure alone (5.7 t ha^{-1}) and between NPK fertilizer alone (8.55 t ha^{-1}) and combination of chicken manure and NPK fertilizer (10.55 t ha^{-1}). The best BCR was obtained in the combination of chicken manure and NPK fertilizer (2.09) compared with the absolute control (1.12), chicken manure alone (1.75) and NPK fertilizer alone (1.62).

Yadav *et al*. (2014) studied that the integrated use of synthetic fertilizers and organic manures showed the significant impact on growth and yield attributes of potato. The highest average number of tuber (984.2×103 t ha^{-1}) and yield of tubers (12.4 t ha^{-1}) were recorded with application of 75% RDF through fertilizers and 25% RDN through FYM in potato.

Ahmad *et al*. (2015) studied that the application of chemical fertilizers has realized the need for application of organic manure to meet the increasing requirements of growing plants. This review briefly presents the scope of application of chemical fertilizers and organic manure for sustainable productivity and quality of carrot roots.

An appropriate combination of chemical fertilizers and organic manures is a possible way-forward to achieve reasonable yield and quality.

Khalid *et al*. (2015) studied on the effect of integrated nutrient management on growth and yield attributes of radish (*Raphanus sativus* L.). The application of integrated nutrient like inorganic (NPK @ 80:60:60 kg ha^{-1}), organic (FYM @ 20 tones ha^{-1}) and bio-fertilizers (*Azotobacter*, 5 kg ha^{-1}) + phosphate solubilizing bacteria, (5 kg ha^{-1}) may be adopted for commercial utilization of radish, thus T_8 (NPK + FYM + PSB @ 80:60:60 kg ha^{-1} + 10 t ha^{-1} + 5 kg ha^{-1}) proved to best treatment.

Sarma *et al*. (2015) revealed that the combined applications of *Azotobactor*, farmyard manure (FYM), rock phosphate (RP) and phosphate solubilizing bacteria (PSB) improved the root yield and other growth traits viz. root girth, number of functional leaves and stalk weight of carrot. The highest root yield (19.60 t ha^{-1}) was obtained under this treatment. However, the application of *Azotobacter*, vermicompost, RP and PSB also improved the yield.

Zeid *et al*. (2015) concluded that the use of both organic materials i.e. chicken manure and inorganic fertilizers (at 50% of the recommended doses) gained the highest values of most plant growth characteristics and nutrient contents of radish plants. Improvement in radish growth was principally due to increase in nutrients availability in soil. Hence, integrated use of organic materials with inorganic fertilizers would be a better and practical approach to sustain soil fertility and productivity.

Messele (2016) reported that the application of 309 kg ha^{-1} orga + 411 kg N ha^{-1} as a source urea and 309 kg ha^{-1} orga + 68 kg N ha^{-1} as source urea increase plant height by 145.15% and 143.70% over control. Similarly, the application of 309 kg ha^{-1} orga + 411 kg N ha^{-1} as source urea and 309 kg ha^{-1} orga + 68 kg N/ha as source urea increased root weight by 174.33% and 149.23% over control. There was also an increased in yield (t ha^{-1}) over the control for the application of 309 kg ha^{-1} orga + 411 kg N ha^{-1} as source urea and 309 kg ha^{-1} orga + 68 kg N ha^{-1} as source urea increased by 231.22% and 149.08%, respectively. This study recommended farmers to apply 309 kg ha^{-1} orga + 411 kg N ha^{-1} as source urea.

Appiah *et al*. (2017) reported that the growth and yield response of carrot to different green manures and plant spacing. The result revealed that the application of 10 t ha^{-1} *Mucuna pruriens*, *Chromolaena odorata*, *Gliricidia sepium* and 300 Kg ha^{-1} NPK improved the vegetative growth of carrot and translocated the assimilates into the final gross and marketable yield of the root compared to the control. Application of 300 kg ha^{-1} NPK was found suitable for maximum gross and marketable yields (28.73 t/ha and 27.23 t ha^{-1}, respectively) in 2015. In 2016, *Mucuna pruriens*, *Chromolaena odorata*, and *Gliricidia sepium* treatments produced gross and marketable yields similar to 300 kg ha^{-1} NPK. With the spacing regime, 25 x 10 cm produced maximum gross and marketable yield in both years.

Daba *et al*. (2018) reported that cattle manure applications with four treatments (0, 5, 10 and 18 t ha^{-1}) were used. The finding revealed that application of cattle manure on carrot showed a highly significant effect for growth parameters (plant height, root length and root diameter). Application of cattle manure at 10 tones ha^{-1} increased carrot root weight by 48.8 % compared to the non-fertilized control treatment.

Desire *et al*. (2018) reported that the plants treated with IMO fertilizers produced potato tubers with the heaviest weight (241.64 ± 32.94 g), followed by those treated with EM manure (227.62 ± 44.58 g) and the control which produced tubers with the least weight (125.66 ± 31.63 g). Statistical analysis revealed significant differences ($p \leq 0.05$) between plants treated and control plants.

Hasan *et al*. (2018) reported that vermicompost and organic mulching is an environment friendly component used as a bio fertilizer. The highest marketable yield and gross yield (27.68 t ha^{-1}) of the root (26.35 t ha^{-1}) were recorded from V_2 while the lowest from control (V_0). The highest marketable yield (27.89 t ha^{-1}) and the gross yield (29.48 t ha^{-1}) of root observed from M_2 while the lowest control (M_0) under mulching treatment. Similarly, the highest marketable yield (33.24 t ha^{-1}) and gross yield (34.45 t ha^{-1}) of root were marked from V_2M_2 and the lowest from V_0M_0 under combined treatment. The highest (3.64) benefit-cost ratio was recorded from V_2M_2 while the lowest (1.68) from V_3M_0 and it was indicated that vermicompost @ 4 t ha^{-1} with water hyacinth mulching was found suitable for carrot cultivation.

Kumar and Gupta (2018) reported that the plant heights were found to be 50 cm in vermicompost, 41 cm in cowdung, 39 cm in urea and 17 cm in control treatment. Weight of the tuber was observed to be 152 g in vermicompost, 133 gm in cowdung, 120 gm in urea, and 49 gm in control treatment. The number of fruits/plant was found to be 44 in vermicompost, 36 in cowdung, 25 in urea and 15 in control treatment. The dry matters yield was 41.36 gm in vermicompost, 39.92 gm in cowdung, 35.25 gm in urea and 21.50 gm control treatment.

Rahman *et al.* (2018) reported that the different doses of manures and fertilizers. Results from our study revealed that maximum fresh weight (3.57 kg plot^{-1}), individual root weight (101.90 g), root length (14.64 cm), root diameter (3.27 cm), total yield (23.78 t ha^{-1}), marketable yield (20.53 t ha^{-1}) and beta-carotene content (8.78 mg 100^{-1} g) were recorded from F_5 treatment. On the other hand, the interaction effect of M_1F_5 performed superior in producing yield components and beta-carotene content of root compared to other combinations. The highest marketable yield (25.10 t ha^{-1}) along with best economic gross return (TK. 2, 47, 167 ha^{-1}) and the benefit-cost ratio (2.91) were also noted from M_1F_5.

Afrin *et al*. (2019) found that the treatment combination, irrigation at 7 day's interval with mixed fertilizer (I_7F_2) produced the highest plant height (50.42 cm), number of leaves (11.67), diameter of root (3.90 cm), length of root (23.20 cm), fresh weight of individual root (106.20 g), gross yield (53.66 t/ha) and marketable yield (46.91 t/ha). The lowest plant height (32.75 cm), number of leaves (7.83), diameter of root (3.10 cm), length of root (13.00 cm), fresh weight of individual root (65.00 g), gross yield (32.00 t/ha) and marketable yield (26.72 t/ha) were found from the treatment combination of no irrigation with no fertilizer (I_0F_0). Gross yield and marketable yield per hectare were 40.37% and 43.04% higher, respectively in irrigation at 7 day's interval with mixed fertilizer than other treatments combination.

Bender *et al*. (2020) observed that the average yield in organic vegetable production is up to 33% lower than in conventional production. This difference could be due to higher fertilization rates in conventional, compared to organic, farming. We aimed to compare yield and quality characteristics of carrots produced under equal nitrogen fertilization rates over four years in organic and conventional conditions. We found a 14.5% higher marketable, and 10.0% lower discarded, yield in the organic compared to the average conventional treatments. In addition, carrots managed organically had 14.1% lower nitrate.

Merlin *et al*. (2020) studied their effect on yield attributes and chemical composition in three varieties of *Daucus carota* L. Yield, carbohydrates and carotenoids were significantly higher when using chicken manure as fertilizer. Compost fertilizer enhances important reducing sugars. Treatment using NPK fertilizer induced more proteins and iron. Calcium level was high when using either compost or chicken manure as fertilizer. Better Sweetness was obtained when using chicken manure. Chicken manure or compost; used alone or associated with NPK fertilizer increased agronomic and nutritional characteristics and in carrots.

Singh *et al*. (2020) studied on carrot (*Daucus carota* L.) var. Pusa Kesar. During experiment, growth parameters viz., plant height, number of leaves per plant, root length and root diameter was the highest in treatment T_{11} (FYM 10 t/ha + vermicompost 2.5 t/ha + biofertilizer 2 kg/ha + 50% NPK) at 40, 60 and 80 DAS. The root yield per hectare and dry weight of root was also recorded the highest. The quality characters TSS was recorded maximum in treatment T_1 (FYM 20 t/ha).

Valsikova-Frey *et al*. (2021) found that the ´Bastia F_1´ variety of carrot in variant 3, with Rokohumin fertilizer reached the highest yields (37.1-39.5 tha^{-1}) of two-year cultivation period. The lowest yield was recorded in control variants, 18.3-19.2 tha^{-1} for ´Bastia F_1´ and 14.1-16.3 tha^{-1} for ´Berlin $F_{1.}$ For ´Bastia F_1´ we measured the highest amount (10.3%) of soluble solids (refractometric drymatter) by variant 3. Carotenoid content was the highest (22.74 mg/100 g) in the ´Bastia F_1´ variety in variant V_2. The lowest carotenoids (13.3 to 14.84 mg/100 g) had both varieties in the control variant. The best variants in the carotenoid content in both years were for variants V_3, which were fertilized with liquid organic fertilizer.

Yusuf *et al*. (2021) observed that the twelve carrot varieties in different colours and sizes were investigated for chemical properties. Purple-coloured carrot samples demonstrated the highest results for total sugar (11.2 g/100 g fm), total organic acid (2.8 g/100 g fm), total polyphenolic contents (224.4 mg/100 g fm), and anti-oxidant activities (17.1 mmol Trolox equivalents/100 g dm). In turn, the lowest results were observed in normal yellow carrot for total polyphenols (7.3 mg/100 g fm), and anti-oxidant activities (2.5 mmol Trolox equivalents/100 g dm); besides, the lowest total tetraterpenoids were determined in micro-white carrot 0.2 mg/100 g fm.

Amartey *et al*. (2022) investigate that the combining organic manures and inorganic fertilizers increased the growth and yield of carrot greater than the control and sole fertilizers. Plant height and canopy width were the greatest for the 5 t/ha CD + 5 t/ha PM and 5 t/ha PM + 5 t/ha GP in both seasons. Carrot root yields in both seasons for the organic and inorganic combinations ranged from 24.3-54.2 t/ha, which was 9-14% and 25-95% greater than the sole fertilizers (22.2-47.6 t/ha) and control (19.4-27.8 t/ha), respectively. Root yields in the major and minor seasons were highest for 5 t/ha CD + 5 t/ha GP and 5 t/ha CD + 5 t/ha PM, respectively.

Vikram *et al*. (2022) recorded the maximum carrot plant height at harvest, leaf length, leaf count, and leaf fresh weight were recorded in treatment T_7 (1/2 recommended NPK + ½ green leaf manure + biofertilizer i.e. *Azotobacter* and *phosphobacteria* each at 5 kg/ha) followed by the application of T_9 (recommended dose of NPK @ 80:60:60 kg/ha). The maximum length of root, diameter of root, yield per plot (kg), yield per hectare (q) were recorded by the application of T_7 followed by the application of T_9 besides, improvement in quality parameter were observed by the various sources of integrated nutrient management. The maximum TSS content were recorded by the application of T_7.

CHAPTER III
MATERIALS AND METHODS

The field experiment entitled "effect of different BARI IMO solution with inorganic fertilizers on growth, yield and quality of carrot" was conducted during November to February (rabi season) of 2019-20. The techniques adopted and details of materials used during the course of investigation are described here under.

3.1 Location of the experimental field

The experiment was conducted at the Olericulture Research Field- 2, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during the rabi season of 2019-20.

3.2 Climate of the experimental area

The experimental area is characterized by subtropical rainfall during the month of May to September (Anonymous, 1988) and scattered rainfall during the rest of the year. Information regarding average monthly temperature as recorded by Bangladesh Agricultural Research Institute (Weather Station) Joydebpur, Gazipur during the period of study has been presented in Appendix I.

3.3 Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5, ECE-25.28 (Haider, 1991). The analytical data of the soil sample collected from the experimental area were determined in the Soil Resource Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Plant materials collection

The carrot variety used in the experiment was ''New Kuroda''. This is a high yielding variety and the healthy seeds were bought from commercial seed market at Siddik Bazar, Gulisthan in Dhaka.

3.5 Source of irrigation

Deep tubewell is source of irrigation and experimental field was connected with irrigation channel and pipes. Every experimental plot had a good irrigation facility. When needed irrigation was done.

3.6 Treatments of the experiment

The experiment consisted of two factors as follows:

Factor A: Four levels of BARI IMO (Indigenous micro-organism) solution

S_0= Control (No BARI IMO solution)

S_1= 150 ml/L BARI IMO solution

S_2= 250 ml/L BARI IMO solution

S_3= 350 ml/L BARI IMO solution

Factor B: Four levels of inorganic fertilizer

F_1= 25% RDF (Recommended Dose of Fertilizer)

F_2= 50% RDF

F_3= 75% RDF

F_4= 100% RDF

Two factors consist of sixteen (4×4= 16) treatments combination. These are as follows:

S.N.	Treatment combination	Symbol
1	No IMO solution with 25% RDF	S_0F_1
2	No IMO solution with 50% RDF	S_0F_2
3	No IMO solution with 75% RDF	S_0F_3
4	No IMO solution with 100% RDF	S_0F_4
5	150 ml/L IMO solution with 25% RDF	S_1F_1
6	150 ml/L IMO solution with 50% RDF	S_1F_2
7	150 ml/L IMO solution with 75% RDF	S_1F_3
8	150 ml/L IMO solution with 100% RDF	S_1F_4
9	250 ml/L IMO solution with 25% RDF	S_2F_1
10	250 ml/L IMO solution with 50% RDF	S_2F_2
11	250 ml/L IMO solution with 75% RDF	S_2F_3
12	250 ml/L IMO solution with 100% RDF	S_2F_4
13	350 ml/L IMO solution with 25% RDF	S_3F_1
14	350 ml/L IMO solution with 50% RDF	S_3F_2
15	350 ml/L IMO solution with 75% RDF	S_3F_3
16	350ml/L IMO solution with 100% RDF	S_3F_4

3.7 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors with three replications. An area of 22.4 m × 7.2 m was divided into three equal blocks. Each block was consisting of 16 plots where 16 treatments were allotted randomly. There were 48 unit plots in the experiment. The size of each plot was 1.40 m × 0.90 m. The distance between two blocks and two plots were kept 1 m and 0.5 m, respectively. A layout of the experiment has been shown in figure 1.

3.8 Cultivation procedure

3.8.1 Land preparation

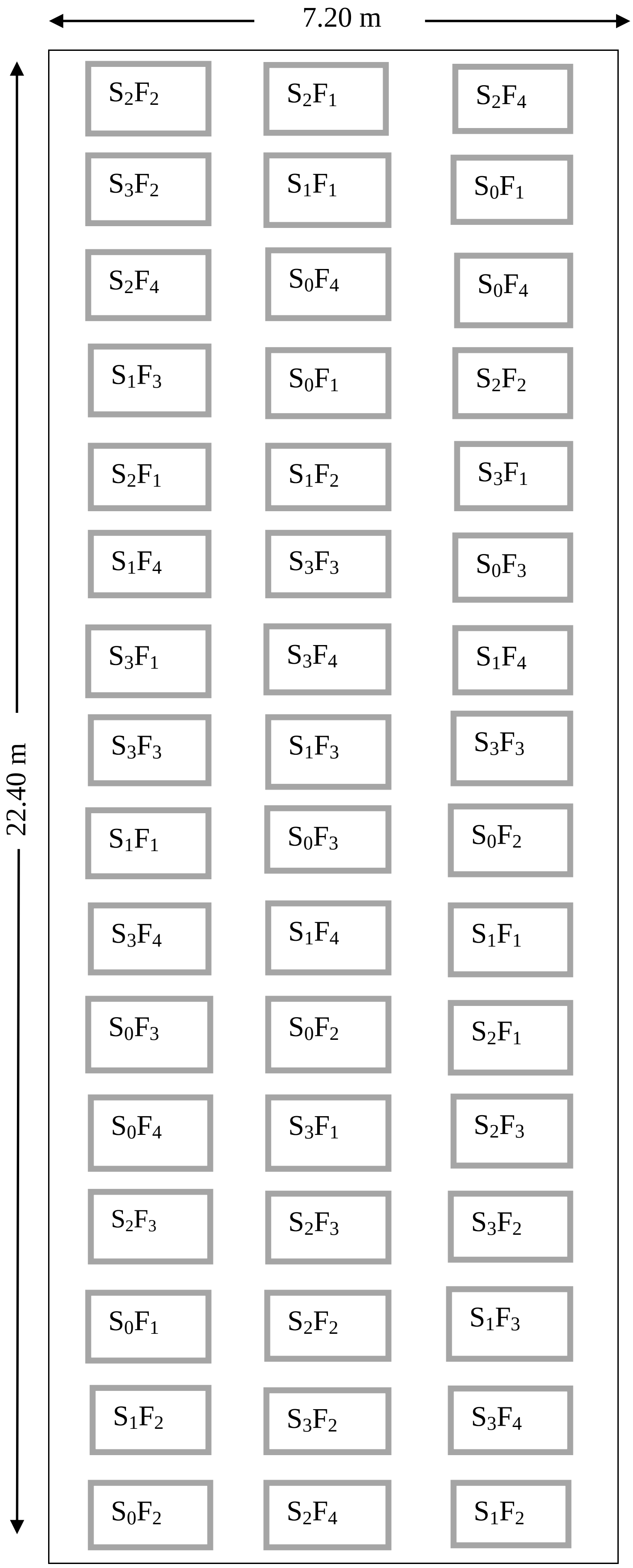
The selected land for the experiment was first open on November, 2019 by disc plough and it was exposed to sun light for six days prior to next ploughing. The land was ploughed five times by tractor to obtain good tilth. Laddering to break the soil clods and pieces was followed with each ploughing. All weeds, stubbles and stones were removed and the land was finally prepared through addition of the basal doses of manures and inorganic fertilizers according to the treatment. Plots were prepared according to design and layout. Finally soil of each plot was treated by Sevin 80 WP @ 2 kg/ha to protect the young plant from the attack of mole cricket, cutworm and ants. Irrigation channels were made around each block.

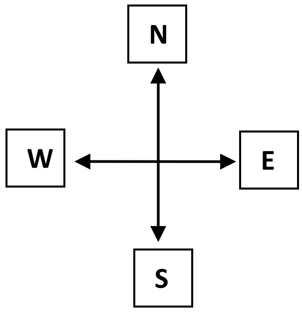
3.8.2 Manures and fertilizers and its methods of application

Fertilizer	Quantity	Application method
Cowdung	15 t/ha	Basal dose
Urea	400 Kg/ha	20, 35 and 50 DAS
TSP	300 Kg/ha	Basal dose
MoP	250 Kg/ha	20, 35 and 50 DAS mixed with urea
Gypsum	60 kg/ ha	20, 35 and 50 DAS mixed with urea

Source: Rashid (1999).

According to Rashid (1999), the entire amount of cowdung and TSP were applied as basal dose during land preparation. Urea, TSP and MoP were applied at the rate of 400 kg/ha, 300 kg/ha and 250 kg/ha, respectively. Urea and MoP were used as top dressing in equal splits at 20, 35 and 50 days after sowing.





Legend

Plot size: 1.40 m × .90 m

Total length: 22.40 m

Total breadth: 7.20 m

Distance between plot: 0.50 m

Replication distance:1.00 m

Treatments

Factor A: Four levels of BARI IMO (Indigenous micro-organism) solution

S_0= Control (No BARI IMO solution)

S_1= 150 ml/L BARI IMO solution

S_2= 250 ml/L BARI IMO solution

S_3= 350 ml/L BARI IMO solution

Factor B: Four levels of inorganic fertilizer

F_1= 25% RDF (Recommended Dose of Fertilizer)

F_2= 50% RDF

F_3= 75% RDF

F_4= 100% RDF

Figure 1. Layout of the experimental plot

3.8.3 Preparation and application of IMO solution

IMO solution was prepared first in Bangladesh by the Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI) (Nazim *et al*., 2017). They invented two types of IMO solution viz., BARI IMO solution 1 and BARI IMO solution 2. IMO solution 1 contains the anaerobic micro-organisms such as *Shewanella onidensis* and IMO solution 2 contains the aerobic micro-organisms such as *Bacillus*, *Pseudomonas*, *Mycorrhiza* etc. The stock solution of IMO was taken 150 ml and it was dissolved into 1 liter of distilled water. In the same way, we were prepared 250 ml/L and 350 ml/L IMO solution as per requirement. Application of IMO solution was done in soil and foliage at 15 day's interval. The IMO solution was applied at 20, 35, 50 and 65 days after sowing. Following elements needed for making each 200 liter IMO solution 1 and IMO solution 2 (anaerobic and aerobic).

Sl	Item Name	Amount	Sl	Item Name	Amount
1.	Milk	2 liters	8.	Expired or rotten breads	400 g
2.	Raw cowdung	8 kg	9.	200 L. plastic drum with lid	2 pieces
3.	Rice husk	4 kg	10.	Plastic bottle	1 piece
4.	organic manure	4 kg	11.	Bamboo stick	1 piece
5.	Termite colony soil	4 kg	12.	Medical saline set	1 set
6.	Rotten plant leaves	4 kg	13.	Masking tape	1 roll
7.	Molasses	4 liters	14.	Pure water	200 L

Source: Nazim *et al*. (2017).

All of the items had mixed in two 200 L plastic drum separately and covered with lid. For anaerobic solution making the drum lid had covered tightly and wrapped by the masking tape then kept undisturbed for 25-30 days and for aerobic solution making this drum had opened every day and mixed nicely for 25-30 days. After that the solutions had been poured and sieved in two separate drums. This was the stock IMO solution and ready to use.

3.9 Seed soaking and treatment

Carrot seeds were soaked into water for 12 hours and then wrapped with a piece of thin cloth prior to sowing. Then they were spread over polythene sheet in sun for three hours to dry. The seeds were treated with Bavistin 50 DF @ 3 g/100 g seed.

3.10 Seed rate and seed sowing

Seeds were used at the rate of 3.5 Kg/ha as narrated by Rashid (1999), consequently 60 g of seeds were used for the experimental area. The seeds were mixed with sand

(One part of seed with four parts of sand) then sown in the plot on November, 2019. Marked the rows with spacing of 30 cm and made a shallow furrow at a depth 1.0 cm in each plot.

3.11 Intercultural operations

When the plants establishing in the plots they were always kept under careful observation. Various intercultural operations were accomplished for better growth and development of germinated plants.

3.11.1 Thinning and earthing up

Emergence of seedlings started about six days after sowing. Thinning was done at two stages like 15 and 30 days after sowing in order to keep a healthy plant in each hill and maintained 20 cm plant to plant distance. Shallow earthing up was done after thinning.

3.11.2 Weeding

Weeding was done at two times. First weeding was done after 15 days of sowing when seedlings were thinned. Second weeding was done after 30 days of sowing.

3.11.3 Insects and diseases management

Precautionary measure against Fusarium rot was taken by spraying Dithane M 45 @ 2 g/liter water. The crop was infested by cutworms (*Agrotis ipsilon*) during the early stage of growth of seedlings in the month of December. This insect was controlled initially by beating and hooking, afterwards by spraying Dieldrin 20 EC @ 0.1%.

3.12 Harvesting

The crop was harvested after 90 days from seed sowing when leaves become pale yellow in color. Harvesting was done plot wise by uprooting the plants manually by hand. The soil and lateral roots adhering to the tuberized conical roots were properly cleaned.

3.13 Collection of data

3.13.1 Plant height (cm)

The plant height was measured with the help of a meter scale from the ground level of the root up to the tip of leaf at 30, 50, 70 and at harvest days after sowing and data were recorded by calculating the average value from five plants.

3.13.2 Number of leaves plant^{-1}

Number of leaves was counted 20 day's interval and was started from 30 days after sowing and continued to harvest, i.e. 30, 50, 70 and at harvest (90) DAS. Five plants in each plot were used to count number of leaves per plant and data were recorded by calculating the average value.

3.13.3 Length of root (cm)

After harvesting the length of root of five plants were measured of each treatment from the base to apex by a measuring scale and the mean was calculated accordingly.

3.13.4 Diameter of root (cm)

After harvesting the diameter of root of five plants were measured at the middle portion approximately 2.0 cm below the shoulder by a Vernier calipers and the mean diameter of roots was calculated for each treatment plots.

3.13.5 Root pith flesh ratio

Root pith flesh ratio was measured through dividing of dimeter of root by diameter of pith and multiply with hundred for explain in percentage. Hence, it is a ratio data so there is no unit for this parameter. For this measurement ten roots were used.

3.13.6 Root dry matter content (%)

Five selected carrot roots were used to determine root dry weight. Immediate after harvesting roots were weighed initially, then chopped and kept it in an oven at 70-80^0 C for 72 hours in order to get constant weight. (AOAC, 1994). The dry weight of root was measured by electric balance and was considered as dry weight and recorded in gram (g) and finally dry matter content was calculated by the following formula.

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

3.13.7 Leaf dry matter content (%)

Leaves were detached from the root and kept in an oven at 70-80^{0}C for 72 hours until reached constant weight. After drying, the leaves were kept in a desiccators containing blur silica gel. Fifteen minutes later the samples were weighed by using electric balance and recorded in gram (g) and following formula was used to calculate the dry matter content of leaves.

$$\% \text{ Dry matter content of leaves} = \frac{\text{Dry weight of leaves}}{\text{Fresh weight of leaves}} \times \mathbf{100}$$

3.13.8 Leaf weight per plant (g)

Leaves of five fresh plants in each plot were detached by sharp knife and fresh weight was taken by using a balance and recorded in gram (g) by making average value.

3.13.9 Individual root weight (g)

Five selected carrot roots were used to determine the fresh weight of root. Modified roots were detached by knife from the foliage part and fresh weight was taken by using balance and recorded in gram (g) by calculating the average value.

3.13.10 Number branched root (%)

After harvest the branched roots are counted and the percentage was calculated by the following formula-

$$\% \text{ of branched root} = \frac{\text{Number of branched root}}{\text{Total number of root harvested}} \times \mathbf{100}$$

3.13.11 Yield (t/ha)

Gross yield of roots per hectare was calculated by using the following formula-

$$\text{Gross yield} = \frac{\text{Yield per plot (kg)} \times 10000 \text{ m}^2}{\text{Area of plot in square meter (m}^2\text{)} \times 1000 \text{ Kg}}$$

3.13.12 Marketable yield (t/ha)

When the carrots were harvested from the plot; there were found branched root, cracked root, solarized root, deformed root, etc. types of roots. From this bulk lot the good quality in appearance was separated as the marketable yield getting the good price in market. Marketable yield of roots per hectare was calculated by conversion of the marketable root weight per plot and calculated in ton/ha.

3.13.13 Tritable acidity (%)

Tritable acidity which expressed as (%) was determined by titration with 0.1 mol/L NaOH to pH 8.1 according to the method by Ranganna (1986). Five carrots from each treatment were analyzed and the mean value was used. Mainly tritable acidity is done to determine the citric acid amount.

3.13.14 Vitamin C content (mg/100 g)

Vitamin C content of roots from each treatment was determined by the usual titration method 2, 6 dichlorophenol indophenols dye. It indicates the amount of ascorbic acid mainly. The end point was marked by the appearance of pink color. It was expressed as mg of ascorbic acid per 100 g of sample and calculated by using following formula

$$\text{Vitamin C} = \frac{\text{Titrated value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot extract taken} \times \text{Weight of sample taken for estimation}} \times \mathbf{100}$$

$$\text{Dye factor} = \frac{0.5}{\text{Titrated value}}$$

3.13.15 Measurements of surface colour

External surface colour was examined with a Chroma Meter (Model CR-400, Minolta Corp, Japan). CIE L*, a*, b* coordinates were recorded using D65 illuminants and a 10°standard observer as a reference system. L* is lightness, a* (-greenness to + redness) and b* (-blueness to + yellowness) are the chromaticity coordinates. The a* and b* values were transformed to Chroma (c) and hue angle (h^0) automatically in this Chroma meter. Before measurement, the equipment was calibrated against a standard white tile. Two readings were taken at equatorial regions on each carrot, taking five carrots from each treatment. Measurements were done in triplicate.

3.13.15.1 Chroma Value L

Chroma value L denotes the darkness or brightness of the product. The more the L value denotes the brighter or attractive the product. It had been measured by the Chroma meter named CR-400 Head, (Diffuse illumination/ 0<° viewing angle; specular component included/Conforms to JIS Z 8722 condition c standard, Detector-Silicon photocells, display ranges- Y: 0.01% to 160.00% (reflectance) made in Japan. It gave the direct reading of L value after calculation of a* and b* mean value.

3.13.15.2 Chroma Value C

Chroma value C denotes the maturity or green to reddish color of the product. The more the C value denotes the attractive orange color the product. It is also related with beta carotene content. It had been measured by the chroma meter named CR-400 Head, (Diffuse illumination/ 0<° viewing angle; specular component included/Conforms to JIS Z 8722 condition c standard, Detector-Silicon photocells, display ranges- Y: 0.01% to 160.00% (reflectance) made in Japan. It gave the direct reading of C value after calculation of a* and b* mean value.

3.13.15.3 Chroma Value H

Chroma value H denotes the hue angle or blue to yellowish color of the product. The more the H value denotes the good carrot color. It had been measured by the Chroma meter named CR-400 Head, made in Japan. It gave the direct reading after calculation hue angle of the mean data.

3.13.16 Firmness of root

Firmness was analyzed by Fruit Texture Analyzer (GUSS, Model Number: GS-25, SA). Firmness measurement was taken as the maximum penetration force reached during the tissue breakage and determined with 8 mm dia. flat end probe was pushed to a depth of 3 mm into carrot (same position of each sample) at 5 mm per sec speed. The utmost penetration force was used as firmness value of carrot in Kg. Five carrot (two opposite locations for each) from each replication were analyzed and the mean value was used.

3.13.17 Total Soluble Solid (TSS) (%)

A hand refract meter was used for the determination of TSS of roots. The hand refractometer was thoroughly washed and cleaned with distilled water and subsequently with ethyl alcohol. After drying, shadow level was adjusting to zero (0) marks with a drop of water and it was then blatted degree Brix of the provided carrot juice was recorded.

3.13.18 β-carotene content (mg/100 g)

ß-carotene which expressed as ppm (mg/1000 g) was analyzed according to AOAC (1994) using spectrophotometer (T60). Five carrots from each replication were analyzed and the mean value was used.

3.13.19 Total sugar and reducing sugar content (%)

Total sugar and reducing sugar which expressed as (%) was determined according to the method by Ranganna (1986).

3.14 Economic analysis

In computing economics, the varying levels of manure and different types of mulches were taken into consideration apart from other costs common to all the treatments as per package of practices.

3.14.1 Cost of production

The prices of all the inputs and the labor cost prevailed at the time of their use were taken into consideration while working out the cost of cultivation and expressed as taka per hectare.

3.14.2 Gross returns

Gross returns were calculated on the basis of the prevailing market price and the marketable yield produced per hectare.

3.14.3 Net returns

Net returns were arrived after deducting the cost of cultivation from the gross returns of the marketable produce on hectare basis and expressed in taka per hectare.

Net returns per hectare= Gross returns per hectare – total cost per hectare

3.14.4 Benefit Cost Ratio (BCR)

In order to find out announcement of one taka the gross return obtained from individual treatment was divided by its respective cost incurred in its application.

$$\text{Benefit cost ratio} = \frac{\text{Gross returns (Tk./ha)}}{\text{Total cost of production (Tk./ha)}}$$

3.15 Statistical analysis

The collected data for various traits were statistically analyzed using Statistix 10 computer package programme. The mean for all the treatments was calculated and the analysis of variance for each of the characteristics was performed by F (variance ratio) test. The differences between treatment means were separated by Duncan's Multiple Range Test according to Steel *et al*. (1997) for the interpretation of the results.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present experiment were presented in tables 1 to 15 and figures 2 to 5 on the effect of BARI IMO solution with inorganic fertilizer on growth, yield and quality of carrot. The analysis of variance (ANOVA) of the data on different plant characters obtained from present investigation were presented in Appendices IV to XI. The tabulated results and graphical presentation have been discussed below under the following headings.

4.1 Plant height (cm)

Plant height is one of the important growths contributing character for carrot. Plant height of carrot has measured at 30, 50, 70 days after sowing and at harvest (90 DAS). It was observed that different levels of BARI IMO solution application influenced significantly on plant height of carrot except 30 DAS (Appendix IV & V). During the growth period, plant height increased gradually and reached to peak at harvest. The maximum plant height was observed at S_3 treatment at 50 DAS, 70 DAS and at harvest. However, the maximum plant height was found (54.38 cm) from the S_3 (350 ml/L IMO solution) treatment at harvest, while the minimum height was observed (46.50 cm) from S_0 (control) treatment (Figure 2).

Significant variation was observed on plant height influenced for different doses of inorganic fertilizer application in the growth period over 25% RDF (Appendix IV & V). Application of fertilizers in soil and it added the nutrient to the soil and influenced on plant height. Among the treatments F_4 (100% of RDF) produced the tallest plant (28.50 cm, 42.50 cm, 53.50 cm and 59.50 cm) at 30, 50, 70 DAS and at harvest, respectively and followed by the F_3 (75% RDF) at the same DAS, respectively. The shortest plant was observed for the F_1 (25% RDF) treatment (Figure 3).

Significant variation was observed on plant height influenced for different doses of inorganic fertilizer application in the growth period over 25% RDF (Appendix IV & V). Application of fertilizers in soil and it added the nutrient to the soil and influenced on plant height.

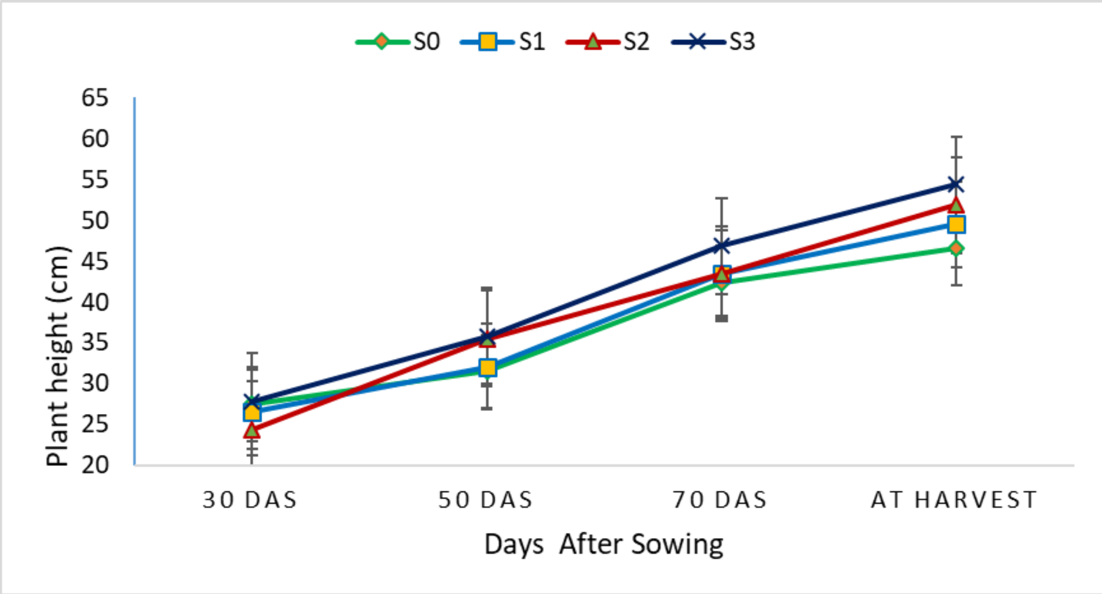


Figure 2. Effect of BARI IMO solution on plant height at different days after sowing

[Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L]

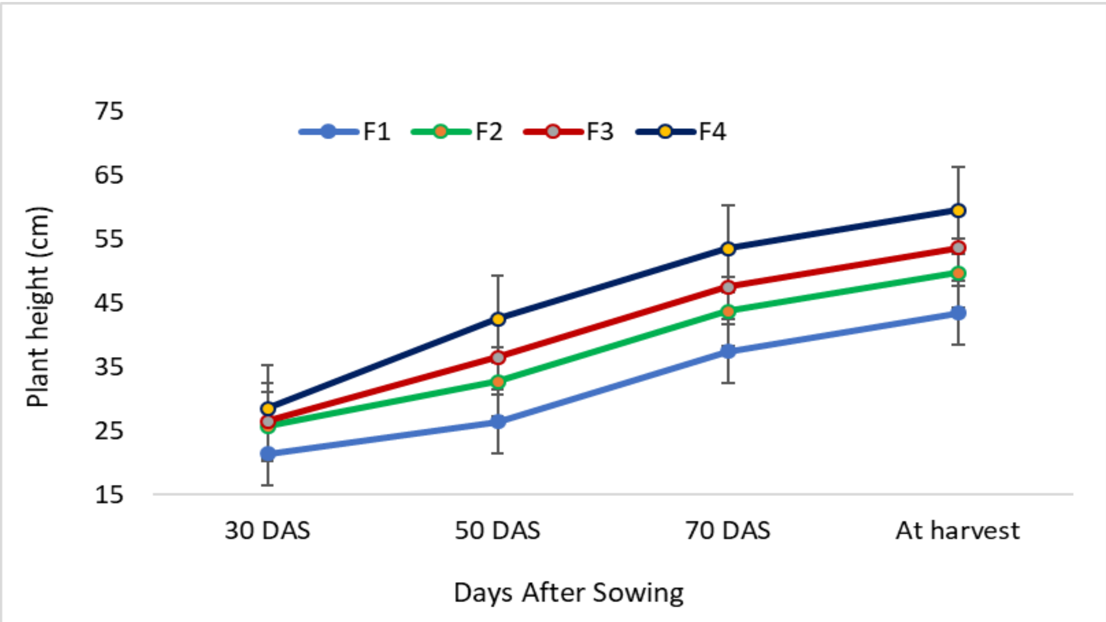


Figure 3. Effect of inorganic fertilizers on plant height at different days after sowing

[Here, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

Among the treatments F_4 (100% of RDF) produced the tallest plant (28.50 cm, 42.50 cm, 53.50 cm and 59.50 cm) at 30, 50, 70 DAS and at harvest, respectively and followed by the F_3 (75% RDF) at the same DAS, respectively. The shortest plant was observed for the F_1 (25% RDF) treatment (Figure 3); (Appendix IV & V).

The combined effect of IMO solution and inorganic fertilizers was found significantly influenced in terms of plant height of carrot (Appendix V). The maximum plant height (37.00 cm, 45.00 cm, 56.00 cm and 62.00 cm) was recorded from S_3F_4 (350 ml/L IMO solution and 100% RDF) treatment combination at 30, 50, 70 DAS and at harvest, respectively. On the other hand, the minimum plant height (14.00 cm, 22.00 cm, 33.00 cm and 39.00 cm) was found in plants of plot S_0F_1 (No IMO Solution and 25% RDF) treatment combination at 30, 50, 70 DAS and at harvest, respectively (Table 1). Plants treated with both EM and IMO solution recorded the best results in morphological parameters. These results are in accordance with that of Mbatha (2008), who showed that application of organic solution influenced significantly the height, the number of leaves and length of the carrot. Best results of morphological parameters obtained with IMO solution can be explained by the fact that it had the capacity of atmospheric nitrogen fixation; and that nitrogen is necessary for the development of all parts of plant. Nutrients normally unavailable, active biological substances (mineral, vitamins, nucleotides and antioxidants) and enzymes produced by IMO through the decomposition of organic materials stimulate other microorganisms in their activity and impulse soil mineralization then fortification of plants.

Table 1. Combined effect of different doses of BARI IMO solution with inorganic fertilizers on plant height of carrot

Treatments	Plant height (cm)			
	30 DAS	50 DAS	70 DAS	At harvest
S_0F_1	14.00 g	22.00 g	33.00 g	39.00 g
S_0F_2	28.00 cdef	36.00 cdef	47.00 cdef	53.00 cdef
S_0F_3	33.00 abcd	41.00 abcd	52.00 abcd	58.00 abcd
S_0F_4	35.00 ab	43.00 ab	54.00 ab	60.00 ab
S_1F_1	13.00 g	21.00 g	32.00 g	38.00 g
S_1F_2	29.00 bcde	37.00 bcde	48.00 bcde	54.00 bcde
S_1F_3	27.00 def	35.00 def	46.00 def	52.00 def
S_1F_4	31.67 abcd	39.67 abcd	50.67 abcd	56.67 abcd
S_2F_1	11.00 g	19.00 g	30.00 g	36.00 g
S_2F_2	28.67 bcde	36.67 bcde	47.67 bcde	53.67 bcde
S_2F_3	23.67 ef	31.67 ef	42.67 ef	48.67 ef
S_2F_4	34.33 abc	42.33 abc	53.33 abc	59.33 abc
S_3F_1	21.67 f	29.67 f	40.67 f	46.67 f
S_3F_2	27.33 def	35.33 def	46.33 def	52.33 def
S_3F_3	30.67 abcd	38.67 abcd	49.67 abcd	55.67 abcd
S_3F_4	37.00 a	45.00 a	56.00 a	62.00 a
LSD $_{(0.05)}$	6.95	6.91	6.88	6.93
CV (%)	15.69	12.06	9.15	8.08

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

4.2 Number of leaves per plant

Number of leaves was another important growth contributing character for carrot. Number of leaves of carrot has recorded at 30, 50, 70 days after sowing and at harvest. It was observed that different levels of IMO solution application influenced significantly on number of leaves of carrot (Appendix VI & VII). During the growth period, number of leaves increased gradually and reached to peak at harvest.

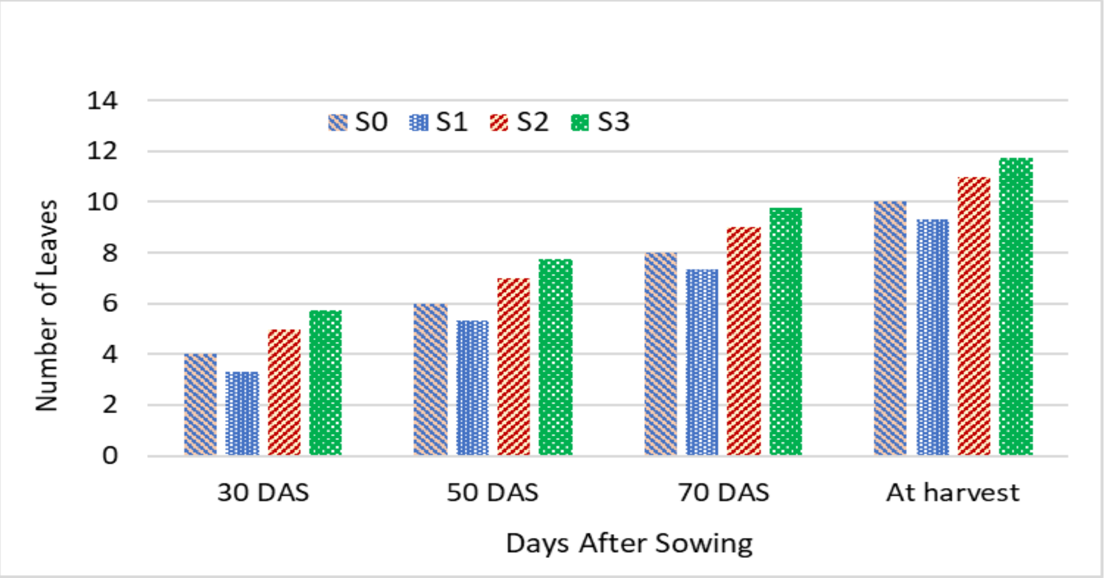


Figure 4. Effect of BARI IMO solution on number of leaves plant^{-1} at different days after sowing

[Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L]

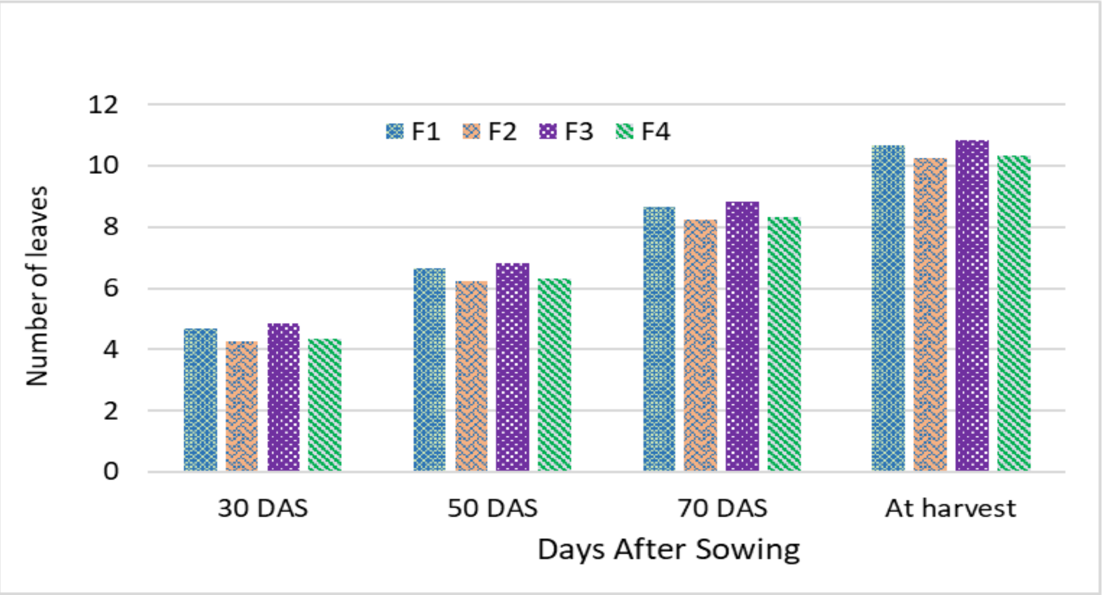


Figure 5. Effect of inorganic fertilizers on number of leaves plant^{-1} at different days after sowing

[Here, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

The maximum number of leaves was observed at S_3 (350 ml/L IMO solution) treatment at 30 DAS, 50 DAS, 70 DAS and at harvest. However, the maximum number of leaves was found (11.75) from the S_3 (350 ml/L IMO solution) treatment at harvest, while the minimum was observed (46.50 cm) from S_0 (control) treatment (Figure 4).

Significant variation was observed on number of leaves influenced for different doses of inorganic fertilizer application in the growth period over 25% RDF (Appendix VI & VII). Application of fertilizers in soil and it added the nutrient to the soil and influenced on number of leaves. Among the treatments F_3 (75% of RDF) produced the maximum number of leaves plant (4.83, 6.66, 8.33 and 11.66) at 30, 50, 70 DAS and at harvest, respectively and followed by the F_3 (75% RDF) at the same DAS, respectfully which was statistically similar with F_4 (100% RDF) treatment. The minimum number of leaves was observed for the F_1 (25% RDF) treatment (Figure 5).

The combined effect of IMO solution and inorganic fertilizers was found significantly influenced in terms of number of leaves of carrot (Appendix VII). The maximum number of leaves (6.67, 8.66, 10.67 and 12.67) was recorded from S_3F_4 (350 ml/L IMO solution and 100% RDF) treatment combination at 30, 50, 70 DAS and at harvest, respectively which was statistically similar to S_2F_2 (250 ml/L IMO solution and 50% of RDF) treatment combination and S_3F_2 (350 ml/L IMO solution and 50 % of RDF) treatment combination. On the other hand, the minimum number of leaves (2.00, 4.33, 6.00 and 8.00) was found in plants of plot S_0F_1 (No IMO Solution and 25% RDF) treatment combination at 30, 50, 70 DAS and at harvest, respectively (Table 2). Similar findings have been reported by Mbatha (2008).

Table 2. Combined effect of different doses of BARI IMO solution with inorganic fertilizers on number of leaves of carrot

Treatments	Number of leaves			
	30 DAS	50 DAS	70 DAS	At harvest
S_0F_1	2.00 e	4.00 e	6.00 e	8.00 e
S_0F_2	3.00 de	5.00 de	7.00 de	9.00 de
S_0F_3	4.00 cd	6.00 cd	8.00 cd	10.00 cd
S_0F_4	4.00 cd	6.00 cd	8.00 cd	10.00 cd
S_1F_1	3.00 de	5.00 de	7.00 de	9.00 de
S_1F_2	5.00 bc	7.00 bc	9.00 bc	11.00 bc
S_1F_3	5.00 bc	7.00 bc	9.00 bc	11.00 bc
S_1F_4	3.33 d	5.33 d	7.33 d	9.33 d
S_2F_1	5.33 b	7.33 b	9.33 b	11.33 b
S_2F_2	6.00 ab	8.00 ab	10.00 ab	12.00 ab
S_2F_3	5.33 b	7.33 b	9.33 b	11.33 b
S_2F_4	3.33 d	5.33 d	7.33 d	9.33 d
S_3F_1	5.33 b	7.33 b	9.33 b	11.33 b
S_3F_2	6.00 ab	8.00 ab	10.00 ab	12.00 ab
S_3F_3	5.00 bc	7.00 bc	9.00 bc	11.00 bc
S_3F_4	6.67 a	8.67 a	10.67 a	12.67 a
$LSD_{(0.05)}$	1.02	1.04	1.07	1.01
CV (%)	13.60	9.43	7.21	5.84

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= ,250 ml/L S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

4.3 Length of root (cm)

A significant variation was observed on root length due to use of different level of IMO solution (Appendix VIII). The longest root length 16.83 cm was recorded from S_3 (350 ml/L IMO solution) treatment while the shortest root length 10.12 cm was observed from S_0 (control) treatment (Table 3). It might be due to the fact that organic solution may be responsible for creating favorable soil conditions and supplying the required plant nutrients for better growth and development, which help to the prolongation of maximum root length. This finding is an agreement with the result of Schuch *et al.* (1999), they reported that the root length of carrot varied with different amount of manure application.

Root length differed significantly due to the different fertilizer application (Appendix

VIII). The maximum root length (14.42 cm) was recorded at treatment F_3 (75% RDF) and it was statistically identical to F_2 (13.42 cm) and F_4 (13.53 cm) treatment. On the other hand, the minimum root length (11.75 cm) was found at F_1 (25% RDF) treatment. The increase in root length due to different doses of fertilizers was which supplied the nutrient properly (Table 4).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on root length of carrot (Appendix VIII). The longest root 18.67 cm was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) which was statistically similar (16.67 cm) to the treatment combination of S_3F_4 (350 ml/L IMO solution and 100% of RDF). The shortest root length (7.00 cm) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment which was statistically similar to S_1F_1 (150 ml/L IMO Solution and 25% RDF) treatment combination (Table 5). The beneficial effect of combined application of organic fertilizer (IMO or compost) and inorganic fertilizer might be attributed to the increased efficacy of inorganic fertilizers and supply of all the essential nutrients in a balanced amount owing to their control release coinciding with the stage of root growth (Kumar *et al*. 2014). Similar findings have been reported by (Sunandarani and Malareddy, 2007).

4.4 Diameter of root (cm)

A significant variation was observed on root diameter due to use of different level of IMO solution application (Appendix VIII). The maximum root diameter 4.26 cm was recorded from S_3 (350 ml/L IMO solution) treatment while the minimum root diameter 1.65 cm was observed from S_0 (control) treatment (Table 3). It might be due to the fact that organic solution may be responsible for creating favorable soil conditions and supplying the required plant nutrients for better growth and development, which help to the prolongation of maximum root diameter.

Root diameter differed significantly due to the different fertilizer application (Appendix VIII). The maximum root diameter (3.90 cm) was recorded at treatment of F_4 (100% RDF). On the other hand, the minimum root diameter (2.46 cm) was found at F_1 (25% RDF) treatment. The increase in root diameter due to different doses of fertilizers was which supplied the nutrient properly (Table 4).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on root diameter of carrot (Appendix VIII). The highest root diameter 4.87 cm was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) which was statistically identical to S_2F_4 treatment combination (4.80 cm) and similar (4.53 cm) to the treatment combination of S_3F_4 (350 ml/L IMO solution and 100% of RDF). The lowest root diameter (1.10 cm) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment which was statistically similar to S_0F_2 (1.10) treatment combination (Table 5). These findings are in agreement with those reported by (Kumar *et al*., 2014); Vikram *et al*. (2022) in carrot.

4.5 Root pith flesh ratio

A significant variation was found on root pith flesh ratio due to use of different level of IMO solution application (Appendix VIII). The maximum root flesh pith ratio 1.93 was recorded from S_3 (350 ml/L IMO solution) treatment while the minimum root pith flesh ratio 1.60 was observed from S_0 (control) treatment (Table 3). Organic matter in an important factor for reducing the pith diameter. The root with the lower pith diameter is demandable. Sometimes the consumers dislike the larger pith containing root.

Root pith flesh ratio differed significantly due to the different fertilizer application (Appendix VIII). The maximum root pith flesh ratio (1.94) was recorded at treatment of F_3 (75% RDF) which was statistically similar to (1.87) F_2 (50% RDF) and (1.81) F_4 (100% RDF) treatments. On the other hand, the minimum root pith flesh ratio (1.75) was found at F_1 (25% RDF) treatment. (Table 4).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on root pith flesh ratio of carrot (Appendix VIII). The highest root pith flesh ratio 2.14 was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) which was statistically similar to S_1F_2, S_1F_3, S_2F_1, S_2F_2, S_2F_3 and S_2F_4 treatment combination. The lowest root pith flesh ratio (1.48 cm) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment which is statistically identical to S_0F_2 (1.50) and similar to S_0F_3 (1.71), S_0F_4 (1.73) and S_1F_1 (1.72) treatment combination (Table 5).

4.6 Root dry matter content (%)

A significant variation was found on root dry matter content due to use of different level of IMO solution application (Appendix VIII). The maximum root dry matter content 15.55% was recorded from S_3 (350 ml/L IMO solution) treatment while the minimum root dry matter content 13.11% was observed from S_0 (control) treatment which was statistically similar to S_1 (13.83%) treatment (Table 3).

Root dry matter content differed significantly due to the different fertilizer application (Appendix VIII). The maximum root dry matter content (14.82%) was recorded at treatment of F_3 (75% RDF) which was statistically similar to (14.56%) F_2 (50% RDF) and (14.79%) F_4 (100% RDF) treatments. On the other hand, the minimum root dry matter content (12.45%) was found at F_1 (25% RDF) treatment (Table 4).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on root dry matter content of carrot (Appendix VIII). The highest root dry matter content 17.78 % was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) which was statistically similar to S_3F_4 treatment combination. The minimum root dry matter content (11.81%) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment which was statistically identical to S_1F_1 (11.85%) and S_2F_1 (11.91%) treatment combination (Table 5). Root dry content and leaf dry mater content was increased when different amount of IMO solution with fertilizer applied. These findings are in agreement with those reported by Ali *et al.,* (2016) in carrot.

4.7 Leaf dry matter content (%)

A significant variation was found on leaf dry matter content due to use of different level of IMO solution application (Appendix VIII). The maximum leaf dry matter content 15.69% was recorded from S_3 (350 ml/L IMO solution) treatment while the minimum leaf dry matter content 13.38% was observed from S_0 (control) treatment (Table 3).

Leaf dry matter content differed significantly due to the different fertilizer application (Appendix VIII). The maximum leaf dry matter content (15.37%) was recorded at treatment of F_3 (75% RDF) which was statistically similar to (14.9 %) F_2 (50% RDF) and (15.11%) F_4 (100% RDF) treatments. On the other hand, the minimum leaf dry matter content (12.66%) was found at F_1 (25% RDF) treatment (Table 4).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on leaf dry matter content of carrot (Appendix VIII). The maximum leaf dry matter content 17.75% was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) which was statistically similar to S_3F_4 (16.38 %) treatment combination. The minimum leaf dry matter content (11.76%) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment which was statistically similar to S_2F_1 (12.42%) and S_0F_3 (12.86%) treatment combination (Table 5). The increase in leaf dry weight with the changed in inorganic fertilizer may be attributed to the role of it in stimulatory leaf growth, increase in chlorophyll content and causing canopy regeneration and directs photosynthesis into top production rather than root storage**.** This result was supported by Ali *et al*. (2016).

Table 3. Effect of different doses of BARI IMO solution on length of root, root diameter, root pith flesh ratio, root dry matter content and leaf dry matter content of carrot

Treatments	Length of root (cm)	Root Diameter (cm)	Root flesh pith ratio	Root dry matter content (%)	Leaf dry matter content (%)
S_0	10.12 d	1.65 d	1.60 b	13.11 c	13.38 c
S_1	11.75 c	3.40 c	1.87 a	13.83 bc	14.57 b
S_2	14.42 b	3.98 b	1.88 a	14.13 b	14.48 b
S_3	16.83 a	4.26 a	1.93 a	15.55 a	15.69 a
LSD $_{(0.05)}$	1.12	0.22	0.17	0.98	0.88
CV (%)	10.19	8.17	11.27	8.33	7.52

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml/L, S_3= 350ml/L]

Table 4. Effect of different inorganic fertilizers doses on length of root, root diameter, root pith flesh ratio, root dry matter content and leaf dry matter content of carrot

Treatments	Length of root (cm)	Root Diameter (cm)	Root flesh pith ratio	Root dry matter content (%)	Leaf dry matter content (%)
F_1	11.75 b	2.46 c	1.75 b	12.45 b	12.66 b
F_2	13.42 a	3.43 b	1.87 ab	14.56 a	14.97 a
F_3	14.42 a	3.51 b	1.94 a	14.82 a	15.37 a
F_4	13.53 a	3.90 a	1.81 ab	14.79 a	15.11 a
LSD $_{(0.05)}$	1.14	0.24	0.19	0.93	0.91
CV (%)	10.19	8.17	11.27	8.33	7.52

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

Table 5. Combined effect of different doses of BARI IMO solution with inorganic fertilizers on length of root, root diameter, root pith flesh ratio, root dry matter content and leaf dry matter content of carrot

Treatments	Length of root (cm)	Root Diameter (cm)	Root flesh pith ratio	Root dry matter content (%)	Leaf dry matter content (%)
S_0F_1	7.00 i	1.10 g	1.48 c	11.81 h	11.76 g
S_0F_2	13.00 ef	1.10 g	1.50 c	13.67 d-h	13.79 def
S_0F_3	12.00 fg	2.10 f	1.71 bc	12.69 fgh	12.86 efg
S_0F_4	8.47 hi	2.00 f	1.73 bc	13.84 d-g	14.45 cde
S_1F_1	7.33 i	2.40 f	1.72 bc	11.85 h	13.75 def
S_1F_2	10.00 gh	3.50 de	1.96 ab	14.39 b-f	15.10 bcd
S_1F_3	16.00 bc	4.30 b	2.00 ab	13.73 d-h	14.53 cde
S_1F_4	13.67 def	4.50 ab	1.79 bc	13.91 c-g	14.88 bcd
S_2F_1	12.00 fg	3.10 e	2.02 ab	11.91 h	12.42 fg
S_2F_2	16.00 bc	4.57 ab	1.85 ab	14.34 b-f	15.11 bcd
S_2F_3	14.33 cde	3.77 cd	1.99 ab	14.95 b-e	15.29 bcd
S_2F_4	15.33 bcd	4.80 a	1.85 ab	15.42 bcd	15.75 bc
S_3F_1	15.67 bcd	3.43 de	1.76 bc	12.45 fgh	12.71 efg
S_3F_2	16.33 bc	4.50 ab	1.77 bc	15.83 abc	15.89 bc
S_3F_3	18.67 a	4.87 a	2.14 a	17.78 a	17.75 a
S_3F_4	16.67 ab	4.53 ab	1.86 ab	16.12 ab	16.38 ab
$LSD_{(0.05)}$	2.25	0.45	0.34	1.96	1.82
CV (%)	10.19	8.17	11.27	8.33	7.52

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2=250 ml /L, S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

4.8 Leaf weight plant^{-1} (g)

A significant variation was found on leaf weight plant^{-1} due to use of different level of IMO solution application (Appendix IX). The maximum leaf weight 67.49 g was recorded from S_3 (350 ml/L IMO solution) treatment which was statistically similar to S_1 (63.93 g), S_2 (66.90 g) treatment while the minimum leaf weight (54.27 g) was observed from S_0 (control) treatment (Table 6).

Leaf weight plant^{-1} differed significantly due to the different fertilizer application (Appendix IX). The maximum leaf weight (70.52 g) was recorded at treatment of F_3 (75% RDF) which was statistically similar to (67.31 g) F_2 (50% RDF) and (69.66 g)

F_4 (100% RDF) treatments. On the other hand, the minimum leaf weight (45.10 g) was found at F_1 (25% RDF) treatment (Table 7).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on leaf weight plant^{-1} of carrot (Appendix IX). The maximum leaf weight plant^{-1} (78.29 g) was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) which was statistically similar to S_1F_2, S_1F_3, S_1F_4, S_2F_2, S_2F_3, S_2F_4, S_3F_2 and S_3F_4 treatment combination. The minimum leaf weight plant^{-1} (40.73 g) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment which was statistically similar to S_1F_1 (42.80 g) treatment combination (Table 8). Similar findings have been reported by Ali *et al*., (2016).

4.9 Individual Root weight (g)

A significant variation was found on individual root weight due to use of different level of IMO solution application (Appendix IX). The maximum individual root weight 120.82 g was recorded from S_3 (350 ml/L IMO solution) treatment while the minimum individual root weight (101.23 g) was observed from S_0 (control) treatment (Table 6).

Individual root weight differed significantly due to the different fertilizer application (Appendix IX). The maximum individual root weight (123.57 g) was recorded at treatment of F_3 (75% RDF) which was statistically similar to (116.32 g) F_4 (100% RDF) treatments. On the other hand, the minimum individual root weight (86.72 g) was found at F_1 (25% RDF) treatment (Table 7).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on individual root weight of carrot (Appendix IX). The maximum individual root weight plant (136.98 g) was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) which was statistically similar to S_3F_2 treatment combination. The minimum individual root weight plant (74.00 g) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment which was statistically similar to S_1F_1 (84.67 g) and treatment combination (Table 8). This was attributed due to solubilizing effect of plant nutrients by the addition of IMO solution leading to increased uptake of NPK. Organic manure plays a direct role in plant growth as a source of all necessary macro and micro-nutrients in available forms during mineralization, improving physical and physiological properties of soil. Similar findings have been reported by (Kumar *et al*., 2014).

4.10 Number of branched root (%)

A significant variation was found on number of branched root due to use of different level of IMO solution application (Appendix IX). It was one of the desirable characters of the carrot. The lower the number of branched roots ensures the good quality of root. The minimum number of branched root 8.0 % was recorded from S_3 (350 ml/L IMO solution) treatment while the maximum number of branched root (16.75%) was observed from S_0 (control) treatment (Table 6).

Number of branched roots differed significantly due to the different fertilizer application (Appendix IX). The minimum number of branched root (10.0%) was recorded at treatment of F_4 (100% RDF) treatments. On the other hand, the maximum number of branched root (19.00%) was found at F_1 (25% RDF) treatment (Table 7).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on number of branched roots of carrot (Appendix IX). The minimum number of branched root plant (4.0%) was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) treatment combination and followed by (6.0%) S_3F_2 which was statistically identical to S_3F_4 treatment combination. The maximum number of branched root plant (22.0%) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination (Table 8). These findings are supported by the findings of (Netra Pal, 2001), who reported that the branching of carrot root is a major problem in many carrots growing area. Although the tendency of branching seems to be controlled by genetic factors, a number of other factors may be involved. The branching is reduced by low nitrogen and increases as the amount of nitrogen in the soil increases. High soil concentration of ammonium compounds causes more serious branching or splitting than by other forms of nitrogen. Carrot branching is not affected due to time of sowing or variety. Wider the spacing, the greater is the amount of branching and large roots are more likely to branch than small ones.

4.11 Yield (t/ha)

A significant variation was found on yield due to use of different level of IMO solution application (Appendix IX). The maximum yield 24.52 t/ha was recorded from S_3 (350 ml/L IMO solution) treatment which was statistically similar to S_2 (23.55 t/ha) treatment while the minimum yield (20.39 t/ha) was observed from S_0 (control) treatment (Table 6).

Yield of carrot differed significantly due to the different fertilizer application (Appendix IX). The maximum yield (24.60 t/ha) was recorded at treatment of F_3 (75% RDF) treatment which was statistically identical to (24.50 t/ha) F_4 (100% RDF). On the other hand, the minimum yield (18.05 t/ha) was found at F_1 (25% RDF) treatment (Table 7).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on yields of carrot (Appendix IX). The maximum yield plant (26.49 t/ha) was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) treatment combination which was statistically similar to S_2F_4 (25.31 t/ha) (250 ml/L IMO solution and 100% of RDF) treatment combination. On the other hand, the minimum yield (15.20 t/ha) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination which was statistically similar to S_1F_1 (150 ml/L IMO solution and 25% RDF) (Table 8). This is in conformity with the studies concluded by Amartey *et al*. (2022). Jensen *et al*., (2006) explained that IMO had the capacity to increase the rate of decomposition of substances inside soil, increasing the availability of nutrients and improve the nutritional status of plants through yield, the reduction of pathogenic microorganisms and increased plant defense mechanisms. Similar findings have been reported by (Rao *et al*., 2009) in onion, (Barman *et al*., 2014) in potato, (Narayan *et al*., 2014) in potato and (Kumar *et al*., 2014) in carrot.

4.12 Marketable yield (t/ha)

A significant variation was found on marketable yield due to use of different level of IMO solution application (Appendix IX). The maximum marketable yield 22.41 t/ha was recorded from S_3 (350 ml/L IMO solution) treatment which was statistically similar to S_2 (21.46 t/ha) treatment while the minimum marketable yield (17.35 t/ha) was observed from S_0 (control) treatment (Table 6).

Marketable yield of carrot differed significantly due to the different fertilizer application (Appendix IX). The maximum marketable yield (22.63 t/ha) was recorded at treatment of F_3 (75% RDF) treatment which was statistically identical to (21.87 t/ha) F_4 (100% RDF). On the other hand, the minimum marketable yield (15.09 t/ha) was found at F_1 (25% RDF) treatment (Table 7).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on marketable yield of carrot (Appendix IX). The maximum marketable yield of plant (25.24 t/ha) was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) treatment combination which was statistically similar to S_2F_4 (22.40 t/ha), S_3F_2 (23.69 t/ha) and S_3F_4 (24.23 t/ha) treatment combination. On the other hand, the minimum marketable yield plant (12.39 t/ha) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination which was statistically similar (15.40 t/ha) to S_1F_1 (150 ml/L IMO solution and 25% RDF) (Table 8). This result indicates that application of higher amount of inorganic fertilizers alone or in combination with Bio-fertilizer negatively influenced the marketable yield of carrot root**.** Bender *et al*. (2009) reported that marketable yield of organic carrots was 11.53% higher than that of conventionally grown carrots with the application of chemical fertilizers (N 115, P 40 and K 152 kg ha-1) and pesticides. Similar findings have been reported by Rahman *et al*. (2018).

Table 6. Effect of different doses of BARI IMO solution on leaf weight per plant, individual root weight, number of branched root, yield and marketable yield of carrot

Treatments	Leaf weight plant^{-1} (g)	Individual root weight (g)	Number branched root (%)	Yield (t/ha)	Marketable yield (t/ha)
S_0	54.27 b	101.23 c	16.75 a	20.39 c	17.35 c
S_1	63.93 a	110.13 b	15.00 b	22.47 b	20.02 b
S_2	66.90 a	113.42 b	11.92 c	23.55 ab	21.46 ab
S_3	67.49 a	120.82 a	8.00 d	24.52 a	22.41 a
LSD $_{(0.05)}$	4.54	7.32	0.44	1.74	1.85
CV (%)	8.64	7.87	3.9	9.13	10.85

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L]

Table 7. Effect of different doses of inorganic fertilizers on leaf weight per plant, individual root weight, number of branched root, yield and marketable yield of carrot

Treatment	Leaf weight plant^{-1} (g)	Individual root weight (g)	Number branched root (%)	Yield (t/ha)	Marketable yield (t/ha)
F_1	45.10 b	86.72 c	19.00 a	18.05 c	15.09 c
F_2	67.31 a	109.00 b	11.67 b	21.77 b	19.65 b
F_3	70.52 a	123.57 a	11.00 c	24.60 a	22.63 a
F_4	69.66 a	116.32 a	10.00 d	24.50 a	21.87 a
LSD $_{(0.05)}$	4.54	7.30	0.42	1.72	1.83
CV (%)	8.64	7.87	3.9	9.13	10.85

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

Table 8. Combined effect of different doses of BARI IMO solution with inorganic fertilizers on leaf weight per plant, individual root weight, number of branched-root, yield and marketable yield of carrot

Treatments	Leaf weight plant^{-1} (g)	Individual root weight (g)	Number branched root (%)	Yield (t/ha)	Marketable yield (t/ha)
S_0F_1	40.73 d	74.00 i	22.00 a	15.20 f	12.39 g
S_0F_2	55.93 bc	120.27 bcd	16.00 d	21.68 cde	18.68 def
S_0F_3	59.80 b	104.27 efg	15.00 e	22.24 bcd	17.24 ef
S_0F_4	60.60 b	106.40 def	14.00 f	22.45 bcd	21.08 bcd
S_1F_1	42.80 d	84.67 hi	20.00 b	17.33 f	15.40 fg
S_1F_2	70.20 a	123.60 abc	14.00 f	22.28 bcd	21.06 bcd
S_1F_3	71.00 a	110.27 cdef	14.00 f	22.45 bcd	19.92 cde
S_1F_4	71.73 a	122.00 bc	12.00 g	22.28 bcd	21.20 bcd
S_2F_1	49.19 cd	90.67 gh	18.00 c	18.53 ef	16.08 f
S_2F_2	72.33 a	124.13 abc	10.67 h	22.12 bcd	21.26 bcd
S_2F_3	73.00 a	124.50 abc	11.00 h	23.03 bcd	21.10 bcd
S_2F_4	73.07 a	114.40 b-e	8.00 i	25.31 ab	22.40 abc
S_3F_1	47.66 cd	97.55 fgh	16.00 d	21.14 de	16.49 ef
S_3F_2	70.78 a	126.27 ab	6.00 j	22.23 bcd	23.69 ab
S_3F_3	78.29 a	136.98 a	4.00 k	26.49 a	25.24 a
S_3F_4	73.22 a	122.49 abc	6.00 j	25.43 ab	24.23 ab
LSD $_{(0.05)}$	9.09	14.61	0.84	3.45	3.67
CV (%)	8.64	7.87	3.9	9.13	10.85

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

4.13 Tritable acidity (%)

A significant variation was found on tritable acidity due to use of different level of IMO solution application (Appendix X). The maximum tritable acidity 0.80% was recorded from S_1 (150 ml/L IMO solution) treatment while the minimum tritable acidity (0.27 %) was observed from S_0 (control) treatment (Table 9).

Tritable acidity of carrot differed significantly due to the different fertilizer application (Appendix X). The maximum tritable acidity (0.65%) was recorded at treatment of F_2 (50% RDF) treatment. On the other hand, the minimum tritable acidity (0.33%) was found at F_4 (100% RDF) treatment which was statistically identical to (0.34%) F_3 (75% RDF) (Table 10).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on tritable acidity of carrot (Appendix X). The maximum tritable acidity plant (1.28%) was observed from the treatment combination of S_1F_2 (150 ml/L IMO solution and 50% of RDF) treatment combination. On the other hand, the minimum tritable acidity plant (0.26%) was recorded from S_0F_2 (No IMO solution and 50% RDF) treatment combination which was statistically identical to (0.26 %) to S_1F_3, S_1F_4 and S_2F_3 treatment combination (Table 11).

4.14 Vitamin C content (mg/100 g)

A significant variation was found on Vitamin C content due to use of different level of IMO solution application (Appendix X). The maximum vitamin C content 28.50 mg was recorded from S_3 (IMO solution 350ml/L) treatment which was statistically similar to S_1 (27.00 mg) while the minimum vitamin C content (25.00 mg) was observed from S_0 (control) treatment which was statistically identical to S_2 (25.83 mg) (Table 9).

Vitamin C content of carrot differed significantly due to the different fertilizer application (Appendix X). The maximum vitamin C content (33.00 mg) was recorded at treatment of F_4 (100% RDF) treatment. On the other hand, the minimum Vitamin C content (22.83 mg) was found at F_3 (75% RDF) treatment which was statistically identical to (23.50 mg) F_2 (50% RDF) (Table 10).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on vitamin C content of carrot (Appendix X). The maximum Vitamin C content plant (42.00 mg) was observed from the treatment combination of S_3F_4 (350 ml/L IMO solution and 100% of RDF) treatment combination. On the other hand, the minimum vitamin C content plant (16.00 mg) was recorded from S_0F_3 (No IMO solution and 75% RDF) treatment combination which was statistically identical to (20.00 mg) to S_0F_2 (No IMO solution and 50% RDF) treatment combination (Table 11). This result indicates that reduction of vitamin C content occurred due to application of Bio-fertilizer alone or in combination with inorganic fertilizers. Similar result was also reported by Bender *et al*. (2009), and they stated that the contents of vitamin C and nitrogen were significantly lower in organically grown carrot than in conventionally grown carrot.

4.15 Chroma Value L

A significant variation was found on Chroma value L due to use of different level of IMO solution application (Appendix X). It denotes the darkness or brightness of the product (Urbonaviciene *et al*., 2012). Higher the value indicates that brighter the carrot and ensures the high market price. The maximum Chroma value L 47.83 was recorded from S_3 treatment which was statistically similar to S_1 (47.16) and S_2 (47.20) while the minimum Chroma value L (44.80) was observed from S_0 (control) (Table 9).

Chroma value L of carrot was not significantly varied due to the different fertilizer application (Appendix X). The maximum Chroma value L (47.46) was recorded at treatment of F_4 (100% RDF) treatment. On the other hand, the minimum Chroma value L (43.81) was found at F_1 (25% RDF) treatment (Table 10).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on Chroma value L of carrot (Appendix X). The maximum Chroma value L (49.97) was observed from the treatment combination of S_3F_4 (350 ml/L IMO solution and 100 % of RDF) which was statistically identical to (49.64) to S_3F_3 treatment combination. On the other hand, the minimum Chroma value L (41.85) was recorded from S_1F_1 (150 ml/L IMO solution and 25% RDF) treatment combination (Table 11). This is in conformity with the studies conducted by Stinco *et al*. (2019); Yusuf *et al*. (2022).

4.16 Chroma value C

A significant variation was found on Chroma value C due to use of different level of IMO solution application (Appendix X). It indicates the maturity color that means green to reddish color of the carrot. Maximum carrot was orange in color. So, higher the C value indicates the better orange color of root (Urbonaviciene *et al*., 2012). It can be also co-related by the beta carotene. Higher C value also denotes the higher beta carotene content of the carrot (Lyu *et al*., 2021). The maximum Chroma value C (35.68) was recorded from S_2 (250 ml/L IMO solution) treatment while the minimum Chroma value C (29.92) was observed from S_1 (150 ml/L IMO solution) (Table 9).

Chroma value C of carrot was not significantly varied due to the different fertilizer application (Appendix X). The maximum Chroma value C (34.53) was recorded at treatment of F_2 (50% RDF) treatment. On the other hand, the minimum Chroma Value-C (30.24) was found at F_3 (75% RDF) treatment (Table 10).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on Chroma value C of carrot (Appendix X). The maximum Chroma value C (40.09) was observed from the treatment combination of S_2F_4 (250 ml/L IMO solution and 100% of RDF). On the other hand, the minimum Chroma value C (26.06) was recorded from S_1F_3 (150 ml/L IMO solution and 75 % of RDF) treatment combination (Table 11). The result was similar to the findings of Stinco *et al*. (2019); Yusuf *et al*. (2022).

4.17 Chroma value H

A significant variation was found on Chroma value H due to use of different level of IMO solution application (Appendix X). It denotes the hue angle that means green to yellow color (Araya *et al*., 2009). The higher the hue angle indicates the maximum yellowish color of the root (Lyu *et al*., 2021). The maximum Chroma value H (65.14) was recorded from S_2 (250 ml/L IMO solution) treatment while the minimum Chroma value H (62.75) was observed from S_3 (350 ml/L IMO solution) (Table 9).

Chroma value H of carrot was not significantly varied due to the different fertilizer application (Appendix X). The maximum Chroma value H (64.39) was recorded at treatment of F_3 (75% RDF) treatment. On the other hand, the minimum Chroma value H (61.38) was found at F_1 (25% RDF) treatment (Table 10).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on Chroma value H of carrot (Appendix X). The maximum Chroma value H (65.21) was observed from the treatment combination of S_2F_3 (250 ml/L IMO solution and 75% of RDF). On the other hand, the minimum Chroma value H (61.83) was recorded from S_0F_1 (no IMO solution and 25% RDF) treatment combination (Table 11). This is in conformity with the studies conducted by Pirnia and Shadi (2015).

Table 9. Effect of different doses of BARI IMO solution on tritable acidity, vitamin C content and color of carrot

Treatments	Tritable acidity (%)	Vitamin C content (mg/100 g)	Chroma value		
			L	C	H
S_0	0.27 d	25.00 b	44.80 b	32.37 b	63.93 b
S_1	0.80 a	27.00 ab	47.16 ab	29.92 c	63.49 b
S_2	0.45 b	25.83 b	47.20 ab	35.68 a	65.14 a
S_3	0.38 c	28.50 a	47.83 a	32.74 b	62.75 c
LSD $_{(0.05)}$	0.03	2.15	1.04	1.38	0.59
CV (%)	6.89	9.87	2.58	5.03	1.08

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L]

Table 10. Effect of different doses of inorganic fertilizers on tritable acidity, vitamin C content and color of carrot

Treatments	Tritable acidity (%)	Vitamin C content (mg/100 g)	Chroma value		
			L	C	H
F_1	0.58 b	27.00 b	43.81	32.52 b	61.38 c
F_2	0.65 a	23.50 c	47.32	34.53 a	63.38 b
F_3	0.34 c	22.83 c	47.41	30.24 c	64.39 a
F_4	0.33 c	33.00 a	47.46	31.42 b	63.15 b
LSD $_{(0.05)}$	0.02	2.18	1.01	1.36	0.57
CV (%)	6.89	9.87	2.58	5.03	1.08

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

Table 11. Combined effect of different doses of BARI IMO solution with inorganic fertilizers on tritable acidity vitamin C content and color of carrot

Treatments	Tritable acidity (%)	Vitamin C content (mg/100 g)	Chroma value		
			L	C	H
S_0F_1	1.15 b	30.00 b	47.19 de	35.59 bc	61.83 f
S_0F_2	0.26 f	20.00 ef	44.81 f	30.33 d	63.71 cd
S_0F_3	0.47 d	16.00 f	46.91 de	33.53 c	63.18 de
S_0F_4	0.39 e	22.00 de	48.31 abcd	30.03 d	63.42 de
S_1F_1	0.73 c	30.00 b	41.85 g	29.24 d	63.47 de
S_1F_2	1.28 a	26.00 bcd	49.47 abc	34.49 bc	62.78 def
S_1F_3	0.26 f	24.00 cde	47.74 bcd	26.06 e	64.64 bc
S_1F_4	0.26 f	28.00 bc	49.58 ab	29.89 d	63.05 de
S_2F_1	0.77 c	30.00 b	48.21 abcd	28.97 d	65.60 ab
S_2F_2	0.38 e	22.00 de	47.77 bcd	37.16 b	65.21 ab
S_2F_3	0.26 f	22.00 de	45.35 ef	36.48 b	65.94 a
S_2F_4	0.38 e	23.33 de	47.45 cd	40.09 a	63.79 cd
S_3F_1	0.38 e	24.00 cde	44.49 f	36.28 b	63.02 de
S_3F_2	0.38 e	26.00 bcd	47.21 de	36.14 bc	65.42 ab
S_3F_3	0.38 e	22.00 de	49.64 ab	29.06 d	63.79 cd
S_3F_4	0.38 e	42.00 a	49.97 a	29.48 d	62.34 ef
LSD $_{(0.05)}$	0.054	4.37	2.03	2.73	1.15
CV (%)	6.89	9.87	2.58	5.03	1.08

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

4.18 Firmness of root

A significant variation was found on firmness due to use of different level of IMO solution application (Appendix XI). The maximum firmness 48.22 was recorded from S_2 (250 ml/L IMO solution) treatment while the minimum firmness 45.87 was observed from S_0 (control) treatment (Table 12).

Firmness of carrot differed significantly due to the different fertilizer application (Appendix XI). The maximum Firmness 49.08 was recorded at treatment of F_4 (100% RDF) treatment. On the other hand, the minimum firmness 43.74 was found at F_1 (25% RDF) treatment (Table 13).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on firmness of carrot (Appendix XI). The maximum firmness of plant (52.68%) was observed from the treatment combination of S_2F_4 (250 ml/L IMO solution and 100% of RDF) treatment combination. On the other hand, the minimum firmness of plant 40.91 was recorded from S_2F_1 (250 ml/L IMO solution and 25% RDF) treatment combination. (Table 14).

4.19 TSS (%)

A significant variation was found on TSS due to use of different level of IMO solution application (Appendix XI). The maximum TSS 8.94% was recorded from S_3 (350 ml/L IMO solution) treatment while the minimum TSS 8.83% was observed from S_0 (control) treatment (Table 12).

TSS of carrot differed significantly due to the different fertilizer application (Appendix XI). The maximum TSS 8.93% was recorded at treatment of F_4 (100% RDF) treatment. On the other hand, the minimum TSS 8.66 % was found at F_1 (25% RDF) treatment (Table 13).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on TSS of carrot (Appendix XI). The maximum TSS of plant 9.07% was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% RDF) treatment combination. On the other hand, the minimum TSS of plant 8.50% was recorded from S_0F_2 (No IMO solution and 50% RDF) treatment combination which was statistically identical to 8.50% to S_1F_2 (150 ml/L IMO solution and 50% RDF) and S_2F_2 8.50% (250 ml/L IMO solution and 50% RDF) treatment combination (Table 14). This is in conformity with the studies conducted by (Kumar *et al*., 2014); Valsikova-Frey *et al*. (2021).

4.20 β carotene content (mg/100 g)

A significant variation was found on β carotene due to use of different level of IMO solution application (Appendix XI). The maximum β carotene 27.32 mg/100 g was recorded from S_3 (350 ml/L IMO solution) treatment while the minimum β carotene 13.47 mg/100 g was observed from S_0 (control) treatment (Table 12).

β carotene of carrot differed significantly due to the different fertilizer application (Appendix XI). The maximum β carotene 31.14 was recorded at treatment of F_3 (75%

RDF) treatment. On the other hand, the minimum β carotene 20.16 mg/100 g was found at F_1 (25% RDF) treatment (Table 13).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on β carotene of carrot (Appendix XI). The maximum β carotene of plant 36.85 mg/100 g was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) treatment combination. On the other hand, the minimum β carotene of plant 6.44 mg/100 g was recorded from S_1F_3 (150 ml/L IMO solution and 75% RDF) treatment combination (Table 14). Similar result is also reported by Bender *et al*. (2009), they also stated that the contents of β carotene was significantly higher in organically grown carrot.

4.21 Total sugar content (%)

A significant variation was found on total sugar content due to use of different level of IMO solution application (Appendix XI). The maximum total sugar content 10.41% was recorded from S_3 treatment while the minimum total sugar content 9.46% was observed from S_2 treatment (Table 12).

Total sugar content of carrot differed significantly due to the different fertilizer application (Appendix XI). The maximum total sugar content 10.51% was recorded at treatment of F_4 (100% RDF) treatment. On the other hand, the minimum total sugar content 9.34% was found at F_1 (25% RDF) treatment (Table 13).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on total sugar content of carrot (Appendix XI). The maximum total sugar content of plant 11.09% was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) treatment combination. On the other hand, the minimum total sugar content of plant 9.13% was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination which was statistically identical to 9.13% to S_2F_1 (250 ml/L IMO solution and 25% RDF) treatment combination (Table 14). This result indicates that the application of inorganic fertilizers along with Biomeal positively influenced on sugar contents in carrot. This result was supported by Yan *et al*. (2004). Bender *et al*. (2009) reported that the contents of dry matter, total sugars and soluble solids were insignificant in organically grown carrot than in conventionally grown carrot.

Table 12. Effect of different doses of BARI IMO solution on firmness of root, TSS, β carotene content, total sugar content and reducing sugar content of carrot

Treatments	Firmness of root	TSS (%)	β carotene content (mg/100 g)	Total sugar content (%)	Reducing sugar content (%)
S_0	45.87 b	8.83 b	13.47 c	10.04 b	2.80 b
S_1	47.40 ab	8.49 c	19.54 b	9.85 b	2.88 a
S_2	48.22 a	8.85 ab	26.03 a	9.46 c	2.90 a
S_3	46.01 b	8.94 a	27.32 a	10.41 a	2.88 a
LSD $_{(0.05)}$	2.19	0.11	1.77	0.28	0.06
CV (%)	5.55	1.29	9.72	3.09	2.15

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L]

Table 13. Effect of different doses of inorganic fertilizers on firmness of root, TSS, β carotene content, total sugar content and reducing sugar content of carrot

Treatments	Firmness of root	TSS (%)	β carotene content (mg/100 g)	Total sugar content (%)	Reducing sugar content (%)
F_1	43.74 b	8.66 c	20.16 b	9.34 c	2.82 b
F_2	48.85 a	8.72 bc	14.14 c	9.82 b	2.85 b
F_3	45.82 b	8.81 b	31.14 a	9.78 b	2.95 a
F_4	49.08 a	8.93 a	20.91 b	10.51 a	2.84 b
LSD $_{(0.05)}$	2.17	0.09	1.74	0.25	0.05

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

Table 14. Combined effect of different doses BARI IMO solution with inorganic fertilizers on firmness of root, TSS, β carotene content, total sugar content and reducing sugar content of carrot

Treatments	Firmness of root	TSS (%)	β carotene content (mg/100 g)	Total sugar content (%)	Reducing sugar content (%)
S_0F_1	45.03 def	8.93 abc	22.07 d	9.13 e	2.59 e
S_0F_2	47.19 cd	8.50 e	35.24 ab	9.71 bcd	2.75 d
S_0F_3	44.38 def	8.93 abc	33.31 bc	10.08 b	2.97 a
S_0F_4	46.89 d	8.83 bcd	13.48 ef	9.25 de	2.86 bc
S_1F_1	46.96 d	8.67 de	31.14 c	9.67 bcd	2.94 ab
S_1F_2	45.52 de	8.50 e	33.80 abc	11.03 a	2.86 bc
S_1F_3	45.52 de	8.80 cd	6.44 h	9.56 cde	2.94 ab
S_1F_4	51.60 ab	8.00 f	7.50 gh	9.79 bc	2.78 cd
S_2F_1	40.91 f	9.04 b	12.42 ef	9.13 e	3.03 a
S_2F_2	51.40 abc	8.50 e	23.84 d	9.56 cde	2.94 ab
S_2F_3	47.87 bcd	9.00 ab	7.04 h	9.34 cde	2.86 bc
S_2F_4	52.68 a	8.80 cd	10.56 fg	10.78 a	2.78 cd
S_3F_1	42.08 ef	9.00 ab	15.01 e	10.12 b	2.70 d
S_3F_2	51.31 abc	8.80 cd	31.67 c	10.66 b	2.86 bc
S_3F_3	45.52 de	9.07 a	36.85 a	11.09 a	3.03 a
S_3F_4	45.13 def	9.00 ab	25.03 d	11.05 a	2.94 ab
$LSD_{(0.05)}$	4.34	0.18	3.4	0.51	0.10

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

4.22 Reducing sugar content (%)

A significant variation was found on reducing sugar content due to use of different level of IMO solution application (Appendix XI). The maximum reducing sugar content (2.90%) was recorded from S_2 (250 ml/L IMO solution) treatment which was statistically similar to (2.88%) S_1 (150 ml/l IMO solution) and (2.88%) S_3 (350 ml/L IMO solution) treatments. On the other hand, the minimum reducing sugar content 2.80 % was observed from S_0 (control) treatment (Table 12).

Reducing sugar content differed significantly due to the different fertilizer application (Appendix XI). The maximum reducing sugar content (2.95%) was recorded at treatment of F_3 (75% RDF) while the minimum reducing sugar content (2.82%) was found at F_1 (25% RDF) treatment which was statistically similar to (2.85%) F_2 (50% RDF) and (2.84%) F_4 (100% RDF) treatments (Table 13).

The combined effect of IMO solution and different doses of fertilizers showed significant variation on reducing sugar content of carrot (Appendix XI). The highest reducing sugar content 3.03% was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) which was statistically similar to (3.03%) S_2F_1 treatment combination. The minimum reducing sugar content (2.59%) was recorded from S_0F_1 treatment which was statistically identical to S_3F_1 (2.70%) treatment combination (Table 14). Korolev *et al*. (2000) showed that solutes contained inside carrot root followed four stages of development: the first stage (0 to 10 days) is the accumulation of amino acids, the second stage (10 to 30 days) is ionic stage, the third stage (30 to 50 days) is hexose stage during which the concentration of glucose, fructose and sucrose increase up to a maximum and the fourth stage (50 to 90 days) or sucrose stage is the stage where the sucrose is abundant inside roots.

4.23 Economic analysis

Economics was the major criteria to evaluate the best treatments which were economically sound and that can be accepted by farming community. The cost of cultivation, gross and net returns in addition to benefit cost ratio of different treatment combinations studied in the present investigation was presented in (Table 15 and Appendix XII & XIII).

4.23.1 Cost of production

The total expenditure was observed to range from Tk. 2,20,052/- (S_0F_1) to 2,52,277/- (S_3F_4). Among all the inputs used in the present investigation, labor contributes more to the cost of cultivation (Table 15 and Appendix XII & XIII).

4.23.2 Gross returns

Gross returns for different treatment combinations in the present investigation ranged from Tk. 3,09,750/- (S_0F_1) to Tk. 6,31,000/- (S_3F_3). Among all the treatment combinations studied, S_3F_3 gave highest gross returns of Tk. 6,31,000/- followed by 6,05,750/- (S_3F_4) (Table 15).

Table 15. Cost and return analysis of carrot production as influenced by BARI IMO solution and inorganic fertilizers

Treatments	Cost of Production (Tk. /ha)	Marketable yield (t/ha)	Gross return (Tk. /ha)	Net Return (Tk. /ha)	BCR
S_0F_1	220052	12.39	309750	89698	1.41
S_0F_2	228738	18.68	467000	238262	2.04
S_0F_3	236594	17.24	431000	194406	1.82
S_0F_4	244449	21.08	527000	282551	2.16
S_1F_1	223407	15.40	385000	161593	1.72
S_1F_2	232093	21.06	526500	294407	2.27
S_1F_3	239948	19.92	498000	258052	2.08
S_1F_4	247804	21.20	530000	282196	2.14
S_2F_1	225643	16.08	402000	176357	1.78
S_2F_2	234329	21.26	531500	297171	2.27
S_2F_3	242185	21.10	527500	285315	2.18
S_2F_4	250041	22.40	560000	309959	2.24
S_3F_1	227880	16.49	412250	184370	1.81
S_3F_2	236566	23.69	592250	355684	2.50
S_3F_3	244421	25.24	631000	386579	2.58
S_3F_4	252277	24.23	605750	353473	2.40

[Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

4.23.3 Net returns

Highest net returns per hectare of Tk. 386579/- in carrot cultivation under different treatment combinations of organic manure and mulches studied was obtained with the S_3F_3 (Tk. 386,579/-) followed by S_3F_4 (TK. 353,473/-) whereas lowest net returns of Tk. 89,698/- was observed with S_0F_1 (Table 15).

4.23.4 Benefit cost ratio

Among all the treatment combinations studied in the present investigation, S_3F_3 resulted in highest benefit cost ratio of 2.58 followed by S_3F_4 (2.40). Further, lowest benefit cost ratio of 1.41 was obtained from S_0F_1 (Table 15).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Olericulture Research Field- 2, Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the November, 2019 to February, 2020 to evaluate the "effect of BARI IMO solution with inorganic fertilizers on growth, yield and quality of carrot". The experiment consisted of two following factors as Factor A: Four levels of IMO (Indigenous micro-organisms) solution, viz., S_0=Control (No IMO solution), S_1=150 ml/L IMO solution, S_2=250 ml/L IMO solution, S_3=350 ml/L IMO solution and Factor B: Four levels of inorganic fertilizer, viz., F_1= 25% RDF (Recommended Dose of Fertilizer), F_2=50% RDF, F_3=75% RDF, F_4=100% RDF. There were altogether 16 treatment combinations. There was significant variation was recorded among the different IMO solution and inorganic fertilizers in respect of most of the characters studied.

The maximum plant height was observed at S_3 treatment at 50 DAS, 70 DAS and at harvest and it was found (54.38 cm) from the S_3 (350 ml/L IMO solution) treatment at harvest. Among the inorganic fertilizer treatments F_4 (100% of RDF) produced the tallest plant (28.50 cm, 42.50 cm, 53.50 cm and 59.50 cm) at 30, 50, 70 DAS and at harvest respectively. In the case of combined treatments, the maximum plant height (37.00 cm, 45.00 cm, 56.00 cm and 62.00 cm) was recorded from S_3F_4 (350 ml/L IMO solution and 100% RDF) treatment combination at 30, 50, 70 DAS and at harvest, respectively while the minimum was found from control treatment combination for all the DAS.

The maximum number of leaves was observed at S_3 (350 ml/L IMO solution) treatment at 30 DAS, 50 DAS, 70 DAS and at harvest and it was found (11.75) from the S_3 treatment at harvest. Among the inorganic treatments F_3 (75% of RDF) produced the maximum number of leaves plant (4.83, 6.66, 8.33 and 11.66) at 30, 50, 70 DAS and at harvest, respectively while the number of leaves (6.67, 8.66, 10.67 and 12.67) was recorded from S_3F_4 (350 ml/L IMO solution and 100% RDF) treatment combination at 30, 50, 70 DAS and at harvest, respectively while the minimum was found from control treatment combination for all the DAS. The longest root length

16.83 cm was recorded from S_3 (350 ml/L IMO solution) treatment and 14.42 cm was recorded at treatment F_3 (75% RDF) and it was statistically identical to F_2 (13.42 cm) and F_4 (13.53 cm) treatment. On the other hand, the longest root 18.67 cm was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) while the shortest root (7.00 cm) was found from S_0F_1 (No IMO solution and 25% RDF) treatment combination.

The maximum root diameter 4.26 cm was recorded from S_3 (350 ml/L IMO solution) treatment while the minimum root diameter 1.65 cm from S_0 (Control) and 3.90 cm was recorded at treatment of F_4 (100% RDF). On the other hand, the highest root diameter 4.87 cm was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) and the shortest root diameter (1.10 cm) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination. The maximum root pith flesh ratio 1.93 was recorded from S_3 (350 ml/L IMO solution) treatment and 1.94 was found at treatment of F_3 (75% RDF) and 2.14 was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) and the shortest root-pith flesh ratio (1.48 cm) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment. The maximum root dry matter content 15.55% was recorded from S_3 (350 ml/L IMO solution) treatment and 14.82% was recorded at treatment of F_3 (75% RDF) treatments and 17.78% was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) while minimum root dry matter content (11.81%) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination.

The maximum leaf dry matter content 15.69% was recorded from S_3 (350 ml/L IMO solution) treatment and 15.37% was recorded at treatment of F_3 (75% RDF) treatments and the 17.75% was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) treatment combination while the minimum leaf dry matter content (11.76%) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination.

The maximum leaf weight 67.49 g was recorded from S_3 (350 ml/L IMO solution) treatment while the minimum leaf weight (54.27 g) was observed from S_0 (control) treatment. The maximum leaf weight (70.52 g) was recorded at treatment of F_3 (75% RDF). On the other hand, the minimum leaf weight (45.10 g) was found at F_1 (25%

RDF) treatment. The maximum leaf weight plant^{-1} (78.29 g) was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) and the minimum (40.73 g) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination. The maximum individual root weight 120.82 g was recorded from S_3 (350 ml/L IMO solution) treatment and 123.57 g was recorded at treatment of F_3 (75% RDF) and 136.98 g was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF). On the other hand, the minimum (74.00 g) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination. The minimum number of branched root 8.0% was recorded from S_3 (350 ml/L IMO solution) treatment and 10.0% was recorded at treatment of F_4 (100% RDF) treatments and the minimum number of branched root plant (4.00%) was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) treatment combination while the maximum (22%) was found from S_0F_1 (No IMO solution and 25% RDF) treatment combination.

The maximum yield 24.52 t/ha was recorded from S_3 (350 ml/L IMO solution) treatment and the maximum yield (24.60 t/ha) was recorded at treatment of F_3 (75% RDF) treatment which was statistically identical to (24.50 t/ha) F_4 (100% RDF). On the other hand, the maximum yield 26.49 t/ha was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) treatment combination and the minimum yield (15.20 t/ha) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination. The maximum marketable yield 22.41 t/ha was recorded from S_3 (350 ml/L IMO solution) treatment and 22.63 t/ha was recorded at treatment of F_3 (75% RDF). On the other hand, the maximum marketable yield of plant (25.24 t/ha) was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) treatment combination and the minimum marketable yield (12.39 t/ha) was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination.

The maximum tritable acidity 0.80% was recorded from S_1 (150 ml/L IMO solution) treatment and 0.65% was recorded at treatment of F_2 (50% RDF) treatment. On the other hand, 1.28% was observed from the treatment combination of S_1F_2 (150 ml/L IMO solution and 50% of RDF) treatment combination whereas, the minimum tritable acidity plant (0.26%) was recorded from S_0F_2, S_1F_2, S_1F_3 and S_2F_3 treatment combination. The maximum vitamin C content 28.50 mg was recorded from S_3 (350 ml/L IMO solution) treatment and 33.00 mg was recorded at treatment of F_4 (100% RDF) treatment and 42.00 mg was observed from the treatment combination of S_3F_4 (350 ml/L IMO solution and 100% of RDF) treatment combination. On the other hand, the minimum vitamin C content plant (16.00 mg) was recorded from S_0F_3 (No IMO solution and 75% RDF) treatment combination.

The maximum Chroma Value L 47.83 was recorded from S_3 (350 ml/L IMO solution) treatment and 47.46 was recorded at treatment of F_4 (100% RDF) treatment and 49.97 was observed from the treatment combination of S_3F_4 (350 ml/L IMO solution and 100% of RDF). The maximum Chroma Value C (35.68) was recorded from S_2 (250 ml/L IMO solution) treatment and 34.53 was recorded at treatment of F_2 (50% RDF) treatment and 40.09 was observed from the treatment combination of S_2F_4 (250 ml/L IMO solution and 100% of RDF). The maximum Chroma value H (65.14, 64.39 and 65.94) was found from S_2, F_3 and S_2F_3 treatment whereas minimum (61.83) was observed from S_0F_1 treatment.

The maximum firmness 48.22 was recorded from S_2 treatment and 49.08 was recorded at treatment of F_4 treatment and 52.68 was observed from the treatment combination of S_2F_4 treatment combination. Whereas, the minimum firmness of plant 40.91 was recorded from S_2F_1 treatment combination. The maximum TSS 8.94% was recorded from S_3 (350 ml/L IMO solution) treatment and 8.93% was recorded at treatment of F_4 (100% RDF) treatment and 9.07% was observed from the treatment combination of S_3F_3 treatment combination. Whereas, the minimum TSS of plant 8.50% was recorded from S_0F_2 (No IMO solution and 50% RDF) treatment combination. The maximum β carotene 27.32 mg/100 g was recorded from S_3 (350 ml/L IMO solution) treatment and 31.14 was recorded at treatment of F_3 (75% RDF) treatment and 36.85 mg/100 g was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) and the minimum β carotene of plant 6.44 mg/100 g was recorded from S_1F_3 (150 ml/L IMO solution and 75% RDF) treatment combination.

The maximum total sugar content 10.41% was recorded from S_3 (350 ml/L IMO solution) treatment and 10.51% was recorded at treatment of F_4 (100% RDF) treatment and 11.09% was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) whereas, the minimum total sugar content of plant 9.13% was recorded from S_0F_1 (No IMO solution and 25% RDF) treatment combination. The maximum reducing sugar content (2.90%) was recorded from S_2 (250 ml/L IMO solution) treatment and 2.95% was recorded at treatment of F_3 (75% RDF) and 3.03% was observed from the treatment combination of S_3F_3 (350 ml/L IMO solution and 75% of RDF) and the minimum reducing sugar content (2.59%) was observed from S_0F_1 (No IMO solution and 25% RDF) treatment combination. The highest gross return (Tk. 631,000/-), net return (Tk. 386,579/-) and BCR (2.58) were obtained from S_3F_3 where the lowest gross return (Tk. 309,750/-), net return (Tk. 89,698/-) and BCR (1.41) were found from S_0F_1 treatment combination.

From the above results it can be concluded that the 350 ml/L BARI IMO solution and 75% recommended doses of fertilizers can give the better yield, economic benefit and quality carrot production.

Recommendation

From the results of the experiment and subsequent discussion, it may be suggested that

1. More research work should be needed to find out harmful micro-organism present in this BARI IMO solution and how to overcome this problem.
2. Further experiment should be needed to specify the more accurate doses of BARI IMO solution and inorganic fertilizers combination for economic benefit.

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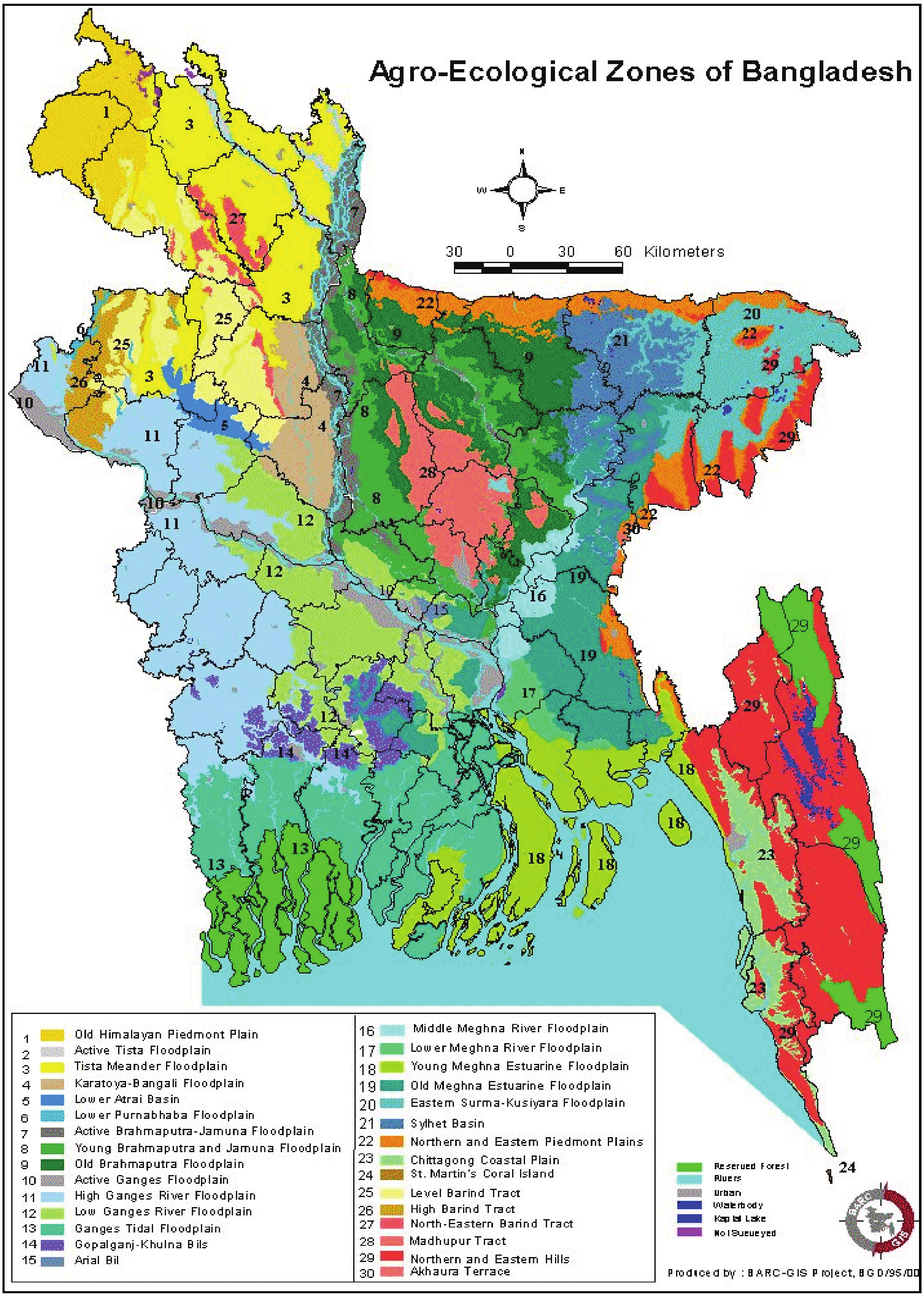
APPENDICES

Appendix I. Map showing the experimental site under the study



The Experimental site under study

Appendix II. Monthly average temperature, relative humidity and rainfall of the experimental site during the period from October 2019 to April 2020

Month	Air temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
October, 19	29.3	19.1	82	39
November, 19	26.8	17.3	79	0
December, 19	23.4	14.7	75	0
January, 20	23.5	13.6	69	0
February, 20	27.1	14.5	66	5
March, 20	33.4	20.2	57	13
April, 20	36.3	22.6	53	17

Source: Bangladesh Agricultural Research Institute (Weather Station) Joydebpur, Gazipur

Appendix III. Morphological, physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Olericulture Research Field- 2, BARI, Joydebpur, Gazipur.
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land Type	Medium high land
Soil Series	Gazipur
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

Source: Soil Resource Development Institute (SRDI), Khamarbari, Dhaka

B. Physical composition of the soil

Constituents	Percent (%)
Sand	27
Silt	43
Clay	30

Source: Soil Resource Development Institute (SRDI), Khamarbari, Dhaka

C. Chemical composition of the soil

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.45
Total nitrogen (%)	0.03
Available P (ppm)	20
Exchangeable K (%)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI), Khamarbari, Dhaka

Appendix IV. Plant height of carrot as influence by BARI IMO solution and inorganic fertilizers

Treatments	Plant height (cm)			
	30 DAS	**50 DAS**	**70 DAS**	**At harvest**
Effect of BARI IMO solution				
S_0	27.50	31.50 b	42.43 c	46.50 d
S_1	26.50	32.10 b	43.50 b	49.50 c
S_2	24.42	35.52 a	43.42 b	51.82 b
S_3	27.83	35.83 a	46.83 a	54.38 a
LSD $_{(0.05)}$	3.47	2.21	1.47	2.52
CV (%)	15.69	12.06	9.15	8.08
Effect of inorganic fertilizer				
F_1	18.42 d	26.42 c	37.42 d	43.42 d
F_2	24.75 c	32.75 b	43.75 c	49.75 c
F_3	28.58 b	36.58 b	47.58 b	53.58 b
F_4	34.50 a	42.50 a	53.50 a	59.50 a
LSD $_{(0.05)}$	2.15	4.11	3.07	2.78
CV (%)	15.69	12.06	9.15	8.08

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

Appendix V. Analysis of variance of data on plant height at different DAS of carrot plant

Source of variation	Degrees of freedom (df)	Mean sum of square of plant height at			
		30 DAS	50 DAS	70 DAS	At harvest
Factor A (BARI IMO solution)	3	28.41	29.44*	30.39**	28.45**
Factor B (Inorganic fertilizer)	3	545.91**	543.88*	544.96**	546.87**
Interaction (A × B)	9	126.33**	125.45**	127.55**	126.67**
Error	30	17.37	19.47	17.33	18.35

*Significant at 5% level of probability
**Significant at 1% level of probability
NS-non significant

Appendix VI. Leaf number of carrot as influence by BARI IMO solution and inorganic fertilizers

Treatments	Number of leaves			
	30 DAS	**50 DAS**	**70 DAS**	**At harvest**
Effect of BARI IMO solution				
S_0	4.00 c	6.00 c	8.00 c	10.00 c
S_1	3.33 d	5.33 d	7.33 d	9.33 d
S_2	5.00 b	7.00 b	9.00 b	11.00 b
S_3	5.75 a	7.75 a	9.75 a	11.75 a
LSD $_{(0.05)}$	0.51	0.63	0.56	0.66
CV (%)	13.60	9.43	7.21	5.84
Effect of inorganic fertilizers				
F_0	4.67 ab	6.67 ab	8.67 ab	10.67 ab
F_1	4.25 b	6.25 b	8.25 b	10.25 b
F_2	4.83 a	6.83 a	8.83 a	10.83 a
F_3	4.33 ab	6.33 ab	8.33 ab	10.33 ab
LSD $_{(0.05)}$	0.51	0.54	0.58	0.64
CV (%)	13.60	9.43	7.21	5.84

[Means in a column having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability; Here, S_0= No IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF]

Appendix VII. Analysis of variance of data on number of leaves at different DAS of carrot plant

Source of variation	Degrees of freedom (df)	Mean sum of square of leaf number at			
		30 DAS	50 DAS	70 DAS	At harvest
Factor A (BARI IMO solution)	3	13.68**	13.66**	13.56**	13.67**
Factor B (Inorganic fertilizer)	3	0.90*	0.91*	0.94*	0.91*
Interaction (A × B)	9	3.32**	3.81**	3.80**	3.82**
Error	30	0.37	0.36	0.34	0.38

*Significant at 5% level of probability
**Significant at 1% level of probability
NS-non significant

Appendix VIII. Analysis of variance of data on different parameters of carrot plant

Source of variation	Degrees of freedom (df)	Mean sum of square				
		Length of root (cm)	**Root diameter (cm)**	**Root pith ratio**	**Root dry matter content (%)**	**Leaf dry matter content (%)**
Factor A (BARI IMO solution)	3	105.063**	16.463**	0.1345*	12.482**	10.688**
Factor B (Inorganic fertilizer)	3	14.863**	4.501**	0.076	15.657**	18.899*
Interaction (A × B)	9	22.645**	2.89**	0.053	3.16*	2.82*
Error	30	1.832	0.0737	0.04311	1.3918	1.1923

*Significant at 5% level of probability
**Significant at 1% level of probability
NS-non significant

Appendix IX. Analysis of variance of data on different parameters of carrot plant

Source of variation	Degrees of freedom (df)	Mean sum of square				
		Leaf weight plant^{-1} (g)	**Individual root weight (g)**	**Number branched root (%)**	**Yield (t/ha)**	**Marketable yield (t/ha)**
Factor A (BARI IMO solution)	3	449.62**	791.18**	176.83**	37.555**	58.382**
Factor B (Inorganic fertilizer)	3	1759.63**	3356.13**	203**	118.462**	147.326**
Interaction (A × B)	9	21.81*	115.08*	4.833**	1.394**	5.784**
Error	30	29.74	76.78	0.254	4.303	4.857

*Significant at 5% level of probability
**Significant at 1% level of probability
NS-non significant

Appendix X. Analysis of variance of data on different parameters of carrot plant

Source of variation	Degrees of freedom (df)	Mean sum of square				
		Tritable acidity (%)	**Vitamin C content (mg/100 g)**	**Chroma value L**	**Chroma value C**	**Chroma value H**
Factor A (BARI IMO solution)	3	0.63215*	27.667*	2.1734	66.743**	12.03**
Factor B (Inorganic fertilizer)	3	0.31903**	259.667**	1.0821	20.968**	5.090**
Interaction (A × B)	9	0.181**	179.44**	23.087**	50.724**	1.624**
Error	30	0.00107	6.883	1.4829	2.6963	0.4772

*Significant at 5% level of probability
**Significant at 1% level of probability
NS-non significant

Appendix XI. Analysis of variance of data on different parameter of carrot plant

Source of variation	Degrees of freedom (df)	Mean sum of square				
		Firmness of root	**TSS (%)**	**β carotene content (mg/100 g)**	**Total sugar content (%)**	**Reducing sugar content (%)**
Factor A (BARI IMO solution)	3	15.307*	0.464**	491.104**	1.879**	0.026**
Factor B (Inorganic fertilizer)	3	78.710**	0.162**	596.49*	1.808**	0.042**
Interaction (A × B)	9	26.671**	0.203**	260.871**	0.876**	0.049**
Error	30	6.774	0.01276	4.404	0.09406	0.00381

*Significant at 5% level of probability
**Significant at 1% level of probability
NS-non significant

Appendix XII. Input cost per ha

Treatments Combination	Labour Cost (TK.)	Ploughing Cost (TK.)	Seed cost (TK.)	Irrigation Cost (TK.)	Pesticides cost (TK.)	BARI IMO solution cost (TK.)	Inorganic fertilizers cost (TK.)				Sub Total (A)
							Urea	TSP	MP	Gypsum	
S_0F_1	70000	15000	20000	15000	5500	0	2375	2000	1400	1250	132525
S_0F_2	70000	15000	20000	15000	5500	0	4750	4000	2800	2500	139550
S_0F_3	70000	15000	20000	15000	5500	0	7125	6000	4200	3750	146575
S_0F_4	70000	15000	20000	15000	5500	0	9500	8000	5600	5000	153600
S_1F_1	70000	15000	20000	15000	5500	3000	2375	2000	1400	1250	135525
S_1F_2	70000	15000	20000	15000	5500	3000	4750	4000	2800	2500	142550
S_1F_3	70000	15000	20000	15000	5500	3000	7125	6000	4200	3750	149575
S_1F_4	70000	15000	20000	15000	5500	3000	9500	8000	5600	5000	156600
S_2F_1	70000	15000	20000	15000	5500	5000	2375	2000	1400	1250	137525
S_2F_2	70000	15000	20000	15000	5500	5000	4750	4000	2800	2500	144550
S_2F_3	70000	15000	20000	15000	5500	5000	7125	6000	4200	3750	151575
S_2F_4	70000	15000	20000	15000	5500	5000	9500	8000	5600	5000	158600
S_3F_1	70000	15000	20000	15000	5500	7000	2375	2000	1400	1250	139525
S_3F_2	70000	15000	20000	15000	5500	7000	4750	4000	2800	2500	146550
S_3F_3	70000	15000	20000	15000	5500	7000	7125	6000	4200	3750	153575
S_3F_4	70000	15000	20000	15000	5500	7000	9500	8000	5600	5000	160600

Here, S_0= No BARI IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF

Appendix XIII. Total cost of production per ha

Treatments Combination	Cost of lease of land for 6 months (13 % of value of land Tk. 10,00,000/year) (B)	Sub Total Cost of production (A+B)	Interest on running capital for 6 months (Tk. 8% of cost per year) (C)	Total (A+B+C) (TK.)	Miscellaneous cost (Tk.) 5% of the input cost	Grand Total Cost of Production (TK.)
S_0F_1	65000	197525	12383	209908	10144	220052
S_0F_2	65000	204550	13296	217846	10892	228738
S_0F_3	65000	211575	13752	225327	11266	236594
S_0F_3	65000	218600	14209	232809	11640	244449
S_1F_1	65000	200525	12578	213103	10304	223407
S_1F_2	65000	207550	13491	221041	11052	232093
S_1F_3	65000	214575	13947	228522	11426	239948
S_1F_4	65000	221600	14404	236004	11800	247804
S_2F_1	65000	202525	12708	215233	10410	225643
S_2F_2	65000	209550	13621	223171	11159	234329
S_2F_3	65000	216575	14077	230652	11533	242185
S_2F_4	65000	223600	14534	238134	11907	250041
S_3F_1	65000	204525	12838	217363	10517	227880
S_3F_2	65000	211550	13751	225301	11265	236566
S_3F_3	65000	218575	14207	232782	11639	244421
S_3F_4	65000	225600	14664	240264	12013	252277

Here, S_0= No BARI IMO solution, S_1= 150 ml/L, S_2= 250 ml /L, S_3= 350 ml/L, F_1= 25% RDF, F_2= 50% RDF, F_3= 75% RDF, F_4= 100% RDF

PLATES

Plate 1. BARI IMO solution

Plate 2. Experimental plot

Plate 3. Some carrots after harvesting

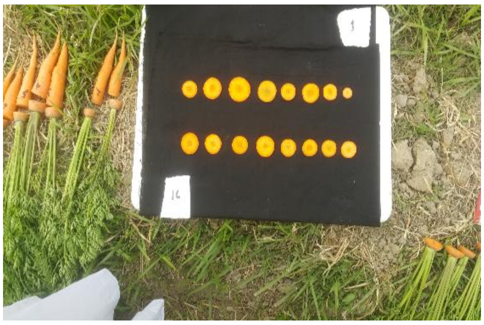


Plate 4. Horizontal section of carrot

Plate 5. Weight measuring of 100 g fresh carrot

Plate 6. Carrots are being prepared for taking oven dry weight