EFFECT OF PHOSPHORUS AND BORON ON THE GROWTH AND YIELD OF CARROT

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EFFECT OF PHOSPHORUS AND BORON ON THE GROWTH AND YIELD OF CARROT

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TO

MY BELOVED PARENTS

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Phosphorus and Boron on the Growth and Yield of Carrot"** submitted to the Department of Horticulture, 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 bona fide research work carried out by **Nurun Nahar**, Registration Number: **04-01462** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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ABSTRACT

The experiment was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2008 to February 2009. The experiment consisted of two factors. Factor A: four levels of phosphorus viz., P_0: 0 kg (control), P_1: 50 kg, P_2: 60 kg, and P_3: 70 kg P_2O_5/ha respectively and Factor B: three levels of boron viz., B_0: 0 kg (control), B_1: 1.5 kg, and B_2: 2.0 kg H_3BO_3/ha respectively. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The significant variation was observed in different parameters. For Phosphorus highest yield (37.64 t/ha) was found from P_3 and lowest (27.79 t/ha) from P_0. For Boron highest yield (36.07 t/ ha) was found from B_2 and lowest (31.17 t/ha) from B_0. For combined effect highest yield (38.91 t/ha) was found from P_3B_2 and lowest (20.14 t/ha) from P_0B_2. The highest benefit cost ratio was found in P_3B_2. So, 70 Kg Phosphorus with 2 kg Boron was found suitable for growth and yield of carrot.

LIST OF ABBREVIATED TERMS

ABBREVIATION	FULL NAME
AEZ	Agro-Ecological Zone
et al.	and others
BBS	Bangladesh Bureau of Statistics
Cm	Centimeter
°C	Degree Celsius
DAS	Date After Seeding
etc	Etcetera
FAO	Food and Agriculture Organization
g	Gram
ha	Hectare
hr	Hour
kg	Kilogram
m	Meter
mm	Millimeter
Mo	Month
MP	Muriate of Potash
no.	Number
%	Percent
RCBD	Randomized Complete Block Design
m^2	Square meter
TSP	Triple Super Phosphate
UNDP	United Nations Development Program

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CHAPTER I

INTRODUCTION

Carrot (*Daucus carota* L.) is a member crop of Apiaceae family (Peirce, 1987). It is considered to be a native of Mediterranean region (Shinohara, 1984). It consists of about 250 genera and approximately 2800 species of widely distributed, generally herbaceous plants (Rubatzky *et al*., 1999). It is mainly a temperate crop grown during spring in temperate countries and during winter in tropical and subtropical countries of the world (Bose and Som, 1990). Carrot grows successfully in Bangladesh during Rabi season and mid November to early December is the best time for its cultivation to get satisfactory yield (Rashid, 2004).

From nutritional point of view carrot is a very important root crop. It contains appreciable amount of carotene, thiamine and riboflavin (Sharfuddin and Siddique, 1985). It is an excellent source of iron, vitamin-A, Vitamin-B, Vitamin-C and sugar (Yawalkar, 1985). Carrot roots play an important role to protect the blindness of childrens providing Vitamin-A. Furthermore, it has some other important medicinal values (Bose and Som, 1990). In Bangladesh the production statistics of carrot is not available. Rashid (2004) mentioned an average yield of carrot was 27 tons per hectare. This production is relatively low compared to other carrot producing countries, like Switzerland, Denmark, Sweden, UK, Australia and Israel, where the average per hectare yields are reported to be 40.88, 42.67, 51.88, 54.88, 56.70 and 64.20 tones, respectively (FAO, 2004).

The low yield of carrot in Bangladesh however is not an indication of low yielding potentially of this crop, but of the fact that the low yield may be attributed to a number of reasons, viz. unavailability of quality seeds of high yielding varieties, fertilizer management, disease and insect infestation and improper irrigation facilities. Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). To attain considerable production and quality yield for any crops it is necessary to proper management including ensuring the availability of essential nutrient components in proper doses. Carrot thrives well in a fertile, clay loam soil because it requires considerable amounts of nutrients to sustain rapid growth in short time. A large amount of fertilizer is required for the growth and development of vegetable crops (Opena *et al*., 1988).

Phosphorus is one of the important essential macro elements for the normal growth and development of plant. The phosphorus requirements vary depending upon the nutrient content of the soil (Bose and Som, 1990). Phosphorus shortage restricted the plant growth and remains immature (Hossain, 1990). Carrot is a short duration crop, for that easily soluble fertilizer like as phosphorus should be applied in the field. On the other hand nutrient availability in a soil depends on some factors, among them balance fertilizer is the important one. Again secondary mechanism of interference was the absorption of phosphorus from the soil through luxury consumption, increasing the tissue content without enhancing smooth biomass accumulation (Santos *et al.*, 2004).

Boron has effect on many functions of the plant such as hormone movement, active salt absorption, flowering & fruiting process, pollen germination, carbohydrates and nitrogen metabolism and water relations in the plants. The increase in vegetative growth could be attributed to physiological role of boron and its involvement in the metabolism of protein, synthesis of pectin, resynthesis of adenosine triphosphate (ATP) and translocation of sugar at development of the flowering and fruiting stages (Bose and Tripathi, 1996). Boron deficiency causes reduced root growth, brittle leaves and necrosis of shoot apex. Boron affects the cambium and phloem tissues of storage root or stem, apical meristems of leaves, vascular cambia of other organs, which are capable of meristematic activities (Singh and Gangwar, 1991).

Considering the above circumstances, the present investigation was undertaken with the following objectives:

- to find out the optimum dose of phosphorus on growth and yield of carrot;
- to determine the effect of boron on growth and yield of carrot;
- to determine the combined effect of phosphorus and boron on the growth and yield of carrot as well as ensuring the higher yield.

CHAPTER II

REVIEW OF LITERATURE

Carrot is an important modified root crop which attracted less concentration in respect of various agronomic aspects by the vegetable growers and the researchers. So, very few research works related to carrot cultivation have been carried out in our country. The research work so far done in Bangladesh and in the World is not adequate and conclusive. However, some of the important and informative works and research findings related to the application of phosphorus and boron on modified root crops so far been done at home and abroad reviewed in this chapter under the following heads-

2.1 Effect of phosphorus on growth and yield of root crops

Tareen *et al*. (2005) conducted an experiment with N: P fertilizers at 0: 0, 50: 50, 65: 60, 80: 70, 95: 80 and 110: 90 kg/ha were supplied to carrot cv. 'Nantes' during 2001-02 and 2003-04 in Pakistan. The parameters tested were: leaf length, root length, number of leaves/plant, root diameter, leaf weight/plant, single root weight and root yield/ha. N : P at 110:90 kg/ha produced the maximum values for all parameters, but these values were not significantly different from those obtained with 95: 80 kg/ha. During the second year, N: P at 95: 80 kg/ha produced 12.244 mt/ha, while N: P at 110: 90 kg/ha produced 15.245 mt/ha.

A study was conducted by Araujo *et al*. (2004) in Dourados, Mato Grosso do Sul, Brazil, in 1998 to evaluate the effects of P (at 2.97, 17.68, 29.47, 41.26 and 56.02 kg/ha) and chicken manure (CM) at 1.0, 6.0, 10.0, 14.0 and 19.0 t/ha on yield and shelf life of carrot cv. Brasilia roots. Harvests of plants were performed at 90 and 105 days after sowing. The combination of intermediate levels of P and CM promoted the greatest productions of commercial root fresh matter, as well as small mass loss in storage for the 2 dates of harvest. The tolerable value of mass losses (14.64%) when the roots wither was higher than presented in literature (8.00%).

Uddin *et al*. (2004) conducted a 2-year field experiment at the Regional Agricultural Research Station, BARI, Hathazari, Bangladesh in the year 2000-01 and 2001-02 on the fertilizer requirement of carrot, as influenced by different levels of NPKS and cowdung. Six combinations of NPKS (N:P:K:S at 120:45:120:30, 120:40:90:30, 90:30:60:20 and 60:15:30:10 kg/ha) and cowdung (0 and 5 t/ha) were used in this investigation. Different combinations of NPKS and cowdung showed significant 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 root yield of 27.22 t ha^{-1}, which was 30.3% higher over control treatment. The highest marginal rate of return (76.33%) also obtained from the same treatment.

Anez and Espinoza (2002) carried out an experiment on a Typical Humitropept sandy loam soil at Santa Rosa experimental station, State of Merida, Venezuela, to determine if part of total amount of nutrient (N, P, K) of carrot (cv. Colmar) requirements, supplied with chemical fertilizer, could be substituted for organic fertilizer (poultry manure - fertipollo) without decreasing significantly the crop yield. Five levels of poultry manure "E" (0, 5, 10, 15 or 20 t/ha) and four doses of chemical fertilizer "Q" (0, 50 kg N/ha + 16.67 kg P_2O_5/ha + 66.67 kg K_2O/ha, 100 kg N/ha + 33.33 kg P_2O_5/ha + 133.33 kg K_2O/ha and 150 kg N/ha + 50 kg P_2O_5/ha + 200 kg K_2O/ha) were tested using a split-plot arrangement of treatments in a randomized blocks design with four replications. The yield of marketable roots was significantly influenced by E × Q interaction proving that organic and chemical fertilizers complemented their effects to increase such a yield. Total root yield and biomass of top production were significantly and independently affected by the chemical fertilizer doses used.

An experiment was conducted by Lazar and Dumitras (1997) in Romania, during 1995-97 on carrot cultivars ‘Nantes’ and ‘Chantenay’ to study the effect of sowing date and fertilizer application on the yield and quality of carrot roots. The treatments comprised: late-March and early-June sowing; 110 kg KCl + 150 kg NH_4NO_3/ha; and 150 kg KNO_3 + 100 kg NH_4NO_3/ha and reported that the application of KNO_3 increased the yield and quality of carrot roots.

A study was conducted by Aslam *et al*. (2003) to assess the effect of NPK fertilizers on NO_3 accumulation in carrot (*Daucus carota*) at Ayub Agricultural Research Institute, Faisalabad, Pakistan. Four N (0, 25, 50, 75 kg ha^{-1}), three P_2O_5 (0, 50, 75 kg ha^{-1}) and two K_2O rates (0, 25 kg ha^{-1}) were applied. They reported that increasing fertilizer rates increased NO_3 concentration over the control in carrot. Conversely, the NO_3 concentration in carrot increased significantly over the control either with N applied alone or with P. A balanced use of N and P (2:1) fertilizers reduced the NO_3 accumulation. Additionally, the doses of NPK fertilizers applied in this study did not pose health hazards to the consumers.

Akhilesh *et al*. (2003) conducted a field experiment during the summer season of 2000 and 2001 in Lahaul valley under high-hill dry-temperate zone of Himachal Pradesh, India to study the effects of integrated use of farmyard manure, and N, P and K fertilizers on the yield components and root yield of carrot. Three levels of N, P and K (50, 100 and 150% of the recommended rates of 50:40:35 kg N : P_2O_5 : K_2O/ha) and 3 levels of farmyard manure (0, 10 and 20 t/ha) were evaluated in split-plot design with 3 replications. The application of 100% NPK was superior over the other fertilizer combinations in terms of root yield, whereas 100 and 150% of the recommended rate were equally effective and significantly better than the 50% level with regard to the other characters. The highest net return (155000 rupees/ha) and a benefit : cost ratio of 4.37 were obtained with 10 t farmyard manure/ha + 100% of the recommended NPK rate.

The effects of N (0, 40, 60 and 80 kg/ha) and P (0, 20, 40 and 60 kg/ha) rates on the performance of carrot cv. ‘Nantes’ were studied by Ravinder and Kanwar (2002) in Solan, Himachal Pradesh, India during 1997/98 and 1998/99. P and 50% of the N were applied during transplanting. The remaining N was applied in equal splits during bolting and flower initiation. Plant height, number of umbels per plant and seed yield was positively correlated, whereas number of days to 50% flowering was negatively correlated with the N rate. Thus, 80 kg N/ha resulted in the greatest plant height (169 cm), secondary (10.5) and tertiary (33.8) umbels per plant, and seed yield per plant (40.5 g) or hectare (15.27 quintal). The lowest number of days to 50% flowering (166) was obtained with 0 N/ha. Similarly, the highest P rate (60 kg/ha) gave the highest number of secondary (10.7) and tertiary (24.4) umbels per plant, and seed yield per plant (30.9 g) or hectare (11.65 quintal).

Dry matter content and concentration of macro elements (N, C, P, K, Ca, Mg) in field-grown cabbage and carrot produced in Estonia were determined by Leis and Lepik (2001). Concentrations of macronutrients in cabbage were N=153 and 187; P=20 and 29; K=208 and 187; Ca=28 and 33; Mg=10 and 12 mg/100 g of raw material, in 1999 and 2000, respectively. In carrot the mean values were N=155, P=30, K=276, Ca=23, and Mg=13 mg/100 g raw material. Macronutrient levels, except N, in studied crops were low compared with values published in literature.

Data on soil analyses, fertilizer use and yields were collected from carrot producers converting to integrated production in 1997, to identify changes in fertilizer practice and effects on yield by Salo *et al*. (1999). On carrot fields, the average total N rate was 80 kg/ha, which was unaffected by soil organic matter content and by the preceding crop. Corresponding P rates averaged 35 kg/ha and K rates 131 kg/ha. The P rate was reduced when soil P analyses were high, but K rate was not adjusted for soil K. The resulting changes in N, P and K rates had no influence on the carrot yield, which averaged 49 t/ha.

Fertigation was compared to broadcast application of solid NPK fertilizer with cabbage (cv. Castello), carrot (cv. Panther) and onion (cv. Sturon) by Salo *et al*.

(2002). In the broadcast application, P and K were given as a single application in spring and N was split according to the existing recommendations. Treatments did not affect carrot and onion growth, but cabbage growth and nutrient uptake were still decreased by fertigation towards the middle of the growing period. At harvest, cabbage yields and nutrient uptakes were similar between the treatments. Carrot yielded according to the samplings close to 90 t/ha and nutrient uptake in roots and leaves was 180-190 kg N/ha, 23-30 kg P/ha and 325-444 kg K/ha.

A pot experiment was conducted by Gaweda (2001) during 1997-98, in Poland to study the effect of P treatment (50, 200 and 800 kg/dry weight) on Pb accumulation by carrot cultivars Karo F_1 and Kama F_1 and lettuce cultivars 'Syrena' and 'Ara'. Raising P contents in the substrate from 50 to 800 mg/kg decreased carrot root Pb content on the average by 44% and in lettuce leaves on the average by 33%.

An experiment was conducted by Lyngdoh (2001) to evaluate the response of carrot cv. 'Early Nantes' to varying levels of N, P and K in the agroecological conditions in Meghalaya, India. The different of N, P and K rates did not have any strong influence on the vegetative growth of the plant. Root length increased significantly with the N levels in a dose-dependent manner, while the effect of P was significant but differed between years. The moderate level of K resulted in the longest root. No significant difference in root diameter was observed due to variation in nutrient application. The highest N level and moderate K level produced the greatest yield. There were strong positive correlations between the levels of N and K and root weight and yield per plot. K played a key role in increasing the root TSS value. Results suggest that a fertilizer rate of N:P:K at 80:50:80 kg/ha may be applied to increase carrot yield with quality roots under the agro climatic conditions of Meghalaya.

Soils ploughed in autumn were loosened by different tillage tools, or compacted to a depth of 25-30 cm by a tractor weighing 3 Mg (once or three times) before seed bed preparation for carrot under moist soil condition was reported by Pietola and Salo (2000). Sprinkler irrigation was also applied to mineral soils when the soil moisture in top soil was 50% of plant-available water capacity, and the response of additional N application of 30 kg ha^{1} was studied in an organic soil. Higher soil moisture tended to promote nutrient uptake, as the P content of carrot tap roots was increased by irrigation in loam. Compaction of organic soil low in P increased P and K contents and uptake by carrot roots and shoots. In severely compacted clay soil, the nutrient use decreased by increasing soil compactness. NO_3-N contents were the highest in early season (25-30 mg kg^{-1} fresh matter) and decreased with advancing season.

Sixteen treatment combinations were tested by Rao and Maurya (1998) for seed yield and yield attributing traits of carrot cv. ‘Nantes’ during 1996-97, 1997-98 and 1998-99 at Uttar Pradesh, India. Early flowering plant height, number of secondary and tertiary umbels per plant, seed yield per plant and per ha significantly increased linearly with the increasing rate of nitrogen and these were maximum at the highest rate of 80 kg/ha. Significant increase in number of umbels and seed yield per plant and per ha was also observed due to higher rates of phosphorus. However, the extent of increase in seed yield and yield traits due to nitrogen was higher compared to increase by phosphorus. The maximum seed yield of 15.34 q/ha and 12.76 q/ha was obtained with the application of 80 kg N/ha and 60 kg P_2O_5/ha, respectively.

An experiment was conducted by Zdravkovic *et al*. (2007) with different types of fertilization on some carrot cultivars. The cultivars used were: 'Nantes SP-80', 'Amsterdam early', 'Long blunt heartless – Laros', 'Flaker' and 'Braunsvajska'. In the course of two years, the cultivars were fertilized in three ways: (1) using manure at 50 t/ha; (2) NPK (15: 15: 15) at 670 kg/ha; and (3) calcium ammonium nitrate (CAN) at 670 kg/ha. A non-fertilized group was also used as the control. There were significant differences depending upon the manner of fertilizer application. The average yield achieved by fertilizer application was significant. Chemical analyses were also conducted on the carrot roots and juice. NPK fertilizer application increased the contents of dry matter, ash, protein, calcium and copper.

Six field studies over a 3-yr period evaluated the yield response of carrot on sandy to loamy sand Orthic Podzol soils by Sanderson and Sanderson (2006). Treatments consisted of pre-plant broadcast applied P at 0, 33, 66, 99 or 132 kg ha-1 on sites where residual P levels ranged from 81 to 162 micro g P g^{-1}. When the total yield response of carrots to increasing P levels was fitted to a quadratic response curve, 110 kg P ha^{-1} was required to achieve maximum yield, but an application of as little as 22 kg P ha^{-1} resulted in 95% of maximum marketable yield. This reduced application rate resulted in a saving of 88 kg P ha^{-1} and slowed the buildup of soil P levels. Therefore, by applying more conservative amounts of P fertilizer carrot growers can maintain excellent crop yield while reducing the potential for environmental damage caused by the buildup of soil P.

A research project was carried out by Hassanoghli *et al*. (2007) in Tehran region, Iran for two years to investigate the capabilities of soil and plant in the absorption and storage of waste water contaminants, namely phosphorus, and its transport to drain depth as a result of irrigation practice. A series of lysimeters based on a statistical factorial experiment in the form of randomized complete design (3×3×3) were used. Raw and treated domestic waste water, obtained from Ekbatan Housing Complex and well water (control) were used to irrigate raw edible vegetables including parsley, carrot and tomato. Results showed that the amount of phosphorus leaching through soil to drain depth was between 0.90% and 3.56%, and between 1.03%, and 4.15% of the phosphorus concentration in raw waste water and treated one entered into the soil, respectively. Also, mass balance analyses showed that the average phosphorus reduction ranged from 97.2% to 99.9% of the phosphorus that entered with waste water.

The level and accumulation of nutrients in peruvian carrot under 3 levels of N (0, 150 and 300 kg/ha), P_2O_5 (0, 80 and 160 kg/ha) and K_2O (0, 80 and 160 kg/ha) were studied by Portz *et al*. (2006). The nutrient contents of leaves, corms and roots had no significant correlation with commercial root production. Greater nutrient accumulation in leaves, corms and roots was observed between 150 and 210 DAT [days after transplanting], at 210 DAT, and at 300 DAT, respectively. The fertilizer treatments had significant effects on the nutrient content, but had no significant effects on commercial root production.

A field study was conducted by Selvi *et al*. (2005) in Tamil Nadu, India to investigate the effects of different N, P and K levels on carrot cv. ‘Zino’ performance. Different combinations of N, P and K at 100, 135 and 170 kg/ha were used. Full rates of P and K, and half rate of N were applied at sowing. The remaining N was applied at 30 days after sowing. The highest yield (21.21 t/ha) was obtained under N:P:K rate of 135:135:170, followed by 20.25 and 20.21 t/ha obtained from treatments with 170:100:170 and 170:135:170 kg/ha, respectively. A rate of 170:170:170 kg/ha did not significantly increase the yield, which was low at 18.67 t/ha.

During 1999-2001, investigations concerning the effects of N, P, K, Ca and Mg fertilizer application on the bioaccumulation of cadmium in carrot roots grown on two different soils were carried out by Sady *et al*. (2004). The level of nitrate accumulation in carrot roots depended more on the soil (organic matter content) and on the climate conditions than on the fertilizer application factors. Bioaccumulation of cadmium in carrot roots depended both on the soil properties and on the applied fertilizers.

Aluminium treatment caused a significant decrease in root length and dry matter yield in the shoots and roots of carrot (*Daucus carota* L.) and radish (*Raphanus* *sativus* L.) plants was determined by Ismail (2005). This reduction was concomitant with a decrease in the accumulation of soluble sugars and total amino acids, whereas a significant increase in the proline content of the shoots and roots was detected. Soluble protein remained more or less unchanged when Al was applied at low and moderate levels. However, at higher Al levels, the losses in soluble sugars were accompanied by increases in soluble protein in radish, whereas in carrot the opposite effect was observed. The application of phosphorus fertilizer to al-treated plants counteracted the toxic effect of aluminium by increasing root elongation and dry matter production.

An experiment was conducted by Nigussie *et al*. (2003) in a glasshouse with six P levels: 0, 12, 27, 73, 124 and 234 mg P kg-1 soil, and with six replications. Cabbage attained 80% of its maximum yield already at the level of no P supply, whereas carrot and potato reached only 4 and 16% of their highest yields respectively at this level of P supply. This indicated that cabbage was P-efficient compared to carrot and potato. Root/shoot ratio increased in the order of cabbage < carrot < potato, and was enhanced at lower P levels. Root hair length was not affected by P level, and averaged 0.22, 0.03 and 0.18 mm for cabbage, carrot, and potato, respectively.

Pietola and Salo (2000) reported that higher soil moisture tended to promote nutrient uptake, as the P content of carrot tap roots was increased by irrigation in loam. Compaction of organic soil low in P increased P and K contents and uptake by carrot roots and shoots. In severely compacted clay soil, the nutrient use decreased by increasing soil compactness. NO_3-N contents were the highest in early season (25-30 mg kg^{-1} fresh matter) and decreased with advancing season. In loam, NO_3-N content was increased by irrigation or loosening. Increasing the N fertilisation of organic soil from 30 kg ha^{-1} to 60 kg ha^{-1} increased the NO_3-N content 30%. Soil type and its nutrient status, weather conditions, and growth stage had much more significant influence on the P, K, and Mg contents of carrots than soil treatments.

In a field experiment was conducted by Sparrow and Salardini (1997) on Tasmanian ferrosols (humic eutrudox), potatoes (*Solanum tuberosum*) were planted successively for 2 more seasons on plots which had been limed 2 or 3 years earlier. Carrots (*Daucus carota*) cv. Red Count were grown in these plots 5 years after the liming. Tuber cadmium (Cd) concentrations was not affected by liming in the first potato crop. In the 2nd potato crop, lime decreased tuber Cd by about 30% and carrot root Cd by about 50%. This decrease was attributed to more even and deeper mixing of the lime with the soil during the first potato harvest. Phosphorus (P) fertilizer residues from the earlier potato crops did not significantly affect tuber or root Cd, but there was a positive effect at 1 site where some high Cd-containing P fertilizer had earlier been used. Neither lime nor P fertilizer residues affected potato nor carrot yields.

Vieira *et al*. (1997) carried out a field trials in 1993 in Dourados, Mato Grosso de Sul, Brazil. They applied 5 rates of P ranging from 4.3 to 81.7 kg/ha, as triple superphosphate, and 5 rates of poultry manure ranging from 1 t to 19 t/ha. In general, there was a negative interaction between high rates of P and high rates of poultry manure. The physiological causes of poor performance under regimes of excessive P are examined.

Jaiswal *et al*. (1997) conducted three pre-production verification trials, one each on off-season (summer) radish, carrot and Chinese cabbage. Carrot cultivars ‘New Kuroda’ and ‘Early Nantes’ performed well during the off-season (summer) with ‘Early Nantes’ performing slightly better than ‘New Kuroda’. On average (over 10 locations) ‘Early Nantes’ out yielded ‘New Kuroda’ by 14% irrespective of mulching practice. Farmers and consumers from most of the sites preferred ‘Early Nantes’ for its good yield, attractive root colour and shape, and comparatively higher root sugar content. The use of mulching in carrot was not found useful at any location and produced 710% higher root yields than ‘Minu Early’ and was much preferred by farmers for its bolting resistance, fibre-less roots, marketable root size and shape, low damage in transport and ability to grow even under moisture stress conditions. Similarly, application of chemical fertilizers (80 kg N + 40 kg P_2O_5 + 30 kg K_2O/ha) in addition to compost (40 t/ha) was beneficial at most sites and on average it increased root yield by 43%.

In studies by Volkova (1996) in 1993-94 growing carrots on a sod-podzolic medium clay loam soil, it was found that plant nitrate content depends on the various conditions under which the plants are grown. Application of increasing rates of N in the form of ammonium nitrate increased the content of nitrates in the carrots. The optimum fertilizer rate to obtain acceptable crops on this soil is 120 kg N + 120 kg P + 120 kg K, producing a yield of 40-50 t carrots/ha. Using ammonium and amide forms of N plus potassium sulfate and trace elements, it is possible to produce carrot crops without exceeding the permissible NO_3 level.

Carrots of the table cultivar ‘Losinoostrovskaya 13’ were grown on floodplain alluvial soils in the Moscow region with various NPK fertilizer regimes by Petrichenko *et al*. (1996). The carrots were stored in a cool chamber at 0-1 degrees C, RH 90-95%, in polyethylene bags of capacity 20-25 kg. The carrots were sampled periodically, and quality and losses were determined. The results showed that storage quality depended on the fertilizer regime. Disease incidence and losses were lowest in carrot given 60 kg P + 150 kg K/ha or 90 kg N + 60 kg P + 150 kg K/ha, which gave yields of 60 t/ha.

Konopinski (1995) carried out a field trials near Lublin, Poland, with carrot cv. ‘Perfection’ and beetroot cv. ‘Czerwona Kula’ the plants received N:P:K at 150:150:300 kg/ha (control) or Super Fertilisant of French manufacture containing 11% organic matter, 14% Ca, 3.5% Mg, 4% P_2O_5, 2.5% SO_3 plus all essential microelements. Super Fertilisant was applied at 50 or 100 kg/ha. Using the 100 kg/ha rate gave the best yield increase in carrots and beetroots, viz. 70 and 30% over the control, respectively. Crop quality was also best in this variant.

In a trial conducted by Kadi *et al.* (1994) at the Bajo Seco experimental station in Venezuela, carrot cv. Super Flakkee seeds were sown on 22 Feb. on an Orthoxic Tropudults Ultisol soil to which 0-200 kg P_2O_5, 0-300 kg K_2O and 0-40 t poultry manure/ha had been applied. Thinning was carried out on 15-18 Apr. so that the distance between plants was 3, 6, 9, 12 or 15 cm. The highest yield at harvest (95.6 t/ha) was obtained with 150 kg P_2O_5 + 225 kg K_2O + 10 t poultry manure/ha and a distance of 12 cm between plants (equivalent to 555,555 plants/ha), but the results were not statistically significant.

The effects of N, P, K, S and Ca rate and irrigation regime were studied by Eppendorfer and Eggum (1995) in pot experiments on carrot cv. Nandor. Carrot root DM yields ranged from 27 to 320 g/pot. Yields were reduced most by P and least by S deficiency. Dietary fibre content was only slightly affected by the treatments. In balance trials with rats, increasing protein concentrations in carrot DM increased the true digestibility of protein from 70 to 78%. Digestible energy and gross energy were also increased, from 73 to 83% and from 16.2 to 17.4 kg/g, respectively.

Carrot (cv. Kingston) plants were grown by Hole and Scaife (1993) from seed for 28 days in a range of nutrient solutions omitting N, P, K, Ca, S, Mg, Fe, B, Mn, Zn, Cu and Mo as separate treatments. All treatments except those omitting Mn, Zn, Cu and Mo resulted in effects on plant growth and the development of deficiency symptoms. Parameters governing the shape of the relationship between fractional relative growth rate and plant nutrient concentration were altered until the model predicted the observed final mean DW of deficient plants and time of divergence of this growth curve from that of fully nourished plants. Critical concentrations so obtained were higher than those previously reported for Ca, Fe, N and P in carrots and lower for K, Mg and S.

2.2 Effect of boron on growth and yield of root crops

A field experiment was carried out by Mesquita *et al*. (2005) on a clayey Dystrophic Red Latosol (Oxisol) in Distrito Federal, Brazil, under isohyperthermic regime to evaluate the effect of boron application on carrot (*Daucus carota*) cv. Alvorada root yield. Treatments comprised: 0, 1.7, 3.4, 5.1, 6.8 and 10.2 kg B ha^{-1}. Azomethine-H was used as extractant for boron determination in soil and plant material. The maximum marketable root yield was 50.6 t ha^{-1} obtained under the estimated concentration of 0.55 mg B kg^{-1} in the soil. The critical boron (B) concentration in the soil associated with 90% of the maximum marketable root yield was 0.45 mg kg^{-1}. Carrot cultivars of the 'Flakker' and 'Nanty-types' were sprayed with 0.5% Savabor and 1% Damisol to determine the effects of boron on the flavour of the crop as evaluated by chemical analysis and sensory tests. Boron application increased the carotene content of the crop. Sensory tests detected bitter flavour in carrots and measured its interaction with the sweet flavour.

An experiment was conducted by Eraslan *et al*. (2007) to investigate the impact of exogenous salicylic acid on the growth, physiology and antioxidant activity of carrot (*Daucus carota* L. cv. Nantes) grown under combined stress of salinity and boron toxicity. The treatments consisted of salt (control, NaCl, and Na_2SO_4), boron (-B: 0 and +B: 25 mg B kg^{-1}) and salicylic acid (SA: 0 and +SA: 0.5 mmol SA kg^{-1}). The diameter of the storage root was increased by NaCl salinity in the absence of B toxicity, however, it was increased by Na_2SO_4 salinity under B toxicity.

The effects of boron and niacin deficiency and excess on the growth of carrot *(Daucus carota* cv. nantes) were investigated by Demiray and Dereboylu (2005). The seeds of carrots were directly sowed to soil with less boron, and 6 mg/l boron (0) and 0.5 mg/l nicotinic acid (control, K); and 31 mg/l (5B) boron; and in soil lacking with niacin (nicotinic acid) (0N), 2.5 mg/l (5N); and in soil with 31 mg/l boron and 2.5 mg/l niacin together (5B/5N). Root-shoot length and IAA hormone and pigment (chlorophyll and carotenoid) content were determined in the germinated seeds and in 8-week-old plantlets. According to the results, either boron or niacin lacking or excess boron or excess niacin in the medium, did not affect germination rate. On the other hand, boron deficiency caused an increase in root length and IAA content and an increase in pigment content; while the excess boron and excess niacin caused a decrease in root length and IAA content but an increase in shoot length and a decrease in pigment content, at the end of the eighth week. In contrary, niacin deficiency caused a decrease in root length and shoot length and pigment content, but an excess increase in IAA content.

Dry matter content and concentration of microelements (Mn, Zn, Fe, B, Cu) in field-grown cabbage and carrot produced in Estonia were determined by Leis and Lepik (2001). Concentrations of micronutrients in cabbage were normal except for boron. Micronutrient content in carrots was low.

A field experiment was conducted by Kotur (1998) in Bihar during 1989-92 to evaluate the effects of lime and boron application on 3 cropping sequences: (i) okra [*Abelmoschus esculentus*], french bean (*Phaseolus vulgaris*) carrot; (ii) cowpea I (*Vigna unguiculata*), peas, radish, both initiated in the rainy season; and (iii) cowpea II-capsicum (*Capsicum annuum*), onion, initiated in summer. The yield of all the crops was increased by 3.4 t/ha of lime applied at the start of the rotation; yield was increased by 6% in radish compared to no lime controls. Boron applied at 0.75 kg/ha at the start of the rotation significantly increased the yield by 11% in radish compared to no boron (control), but higher boron levels depressed the yield. In okra, boron at 1.5 kg/ha increased the yield by 15%, while boron at 0.75-2.25 kg/ha or its residue increased the yield by 10-12% in carrot, 17-29% in peas and 25-35% in capsicum. An evaluation of soil pH and hot water-soluble boron in the soil after each crop showed that the reaction of lime with soil and residual levels of boron depended on the crops involved as well as the time or season of application of lime or boron.

The above literature showed the importance of phosphorus and boron in case of carrot production. Hence the research work has been under taken to examine the influence of phosphorus and boron on the growth and yield of carrot.

CHAPTER III

MATERIALS AND METHODS

The study was conducted in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2008 to February 2009 to study the effect of phosphorus and boron on the growth and yield of carrot.

3.1 Experimental site

The experimental site was previously used as vegetable garden and recently developed for research work. The location of the site in $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude with an elevation of 8.2 m from sea level (Anon., 1989).

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988). The analytical data of the soil sample collected from the experimental area were determined in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka. The experimental site was a medium high land and pH of the soil was 5.6. The morphological characters of soil of the experimental plots as indicated by FAO (1988) are presented in Appendix I.

3.3 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). No rainfall of the experimental site was obtained during the entire period of the study. The average maximum and minimum temperature were 25.82^0C and 12.4^0C, repectively during the experimental period. Rabi season is characterized by plenty of sunshine. The maximum and minimum temperature, humidity rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department and have been presented in Appendix II.

3.4 Planting materials

The seed of ‘New Caroda’ variety of carrot were used in this experiment as experimental materials. The seeds were collected from “Hamid Seed Store” Siddique Bazar, Dhaka.

3.5 Treatment of the experiment

The experiment consists of two factors. Details were presented below:

Factor A: Levels of phosphorus (4 levels)

i. P_0: 0 kg P_2O_5/ha (control)

ii. P_1: 50 kg P_2O_5/ha

iii. P_2: 60 kg P_2O_5/ha

iv. P_3: 70 kg P_2O_5/ha

Factor B: Levels of boron (3 levels)

ii. B_0: 0 kg H_3BO_3/ha (control)

ii. B_1: 1.5 kg H_3BO_3/ha

iii. B_2: 2.0 kg H_3BO_3/ha

There were 12 (4 × 3) treatment combinations such as P_0B_0, and P_0B_1, P_0B_2, P_1B_0, P_1B_1, P_1B_2, P_2B_0, P_2B_1, P_2B_2, P_3B_0, P_3B_1 and P_3B_2.

3.6 Layout of the experiment

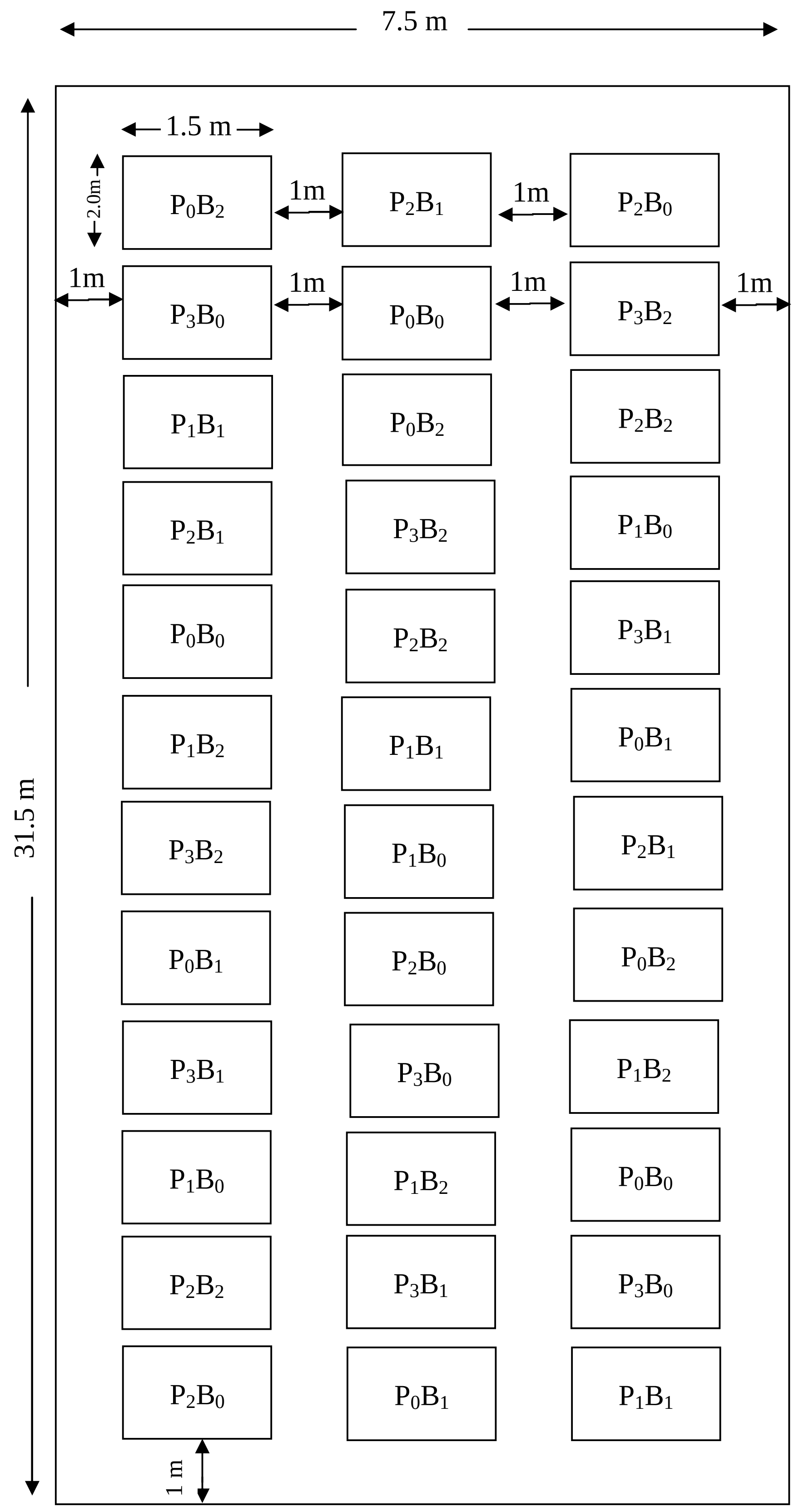
The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the treatment combinations in each plot of each block. Each block was divided into 12 plots where 12 treatment combinations were allotted at random. There were 36 unit plots altogether in the experiment. The size of the plot was 2.0 m × 1.5 m. The distance between two blocks was 1 m and two plots were kept 50 cm. The layout of the experiment is shown in Figure 1.

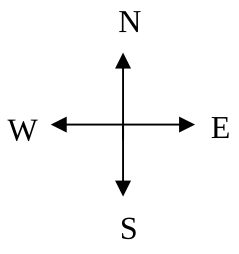
3.7 Land preparation

The selected experimental plot was opened in the 1st week of November 2008 with a power tiller and was exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times, followed by laddering to obtain a good tilth. Weeds and stubbles were removed and finally, obtained a desirable tilth of soil for sowing of carrot seed. The experimental plot was partitioned into the unit plots in accordance with the experimental design.

3.8 Application of manure and fertilizers

Manures and fertilizers that were applied presented in Table 1. The total amount of cowdung, TSP and half of MP and boron was applied as basal dose at the time of land preparation. The rest of MP and total amount of Urea was applied in three installments at 10, 30 and 50 day after seed sowing (Anon., 2005).





Plot size: 2.0 m × 1.5 m
Plot spacing: 50 cm
Between replication: 1.0 m

Factors A: Phosphorus

P_0: 0 kg P_2O_5/ha
P_1: 50 kg P_2O_5/ha
P_2: 60 kg P_2O_5/ha
P_3: 70 kg P_2O_5/ha

Factors B: Boron

B_0: 0 kg H_3BO_3/ha
B_1: 1.5 kg H_3BO_3/ha
B_2: 2.0 kg H_3BO_3/ha

Figure 1. Layout of the experimental plot

Table 1. Dose and date of application of fertilizers in carrot field

Fertilizers and Manures	Dose/ha	Application (%)			
		Basal	10 DAS	30 DAS	50 DAS
Cowdung	10 tonnes	100	--	--	--
Urea	200 kg	--	33.33	33.33	33.33
TSP	As per treatment	100	--	--	--
MP	175 kg	50	16.67	16.67	16.67
Borax	As per treatment	100	--	--	--

3.9 Intercultural operations

3.9.1 Irrigation

Light over-head irrigation was provided with a watering can to the plots immediately after germination of seedlings. Irrigation was also provided at 20 and 40 days after seed sowing (DAS).

3.9.2 Weeding

Weeding was done three times at 10, 30 and 50 DAS sowing followed by irrigation in the plots considering the optimum time for removal weed.

3.9.3 Plant Protection

The crop was protected from the attack of insect-pest by spraying Malathion. The insecticide application were made fortnightly as a matter of routine work from seedling emergence to the end of harvest.

3.10 Harvesting

The crop was harvested depending upon the attaining good sized root and the harvesting was done at 28th February by manually. Enough care was taken during harvesting period to prevent damage of root.

3.11 Data collection

The data were collected from the inner rows of plants of each treatment to avoid the border effect. In each unit plot contain 12 rows 10 plants were selected at random for data collection. Data were collected in respect of the plant growth characters and yield contributing characters and yield of carrot. Data on plant height, number of leaves per plant were counted at 20, 30, 40, 50, 60 DAS and at harvest at February 04, 2010. All other parameters were recorded only at harvest.

3.11.1 Plant height

The height of plant was recorded at 20, 30, 40, 50, 60 DAS and after harvest by using a meter scale and expressed in centimeter. The height was measured from the ground level to the tip of the leaf of an individual plant. Mean value of ten selected plants was calculated for each unit plot.

3.11.2 Number of leaves per plant

Number of leaves per plant was counted and the data were recorded from randomly selected 10 plants at 20, 30, 40, 50, 60 DAS and at harvest and mean value was counted and was expressed in centimeter (cm).

3.11.3 Root length

The length of root was measured using a meter scale as the vertical distance from one side to another side of the widest part of the sectioned modified root and was expressed in centimeter.

3.11.4 Root diameter

The modified root from sample plants was sectioned vertically at the middle position with a sharp knife. The diameter of the root was measured in centimeter (cm) with a meter scale as the horizontal distance from one side to another side of the widest part of the sectioned modified root and their mean value was recorded.

3.11.5 Fresh weight of leaves per plant

The fresh weight of clean leaves was recorded after harvest. The average of 10 plants was recorded and expressed in gram. The weight of the leaves was recorded immediately after harvest.

3.11.6 Fresh weight of roots

The fresh weight of roots was recorded after cleaning. Average of 10 plants were recorded and expressed in gram. The weight of the roots was recorded immediately after harvest.

3.11.7 Dry matter content of leaves

At harvest 150 g leaves sample was taken from randomly selected 10 plants. Then the sample was chopped and dried in the direct sun light for two days and then it was dried in an oven at 70^{0}C for 72 hours, until constant weight was achieved. The dry weight of the sample was recorded in gram and the mean value was calculated. Then the percent dry matter in leaves was calculated by using following formula-

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

3.11.8 Dry matter content of root

At harvest 150 g root sample was taken from randomly selected plants. Then the sample was chopped and dried freshly in the direct sun light for two days and then it was dried in an oven at 70^0C for 72 hours, until constant weight was achieved. The dry weight of the sample was recorded in gram and the mean value was calculated. Then the percent dry matter of root was calculated by using following formula-

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

3.11.9 Branched root

After harvest carrot roots were observed carefully and identified branched roots and it was expressed in percentage.

3.11.10 Cracked root

After harvest carrot roots were observed carefully and identified cracked roots and it was expressed in percentage.

3.11.11 Rotten root

After harvest carrot roots were observed carefully and identified rotten roots and expressed in percentage.

3.11.12 Gross yield per plot

Total yield of carrot per plot was estimated by taking weight of all the plants within a plot and was expressed in kilogram.

3.11.13 Gross yield per hectare

Gross yield per hectare was calculated by converting the weight of gross yield per plot to hectare and was expressed in ton.

3.11.14 Marketable yield per plot

Marketable yield of carrot per plot was estimated as the root weight after removal of branched, cracked and rotten roots and others parts of all the plants within a plot and was expressed in kilogram.

3.11.15 Marketable yield per hectare

Marketable yield of carrot per hectare was calculated by converting the weight of gross yield per plot to hectare and was expressed in ton.

3.12 Statistical analysis

The data obtained for different characters were statistically analyzed. The mean values of all the characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.13 Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of phosphorus and boron fertilizers. All input cost include the cost for lease of land and interest on running capital were considered in computing the cost of production. The interest of running capital was calculated @ 13.5% for six months. The market price of carrot was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

CHAPTER IV

RESULTS AND DISCUSSION

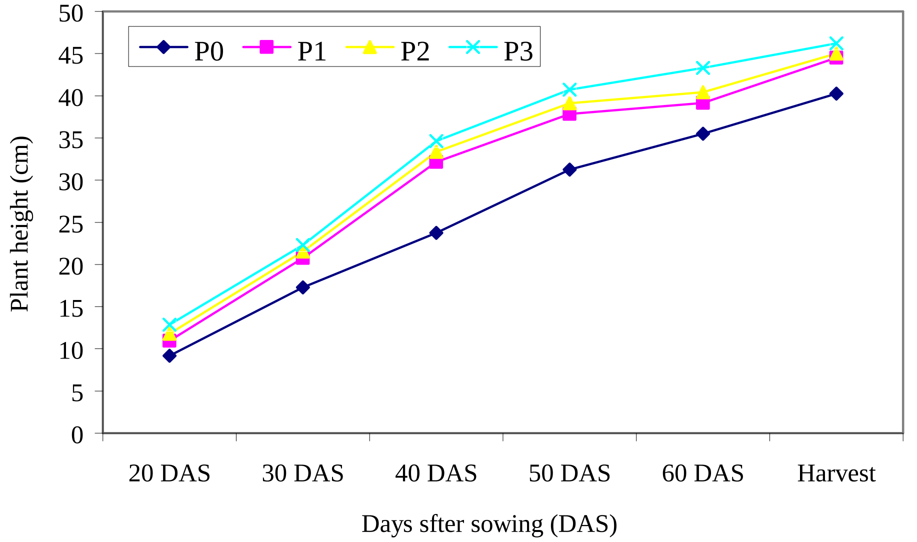
The present study was conducted to determine the effect of phosphorus and boron on the growth and yield of carrot. Data on growth and yield contributing characters and yield were recorded. The analyses of variance (ANOVA) of the data on different characters have been presented in Appendix III-VI. The results have been shown and discussed and possible interpretations are given under the following headings:

4.1 Plant height

Plant height of carrot showed statistically significant differences due to the application of different levels of phosphorus at 20, 30, 40, 50, 60 DAS and at harvest (Figure 2). At 20 DAS, the longest plant (12.85 cm) was recorded from P_3 (70 kg P_2O_5/ha) which was followed (11.78 cm and 10.96 cm) by P_2 (60 kg P_2O_5/ha) and P_1 (50 kg P_2O_5/ha) and they were statistically identical, while the shortest (9.19 cm) from P_0 (0 kg P_2O_5/ha). At 30 DAS, the longest plant was found from P_3 (22.32 cm) which was statistically similar to P_2 (21.54 cm) and followed by P_1 (20.77 cm), whereas the shortest from P_0 (17.28 cm). At 40 DAS, the longest plant was recorded from P_3 (34.62 cm) which was statistically similar to P_2 (33.36 cm) followed by P_1 (32.15 cm), whereas the shortest from P_0 (23.74 cm). At 50 DAS, the longest plant was attained from P_3 (40.72 cm) which was statistically similar to P_2 (39.12 cm) and followed by P_1 (37.84 cm), again the shortest plant was found from P_0 (31.26 cm). At 60 DAS, the longest plant was found from P_3

(43.30 cm) which was followed by P_2 (40.41 cm) and P_1 (39.16 cm) and the shortest plant was from P_0 (35.50 cm). At harvest, the longest plant was recorded from P_3 (46.23 cm) which was statistically similar to P_2 (45.01 cm) followed by P_1 (44.52 cm) and the shortest was obtained from P_0 (40.27 cm). It was found that highest doses of phosphorus ensured optimum vegetative growth for longest plant. Similar results also reported by Akhilesh *et al*. (2003) and Leis and Lepik (2001).

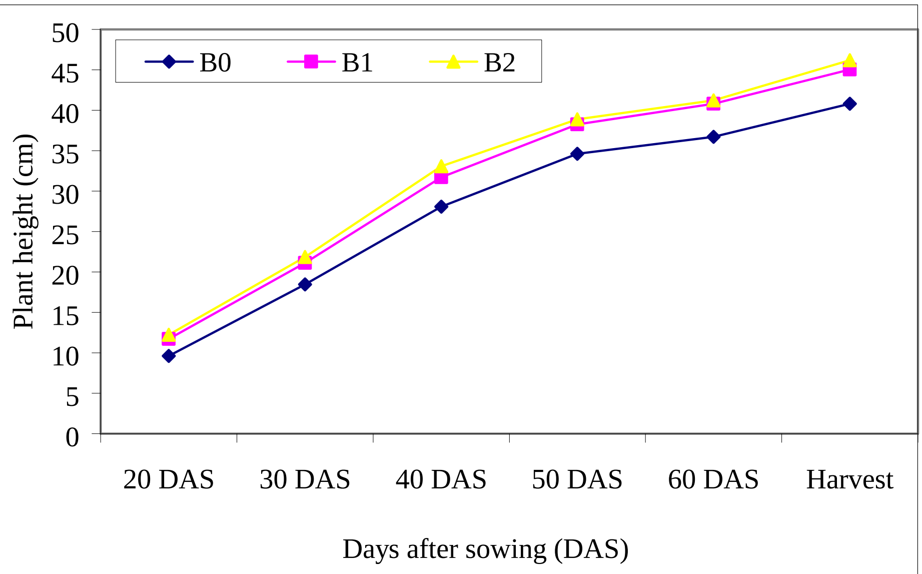
Different levels of boron differ significantly for plant height of carrot at 20, 30, 40, 50, 60 DAS and at harvest (Figure 3). At 20 DAS, the longest plant (12.24 cm) was obtained from B_2 (2.0 kg H_3BO_3/ha) which was statistically identical (11.72 cm) to B_1 (1.5 kg H_3BO_3/ha), whereas the shortest plant (9.63 cm) from B_0 (0 kg H_3BO_3/ha). At 30 DAS, the longest plant was observed from B_2 (21.86 cm) which was statistically identical to B_1 (21.12 cm), while the shortest plant was recorded from B_0 (18.46 cm). At 40 DAS, the longest plant was recorded from B_2 (33.09 cm) which was followed by B_1 (31.72 cm) and the shortest plant was recorded from B_0 (28.08 cm). At 50 DAS, the longest plant was recorded from B_2 (38.87 cm) which was statistically identical to B_1 (38.24 cm), again the shortest plant was obtained from B_0 (34.60 cm). At 60 DAS, the longest plant was recorded from B_2 (41.22 cm) which was statistically identical to B_1 (40.82 cm) and the shortest plant from B_0 (36.73 cm). At harvest, the longest plant was found from B_2 (46.19 cm) which was statistically identical to B_1 (45.02 cm), whereas the shortest plant was recorded from B_0 (40.81 cm). It was found that with the increase of boron plant height increase significantly upto a certain level than increase leisurely. Similar findings also reported by Mesquita *et al*. (2005).



P_0: 0 kg P_2O_5/ha P_1: 50 kg P_2O_5/ha

P_2: 60 kg P_2O_5/ha P_3: 70 kg P_2O_5/ha

Figure 2. Effect of phosphorus on plant height of carrot



B_0: 0 kg H_3BO_3/ha B_1: 1.5 kg H_3BO_3/ha

B_2: 2.0 kg H_3BO_3/ha

Figure 3. Effect of boron on plant height of carrot

Significant variation was recorded due to the combined effect of phosphorus and boron in terms of plant height of carrot at 20, 30, 40, 50, 60 DAS and harvest (Table 2). The longest plant (14.72 cm, 24.86 cm, 38.31 cm, 44.60 cm, 46.70 cm and 49.30 cm) was recorded from P_3B_2 (70 kg P_2O_5 and 2.0 kg H_3BO_3/ha), consequently the shortest plant (8.19 cm, 28.23 cm and 33.03 cm) was obtained from P_0B_2 (0 kg P_2O_5 and 2.0 kg H_3BO_3/ha) at 20, 50 and 60 DAS, respectively while at 30, 40 DAS and at harvest the shortest plant (15.46 cm, 22.03 cm and 37.20 cm) was recorded from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha). It was revealed that optimum level of phosphorus and boron ensured the tallest plant.

4.2 Number of leaves per plant

Different levels of phosphorus showed statistically significant differences in respect of number of leaves per plant at 20, 30, 40, 50, 60 DAS and at harvest (Figure 4). At 20 DAS, the maximum number of leaves per plant (4.27) was recorded from P_3 (70 kg P_2O_5/ha) which was statistically identical to (4.13) to P_2 (60 kg P_2O_5/ha) and followed (3.97) by P_1 (50 kg P_2O_5/ha), again the minimum number (3.18) was recorded from P_0 (0 kg P_2O_5/ha). At 30 DAS, the maximum number of leaves per plant was recorded from P_3 and P_2 and the value was (7.48) followed by P_1 (7.18). On the other hand, the minimum number was recorded from P_0 (6.52). At 40 DAS, the maximum number of leaves per plant was found from P_3 (11.80) which of leaves was followed by P_2 (10.96) and P_1 (10.43) and they were statistically similar, whereas the minimum number was recorded from P_0 (9.57). At 50 DAS, the maximum number of leaves per plant was recorded

Table 2. Combined effect of phosphorus and boron on plant height of carrot

Treatments	Plant height (cm) at					
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
P_0B_0	8.27 g	15.46 g	22.03 h	30.85 f	34.09 fg	37.20 h
P_0B_1	11.10 de	20.03 def	26.21 g	34.71 e	39.38 cde	43.52 def
P_0B_2	8.19 g	16.36 g	22.98 h	28.23 f	33.03 g	40.08 g
P_1B_0	9.31 fg	18.69 f	28.90 f	34.60 e	36.27 efg	41.42 fg
P_1B_1	11.28 cde	21.12 cde	33.06 cd	38.85 cd	39.83 cde	44.85 cde
P_1B_2	12.31 bcd	22.50 bc	34.49 bc	40.07 bc	41.37 bc	47.30 abc
P_2B_0	9.91 ef	19.51 ef	29.88 ef	35.49 de	36.94 def	41.64 fg
P_2B_1	11.67 cd	21.40 cde	33.60 cd	39.27 bc	40.49 bcd	45.30 bcde
P_2B_2	13.76 ab	23.71 ab	36.60 ab	42.59 ab	43.79 ab	48.08 ab
P_3B_0	11.01 de	20.18 def	31.52 de	37.46 cde	39.61 cde	42.98 efg
P_3B_1	12.82 bc	21.93 bcd	34.02 cd	40.12 bc	43.60 ab	46.41 abcd
P_3B_2	14.72 a	24.86 a	38.31 a	44.60 a	46.70 a	49.30 a
$LSD_{(0.05)}$	1.502	1.919	2.454	3.280	3.261	2.812
Level of significance	0.01	0.01	0.01	0.01	0.01	0.05
CV(%)	7.92	5.53	9.68	5.20	7.86	6.77

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha (Control)

P_1: 50 kg P_2O_5/ha

P_2: 60 kg P_2O_5/ha

P_3: 70 kg P_2O_5/ha

B_0: 0 kg H_3BO_3/ha (Control)

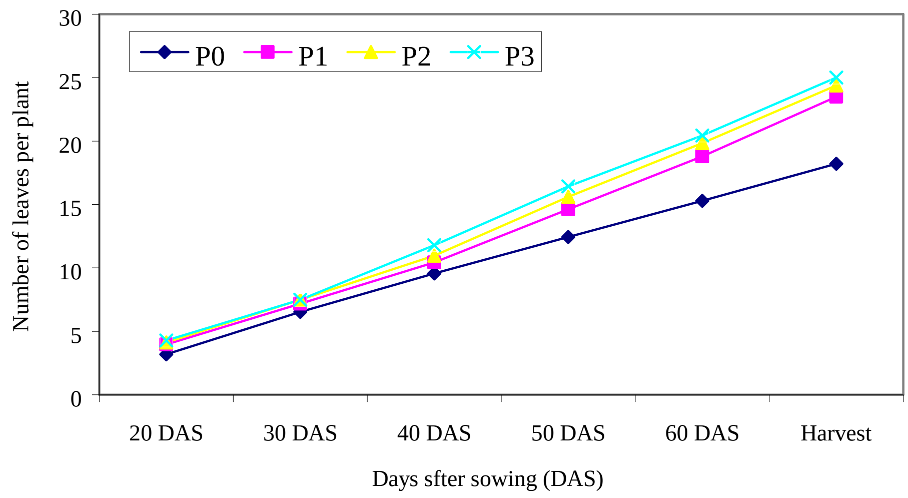
B_1: 1.5 kg H_3BO_3/ha

B_2: 2.0 kg H_3BO_3/ha

from P_3 (16.43) which was followed by P_2 (15.61), while the minimum number from P_0 (12.44) followed by P_2 (14.63). At 60 DAS, the maximum number of leaves per plant was recorded from P_3 (20.44) which was statistically identical to P_2 (19.84) and followed by P_1 (18.79), whereas the minimum number was recorded from P_0 (15.29). At harvest, the maximum number of leaves per plant was obtained from P_3 (25.01) which was statistically similar to P_2 (24.39) and followed by P_1 (23.30), while the minimum number from P_0 (18.22). Maximum number of leaves per plant was found from optimum doses of phosphorus.

Number of leaves per plant differ significantly due to different levels of boron at 20, 30, 40, 50, 60 DAS and at harvest (Figure 5). At 20, 30, 40, 50, 60 DAS and harvest, the maximum number of leaves per plant (4.33, 7.57, 11.26, 15.57, 19.24 and 23.94) was recorded from B_2 (2.0 kg H_3BO_3/ha) which was statistically identical (4.27, 7.55, 11.17, 15.03, 19.08 and 23.86) to B_1 (1.5 kg H_3BO_3/ha), whereas the minimum number (3.06, 6.37, 9.64, 13.74, 17.45 and 20.54) from B_0 (0 kg H_3BO_3/ha). It was found that number of leaves per plant increases with the increasing level of boron.

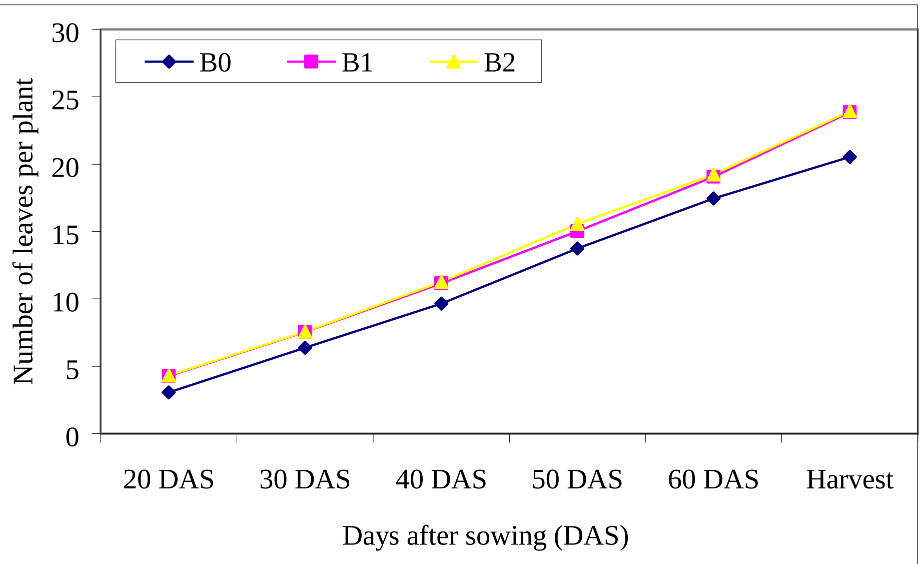
Combined effect of phosphorus and boron showed significant difference on number of carrot leaves per plant at 20, 30, 40, 50, 60 DAS and harvest (Table 3). The maximum number of leaves per plant (4.80, 8.00, 12.90, 17.93, 21.90 and 27.03) was observed from P_3B_2 (70 kg P_2O_5 and 2.0 kg H_3BO_3/ha), while the minimum number of leaves per plant (2.40, 5.87, 8.97, 11.57 and 17.60) was recorded from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha) at 20, 30, 40, 50 DAS and



P_0: 0 kg P_2O_5/ha P_1: 50 kg P_2O_5/ha

P_2: 60 kg P_2O_5/ha P_3: 70 kg P_2O_5/ha

Figure 4. Effect of phosphorus on number of leaves per plant of carrot



B_0: 0 kg H_3BO_3/ha B_1: 1.5 kg H_3BO_3/ha

B_2: 2.0 kg H_3BO_3/ha

Figure 5. Effect of boron on number of leaves per plant of carrot

Table 3. Combined effect of phosphorus and boron on number of leaves per plant of carrot

Treatments	Number of leaves per plant at					
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
P_0B_0	2.40 g	5.87 e	8.97 d	11.57 g	14.93 g	17.60 e
P_0B_1	3.77 d	6.93 c	10.70 bc	14.03 ef	16.50 f	19.23 de
P_0B_2	3.37 ef	6.77 cd	9.03 d	11.73 g	14.43 g	17.83 e
P_1B_0	3.10 f	6.40 d	9.33 d	13.40 f	17.30 ef	21.43 c
P_1B_1	4.30 c	7.60 b	10.93 b	14.93 cde	19.67 cd	24.43 b
P_1B_2	4.50 bc	7.53 b	11.03 b	15.57 cd	19.40 cd	24.63 b
P_2B_0	3.30 ef	6.57 cd	9.77 cd	14.57 def	18.43 de	21.00 cd
P_2B_1	4.43 bc	7.87 ab	11.03 b	15.23 cde	19.87 c	25.90 ab
P_2B_2	4.67 ab	8.00 a	12.07 a	17.03 ab	21.23 ab	26.27 ab
P_3B_0	3.43 e	6.63 cd	10.50 bc	15.43 cd	19.13 cd	22.13 c
P_3B_1	4.57 abc	7.80 ab	12.00 a	15.93 bc	20.30 bc	25.87 ab
P_3B_2	4.80 a	8.00 a	12.90 a	17.93 a	21.90 a	27.03 a
$LSD_{(0.05)}$	0.273	0.339	0.921	1.205	1.278	2.081
Level of significance	0.05	0.05	0.01	0.01	0.01	0.05
CV(%)	10.19	12.80	5.09	4.81	8.06	5.39

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha (Control)

P_1: 50 kg P_2O_5/ha

P_2: 60 kg P_2O_5/ha

P_3: 70 kg P_2O_5/ha

B_0: 0 kg H_3BO_3/ha (Control)

B_1: 1.5 kg H_3BO_3/ha

B_2: 2.0 kg H_3BO_3/ha

harvest, respectively again at 60 DAS the minimum number of leaves per plant (14.43) was obtained from P_0B_2 (0 kg P_2O_5 and 2.0 kg H_3BO_3/ha). It was revealed that optimum level of phosphorus and boron produced the maximum number of leaves per plant.

4.3 Root length

Different levels of phosphorus showed significant differences on root length of carrot (Table 4). The longest root (16.78 cm) was recorded from P_3 (70 kg P_2O_5/ha) which was statistically identical (16.09 cm) to P_2 (60 kg P_2O_5/ha) and the shortest root (12.79 cm) was obtained from P_0 (0 kg P_2O_5/ha). Araujo *et al*. (2004) reported similar findings earlier.

Different levels of boron differ significantly on root length of carrot (Table 4). The longest root of carrot (16.10 cm) was observed from B_2 (2.0 kg H_3BO_3/ha) which was statistically similar (15.44 cm) to B_1 (1.5 kg H_3BO_3/ha), while the shortest root (13.77 cm) from B_0 (0 kg H_3BO_3/ha). Demiray and Dereboylu (2005) reported that while the excess boron it decrease in root length.

Combined effect of phosphorus and boron showed significant variation on root length of carrot (Table 5). The longest root of carrot (18.27 cm) was recorded from P_3B_2 (70 kg P_2O_5 and 2.0 kg H_3BO_3/ha), while the shortest root (11.14 cm) was observed from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha).

Table 4. Effect of phosphorus and boron on yield contributing characters of carrot

Treatments	Root length (cm)	Root diameter (cm)	Fresh weight (g) of		Dry matter content (%) of	
			Leaf	Root	Leaf	Root
Phosphorus						
P_0	12.79 c	2.01 c	60.65 d	105.81 c	6.59 c	8.21 c
P_1	14.74 b	2.48 b	74.73 c	125.58 b	7.97 b	9.55 b
P_2	16.09 a	2.85 a	83.81 b	132.97 ab	8.53 ab	10.43 a
P_3	16.78 a	3.01 a	90.61 a	135.67 a	8.74 a	10.73 a
$LSD_{(0.05)}$	0.961	0.225	5.275	8.937	0.634	0.759
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
Boron						
B_0	13.77 b	2.11 b	71.20 b	108.21 c	7.15 b	8.74 b
B_1	15.44 a	2.73 a	78.46 a	129.47 b	8.24 a	9.95 a
B_2	16.10 a	2.91 a	82.69 a	137.34 a	8.49 a	10.51 a
$LSD_{(0.05)}$	0.833	0.195	4.568	7.740	0.549	0.657
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.51	8.91	6.97	7.31	8.14	7.97

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha (Control)

P_1: 50 kg P_2O_5/ha

P_2: 60 kg P_2O_5/ha

P_3: 70 kg P_2O_5/ha

B_0: 0 kg H_3BO_3/ha (Control)

B_1: 1.5 kg H_3BO_3/ha

B_2: 2.0 kg H_3BO_3/ha

Table 5. Combined effect of phosphorus and boron on yield contributing characters of carrot

Treatments	Root length (cm)	Root diameter (cm)	Fresh weight (g) of		Dry matter content (%) of	
			Leaf	Root	Leaf	Root
P_0B_0	11.14 g	1.71 h	60.26 e	96.47 f	6.34 d	7.37 d
P_0B_1	14.79 cde	2.50 def	62.16 e	124.87 cd	7.64 bc	9.63 bc
P_0B_2	12.45 fg	1.81 h	59.52 e	96.10 f	5.79 d	7.64 d
P_1B_0	13.54 ef	1.97 gh	67.40 de	107.43 ef	6.86 cd	8.51 cd
P_1B_1	14.59 de	2.57 def	76.31 cd	127.76 cd	8.30 b	9.76 bc
P_1B_2	16.09 bcd	2.89 cd	80.48 c	141.54 bc	8.75 ab	10.38 b
P_2B_0	14.79 cde	2.34 fg	75.52 cd	114.77 de	7.62 bc	9.48 bc
P_2B_1	15.91 bcd	2.83 cde	84.13 bc	130.44 cd	8.24 b	10.10 b
P_2B_2	17.56 ab	3.38 ab	91.79 ab	153.70 ab	9.74 a	11.71 a
P_3B_0	15.60 cd	2.44 ef	81.61 c	114.19 de	7.78 bc	9.61 bc
P_3B_1	16.48 bc	3.04 bc	91.25 ab	134.80 c	8.77 ab	10.31 b
P_3B_2	18.27 a	3.56 a	98.97 a	158.03 a	9.68 a	12.29 a
$LSD_{(0.05)}$	1.665	0.390	9.137	15.48	1.097	1.314
Level of significance	0.05	0.01	0.05	0.01	0.01	0.01
CV(%)	6.51	8.91	6.97	7.31	8.14	7.97

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha (Control)
P_1: 50 kg P_2O_5/ha
P_2: 60 kg P_2O_5/ha
P_3: 70 kg P_2O_5/ha

B_0: 0 kg H_3BO_3/ha (Control)
B_1: 1.5 kg H_3BO_3/ha
B_2: 2.0 kg H_3BO_3/ha

4.4 Root diameter

Statistically significant variation was recorded for different levels of phosphorus on root diameter of carrot (Table 4). The highest diameter of root (3.01 cm) was recorded from P_3 (70 kg P_2O_5/ha) which was statistically identical (2.85 cm) to P_2 (60 kg P_2O_5/ha) and the lowest (2.01 cm) was recorded from P_0 (0 kg P_2O_5/ha).

Different levels of boron varied significantly for root diameter of carrot (Table 4). The highest diameter of root (2.91 cm) was recorded from B_2 (2.0 kg H_3BO_3/ha) which was statistically similar (2.73 cm) to B_1 (1.5 kg H_3BO_3/ha) and the lowest (2.11 cm) from B_0 (0 kg H_3BO_3/ha).

Due to combined effect of phosphorus and boron showed significant differences on root diameter of carrot (Table 5). The highest diameter of root (3.56 cm) was found from P_3B_2 (70 kg P_2O_5 and 2.0 kg H_3BO_3/ha), while the lowest (1.71 cm) was recorded from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha).

4.5 Fresh weight of leaves per plant

Fresh weight of leaves per plant of carrot showed statistically significant differences for different levels of phosphorus (Table 4). The highest fresh weight of leaves per plant (90.61 g) was obtained from P_3 (70 kg P_2O_5/ha) which was followed (83.81 g) by P_2 (60 kg P_2O_5/ha), whereas the lowest (60.65 g) was recorded from P_0 (0 kg P_2O_5/ha). Uddin *et al.* (2004) also recorded similar results earlier.

Significant variation was recorded for different levels of boron on fresh weight of leaves per plant of carrot (Table 4). The highest fresh weight of leaves per plant (82.69 g) was found from B_2 (2.0 kg H_3BO_3/ha) which was statistically similar (78.46 g) to B_1 (1.5 kg H_3BO_3/ha), while the lowest was observed from (71.20 g) from B_0 (0 kg H_3BO_3/ha).

Combined effect of phosphorus and boron showed significant differences on fresh weight of leaves per plant of carrot (Table 5). The highest fresh weight of leaves per plant (98.97 g) was recorded from P_3B_2 (70 kg P_2O_5 and 2.0 kg H_3BO_3/ha) which was similar to P_3B_1 (91.25 g). On the other hand, the lowest (59.52 g) was attained from P_0B_2 (0 kg P_2O_5 and 2.0 kg H_3BO_3/ha).

4.6 Fresh weight of roots per plant

Different levels of phosphorus showed statistically significant differences on fresh weight of roots per plant of carrot (Table 4). The highest fresh weight of roots per plant (135.67 g) was recorded from P_3 (70 kg P_2O_5/ha) which was statistically identical (132.97 g) to P_2 (60 kg P_2O_5/ha) and followed (125.58 g) by P_1 (50 kg P_2O_5/ha) and the lowest (105.81 g) was found from P_0 (0 kg P_2O_5/ha).

Different levels of boron differ significantly on fresh weight of roots per plant of carrot (Table 4). The highest fresh weight of roots per plant (137.34 g) was observed from B_2 (2.0 kg H_3BO_3/ha) which was followed (129.47 g) by B_1 (1.5 kg H_3BO_3/ha), while the lowest (108.21 g) from B_0 (0 kg H_3BO_3/ha).

Combined effect of phosphorus and boron showed significant differences on fresh weight of roots per plant of carrot (Table 5). The highest fresh weight of roots per plant (158.03 g) was found from P_3B_2 (70 kg P_2O_5 and 2.0 kg H_3BO_3/ha) which was identical to P_2B_2 (153.70 g), whereas the lowest (96.10 g) was recorded from P_0B_2 (0 kg P_2O_5 and 2.0 kg H_3BO_3/ha).

4.7 Dry matter content of leaf

Significant variation was recorded for different levels of phosphorus in terms of dry matter content of leaf of carrot (Table 4). The highest dry matter content in leaf (8.74%) was found from P_3 (70 kg P_2O_5/ha) which was statistically identical (8.53%) to P_2 (60 kg P_2O_5/ha), and the lowest (6.59%) was observed from P_0 (0 kg P_2O_5/ha).

Dry matter content of leaf of carrot differs significantly for different levels of boron (Table 4). The highest dry matter content in leaf (8.49%) was recorded from B_2 (2.0 kg H_3BO_3/ha) which was statistically similar (8.24%) to B_1 (1.5 kg H_3BO_3/ha) and the lowest (7.15%) from B_0 (0 kg H_3BO_3/ha).

Dry matter content of leaf of carrot showed significant differences due to the combined effect of phosphorus and boron (Table 5). The highest dry matter content of leaf (9.74%) was recorded from P_2B_2 (60 kg P_2O_5 and 2.0 kg H_3BO_3/ha) and the lowest (5.79%) was observed from P_0B_2 (0 kg P_2O_5 and 2.0 kg H_3BO_3/ha).

4.8 Dry matter content of root

Different levels of phosphorus varied significantly on dry matter content of root of carrot (Table 4). The highest dry matter content of root (10.73%) was recorded from P_3 (70 kg P_2O_5/ha) which was statistically identical (10.43%) to P_2 (60 kg P_2O_5/ha) and the lowest (8.21%) was found from P_0 (0 kg P_2O_5/ha).

Different levels of boron differ significantly on dry matter content of root of carrot (Table 4). The highest dry matter content of root (10.51%) was observed from B_2 (2.0 kg H_3BO_3/ha) which was statistically similar (9.95%) to B_1 (1.5 kg H_3BO_3/ha), while the lowest (8.74%) from B_0 (0 kg H_3BO_3/ha).

Phosphorus and boron showed significant differences due to combined effect in terms of dry matter content of root of carrot (Table 5). The highest dry matter content of root (12.29%) was found from the treatment combination of P_3B_2 (70 kg P_2O_5 and 2.0 kg H_3BO_3/ha) and the lowest (7.37%) from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha).

4.9 Branched root

Branched root of carrot showed statistically significant differences due to different levels of phosphorus (Table 6). The maximum branched root (2.55%) was obtained from P_0 (0 kg P_2O_5/ha) which was statistically identical (2.41%) to P_1 (50 kg P_2O_5/ha), consequently the minimum (2.30%) was found from P_2 (60 kg P_2O_5/ha).

Due to application of different levels of boron showed significant differences on branched root of carrot (Table 6). The maximum branched root (2.63%) was observed from B_0 (0 kg H_3BO_3/ha) and the minimum (2.29%) from B_2 (2.0 kg H_3BO_3/ha) which was statistically similar (2.32%) to B_1 (1.5 kg H_3BO_3/ha).

Combined effect of phosphorus and boron showed significant differences for branched root of carrot (Table 7). The maximum branched root (2.76%) was obtained from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha), whereas the minimum (2.16%) was found from P_3B_1 (70 kg P_2O_5 and 1.5 kg H_3BO_3/ha).

4.10 Cracked root

Different levels of phosphorus showed significant differences on cracked root of carrot (Table 6). The maximum cracked root (2.09%) was recorded from P_0 (0 kg P_2O_5/ha) and the minimum (1.64%) from P_1 (50 kg P_2O_5/ha).

Different levels of boron showed statistically significant variation for cracked root of carrot (Table 6). The maximum cracked root (1.99%) was observed from B_0 (0 kg H_3BO_3/ha) which was followed (1.87%) to B_2 (2.0 kg H_3BO_3/ha), while the minimum (1.57%) from B_1 (1.5 kg H_3BO_3/ha).

Combined effect of phosphorus and boron showed significant differences on cracked root of carrot (Table 7). The maximum cracked root (2.37%) was found from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha), whereas the minimum (1.36%) was obtained from P_2B_1 (60 kg P_2O_5 and 1.5 kg H_3BO_3/ha).

Table 6. Effect of phosphorus and boron on yield contributing characters and yield of carrot

Treatments	Branched root (%)	Cracked root (%)	Rotten root (%)	Gross yield		Marketable yield	
				Plot (kg)	Hectare (ton)	Plot (kg)	Hectare (ton)
Phosphorus							
P_0	2.55 a	2.09 a	2.08 a	8.34 b	27.79 b	7.24 c	24.14 c
P_1	2.41 ab	1.64 c	1.69 c	10.55 a	35.15 a	9.95 b	33.16 b
P_2	2.30 b	1.72 bc	1.81 bc	11.08 a	36.92 a	10.52 a	35.08 a
P_3	2.39 b	1.80 b	1.89 b	11.29 a	37.64 a	10.76 a	35.86 a
$LSD_{(0.05)}$	0.148	0.124	0.128	0.814	2.715	0.519	1.730
Level of significance	0.05	0.01	0.01	0.01	0.01	0.01	0.01
Boron							
B_0	2.63 a	1.99 a	2.10 a	9.35 b	31.17 b	8.50 b	28.34 b
B_1	2.32 b	1.57 c	1.61 c	10.77 a	35.89 a	10.05 a	33.51 a
B_2	2.29 b	1.87 b	1.90 b	10.82 a	36.07 a	10.30 a	34.34 a
$LSD_{(0.05)}$	0.128	0.107	0.110	0.705	2.351	0.450	1.499
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.25	7.03	6.88	8.08	8.08	5.52	5.52

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha (Control)

P_1: 50 kg P_2O_5/ha

P_2: 60 kg P_2O_5/ha

P_3: 70 kg P_2O_5/ha

B_0: 0 kg H_3BO_3/ha (Control)

B_1: 1.5 kg H_3BO_3/ha

B_2: 2.0 kg H_3BO_3/ha

Table 7. Combined effect of phosphorus and boron on yield contributing characters

Treatments	Branched root (%)	Cracked root (%)	Rotten root (%)
P_0B_0	2.76 a	2.37 a	2.33 a
P_0B_1	2.68 ab	2.04 b	2.04 b
P_0B_2	2.21 c	1.86 bc	1.87 bc
P_1B_0	2.76 a	1.77 c	1.92 bc
P_1B_1	2.26 c	1.40 d	1.43 e
P_1B_2	2.22 c	1.75 c	1.73 cd
P_2B_0	2.42 bc	1.88 bc	2.06 b
P_2B_1	2.18 c	1.36 d	1.46 e
P_2B_2	2.30 c	1.91 bc	1.93 bc
P_3B_0	2.58 ab	1.96 bc	2.10 b
P_3B_1	2.16 c	1.49 d	1.52 de
P_3B_2	2.42 bc	1.95 bc	2.05 b
$LSD_{(0.05)}$	0.257	0.214	0.221
Level of significance	0.01	0.01	0.01
CV(%)	6.25	7.03	6.88

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha (Control)	B_0: 0 kg H_3BO_3/ha (Control)
P_1: 50 kg P_2O_5/ha	B_1: 1.5 kg H_3BO_3/ha
P_2: 60 kg P_2O_5/ha	B_2: 2.0 kg H_3BO_3/ha
P_3: 70 kg P_2O_5/ha	

Table 8. Combined effect of phosphorus and boron on yield of carrot

Treatments	Gross yield		Marketable yield	
	Plot (kg)	Hectare (ton)	Plot (kg)	Hectare (ton)
P_0B_0	8.54 f	28.47 f	6.04 g	20.14 g
P_0B_1	9.36 f	31.21 f	8.43 e	28.11 e
P_0B_2	7.11 g	23.69 g	7.25 f	24.17 f
P_1B_0	9.47 ef	31.55 ef	8.85 e	29.51 e
P_1B_1	10.94 bcde	36.46 bcde	10.18 bcd	33.93 bcd
P_1B_2	11.23 abc	37.44 abc	10.81 ab	36.04 ab
P_2B_0	9.59 def	31.97 def	9.28 de	30.93 de
P_2B_1	11.04 bcd	36.79 bcd	10.83 ab	36.09 ab
P_2B_2	12.60 a	42.01 a	11.47 a	38.22 a
P_3B_0	9.80 cdef	32.68 cdef	9.83 cd	32.76 cd
P_3B_1	11.73 ab	39.10 ab	10.77 abc	35.90 abc
P_3B_2	12.34 ab	41.14 ab	11.67 a	38.91 a
$LSD_{(0.05)}$	1.411	4.702	0.899	2.997
Level of significance	0.01	0.01	0.05	0.05
CV(%)	8.08	8.08	5.52	5.52

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha (Control)
P_1: 50 kg P_2O_5/ha
P_2: 60 kg P_2O_5/ha
P_3: 70 kg P_2O_5/ha

B_0: 0 kg H_3BO_3/ha (Control)
B_1: 1.5 kg H_3BO_3/ha
B_2: 2.0 kg H_3BO_3/ha

4.11 Rotten root

Statistically significant variation was recorded for different levels of phosphorus in terms of rotten root of carrot (Table 6). The maximum rotten root (2.08%) was observed from P_0 (0 kg P_2O_5/ha) and the minimum (1.69%) was recorded from P_1 (60 kg P_2O_5/ha).

Different levels of boron showed significant variation on rotten root of carrot (Table 6). The maximum rotten root (2.10%) was found from B_0 (0 kg H_3BO_3/ha) which was followed (1.90%) by B_2 (2.0 kg H_3BO_3/ha) and the minimum (1.61%) from B_1 (1.5 kg H_3BO_3/ha).

Rotten root of carrot showed significant differences due to the combined effect of phosphorus and boron (Table 7). The maximum rotten root (2.33%) was recorded from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha), whereas the minimum (1.43%) was obtained from P_1B_1 (50 kg P_2O_5 and 1.5 kg H_3BO_3/ha).

4.12 Gross yield per plot

Different levels of phosphorus showed significant variation on gross yield per plot of carrot (Table 6). The highest gross yield per plot (11.29 kg) was found from P_3 (70 kg P_2O_5/ha) which was statistically identical (11.08 kg and 10.55 kg) to P_2 (60 kg P_2O_5/ha) and P_1 (50 kg P_2O_5/ha), while the lowest (8.34 kg) was obtained from P_0 (0 kg P_2O_5/ha). Salo *et al*. (1999) also reported similar findings.

Significant variation was recorded for different levels of boron in terms of gross yield per plot of carrot (Table 6). The highest gross yield per plot (10.82 kg) was found from B_2 (2.0 kg H_3BO_3/ha) which was statistically similar (10.77 kg) to B_1 (1.5 kg H_3BO_3/ha), whereas the lowest (9.35 kg) from B_0 (0 kg H_3BO_3/ha).

Combined effect of phosphorus and boron showed significant differences on gross yield per plot of carrot (Table 7). The highest gross yield per plot (12.60 kg) was recorded from P_2B_2 (60 kg P_2O_5 and 2.0 kg H_3BO_3/ha), while the lowest (7.11 kg) was recorded from P_0B_2 (0 kg P_2O_5 and 2.0 kg H_3BO_3/ha).

4.13 Gross yield per hectare

Statistically significant variation was recorded for different levels of phosphorus in terms of gross yield per hectare of carrot (Table 6). The highest gross yield per hectare (37.64 ton) was found from P_3 (70 kg P_2O_5/ha) which was statistically identical (36.92 ton and 35.15 ton) to P_2 (60 kg P_2O_5/ha) and P_1 (50 kg P_2O_5/ha) and the lowest (27.79 ton) was attained from P_0 (0 kg P_2O_5/ha).

Gross yield per hectare of carrot differ significantly due to different levels of boron (Table 6). The highest gross yield per hectare (36.07 ton) was obtained from B_2 (2.0 kg H_3BO_3/ha) which was statistically similar (35.89 ton) to B_1 (1.5 kg H_3BO_3/ha), while the lowest (31.17 ton) from B_0 (0 kg H_3BO_3/ha).

A statistically significant variation was recorded due to the combined effect of phosphorus and boron for gross yield per hectare of carrot (Table 7). The highest gross yield per hectare (42.01 ton) was observed from P_2B_2 (60 kg P_2O_5 and 2.0 kg H_3BO_3/ha), whereas the lowest (23.69 ton) was recorded from P_0B_2 (0 kg P_2O_5 and 2.0 kg H_3BO_3/ha).

4.14 Marketable yield

Marketable yield per plot of carrot showed statistically significant differences for different levels of phosphorus (Table 6). The highest marketable yield per plot (10.76 kg) was found from P_3 (70 kg P_2O_5/ha) which was statistically identical (10.52 kg) to P_2 (60 kg P_2O_5/ha) and followed (9.95 kg) by P_1 (50 kg P_2O_5/ha), whereas the lowest (7.24 kg) was obtained from P_0 (0 kg P_2O_5/ha).

Different levels of boron differ significantly for marketable yield per plot of carrot (Table 6). The highest marketable yield per plot (10.30 kg) was found from B_2 (2.0 kg H_3BO_3/ha) which was statistically similar (10.05 kg) to B_1 (1.5 kg H_3BO_3/ha) again the lowest (8.50 kg) from B_0 (0 kg H_3BO_3/ha).

Combined effect of phosphorus and boron showed significant differences for marketable yield per plot of carrot (Table 7). The highest marketable yield per plot (11.67 kg) was obtained from P_3B_2 (70 kg P_2O_5 and 2.0 kg H_3BO_3/ha), while the lowest (6.04 kg) was found from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha). Different levels of phosphorus showed statistically significant differences for gross yield per hectare of carrot (Table 6). The highest marketable yield per hectare (35.86 ton) was recorded from P_3 (70 kg P_2O_5/ha) which was statistically identical (35.08 ton) to P_2 (60 kg P_2O_5/ha) and followed (33.16 ton) by P_1 (50 kg P_2O_5/ha) and the lowest (24.14 ton) was found from P_0 (0 kg P_2O_5/ha). Tareen *et al*. (2005) also reported similar results.

Statistically significant variation was recorded for different levels of boron in terms of marketable yield per hectare of carrot (Table 6). The highest marketable yield per hectare (34.34 ton) was attained from B_2 (2.0 kg H_3BO_3/ha) which was statistically similar (33.51 ton) to B_1 (1.5 kg H_3BO_3/ha), whereas the lowest (28.34 ton) from B_0 (0 kg H_3BO_3/ha). Similar results also reported by Eraslan *et al*. (2007).

Phosphorus and boron showed significant differences for marketable yield per hectare of carrot due to their combined effect of (Table 7). The highest marketable yield per hectare (38.91 ton) was recorded from P_3B_2 (70 kg P_2O_5 and 2.0 kg H_3BO_3/ha), again the lowest (20.14 ton) was recorded from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha). Anez and Espinoza (2002) reported that total root yield was significantly and independently affected by the chemical fertilizer doses used.

4.15 Economic analysis

Under the present experiment input costs for land preparation, seed cost, fertilizer cost and man power required for carrot cultivation for unit plot and converted into cost per hectare. Prices of carrot were considered in market rate basis. The economic analysis was done to find out the gross and net return and the benefit cost ratio in the present experiment and presented under the following headings-

4.15.1 Gross return

In the combination of phosphorus and boron different gross return were recorded under the trial (Table 8). The highest gross return (Tk. 389,100) was obtained from P_3B_2 (70 kg P_2O_5 and 2.0 kg H_3BO_3/ha) and the second highest gross return (Tk. 382,200) was obtained in P_2B_2 (60 kg P_2O_5 and 2.0 kg H_3BO_3/ha). The lowest gross return (Tk. 2,01,000) was obtained from P_0B_0 (0 kg P_2O_5 and 0 kg H_3BO_3/ha).

4.15.2 Net return

In this study, different treatment combination showed different net return (Table 8). The highest net return (Tk. 227,486) was obtained from P_3B_2 and the second highest net return (Tk. 223,948) was obtained from P_2B_2. The lowest net return (Tk. 3,093) was obtained from P_0B_0.

4.15.3 Benefit cost ratio (BCR)

The benefit cost ratio was found different due to different treatment combinations (Table 8). The highest (2.41) benefit cost ratio was found from P_3B_2 and the second highest benefit cost ratio (2.37) was estimated P_2B_2. The lowest benefit cost ratio (1.02) was obtained from P_0B_0. From economic point of view, it is apparent from the above results that P_3B_3 was the more profitable than rest of the treatment combination of phosphorus and boron for carrot production.

Table 9. Cost and return of carrot cultivation as influenced by phosphorus and boron

Treatment Combination	Cost of production (Tk./ha)	Yield of carrot (t/ah)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
P_0B_0	158027	20.14	201400	43373	1.27
P_0B_1	158437	28.11	281100	120663	1.77
P_0B_2	158554	24.17	241700	80646	1.52
P_1B_0	160390	29.51	295100	133710	1.83
P_1B_1	160195	33.93	339300	181105	2.12
P_1B_2	160493	36.04	360400	199907	2.25
P_2B_0	160830	30.93	309300	148470	1.92
P_2B_1	161558	36.09	360900	199342	2.23
P_2B_2	160752	38.22	382200	223948	2.37
P_3B_0	161269	32.76	327600	167331	2.04
P_3B_1	161498	35.90	359000	198002	2.22
P_3B_2	161614	38.91	389100	227486	2.41

P_0: 0 kg P_2O_5/ha (Control)

P_1: 50 kg P_2O_5/ha

P_2: 60 kg P_2O_5/ha

P_3: 70 kg P_2O_5/ha

B_0: 0 kg H_3BO_3/ha (Control)

B_1: 1.5 kg H_3BO_3/ha

B_2: 2.0 kg H_3BO_3/ha

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2009 to February 2010 to study the effect of phosphorus and boron on the growth and yield of carrot. The experiment consisted of two factors. Factor A: Four level of phosphorus, viz. P_0: 0 kg P_2O_5/ha (control), P_1: 50 kg P_2O_5/ha, P_2: 60 kg P_2O_5/ha and P_3: 70 kg P_2O_5/ha; Factor B: Three level of boron, viz. B_0: 0 kg H_3BO_3/ha (control), B_1: 1.5 kg H_3BO_3/ha and B_2: 2.0 kg H_3BO_3/ha. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Data on different growth parameters, yield contributing characters and yield of carrot was recorded. In case of phosphorus fertilizer the longest plant (12.85 cm, 22.32 cm, 34.62 cm, 40.72 cm, 43.30 cm and 46.23 cm) was recorded from P_3, whereas the shortest (9.19 cm, 17.28 cm, 23.74 cm, 31.26 cm, 35.50 cm and 40.27 cm) from P_0. At 20, 30, 40, 50, 60 DAS and harvest, the maximum number of leaves per plant (4.27, 7.48, 11.80, 16.43, 20.44 and 25.01) was found from P_3 whereas the minimum number (3.18, 6.52, 9.57, 12.44, 15.29 and 18.22) from P_0 at 20, 30, 40, 50, 60 DAS and harvest, respectively. The longest root (16.78 cm) was recorded from P_3 and the shortest root (12.79 cm) from P_0. The highest diameter of root (3.01 cm) was recorded from P_3 and the lowest (2.01 cm) from P_0. The highest fresh weight of roots per plant (135.67 g) was recorded from P_3

and the lowest (105.81 g) from P_0. The highest dry matter content in leaf (8.74%) was found from P_3 and the lowest (6.59%) from P_0. The highest dry matter content in root (10.73%) was recorded from P_3 and the lowest (8.21%) from P_0. The maximum branched root (2.55%) was obtained from P_0 and the minimum (2.30%) from P_2. The maximum cracked root (2.09%) was recorded from P_0 and the minimum (1.64%) from P_1. The maximum rotten root (2.08%) was observed from P_0 accordingly the minimum (1.69%) from P_1. The highest gross yield per hectare (37.64 ton) was found from P_3 and the lowest (27.79 ton) from P_0. The highest marketable yield per hectare (35.86 ton) was recorded from P_3 and the lowest (24.14 ton) from P_0.

In case of boron fertilizer, the longest plant (12.24 cm, 21.86 cm, 33.09 cm, 38.87 cm, 41.22 cm and 46.19 cm) was recorded from P_3, whereas the shortest (9.63 cm, 18.46 cm, 28.08 cm, 34.60 cm, 36.73 cm and 40.81 cm) from P_0. At 20, 30, 40, 50, 60 DAS and harvest, the maximum number of leaves per plant (4.33, 7.57, 11.26, 15.57, 19.24 and 23.94) was found from P_3 whereas the minimum number (3.06, 6.37, 9.64, 13.74, 17.45 and 20.54) from P_0 at 20, 30, 40, 50, 60 DAS and harvest, respectively. The longest root of carrot (16.10 cm) was observed from B_2 while the shortest root (13.77 cm) from B_0. The highest diameter of root (2.91 cm) was recorded from B_2 and the lowest (2.11 cm) from B_0. The highest fresh weight of roots per plant (137.34 g) was observed from B_2 while the lowest (108.21 g) from B_0. The highest dry matter content in leaf (8.49%) was recorded from B_2 and the lowest (7.15%) from B_0. The highest dry matter content in root (10.51%) was observed from B_2 while the lowest (8.74%) from B_0. The maximum branched root

(2.63%) was observed from B_0 and the minimum (2.29%) from B_2. The maximum cracked root (1.99%) was observed from B_0 while the minimum (1.57%) from B_1. The maximum rotten root (2.10%) was found from B_0 and the minimum (1.61%) from B_1. The highest gross yield per hectare (36.07 ton) was obtained from B_2, while the lowest (31.17 ton) from B_0. The highest marketable yield per hectare (34.34 ton) was attained from B_2, whereas the lowest (28.34 ton) from B_0.

In case of combined effect of phosphorus and boron the longest plant (14.72 cm, 24.86 cm, 38.31 cm, 44.60 cm, 46.70 cm and 49.30 cm) was recorded from P_3B_2, and the shortest plant (8.19 cm, 28.23 cm and 33.03 cm) was attained from P_0B_2 for 20, 50 and 60 DAS, respectively while at 30, 40 DAS and at harvest the shortest plant (15.46 cm, 22.03 cm and 37.20 cm) was observed from P_0B_0. The maximum number of leaves per plant (4.80, 8.00, 12.90, 17.93, 21.90 and 27.03) was observed from P_3B_2, while the minimum number of leaves per plant (2.40, 5.87, 8.97, 11.57 and 17.60) was recorded from P_0B_0 for 20, 30, 40, 50 DAS and harvest, respectively and at 60 DAS the minimum number of leaves per plant (14.43) was obtained from P_0B_2. The longest root of carrot (18.27 cm) was recorded from P_3B_2 and the shortest root (11.14 cm) was observed from P_0B_0. The highest diameter of root (3.56 cm) was found from P_3B_2 while the lowest (1.71 cm) was recorded from P_0B_0. The highest fresh weight of roots per plant (158.03 g) was found from P_3B_2 whereas the lowest (96.10 g) was recorded from P_0B_2. The highest dry matter content in leaf (9.74%) was recorded from P_2B_2 and the lowest (5.79%) was observed from P_0B_2. The highest dry matter content in root (12.29%) was attained from P_3B_2 and the lowest (7.37%) was found from P_0B_0.

The maximum branched root (2.76%) was obtained from P_0B_0 whereas the minimum (2.16%) was found from P_3B_1. The maximum cracked root (2.37%) was found from P_0B_0 whereas the minimum (1.36%) from P_2B_1. The maximum rotten root (2.33%) was recorded from P_0B_0, and the minimum (1.43%) from P_1B_1. The highest gross yield per hectare (42.01 ton) was observed from P_2B_2 whereas the lowest (23.69 ton) from P_0B_2. The highest marketable yield per hectare (38.91 ton) was recorded from P_3B_2 and the lowest (20.14 ton) from P_0B_0.

The highest gross return (Tk. 389,100) was obtained from P_3B_2 and the lowest gross return (Tk. 201,400) from P_0B_0. The highest net return (Tk. 227,486) was obtained from P_3B_2 and the lowest net return (Tk. 3,093) was obtained from P_0B_0. The highest (2.41) benefit cost ratio estimated from P_3B_2 and the lowest benefit cost ratio (1.02) was obtained from P_0B_0. From economic point of view, it is apparent from the above results that P_3B_2 was the more profitable than rest of the treatment combination of phosphorus and boron for carrot production.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Phosphorus in combination with boron enhances the carrot production.
2. To furnish precise result another level of phosphorus and boron may be included.
3. Before recommendation of phosphorus and boron level to optimize carrot production further study is needed in different agro-ecological zones of Bangladesh for regional adaptability.

4. Another micronutrients may be considered for higher yield of carrot.

REFERENCES

Akhilesh, S., Sharma, R. P., Sonia, S. and Sharma, J. J. 2003. Influence of integrated use of nitrogen, phosphorus, potassium and farmyard manure on the yield-attributing traits and marketable yield of carrot (*Daucus carota*) under the high hills dry temperate conditions of north-western Himalayas. *Indian J. Agril. Sci.*, **73**(9): 500-503.

Alam, M. S., Iqbal, T. M. T., Amin M. and Gaffar, M. A. 1989. Krishitattic Fasaler Utpadan O Unnayan (in Bengali). T. M. Jubair Bin Iqbal, Sirajgonj. pp. 231-239.

Anez, B. and Espinoza, W. 2002. Organic and chemical fertilization inverted interactive or independent effects on carrots production. *Revis. Forel. Venezolana*. **46**(2): 47-54.

Anonymous. (1989). Annual Weather Report, Meteorological Station, Dhaka. Bangladesh.

Anonymous. (2005). Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. p. 14.

Araujo, C., Zarate, N. A. H. and Vieira, M. C. 2004. Production and postharvest mass loss of 'Brasilia' carrot, considering phosphorus and chicken manure doses. *Acta Sci., Agron.,* **26**(2): 131-138.

Aslam, J., Muhammad, I. and Muhammad, I. 2003. Nitrate accumulation in okra and carrot as influenced by fertilizer application. *Pakistan J. Bot.,* **35**(4): 637-640.

Bose, T. K. and Som, M. G. 1990. Vegetable crops in India. Naya Prakash, Calcutta-6. India. pp. 408-442.

Bose, V. S. and Triphathi, S. K. 1996. Effect of micronutrient on growth and yield of cauliflower. *Annl. Agril. Res.*, 18: 391-392.

Demiray, H. and Dereboylu, A. E. 2005. The effects of boron and niacin on the growth of nantes carrot (*Daucus carot*a L.). *Ege Univ.i Ziraat Fak. Der.,* **42**(1): 191-201.

Eppendorfer, W. H. and Eggum, B. O. 1995. Effects of nitrogen, phosphorus, sulphur, potassium, calcium and water stress on yield, mineral and amino acid composition, dietary fibre and nutritive value of carrots. *Soil Pl. Sci.,* **45**(2): 124-131.

Eraslan, F., Inal, A., Gunes, A. and Alpaslan, M. 2007. Impact of exogenous salicylic acid on the growth, antioxidant activity and physiology of carrot plants subjected to combined salinity and boron toxicity. *Sci. Hort.,* **113**(2): 120-128.

FAO. 1988. Production Year Book. Food and Agricultural of the United Nations. Rome, Italy. **42**: 190-193.

FAO. 2004. Production Yearbook. Food and Agriculture Organization, Rome, Italy. 58: 175-176.

Gaweda, M. 2001. The effect of phosphorus content in substrate on lead accumulation by carrot (*Daucus carota* L.) and lettuce (*Lactuca sativa* L. var. capitata L.). *Veg. Crops Res. Bull.,* **54**(1): 195-199.

Gomez, K. A. and Gomez, A. A. 1984. Statistical Procedure for Agricultural Research (2nd edn.). Int. Rice Res. Inst., *A Willey Int. Sci*., Pub., pp. 28-192.

Hassanoghli, A., Liaghat, A. and Mirabzadeh, M. 2007. Investigation of phosphorous leaching to soil depth by irrigation with raw and treated domestic wastewater obtained from Ekbatan treatment plant. *J. Sci. Tech. Agric. Natural Resources*. **10**(4(A)): 29-43.

Hole, C. C. and Scaife, A. 1993. An analysis of the growth response of carrot seedlings to deficiency in some mineral nutrients. *Plant and Soil*. **150**(1): 147-156.

Hossain, M. E. (1990). Effect of different sources of nutrients and mulching on the growth and yield of amaranth. MS Thesis, Dept. Hort., Bangladesh Agri Univ., Mymensingh, Bangladesh. pp. 95.

Islam, J. K. and S. P. Noor, 1982. Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh. *Pakistan J. Sci. Res*., **34** (3-4): 113-119.

Ismail, M. 2005. Aluminium phosphorus interactions on growth and some physiological traits of carrot and radish plants. *Acta Agron.*, **53**(3): 293-301.

Jaiswal, J. P., Subedi, P. P. and Bhattarai, S. P. 1997. Mulching trial on carrot, fertilizer trial on radish and top-dressing trial on Chinese cabbage conducted during 1995/96. Working Paper Lumle Regional Agricultural Research Centre. **97/27**: 16.

Kadi, N., Chacin, F., Zapata, F. and Albarracin, M. 1994. Fertilization and planting density in carrot (Daucus carota L.). Review of Agronomy practice Venezuela. **20**(3/4): 155-165.

Konopinski, M. 1995. Effect of the biological fertilizer Super Fertilisant on the yield and some quality characteristics in carrots and beetroots. Materal presented the conference on biological fertilizer. 1995: 683-686.

Kotur, S. C. 1998. Evaluation of lime, boron and their residue on three cropping sequences of non-cruciferous vegetables for yield, composition of leaf and soil properties on an Alfisol. *Indian J. Agril. Sci.*, **68**(11): 718-721.

Lazar, V. and Dumitras, A. 1997. Impact of certain technological measures on production and quality of carrot roots. Buletin University of Stiinte Agricole Medicine Seria Agriculture Horticulture. **1**(1): 135-139.

Leis, L. and Lepik, A. 2001. Macro- and micronutrients in white cabbage and carrot. *Sodin. Darzi.*, **20**(3(2)): 300-307.

Lyngdoh, G. B. S. 2001. Response of carrot to different levels of nitrogen, phosphorus and potassium. *Hort. J.*, **14**(2): 163-169.

Mesquita, F. M. V., Souza, A. F. and Silva, H. R. 2005. Critical level of boron on carrot cultivated in a cerrado soil. *Hort. Brasil.*, **23**(1): 68-71.

Nemethy, U. H. and Kokai, Z. 2003. Effect of boron fertilisation on the flavour of carrots - applicability of organoleptic analyses to carrots. *Internl. J. Hort. Sci.*, **9**(1): 51-54.

Nigussie, D., Schenk, M. K., Claassen, N. and Steingrobe, B. 2003. Phosphorus efficiency of cabbage (*Brassica oleracea* L. var. capitata), carrot (*Daucus carota* L.), and potato (*Solanum tuberosum* L.). *Plant and Soil*. **250**(2): 215-224.

Opena, R. T., Kuo, C. C. and J. Y, Yoon. 1988. Breeding and Seed Production of Root crops in the Tropics and Subtropics. Tech. Bul., 17, AVRDC. p. 97.

Peirce, L. C. 1987. Vegetable: Characteristics, Production and Marketing, John Wiley and Sons. Inc., Newyork. pp. 251-252.

Petrichenko, N., Romanova, A. V. and Savitskaya, A. K. 1996. Carrot losses during storage depend on the growing conditions. *Kartofel and Ovoshchi*. **3**: 12-13.

Pietola, L. and Salo, T. 2000. Response of P, K, Mg and NO_3-N contents of carrots to irrigation, soil compaction, and nitrogen fertilisation. *Agril. Food Sci. Finland*. **9**(4): 319-331.

Portz, A., Martins, C. A. C., Lima, E. and Zonta, E. 2006. Levels and accumulation of nutrients in peruvian carrot as affected by the application of nitrogen, phosphorus and potassium. *Hort. Brasi.*, **24**(3): 329-333.

Rao, V. K. and Maurya, C. P. 1998. Effect of nitrogen and phosphorus on growth and seed production of Carrot (*Daucus carota* L.) cv. Nantes. *Prog. Hort.*, **30**(3/4): 186-189.

Rashid, M. M. 2004. Sabjibigan, 3rd Edn. Mohammad Mamunur Rashid, Rashid Publishing House, 94, Old DOHS, Dhaka.

Ravinder, S. and Kanwar, H. S. 2002. Effect of nitrogen and phosphorus levels on growth and seed yield of temperate carrot cultivar Nantes. *Himachal J. Agril. Res.*, **28**(1/2): 40-42.

Rubatzky, V. E., Quiros, C. E. and Simon, P. W. 1999. Introduction: Geographic origin and World importance. In: Carrots and Related Vegetable Umbeliferae. CAB publishing Co., New York-100016. USA. pp. 1-21.

Sady, W., Rozek, S. and Smolen, S. 2004. The effect of mineral fertilization on yielding and accumulation of nitrates and cadmium in carrot roots. *Sodi. Darzi.*, **23**(2): 395-403.

Salo, T., Raisio, R. and Tiilikkala, K. 1999. Effectiveness of fertilizer recommendations in Finnish carrot and pea production. *Acta Hort.*, **506**: 37-40.

Salo, T., Suojala, T. and Kallela, M. 2002. The effect of fertigation on yield and nutrient uptake of cabbage, carrot and onion. *Acta Hort.*, **571**: 235-241.

Sanderson, K. R. and Sanderson, J. B. 2006. Prince Edward Island growers can reduce soil phosphorus buildup while maintaining carrot crop yield. *Canadian J. Pl. Sci.*, **86**(5): 1401-1403.

Santos, B. M., Dusky, J. A., Stall, W. M., Bewick, T. A. and Shilling, D. G. 2004. Mechanisms of interference of smooth pigweed and common purslane on lettuce as influenced by phosphorous fertility. *Weed Sci.*, **52**(1): 78-82.

Selvi, D., Thiyageshwari, S. and Chitdeshwari, T. 2005. Effect of different levels of NPK on root yield of carrot (*Daucus carota*) in an acid soil at Nilgiris. *Adv. Pl. Sci.*, **18**(2): 799-801.

Sharfuddin, A. F. M. and Siddique, M. A. 1985. Shabjee Biggan. 1st Edn. Mrs Hasina Akthar Beauty, Bangladesh Agricultural University, Mymensingh. pp. 11-28.

Shinohara, S. E. 1984. Horticultural crops. *Pakistan J. Biol. Sci.*, **3**(2): 13-16.

Singh, D. and Gangwar, R. 1991. Management practices for higher productivity in India a review. *Agric. Rev.*, 12: 15-21.

Sparrow, L. A. and Salardini, A. A. 1997. Effects of residues of lime and phosphorus fertilizer on cadmium uptake and yield of potatoes and carrots. *J. Pl. Nutri.,* **20**(10): 1333-1349.

Tareen, A. Q., Baloch, A. F., Usmanikhail, M. U., Baloch, F. M. and Soomro, N. A. 2005. Effect of different NP levels on root yield and its contributing characters of carrot. *Indus J. Pl. Sci.,* **4**(3): 298-302.

Uddin, A. S. M. M., Hoque, A. K. M. S., Shahiduzzaman, M., Sarker, P. C., Patwary, M. M. A. and Shiblee, S. M. A. 2004. Effect of nutrients on the yield of carrot. *Pakistan J. Biol. Sci.,* **7**(8): 1407-1409.

UNDP. 1988. Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome. pp. 212.

Vieira, M. C., Zarate, N. A. H. and Casali, V. W. D. 1997. Effect of poultry litter and phosphorus on a yield of Peruvian carrot clone BGH 6313. *SOB-Informa*. **15/16**(1): 15-17.

Volkova, E. N. 1996. Measures to reduce the content of nitrates in carrots. *Kartofel and Ovoshchi*. **3**: 13-14.

Yawalkar, K. S. 1985. Vegetable crops in India. Third Edn. Mrs. Yawalkar, Agric-Horticultural Publishing House, 52, Bajoy Nagar, pp. 210-220.

Zdravkovic, M. Damjanovic, M., Cvikic, D. and Zdravkovic, J. 2007. Effects of fertilizers on nutritive characteristics of carrot. *Acta Hort.*, **729**: 361-365.

APPENDICES

Appendix I. Characteristics of Horticulture Farm soil is analyzed by Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture Garden , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	Medium high land
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2009 to February, 2010

Month	Air temperature (^oC)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November, 2009	25.82	16.04	78	00
December, 2009	22.4	13.5	74	00
January, 2010	24.5	12.4	68	00
February, 2010	27.1	16.7	67	30

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1212

Appendix III. Analysis of variance of the data on plant height as influenced by phosphorus and boron of carrot

Source of variation	Degrees of freedom	Mean square					
		Plant height (cm) at					
		20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
Replication	2	0.107	0.104	0.053	1.147	0.730	2.692
Phosphorus (A)	3	21.515**	44.451**	217.932**	155.214**	94.092**	60.578**
Boron (B)	2	23.032**	38.313**	80.507**	63.739**	74.236**	95.989*
Interaction (A×B)	6	4.533**	6.815**	9.514**	23.219**	18.027**	7.161**
Error	22	0.787	1.285	2.100	3.752	3.709	2.758

** Significant at 0.01 level of probability, * Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on number of leaves per plant as influenced by phosphorus and boron of carrot

Source of variation	Degrees of freedom	Mean square					
		Plant height (cm) at					
		20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
Replication	2	0.029	0.042	0.004	0.334	0.003	0.988
Phosphorus (A)	3	2.142**	1.827**	7.891**	26.702**	47.848**	86.574**
Boron (B)	2	6.180**	5.722**	9.895**	10.567**	11.806**	45.134**
Interaction (A×B)	6	0.076*	0.149*	1.373**	2.997**	2.797**	4.147*
Error	22	0.026	0.040	0.296	0.506	0.570	1.510

** Significant at 0.01 level of probability, * Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on yield contributing characters and yield of carrot as influenced by phosphorus and boron

Source of variation	Degrees of freedom	Mean square						
		Days for attaining good size root	Length of root (cm)	Diameter of root (cm)	Fresh weight leaves per plant (g)	Fresh weight root per plant (g)	Dry matter content of roots (%)	Dry matter content leaves (%)
Replication	2	0.194	0.458	0.008	14.951	1.878	0.120	0.229
Phosphorus (A)	3	10.176**	27.788**	1.809**	1510.400**	1637.591**	8.445**	11.481**
Boron (B)	2	48.361**	17.251**	2.107**	405.425**	2724.717**	6.096**	9.762**
Interaction (A×B)	6	10.287**	3.101*	0.287**	63.233*	523.399**	1.942**	2.437**
Error	22	1.255	0.967	0.053	29.113	83.564	0.420	0.602

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on yield contributing characters and yield of carrot as influenced by phosphorus and boron

Source of variation	Degrees of freedom	Mean square						
		Branched root (%)	Cracked root (%)	Rotten roots (%)	Total yield of roots		Marketable yield	
					Kg/plot	t/ha	Kg/plot	t/ha
Replication	2	0.005	0.005	0.014	0.238	2.647	0.049	0.542
Phosphorus (A)	3	0.097*	0.341**	0.237**	16.487**	183.189**	23.618**	262.427**
Boron (B)	2	0.429**	0.566**	0.731**	8.435**	92.718**	11.414**	126.818**
Interaction (A×B)	6	0.098**	0.091**	0.075**	3.443**	38.251**	0.739*	8.213*
Error	22	0.023	0.016	0.017	0.694	7.712	0.282	3.133

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VII. Per hectare production cost of carrot

A. Input cost

Treatment Combination	Labour cost	Ploughing cost	Seed Cost	Insecticide/ pesticides	Irrigation	Manure and fertilizers		
						Cowdung	Urea	TSP
P_0B_0	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	0.00
P_0B_1	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	0.00
P_0B_2	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	0.00
P_1B_0	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	2000.00
P_1B_1	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	2000.00
P_1B_2	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	2000.00
P_2B_0	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	2500.00
P_2B_1	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	2500.00
P_2B_2	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	2500.00
P_3B_0	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	3000.00
P_3B_1	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	3000.00
P_3B_2	16000.00	12000.00	4000.00	7000.00	8000.00	25000.00	2200.00	3000.00

P_0: 0 kg P_2O_5/ha (Control)
P_1: 50 kg P_2O_5/ha
P_2: 60 kg P_2O_5/ha
P_3: 70 kg P_2O_5/ha

B_0: 0 kg H_3BO_3/ha (Control)
B_1: 1.5 kg H_3BO_3/ha
B_2: 2.0 kg H_3BO_3/ha

Appendix VII. Contd.

B. Overhead cost (Tk./ha)

Treatment Combination	Cost of lease of land for 6 months (13.5% of value of land Tk. 1000,000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 13.5% of cost/year	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
P_0B_0	67500	3835	9992	81327	158027
P_0B_1	67500	3943	10145	81587	158437
P_0B_2	67500	3970	10184	81654	158554
P_1B_0	67500	3985	10205	81690	160390
P_1B_1	67500	3843	10003	81345	160195
P_1B_2	67500	3945	10148	81593	160493
P_2B_0	67500	3960	10170	81630	160830
P_2B_1	67500	3993	10216	81708	161558
P_2B_2	67500	3845	10007	81352	160752
P_3B_0	67500	3935	10134	81569	161269
P_3B_1	67500	3968	10180	81648	161498
P_3B_2	67500	3995	10219	81714	161614

P_0: 0 kg P_2O_5/ha (Control)

P_1: 50 kg P_2O_5/ha

P_2: 60 kg P_2O_5/ha

P_3: 70 kg P_2O_5/ha

B_0: 0 kg H_3BO_3/ha (Control)

B_1: 1.5 kg H_3BO_3/ha

B_2: 2.0 kg H_3BO_3/ha