EFFECTS OF INTERCROPPING AND LEVELS OF NITROGEN ON THE GROWTH AND YIELD OF CARROT (*Daucus carota* L.)

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CERTIFICATE

This is to certify that the thesis entitled, "Effects of intercropping and levels of nitrogen on the growth and yield of carrot (*Daucus carota* L.)" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN HORTICULTURE,** embodies the result of a piece of bona fide research work carried out by **Mr. Abu Shamim Mohammad Nahiyan,** Registration No. 23850/00128 under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:

Dhaka, Bangladesh

(Prof. M. A. Mannan Miah)

Supervisor

Dedicated to
My
Parents & Teachers those
who laid the foundation
of my success

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ABSTRACT

A field experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, during October 2004 to February 2005 to study the effects of different intercropping practices and levels of nitrogen on the growth and yield of carrot. Three different intercropping practices viz. non-intercrop, Red amaranth intercrop and Bengal spinach intercrop and three levels of nitrogen viz 0, 200, 250 kg per hectare were used in the study. Carrot was sown as a sole crop at a spacing of 25 x 10 cm and Red amaranth and Bengal spinach were sown in between the two rows of carrot as intercrops. The experiment was carried out in Randomized Complete Block Design with three replications. Leafy vegetables intercropping had significant influence on yield and yield attributes of carrot, except root diameter. The highest root length (16.59 cm), fresh weight of root per plant (135 g), and marketable yield (45.40 t/ha) were recorded from control intercrop (I_0) and lowest were found from Bengal spinach intercrop (I_2). Nitrogen (N) had remarkable effect on growth and yield of carrot. The maximum root length (16.83 cm), root diameter (4.98 cm), fresh weight of root per plant (141.40 g), and marketable yield (47.06 t/ha) were obtained from 250 kg N/ha (N_2) and minimum from control (N_0). In respect of combined effect control intercrop with 250 kg N/ha (I_0N_2) produced highest root length (17.37 cm), root diameter (5.33 cm), fresh weight of root per plant (161.70 g) and marketable yield (52.13 t/ha). Highest intercrop yield (28.33 t/ha) obtained from the I_1N_2 (Red amaranth intercrop and 250 Kg N/ha) treatment. Economic analysis showed that Red amaranth intercrop and 250 Kg N/ha gave maximum economic benefit with the benefit cost ratio of 5.22.

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LIST OF ABBRIVIATIONS

Abstr.	=	Abstract
AEZ	=	Agro Ecological Zone
Agron.	=	Agronomy
Agric.	=	Agriculture
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BCR	=	Benefit Cost Ratio
cm	=	Centimeter
cv.	=	Cultivar
DAS	=	Days After Sowing
DM	=	Dry Matter
DW	=	Dry Weight
et el.	=	*et alii (and others)*
FAO	=	Food and Agricultural Organization
Fig.	=	Figure
FW	=	Fresh Weight
gm	=	Gram
Hort.	=	Horticulture
i.e	=	That is
J	=	Journal
K	=	Potassium

kg	=	Kilogram
LSD	=	Least Significant Difference
m	=	Meter
MP	=	Muriate of potash
N	=	Nitrogen
NS	=	Non-significant
P	=	Phosphorus
Res.	=	Research
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
Soc.	=	Society
t/ha	=	Ton per hectare
Tk.	=	Taka
TSP	=	Triple Super Phosphate
UK	=	United Kingdom
Viz.	=	Namely
%	=	Percentage
@	=	At the rate of

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Bangladesh is a densely populated country. The population of the country is increasing rapidly but food production is not increasing proportionately. So food production needs to be increased many folds. Many efforts have been made to increase the food production of the country and it increased several folds during the past two decades. Further increase of food production through horizontal expansion is not possible due to limited cultivable land. Therefore, food production should be increased vertically through multiple cropping with the adoption of modern varieties, improved cultural techniques and appropriate cropping system.

The intensification of crop production may be done through intercropping systems where two or more crops can be grown simultaneously in the same land at the same time. So, intercropping is one of the techniques of vertical expansion of crop production. It has several advantages over monoculture such as enhancing efficient use of environmental factors (e.g., light, nutrient and soil moisture) and labours, reducing the adverse effect of various biotic and abiotic stresses, providing diversity of food, generating more income, giving stability in production, offering insurance against crop failure, higher return and total productivity per unit area (Akanda and Quayyum, 1982; Gangasarama and Gajendra, 1985; Kushwada, 1985 and Prasad *et al.*, 1985).

Vegetables are the main components of human food that supply proteins, carbohydrates, fats, vitamins and minerals. Per capita vegetable production in Bangladesh is much less than its requirement (Sharfuddin and Siddique, 1985). However, limited scope of bringing additional land for vegetable production demands intervention of growing more vegetables like other form of multiple cropping which can play an important role in increasing vegetable productivity (Rashid, 1987). While intercropping is widely practiced with cereals, the benefit of intercropping vegetables both from economic and dietary aspect have been largely ignored. However, it is viewed that intercropping would be very successful for more vegetable production if proper intercropping combinations are identified through their better compatibility. Intercropping is considered as a very efficient technique in maximizing the vegetable production per unit area, if plant competition is minimized by selecting suitable crops and adoption of proper plant population spatial arrangement, nutrient and moisture management (Willey, 1979; Midmore, 1993). Malnutrition is a common problem in Bangladesh. Vitamin A deficiency is one of the major nutritional problems. Intercropping of carrot with leafy vegetables may give us the opportunity to reduce malnutrition and Vitamin A deficiency of the people of the country.

Carrot (*Daucus carota* L.) a member of the family Apiaceae (Peirce, 1987) is considered to be a native of Mediterranean region (Shinohara, 1984) and its cultivation as a crop also began in that region. It is mainly a temperate crop, grown during spring, through autumn 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, 1993).

From nutritional point of view carrot is a very important root crop. It contains appreciable amount of carotene, thiamin 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 in children providing vitamin A. Furthermore, it has some other important medicinal values (Bose and Som, 1990).

The area under carrot cultivation was 899 thousand hectares with total production of 19374 thousand tones in the world (FAO, 2000). In Bangladesh the production statistics of carrot is not available. Rashid (1993) mentioned an average yield of 25 tones per hectare of carrot. 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, 2000).

Economic of intercropping systems depends on many factors such as production potential of component crops, cost of production and market prices of the commodities. As carrot is planted in rows there is ample scope of intercropping with selected leafy vegetables that will increase the production of total vegetables. For maximum utilization of land, diversified and balanced crop production, intercropping is most demanding for Bangladesh. Several researches have reported on intercropping of carrot. Positive economic results were achieved combining carrot and intercropping yield (Ogbuehi *etal.*,1987; Caetano *et al.*,1999 and Wiech *et al.,* 1995).

Intercropping becomes most productive and economic when both the crops differ in genetic make up, photosynthetic pathway, growth habit, growth duration and demand of different growth resources (Fukai and Trenbath, 1993). Leafy vegetables like Red amaranth and Bengal spinach can be sown in carrot field as intercrops. Moreover, these intercrops are quick growing vegetables, which can be harvested very earlier than carrot with minimum interruption.

Carrot with intercrop of leafy vegetables requires ample supply of plant nutrients specially N for their proper growth and development. However, excessive or under dose of N can affect the growth and yield of both carrot and intercrop. Only an optimum amount of N is necessary to produce maximum yield of good quality carrot. Excess of N tends to increase root splitting and reduces the marketable yield (Orphanos and Krentos, 1988).

Available information in respect of production potential, profitability of carrot –leafy vegetable intercropping system under Bangladesh condition is inadequate. In view of aforesaid situation, the present study was undertaken with the following objectives:

i) To study the growth and yield of carrot under different intercrop combinations

ii) To find out the best compatible intercrop combination of carrot in terms of yield and economic return

iii) To find out the interaction effects of different levels of N with different intercrops on growth and yield of carrot

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Intercropping has great importance in farming practice. Vegetable based intercropping of carrot with leafy vegetables may prove to be most potential in mitigating the vegetable shortage of the country as well as increase the farm income to a considerable extent. However, the research activities on various aspects of carrot cultivation have been reported from different parts of the world but information regarding intercropping is very limited. An effort has been made to review some of relevant research works done in this respect which are described below.

2.1 Effect of intercropping on the growth and yield of carrot

Caetano *et al.* (1999) conducted an experiment in Brazil on the productivity of carrot and lettuce in an intercropping system and reported that both carrot root yield and quality increased when carrot was intercropped with lettuce cultivars Baba-de-Verao, Regina-71, Vitoria, Brasil-303, Carolina, and Elisa. Both crops yield were considered adequate for marketing in intercropping system but carrot root quality declined when carrot was intercropped with the lettuce cultivar Marisa.

De-Negreiros *et al.* (2002) carried out an experiment with five lettuce cultivars (Baba de Verao,Elisa, Great Lakes, Regina and Taina) in two cropping systems (with and without intercropping with the carrot cv. Brasilia). From this experiment they found that the intercropping system gave the best economic performance and carrot root yield was not affected by the competition of lettuce cultivars.

Ogbuehi *et al* (1987) carried out an experiment on intercropping carrot and sweet corn in a multiple cropping system at the Department of Horticulture, The Pennsylvania State University, U.S.A. and reported that intercropping of carrots (*Daucus carota* L.) and sweet corn (*Zea mays* L.) in a multiple cropping system effectively increased the combined yield of these vegetable crops. They also reported that intercropping did not significantly reduce soluble solids and dry foliage weight of the carrots, but the root fresh weight of some of the carrot intercrop treatments was reduced.

In an experiment Ogbuehi (1986) showed that late sowing reduced the growth, development and yield of sweet corn or carrot and intercrop treatments of carrot and sweet corn but had higher gross monetary returns than single crops of either species.

Bezerra *et al.* (2003) carried out an experiment on agroeconomic perfomance of carrot and looseleaf lettuce in two strip arrangements. This experiment consisted of combination of three cropping systems (S_1 = Sole crop; S_2 = three carrot rows alternated with three lettuce rows; and S_3 = four carrot rows alternated with four lettuce rows) with four looseleaf lettuce cultivars (Baba de Verao, Karla, Verdinha and Elisabeth) plus an additional treatment (carrot cv. Brasilia as a sole crop). Evaluations of plant height, and diameter, leaf number per plant and leaf dry matter and yield were made for the lettuce crop. Plant height, shoot fresh matter, total, commercial and classification of roots were obtained for the carrot crop. They found no significant interaction between cropping systems and lettuce cultivars for any lettuce and carrot characteristics. But the cropping system influenced all lettuce and carrot traits. Lettuce cultivars influenced only the leaf number per plant, which was highest for Karla. The yield of both carrot and lettuce in the intercropping systems, although lower than that in sole cropping, represented an additional income source. They also found that the intercropping of Brasilia carrot and Verdinha lettuce in the strip arrangement of four carrot rows alternated with four lettuce rows showed the greatest performance.

Wiech *et al* (1995) conducted a field trial on intercropping carrot with onion and reported significant decrease in poputation of Phytophagous insects *Pasila rosae* and *cicadellids*, which ultimately enhanced crop growth and yield.

Remert (1996) reported that cover crop (*Medicago littoralis*) in carrots reduced carrot damage caused by carrot fly (*Pasila rosae)*. The yield decrease due to competition from the intercrop was quantified and weighed against the benefits of the intercrop in terms of reduced damage caused by carrot fly, soil nitrogen enhancement through N-fixation and deceased weed germination and development.

A field trial was conducted by Remart *et al.* (1996) on intercropping with lucerne as a management strategy for the carrot pest *Pasila rosae* in Sweden and they found that densities of Polyphagous predators were experimentally enhanced and decreased using ingress and egress plots and damage level of carrot root and yield were always lower in intercropping system.

Varela *et al.* (1988) conducted an experiment in the San Jose de Las Latas, Nicaragua on the use of multiple cropping (cabbage-carrot) as a component of integrated pest management of cabbage defoliators and they found that cabbage intercropped with carrot had lower number of *Plutella xylostella* than cabbages grown in monoculture and then ultimately the better economic return came from both crops.

Yildirim *et al.* (2005) had set up an experiment on intercropping where cauliflower (*Brassica oleracea* L. var. botrytis) as a main crop was intercropped with cos lettuce (*Lactuca sativa* L. var. longifoila), leaf lettuce (*L. sativa* L. var. crispa), radish (*Raphanus sativus* L.), onion (*Allium cepa* L.) and snap bean (*Phaseolus vulgaris* L. var. nanus). Each intercrop was planted in the middle of cauliflower rows simultaneously in separate plots. All crops were grown also in pure stands. Results of this study indicated that different intercropping systems compared to sole did not affect some growth characteristics and yield of cauliflower except for radish as an intercrop. Net income increased when cos lettuce, bean, leaf lettuce or onion was grown as intercrop. Nitrogen, phosphorus, potassium, calcium, magnesium and iron content of cauliflower did not vary significantly depending on cropping systems. The study showed that cauliflower based intercrop treatments might provide the highest total yield as well as profitability.

Nankar (1990) reported that intercropping sugarcane with potato controlled weed, reduced production cost and increased net return more than monocrops.

2.2 Effect of nitrogen on the growth and yield of carrot

Sarker (1999) showed that the nitrogen treatment significantly increased yield of carrot per plot per hectare. The application of 150 kg N/ha produced the highest gross yield of 10.0 kg/plot or 67.3 t/ha but the control treatment produced only 6.89 kg per plot or 45.9 t/ha.

Abdel Razik and El-Haris (1997) conducted an experiment during two winter seasons of 1994-1995 and 1995-1996 in Saudi Arabia to find out the effect of four sprinkler irrigation levels (ranging from 301 to 685 mm/season) and four N rates (ranging from 0-300 kg/ha) on growth and yield of carrot. The results revealed that increasing the amounts of applied water resulted in significant increase in plant fresh weight, shoot fresh and dry weight and root diameter. In contrast, the chlorophyll content of leaves decreased with the increments of applied water. In addition, except for plant and shoot length in the first season and root length in the second year N application significantly increased plant fresh weight, shoot fresh and dry weight, plant and shoot fresh weights, length and diameter of root as well as total and root yields per hectare. The optimum treatment for enhancing carrot growth was obtained with 200 kg N/ha and 640-680 mm irrigation water.

Raupp (1996) carried out a long-term trial at Darmstád and compared the effect of composed cattle manure and urine, biodynamic preparation and mineral fertilizer on crop quality. In 1980-1984, a rotation of carrot/beet roots/potatoes/rye was treated with different fertilizer rates resulting in comparable yields. In 1985-1986, a rotation of clover/spring wheat/potatoes (carrot or beet roots during 1988-1990)/rye was given different fertilizer rates to supply equivalent amounts of N: 60,100 or 140 kg N/ha for the cereals and 50, 100 or 150 kg N/ha for the root crops. The negative effects on quality parameters caused by high levels of fertilizers application were less with composed manure compared with mineral fertilizer. Application of biodynamic preparation together with composed manure had some positive effect on crop and improved leaf/root balance with no effect on yield. Eliminating N during the last 2 growing months reduced root FW but no DW. Root nitrate content differed significantly between 514, 155, and 62 ppm, in treatments 1, 2 and 3 respectively. Weight loss during 3 months after storage at 5 °C was significantly lower in treatment 3 (6.9%) than in treatments 1 and 2 (10.1 and 9.7 %, respectively).

Abdel Razik (1996) carried out an experiment during 1992-1993 with carrot cv. Chanenay to study the effect of nitrogen (0-240 kg/ha) and gibberellic acid (GA_3) concentration (0-90 ppm) on carrot yield. Nitrogen source was ammonium sulfate applied in 3 equal doses 30, 50 and 70 days after sowing. GA_3 was applied foliraly, 5 and 8 weeks after sowing. Fresh and dry weights of leaves and roots, number of leaves/plant, weight of root/shoot ratio, total yield and chlorophyll content of the leaves were recorded. Growth parameters increased with N levels except root/shoot weight ratio, in both seasons. Fresh weight and total yield were increased with increasing concentration of N and GA_3. No significant difference was observed between 60 and 90 ppm GA_3 application. Nitrogen and chlorophyll content of the leaves increased with N application levels and decreased with increasing GA_3 concentration.

Sarker (1989) had set up an experiment with different levels of nitrogen, phosphorus and potassium on yield components of carrot and noted that application of nitrogen had significant effect on the root length and individual root weight and no significant effect on root diameter.

Batra and Kallo (1990) conducted experiments during 1979-1980 and 1981-1982 with carrot cv. Gugaon selection. The effect of different levels of N and P fertilizer application on yield and quality were studied. Nitrogen was applied @ 30, 60 or 90 kg/ha. Nitrogen significantly increased the plant height, root length, root diameter, core root diameter, root leaf diameter and yield compared with the control.

Orphanos *et al.* (1988) conducted 8 experiments in the Argaki-Katokopia-Zhodia over a period of 1968-1971 and tested combinations of 4 rates of N (0, 63, 126 and 189 kg per hectare) and 4 rates of P (0, 23, 46, and 69 kg/ha). The test cultivars were Chantnary and Nantes. In 6 of 8 experiments, the yield significantly increased and 63 to 126 kg N per hectare was required for getting maximum yield. At the highest N rate (189 kg/ha) the percentage of exportable yield declined.

Singh and Sharma (1987) reported the response of potato cultivars to nitrogen application where they found that the number of leaves per plant had increasing trend with an increase in nitrogen dose up to 180 kg per hectare.

Wiebe (1987) noted that the effect of plant density and nitrogen supply on yield, harvest date, quality of carrot. The plants were grown at densities ranging from $1000/m^2$ to $1200/m^2$ gave higher yield of marketable roots for late harvest. The response to nitrogen fertilizer ranging 80-140 kg N/ha generally gave the most satisfactory yield.

Patil and Gill (1981) stated that nitrogen and phosphorus application significantly increased the plant height, fresh weight of root and shoot in carrot. Skrbic (1987a) found that nitrogen significantly increased the plant height and the total root yield on an average of 85 t/ha. The yield depended on the quantity of nitrogen fertilizer and it was the highest when 300 kg of nitrogen per hectare was used.

Skrbic (1987b) studied the influence of increasing amount of nitrogen on growth dynamics and total nitrogen content in the roots and leaves of some carrot varieties. It was concluded from the trial that growth was slow at the beginning of the vegetation period and intensive after the formation of 7-8 leaves until physiological maturity was reached.

Hipp (1978) concluded that application of nitrogen @ 56 or 112 kg per hectare increased the yield of carrot. An application of higher dose i.e. 168 kg N per hectare did not improve the yield over 112 kg/ha.

Islam (2001) conducted an experiment with mulches and different levels of nitrogen and potassium on the yield components of carrot and noted that application of nitrogen had significant effect on the cracked and branched root percentage but increased both gross and marketable yield.

Otani (1974) conducted a fertilizer experiment with 3-carrot cultivars using nitrogen as $(NH_4)_2SO_4$. It was reported that plant height increased with the increase of nitrogen supply.

Basso (1968) obtained the greatest increase in carrot root production when 160 kg N was applied with 240 kg P; however the response of N was greater than P.

Deshi *et al.* (1964) showed that application of nitrogen at different doses with other fertilizers significantly increased the plant height. Patil *et al.* (1981) and Skrbic (1987a) also reported similar result.

Balooch *et al.* (1993) in an experiment found that application of 100 kg N per hectare along with 125 kg K_2O and 100 kg P_2O_5 increased root size and weight of carrot.

Evers (1988) in a field experiment observed that root and shoot dry weights were positively correlated in carrot and the yield was increased by the application of N and K.

Michalik (1987) carried out the response of the cv. Nantes to 13 different fertilizer forms applied at various rates. Nitrogen as ammonium nitrate or urea had no significant effect on dry matter. Likewise, potassium as chloride or sulphate had no effect on dry matter.

Bruckner (1986) conducted an experiment over 3 years and reported that increasing the N supply (0-200 kg N/ha) produced a relatively small increase in yields. N @ 100 kg/ha gave the best yield without increasing the NO_3 content in carrot. Cultivars Flakkeer RZ and Flakkeer Karaf had a high uptake of K_2O (242.8 - 326.6 kg/ha) and low uptake of P_2O_5 (62.3-64.6 kg/ha), Ca (39.1 – 58.0 kg/ha) and Mg (19.0 – 26.98 kg/ha).

Habben (1973) stated that high N level promoted carotene formation but K had little effect in this respect. While conducting an experiment on carrot by Sharangi and Paria(1996) applied nitrogen at the rate of 0, 50, 70 and 80 kg in combination with potassium at the rate of 0,40,50 and 60 kg/ha and found that an application of 80 kg N/ha along with 50 kg K/ha produced the heaviest root (120.25 g/root)

Sharangi and Paria (1995) carried out an experiment on a loamy soil with nitrogen fertilizer @ 0, 40, 50 or 60 kg/ha and potassium @ 0, 40, 50 or 60 kg K_2O/ha, phosphorus was applied @ 60 kg/ha and found that the shoot growth, root diameter increased with the increasing rate of nitrogen. Interaction effect between nitrogen and potassium was significant in relation to the plant height, root diameter respectively.

Konopinski (1995) conducted field trial with carrot cv. Perfection. The plants received N: P: K @ 150:150:300 kg/ha (control) or super fertilizer 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 fertilizer was applied @ 50 or 100 kg/ha. Using super fertilizer @ 100 kg/ha gave the best yield in carrot viz. 70 and 30% over the control respectively. Crop quality was also best.

Ali (1994) reported that the N and K showed statistically significant effects on root and yield of carrot and the effects of these two elements were identical. Root yield increased progressively with the increase of both N and K. The maximum root yield of 91.27 t/ha was obtained from the plant fertilized with 200 kg N/ha and minimum (38.55 t/ha) from the plant receiving no nitrogen. Application of nitrogen @ 100, 150 and 200 kg/ha increased the yield of 22.71%, 54.92% and 57.76% respectively over the control. Like N yield was increased by 40.20%, 45.21% and 49.04% due to application of K @ 150, 200 and 250 kg/ha, respectively. The yield of root increased due to interaction effects of N and K and was statistically significant. The highest dose (N_{200}, K_{200} kg/ha) gave the highest yield (108.50 t/ha), which increased the yield by 76.04% over the control.

Evers (1989a) showed that N, P and K content of carrot roots increased with different NPK fertilizer practices. Evers (1989b) further studied different fertilizers practices with carrot and stated that the unfertilized treatments had a tendency to yield higher glucose and fructose and thus also total sugar contents than did the fertilized treatment.

Jacobsen *et al.* (1986) reported that the effects of fertilizers were studied in a field trial involving NPK at 16-5-12 or 14-4-7 with N at 60,120 and 240 kg/ha. Yield was not significantly affected, but the incidence of cavity spot was least at the lowest rate of N and at all rates of N was less with the formulation containing the lower level of K.

Kral Ovic *et al.*(1986) showed that various forms of N at 40 to 200 kg/ha had no effect on root nitrate content when applied with K_2O at 169 kg/ha and P_2O_5 at 67 kg/ha. The harmful nitrate content in plant was said to be caused primarily by high content of dissociated K in the soil with an adequate N supply. Critical K values in the soil were >90 mg/kg for sandy soil and >110 mg/kg for humus clay-loam when nitrate contents in plant exceeded the proposed standards.

Farazi (1983) after conducting an experiment with spacing and fertilizer concluded that the highest yield of carrot (45.5 t/ha) was obtained from the crop fertilized with the highest dose of nitrogen (112 kg N/ha) and potash had no significant effect on the yield of carrot. Both nitrogen and potash had significant effect on the diameter of root but little effect on the length of carrot. The fresh weight of leaves per plant was increased with the increasing level of nitrogen and potash had no effect on the fresh weight of leaves per plant.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site

The present research work was carried out at the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during November 2004 to February 2005.

3.2 Soil

Soil of the experimental plot was silty clay in texture. It belongs to the Madhupur Tract (FAO, 1997) under AEZ No. 28. The land was medium high in nature. The analytical data of the soil sample from the experimental area were determined at the Soil Resources Development Institute, Dhaka, and have been presented in Appendix I.

3.3 Climate

The experimental zone is situated in the sub-tropical climate characterized by heavy rainfall during the month of April to September and scanty rainfall during the rest of the period of the year. Rabi season is characterized by comparatively low temperature and plenty of sunshine. Information regarding monthly maximum and minimum temperature, rainfall, relative humidity, soil temperature as recorded by the Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1212 during the period of study have been presented in Appendix II.

3.4 Planting materials

The experiment was conducted with seeds of sole crop Carrot cv. SB Kuroda, imported from Japan. The seeds were produced and packed by Takii seed Co. Ltd., Kyoto, Japan in a sealed container. Red Amaranth (*Amaranthus tricolor,* Family- Amaranthaceae) and Bengal Spinach (*Beta vulgaris var. bengalensis*, Family-Chenopodiaceae) were grown as intercrops. In the experiment seeds were procured from Alamgir Seed Store, Siddique Bazar, Dhaka.

3.5 Land preparation

The land of experimental field was first opened on October 24, 2004 with a power tiller. Then it was exposed to the sunlight for 7 days prior to the next ploughing. After that the experimental plot was properly prepared through several ploughing and cross ploughing to obtain a good tilth. All weeds and stubbles were removed from the field and bigger clods were broken by laddering and mallet. Well-decomposed cow dung was applied to the plots during land preparation and incorporated to the soil. Finally, the land was uniformly leveled and the soil was finally pulverised.

3.6 Experimental design and layout

The two-factor experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. An area of 166.5 m^2 was divided into three equal blocks. Each block was divided into nine plots where nine treatments were allotted at random. Thus, there were 27 (9x3) unit plots altogether in the experiment. The size of each plot was 2m x 1.5m. The distance between blocks were 1.0 m and 0.5m wide drains were made between the plots. The complete layout of the experiment has been shown in Figure -1.

3.7 Treatments of experiment

Factor A: Different intercrop treatments (three intercrops)

I_0: No intercrop

I_1: Red Amaranth (*Amaranthus tricolor*)

I_2: Bengal Spinach (*Beta vulgaris var. bengalensis*)

Factor B: Different levels of Nitrogen (three levels) which were supplied in the form of urea as follows-

N_0: 0 kg N/ha

N_1: 200 kg N/ha

N_2: 250 kg N/ha

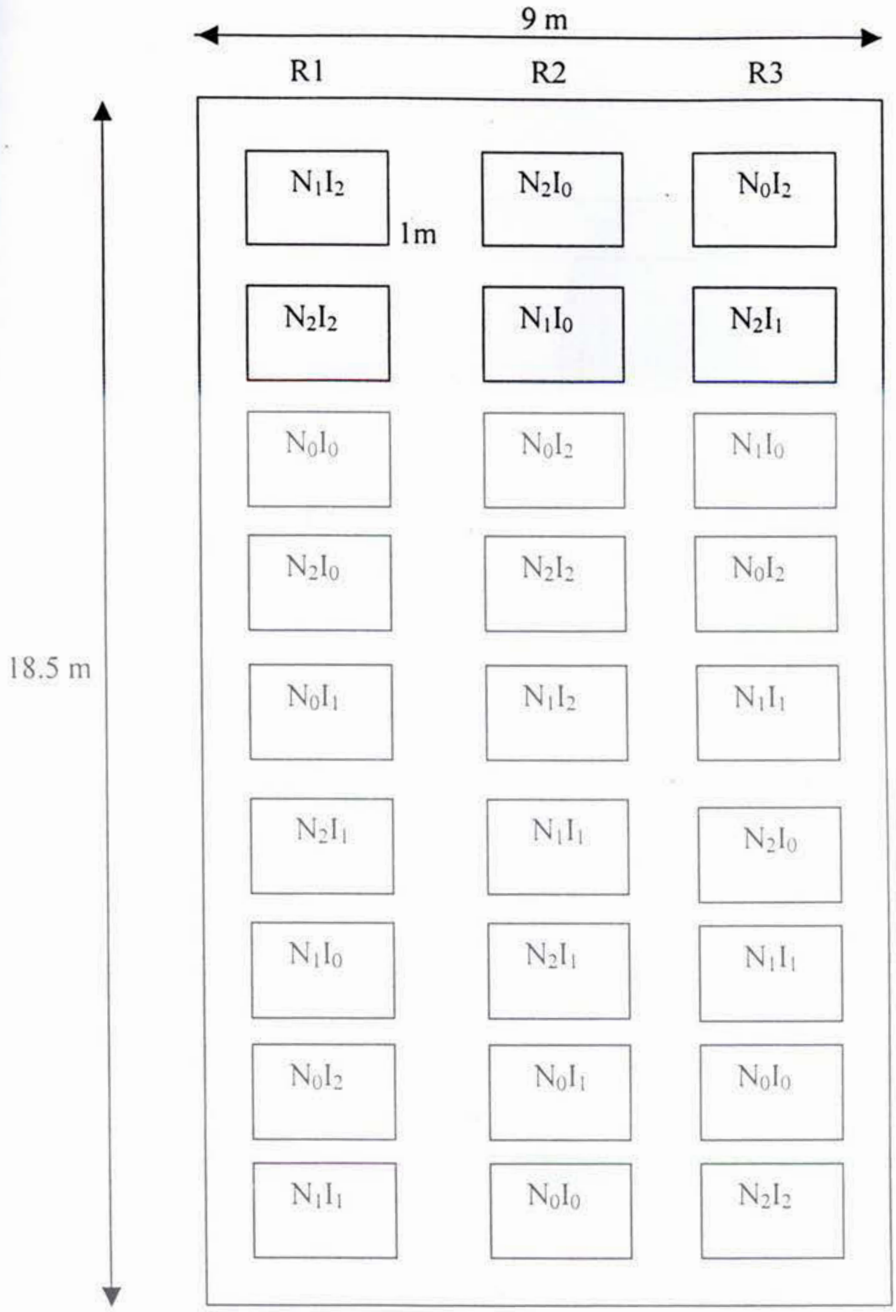

Figure 1. Field layout of the two-factor experiment in Randomized Complete Block Design (RCBD)

Factor A: Inter crop	Factor B: Nitrogen dose	
I_0 = No intercrop	N_0 = 0 kg N/ha	Unit plot size = 2x1.5 m
I_1 = Intercrop Red Amaranth	N_1 = 200 kg N/ha	Between block = 1.0 m
I_2 = Intercrop Bengal Spinach	N_2 = 250 kg N/ha	Between plot = 0.5 m

3.8 Manuring and fertilization

The following doses of manure and fertilizers applied to the soil as recommended by Rashid (1999)

Name of manure and fertilizer	Dose/ha (kg)
Cow dung	10000
Levels of Nitrogen (Urea)	
N_0	0
N_1	200
N_2	250
Triple Super Phosphate (TSP)	125
Muriate of Potash (MP)	175

Unit plot size was 2.0 m x 1.5 m = 3.0 m^2

Well-decomposed cow dung was incorporated to the soil during land preparation and total amount of TSP, 50% MP and 50% urea fertilizers were applied to the plots during final land preparation. The rest amount of MP and urea was top dressed at 50 days interval after sowing the seeds.

3.9 Seed sowing

Carrot seeds were soaked in water for 24 hours and then wrapped with a piece of thin cloth prior to planting. Then they were spread over polythene sheet for 2 hours to dry out. This treatment was given to help quick germination of seeds. The seeds were sown on 1st November 2004. Smalls holes of about 1.5cm depth were made at a distance of 10 cm along the rows spaced at a distance of 25cm. Three seeds were placed in each hole and covered with loose soil. On the other hand, intercrops were sown at the same date between the rows of the carrot plant and covered with soil.

3.10 Intercultural operation

3.10.1 Thinning

Seedlings were thinned out two times. First thinning was done after 20 days of sowing, keeping two seedlings in each hill. The second thinning was done ten days after first thinning, keeping only one seedling in each hill.

3.10.2 Disease and pest management

The crop was not infected with any disease but during the early stage cutworm (*Agrotis ypsilon)* attacked some of the seedlings. This insect was controlled by spraying Dursban 20 EC (at the concentration of 0.02%)

3.11 Harvesting

Carrot was harvested on 9 February, 2005 after 100 days from seed sowing. Harvesting was done by uprooting the plants manually by hand carefully. The soil and fibrous roots adhering to the conical roots were removed and cleaned. Red Amaranth and Bengal Spinach were harvested on December 07, 2004.

3.12 Collection of data

Data were recorded on the following parameters from the sample plants during the course of experiment. Ten plants were sampled from unit plot for the collection of per plant data. The whole plot was harvested to record per plot data.

Data were collected on different growth, yield components and yield. The plants in the outer rows and at the extreme end of the middle rows were excluded from the random selection to avoid the border effect. The following observations were made regarding plant growth, yield and yield attributes as affected by different intercrops and nitrogen doses.

Carrot (Sole crop)

A. Before harvesting

a. Plant height (cm)
b. Leaves per plant (no)

B. After harvesting

a. Fresh weight of leaf per plant (g)
b. Length of root per plant (cm)
c. Diameter of root per plant (cm)
d. Fresh weight of root per plant (g)
e. Root cracking percentage (%)
f. Branched root (%)

g. Gross yield of roots per plot (kg)

h. Gross yield of roots per hectare (ha)

i. Marketable yield of roots per plot (kg)

j. Marketable yield of roots per hectare (t)

Inter crop

Red Amaranth and Bengal Spinach

a. Yield per plot (kg)

b. Yield per hectare (t)

3.13. Before harvesting

During different stages of crop growth data on the following parameters were recorded five times at an interval of 15 days starting from 30 days after sowing (DAS).

3.13.1 Plant height

Plant height was measured in centimeter by a meter scale at 30, 45, 60, 75 and 90 DAS from the point of attachment of the leaf to the ground level up to the tip of the longest leaf.

3.13.2 Number of leaves per plant

All the leaves of each plant were counted separately at 30, 45, 60, 75 and 90 DAS. Only the emerging leaf at growing point of the plant was excluded from the count.

3.14 After harvesting

3.14.1 Length of root per plant (cm)

Average length of the conical roots was measured in cm with the help of a centimeter scale from the proximal end of the conical root to the last point of the tapered end of the root (distal end) in each treatment.

3.14.2 Diameter of root per plant (cm)

To measure the diameter of the roots a slide calipers was used. The average diameter of the roots was measured in cm at every harvest at the thickened portion of the root.

3.14.3 Fresh weight of shoot per plant

Shoots were separated from root by a sharp knife and fresh weight was determined by a triple beam balance in gram (g) and its average value was recorded.

3.14.4 Fresh weight of root per plant (g)

Underground modified carrot roots of ten selected plants were separated by a knife from the attachment of the stem and after cleaning the soil fibrous root weight was taken by the balance in gm and the average value was calculated.

3.14.5 Root cracking percentage

The percent of cracked roots was estimated by using the following formula-

$$\% \text{ Cracked root} = \frac{\text{No. of cracked roots}}{\text{Total no. of roots}} \times 100$$

3.14.6 Branched root percentage

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

$$\% \text{ Branched root} = \frac{\text{No. of branched roots}}{\text{Total no. of roots}} \times 100$$

08 (Hort)

3.14.7 Gross yield of roots per plot (kg)

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

$$\text{Gross yield (kg/plot)} = \frac{\text{Area of single plot } (m^2) \times \text{Average yield per plant (gm)}}{\text{Spacing (m x m)} \times 1000}$$

3.14.8 Gross yield of roots per hectare (t)

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

$$\text{Gross yield (kg/plot)} = \frac{\text{Area (ha)} \times \text{Average yield per plant (gm)} \times 10000}{\text{Spacing (m x m)} \times 1000 \times 1000}$$

3.14.9 Marketable yield of roots per plot (kg)

The marketable yield per plot was calculated by subtracting the total amount of non-marketable yield from the gross yield.

Marketable yield = Gross yield – Non marketable yield (Cracked root + Branched root)

3.14.10 Marketable yield of roots per hectare (t)

Marketable yield of roots per hectare was calculated by conversion of the marketable root weight per plot and recorded in ton (t)

3.15 Statistical analysis

The data collected from the experimental plots were statistically analyzed. The mean value for all the treatment was calculated and the analysis of variance for the character was accomplished by F variance test. The significance of difference between pair of means was tested by the Least Significant Difference (LSD) method at 5% and 1% levels of probability (Gomez and Gomes, 1984)

3.16 Cost and return analysis

Cost and return analysis in details was done according to the procedure of Alam *et al.* (1989)

Chapter 4
Results and Discussion

CAHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the effects of different intercrops, nitrogen and their interaction on vegetative growth and yield of carrot. The growth and yield components such as plant height, leaf number, fresh weight of leaves, root length, diameter of root, fresh weight of root and yield of carrot as influenced by different intercrops and nitrogen are presented in tables 1, 2 & 3 and figures 2, 3, 4, & 5 and appendix III. The result have been discussed and interpretations were done whenever necessary.

4.1 Effects of intercropping and levels of nitrogen on the growth and yield of carrot

4.1.1 Plant height

Application of different intercrops significantly influenced the plant height of carrot (Appendix III). Plant height of carrot increased with increasing time and was higher in plots where no intercrop was used (Figure 2). The maximum plant height attained with control intercrop (I_0) was 50.36 cm at 90 DAS (Days after sowing), which was statistically similar to those of other treatments on different dates of growth. The second highest was 47.72 cm with Red amaranth at the same DAS, which was statistically identical to other treatments on different dates. The minimum plant height was 45.26 cm with Bengal spinach at 90 DAS, which was similar to other treatments on different dates. The highest plant height of carrot in control intercrop (I_0) treatment might be due to the utilization of wider space and lesser competition for nutrients, light and water etc.

The application of nitrogen markedly influenced the plant height of carrot. There was a significant effect of nitrogen fertilizer on plant height (Appendix III) recorded at different DAS (Figure 3). The plant receiving the fertilizer treatment 250 kg N/ha (N_2) was the tallest (50.29 cm) at 90 DAS, which was significantly different from N_1 (200 kg/ha) treatment at the same date. The minimum plant height (45.44 cm) was found with N_0 (control) treatment. The tallest plants at the highest dose received more nutrients, which might have encouraged more vegetative growth. The present result was in agreement with that of Skrbic (1987a) and Patil & Gill (1981).

The interaction effect of intercropping and nitrogen was found to be significant for plant height on different dates (Appendix III). The maximum plant height was 53.55 cm, which was obtained from I_0N_2 (control intercrop and 250 kg N/ha) treatment while the minimum plant height was 43.63 cm in the I_2N_0 (Bengal spinach intercrop and control nitrogen dose) treatment at 90 DAS (Days after sowing). The plant height increased at different days with different combination of treatments (Table 3). As control intercropping and 250 kg N/ha independently produced the highest plant height, so their combined effect was also consistently producing the highest plant height.

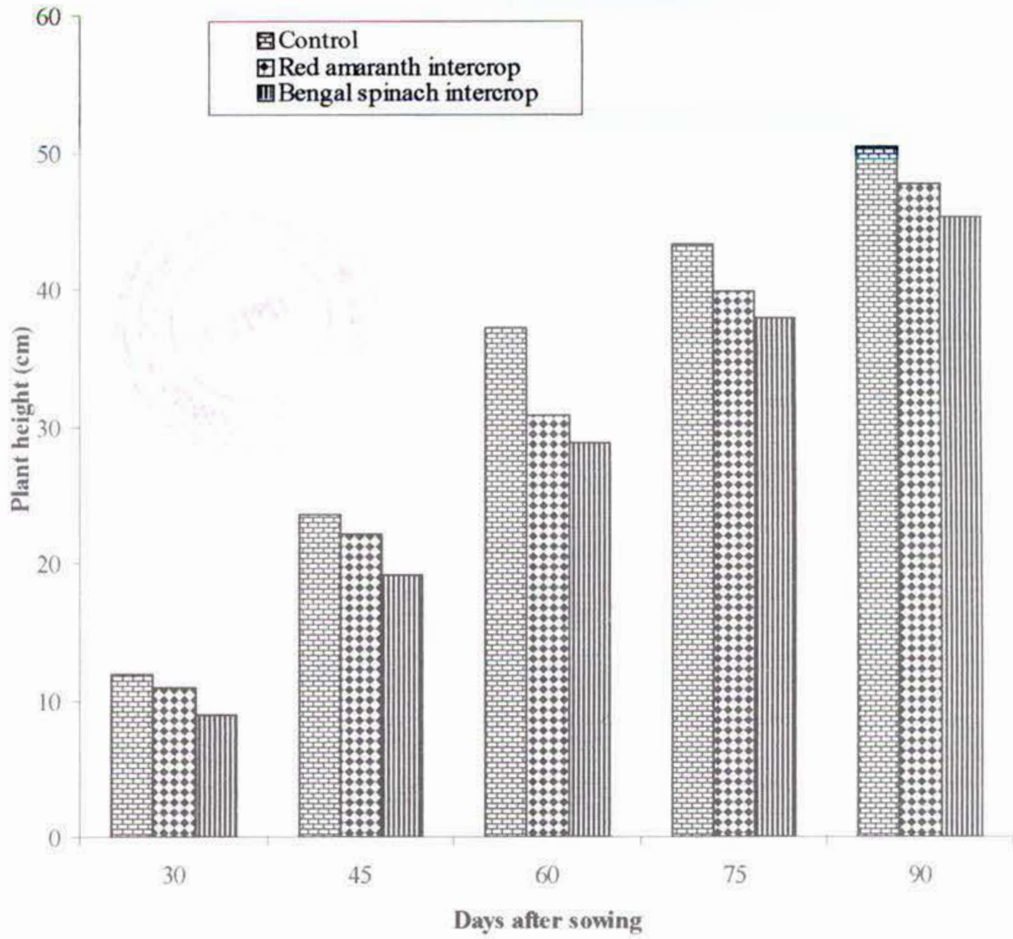

Figure 2. Effect of different intercroping on the plant height of carrot

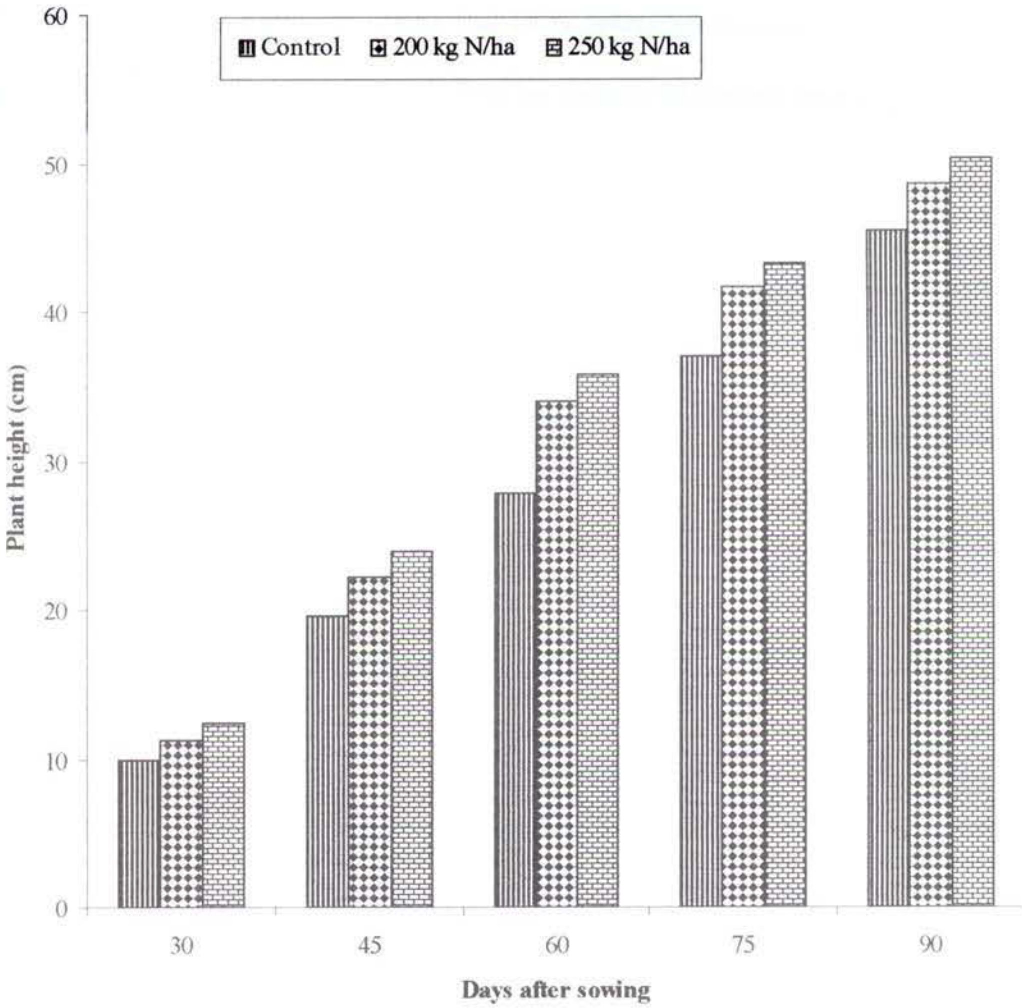

Figure 3. Effect of different nitrogen levels on the plant height of carrot

4.1.2 Number of leaves per plant

Number of leaves of carrot varied significantly due to different intercrop treatments (Appendix III). The number of leaves increased with increasing time (Figure 4). The maximum number of leaves was 16.20 with control intercrop and second number of leaves was 14.42 with red amaranth intercrop, which was not statistically similar at 90 DAS. The minimum number of leaves was 13.72 with I_2 treatments at the same DAS. The higher number of leaves per plant achieved on account of control intercropping treatment was possibly due to greater plant height, which produced more number of leaves. Increased plant density reduced the leaf number and there by leaf area per plant.

The number of leaves produced per plant increased significantly (Appendix III) with increase in the level of nitrogen (Figure 5) fertilizer at different DAS. The maximum number of leaves (16) was produced by the plants receiving 250 kg N/ha, which was statistically dissimilar with N_1 treatment (200 kg N/ha) and the lowest (13.13) by the N_0 treatment. The results clearly showed that the number of leaves per plant gradually increased with increasing levels of nitrogen. The findings of Skrbic (1987b) support these results.

The combined effect of intercropping and nitrogen treatments had significant effect on the number of leaves per plant at different DAS (Appendix III). The maximum number of leaves per plant (18) was counted with I_0N_2 treatment combination at 90 DAS, which was found to be dissimilar with number of leaves per plant (17.13) in I_0N_1 (no intercrop and 200 kg N/ha) treatment combination. The minimum number of leaves per plant (12.46)

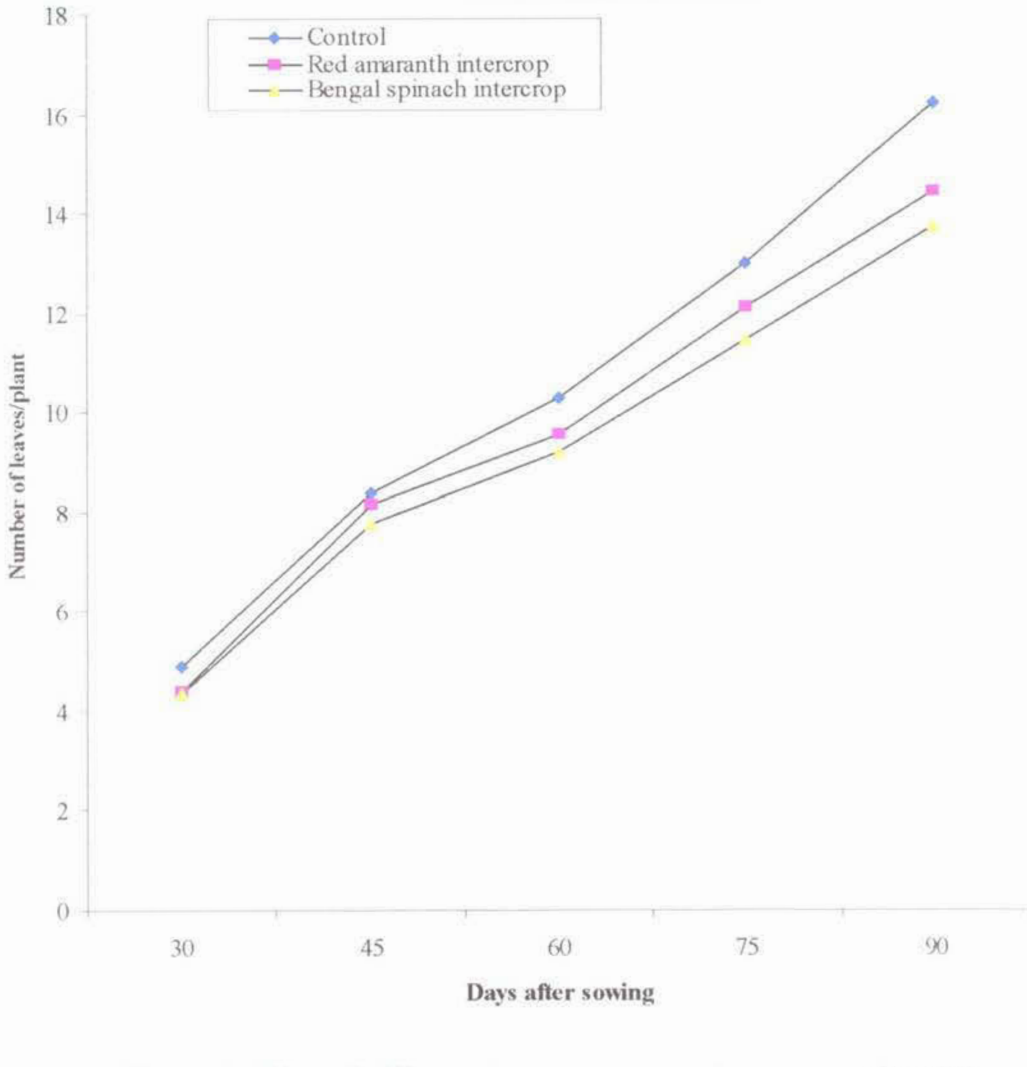

Figure 4. Effect of different intercropping on the number of leaves of carrot

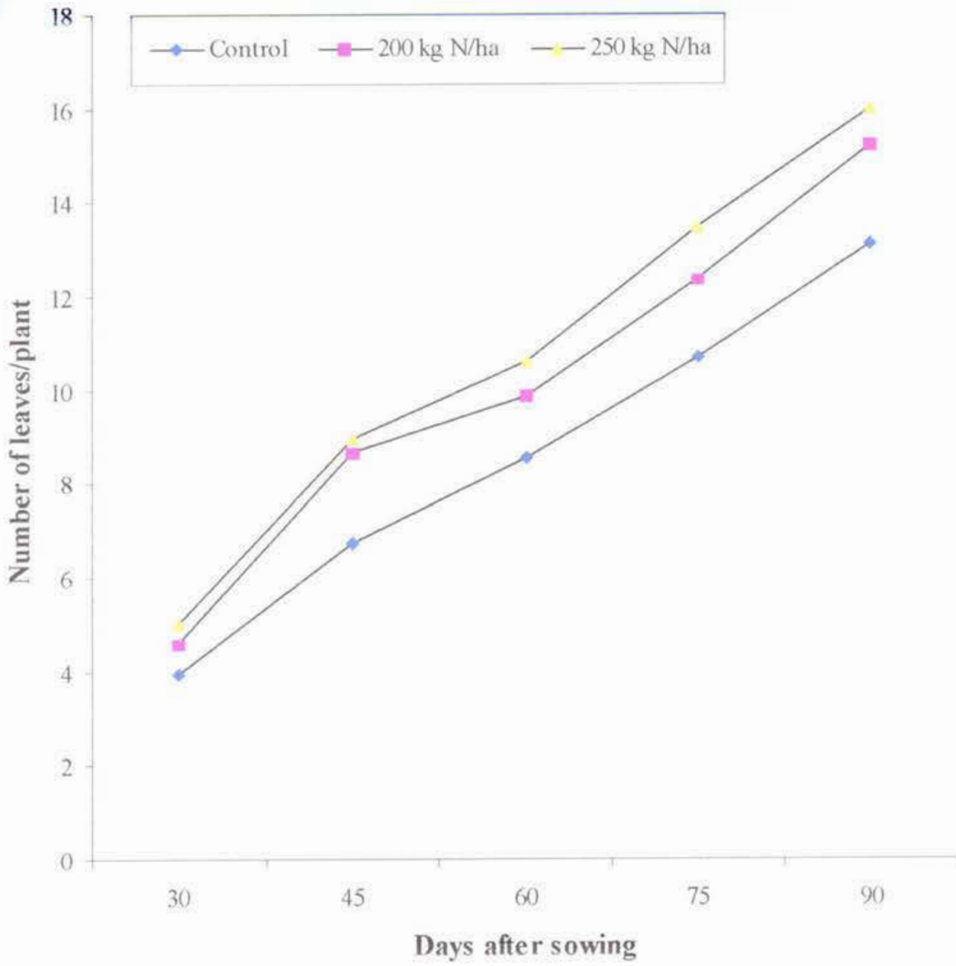

Figure 5. Effect of different nitrogen levels on the number of leaves of carrot

was found in the I_2N_0 treatment. Control intercropping and 250 kg N/ha independently produced the maximum number of leaves due to greater plant height and uptake of maximum nutrient, so their combined effect was also consistently producing the highest leaf number.

4.1.3 Fresh weight of leaves per plant

The fresh weight of leaves per plant was significantly influenced by different treatment combination (Table 1). The maximum fresh weight of leaves per plant (107.20 g) was obtained when carrot was grown alone (I_0). The second highest fresh weight of leaves per plant (92.73 g) was observed in intercrop Red amaranth (I_1) treatment and intercrop Bengal spinach treatment showed minimum fresh weight (86.69 g), which was significantly different from other treatment. Higher fresh weight of leaves as produced by control intercrop treatment was possibly due to higher vegetative growth and maximum utilization of resources around.

There were significant variations in fresh weight of leaves of carrot at harvest (Table 2). The highest fresh weight of leaves (114.10 g) was obtained from the application of 250 kg N/ha that was statistically different with 200 kg N/ha. The lowest fresh weight of leaves per plant (72.66 g) was recorded from the application of no nitrogen. However, the highest plant height along with the maximum number of leaves per plant at the highest nitrogen dose contributed to the highest fresh weight of leaves. This was in agreement with the report of Farazi (1983).

The combined effect of different intercropping and nitrogen treatment was statistically significant for fresh weight of leaves (Table 3). The treatment combination of I_0N_2 produced maximum (125.30 g) fresh weight of leaves, which was statically dissimilar (110.80 g) with I_1N_2 treatment. The minimum fresh weight of leaves (68.81 g) was found in I_2N_0 treatment combination. As the higher dose of nitrogen and different intercrops increased the number of leaves, so their combined effect increased the fresh weight of leaves.

4.1.4 Length of root per plant

Application of different intercrop treatments showed significant influence on the length of root in carrot (Table 1). The effect of control treatment was statistically different from other treatments. The longest root (16.59 cm) was obtained from I_0 treatment, which was significantly different from other treatments. The minimum root length (15.72 cm) was recorded with I_2 treatment where Bengal spinach intercrop was grown. The control intercrop treatment produced the highest root length, which was possibly due to the utilization of wider space and lesser competition for nutrients, light and water etc.

The root length of carrot was significantly influenced by different doses of nitrogen fertilizer (Table 2). The maximum root length (16.83 cm) was recorded in plants receiving 250 kg N/ha, which was found statistically different from 200 kg N/ha while the minimum root length (15.35 cm) was noted for the control treatment. This result revealed that root length increased with the increasing level of nitrogen. The root length may have increased for receiving maximum nutrient from the supplied nitrogen fertilizer. The present result was in agreement with those of Sarker (1989).

Statistical analysis showed that the interaction effect between intercropping and nitrogen had no significant effect on root length of carrot (Table 3). However, the maximum and the minimum root lengths of 17.37 cm and 15.20 cm/plant were observed when intercropping and nitrogen were applied at I_0N_2 and I_2N_0 respectively.

4.1.5 Diameter of root per plant

Intercropping had no significant effect on the diameter of root in carrot production under the present experimental condition. Maximum root diameter (4.53 cm) was recorded from the I_0 treatment and minimum from the I_2 treatment.

The application of different levels of nitrogen showed significant effect on root diameter of carrot at harvest (Table2). The maximum and minimum root diameters of 4.98 cm and 3.01 cm were recorded with 250 kg N/ha and the control treatment respectively. Table 3 showed that root diameter increased gradually with the increased levels of nitrogen doses. The increased dose of nitrogen encouraged more photosynthesis resulting in higher food production and translocation of the same to the storage roots, which ultimately increased the root diameter. This was in agreement with the report of Farazi (1983) and Sharangi and Paria (1995).

The effects of interaction between different intercropping and levels of nitrogen showed significant variation with respect to root diameter of carrot (Table 3). The highest root diameter (5.33 cm) was obtained with no intercrop and 250 kg N/ha treatment. The lowest root diameter (2.84 cm) was found with I_2N_0 treatment.

4.1.6 Fresh weight of root per plant

Root fresh weight significantly varied due to the use of different intercrops in carrot (Table 1). Control treatment was found to produce maximum fresh weight of root (135 g), followed by Red amaranth intercrop (122.50 g), which was statistically dissimilar and better than the Bengal spinach intercrop treatment. The minimum fresh weight of root was produced by the I_2 treatment (118.10 g). It was observed that control (I_0) treatment produced longest root having maximum diameter and that might have contributed to the maximum fresh weight of root. This result has got support of Bezerra *et al.* (2003) in loose-leaf lettuce and carrot.

Different doses of nitrogen had significant effect on root fresh weight of carrot (Table 2). The plant having 250 kg N/ha produced the maximum (141.40 g) root fresh weight and the minimum (105.80 g) was obtained from the control treatment. The increased level of nitrogen produced longer and thicker roots giving higher individual fresh weight. Sarker (1989) mentioned that the fresh weight of roots increased with the increase of nitrogen supply.

The combined effect of different intercropping and nitrogen treatment was statistically significant for fresh weight of roots (Table 3). The treatment combination of I_0N_2 produced the maximum (161.70 g) fresh weight of root, which was statistically dissimilar

(133.30 g) from the I_1N_2 treatment. The minimum root fresh weight (103.30 g) was found in the I_2N_0 treatment combination. As the highest dose of nitrogen and control intercrops produced the maximum length of roots, so their combined effect increased the fresh weight of root.

4.1.7 Cracking percentage of roots

The application of different intercrops had significant effects on cracking of carrot. The highest percentage of root cracking (7.21%) was found with control treatment. The lower percentage of cracked root (4.89%) was obtained from Bengal spinach intercrop treatment (Table 1). Probably control intercrop treatment enhanced more vegetative growth and provided more accumulation of food material, which resulted in more cracking of roots.

The cracking of root was significantly influenced by different levels of nitrogen applied (Table 2). The percentage of cracking root increased with increasing rate of nitrogen applied. The highest cracked root (7.40%) was obtained from 250 kg N/ha, which was statistically dissimilar from 200 kg N/ha. The minimum cracked root percentage of carrot (4.10%) was found in the control treatment. The increase in nitrogen level enhanced the vegetative growth along with tillering that resulted in higher percentage of splitted roots. The result of the experiment corroborates with the findings of Islam (2001) who also obtained higher percentage of cracked root in carrot at higher doses of nitrogen used.

Table 1. Main effect of different intercrops on the growth and yield of carrot

Levels of intercropping	Fresh weight of leaves per plant (gm)	Root length per plant (cm)	Diameter of root per plant (cm)	Fresh weight of root per plant (gm)	Cracked root (%)	Branched root (%)	Gross yield of root per plot (kg)	Marketable yield of root per plot (kg)	Gross yield of root (t/ha))	Marketable yield of root (t/ha)
I_0	107.20	16.59	4.53	135	7.21	6.21	16.20	13.62	54	45.40
I_1	92.73	15.93	4.18	122.50	5.49	5.50	14.70	12.73	49	42.45
I_2	86.69	15.72	3.99	118.10	4.89	5.09	14.17	12.54	47.22	41.80
$LSD_{0.05}$	3.750	0.6368	0.4503	6.466	0.4687	0.2948	0.5861	0.5326	1.809	1.338
$LSD_{0.01}$	5.167	0.8773	0.6204	8.908	0.6458	0.4061	0.8076	0.1776	2.493	1.843
Levels of significance	**	*	NS	**	**	**	**	**	**	**

I_0 = No intercrop
I_1 = Intercrop Red amaranth
I_2 = Intercrop Bengal spinach

** = Significant at 1% level
* = Significant at 5% level
NS = Non Significant

Table 2. Main effect of different nitrogen on the growth and yield of carrot

Levels of nitrogen	Fresh weight of leaves per plant (gm)	Root length per plant (cm)	Diameter of root per plant (cm)	Fresh weight of root per plant (gm)	Cracked root (%)	Branched root (%)	Gross yield of root per plot (kg)	Marketable yield of root per plot (kg)	Gross yield of root (t/ha))	Marketable yield of root (t/ha)
N_0	72.66	15.35	3.01	105.80	4.10	4.55	12.70	11.48	42.33	38.26
N_1	99.93	16.06	4.71	128.30	6.10	5.79	15.40	13.30	51.33	44.34
N_2	114.10	16.83	4.98	141.40	7.40	6.45	16.97	14.12	56.56	47.06
$LSD_{0.05}$	3.750	0.6368	0.4503	6.466	0.4687	0.2948	0.5861	0.5326	1.809	1.338
$LSD_{0.01}$	5.167	0.8773	0.6204	8.908	0.6458	0.4061	0.8076	0.7338	2.493	1.843
Levels of significance	**	**	**	**	**	**	**	**	**	**

N_0 = 0 kg N/ha
N_1 = 200 kg N/ha
N_2 = 250 kg N/ha

** = Significant at 1% level
* = Significant at 5% level
NS = Non Significant

A significant variation was found in percent cracked roots of carrot due to interaction effect of intercropping and nitrogen treatments (Table 3). The treatment effect of I_0N_2 gave maximum percent cracked root (8.89%) and was identically (7.97%) followed by no intercrop and 200 kg N/ha treatment combination and the lowest (3.66%) from the I_2N_0 treatment combination.

4.1.8 Branched root

There was a significant effect of different intercrops on breached root of carrot at harvest (Table 1). The highest percentage of branched root (6.21%) obtained in control treatment was found statistically different from Red amaranth intercrop treatment and the minimum percentage of branched root (5.09%) was recorded in Bengal spinach intercrop treatment. This result revealed that branched root decreased with the use of different intercropping.

The application of nitrogen had significant effect on the percentage of branched root per plot (Table 2). Nitrogen @ 250 kg/ha gave maximum-branched root (6.45%), which was identical with 200 kg N/ha, whereas the minimum branched root (4.55%) was recorded from the control plants. The result of the experiment agreed with the findings of Islam (2001). He reported that when carrot was fertilized with higher doses of nitrogen the percentage of branching in root was also increased.

There was a significant interaction effect of intercropping and nitrogen on the branched root of carrot. Maximum root branching (7.22%) was obtained from I_0N_2 treatment combination whereas the lowest value (4.09%) was recorded at I_2N_0 treatment combination (Table 3).

4.1.9 Gross yield

The yield of carrot per plot was found to be statistically significant due to the effect of intercropping (Table-1). Control treatment produced the highest yield (16.20 kg/plot or 54 t/ha). However, Bengal spinach intercrop treatment produced the lowest root yield (14.17 kg/per plot or 47.22 t/ha). It was evident that non-intercropped plot gave increased yield than intercropped plot Bezerra *et al.* (2003). Higher yields produced by the control treatment were due to lesser competition for nutrient and other growth resources.

Different doses of nitrogen application increased the gross yield of carrot significantly (Table 2). The maximum yield (16.97 kg/plot or 56.56 t/ha) was obtained from the application of 250 kg N/ha and the second highest yield (15.40 kg/plot or 51.33 t/ha) at the rate of application of 200 kg N/ha. The control treatment produced the lowest (12.70 kg/plot or 42.33 t/ha) yield. The yields of N_2 fertilizer treatment were significantly higher over the control. This was in agreement with the report of Islam (2001) and Sharangi and Paria (1996).

Interaction effects of intercrops and nitrogen showed significant difference on gross yield of carrot (Table 3). It was found that I_0N_2 treatment produced the highest gross yield (19.40 kg/plot or 64.68 t/ha), which was statistically dissimilar from I_1N_2 (16 kg/plot or 53.33 t/ha) and the lowest gross yield (12.40 kg/plot or 41.33 t/ha) was produced by I_2N_0 treatment combination. It was probable that root yield increased due to increased root length, root diameter and individual weight of root.

4.1.10 Marketable yield of roots

Marketable yield was calculated by subtracting non-marketable yield from gross yield of carrot. Marketable yield also varied significantly due to different intercropping treatments (Table 1). The highest marketable yield (13.62 kg/plot or 45.40 t/ha) was produced by the I_0 treatment. The second highest marketable yield (12.73 kg/plot or 42.45 t/ha) was produced by I_1 treatment and the lowest marketable yield (12.54 kg/plot or 41.80 t/ha) was recorded from the Bengal spinach intercrop treatment.

The application of different levels of nitrogen increased marketable yield significantly (Table 2). The marketable yield of 14.12 kg/plot or 47.06 t/ha was obtained when 250 kg N/ha was applied to the carrot crop. The application of 200 kg N/ha produced the second highest marketable yield of 13.30 kg/plot or 44.34 t/ha, which was statistically superior to control treatment and that produced 11.48 kg/plot or 38.26 t/ha. The application of 250 and 200 kg N/ha increased the marketable yield of carrot by 23% and 15.89%, respectively over the control. Islam (2001) also observed similar result.

The combined effects of intercropping and nitrogen treatments were found to be significant for producing marketable yield (Table 3). The highest marketable yield (15.64 kg/plot or 52.13t/ha) was recorded with I_0N_2 treatment combination while the lowest (11.37 kg/plot or 37.90t/ha) was observed in I_2N_0 treatment combination.

Table 3. Combined effects of different intercrops and nitrogen on the growth and yield of carrot

Treatments interaction	Plant height (cm)					Leaf number				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_0N_0	10.21	20.49	29.65	38.42	46.39	4.03	7.03	9.13	11.17	13.47
I_0N_1	12.32	24.77	40.33	44.57	51.15	5.13	9.03	10.53	13.77	17.13
I_0N_2	13.31	25.44	41.52	46.70	53.55	5.47	9.10	11.17	14.00	18
I_1N_0	9.80	20.29	27.40	36.61	46.31	3.93	6.83	8.60	10.67	13.47
I_1N_1	10.79	21.36	31.58	40.69	47.45	4.43	8.63	9.67	11.88	14.33
I_1N_2	12.32	24.58	33.30	42.44	49.39	4.83	9.03	10.36	13.73	15.47
I_2N_0	9.70	18.04	26.85	36.12	43.63	3.93	6.30	7.93	10.16	12.46
I_2N_1	10.76	20.58	30.12	38.68	47.23	4.27	8.30	9.33	11.50	14.17
I_2N_2	11.50	21.68	32.52	40.80	47.93	4.80	8.70	10.33	12.73	14.53
$LSD_{0.05}$	1.023	0.5592	2.415	2.676	2.189	0.6265	0.6265	0.5715	1.086	0.8373
$LSD_{0.01}$	1.409	2.310	3.328	3.687	3.017	0.8632	0.8632	0.8632	1.497	1.154
Levels of significance	*	*	**	*	NS	*	*	*	*	**

I_0 = No intercrop
I_1 = Intercrop Red amaranth
I_2 = Intercrop Bengal spinach

N_0 = 0 kg N/ha
N_1 = 200 kg N/ha
N_2 = 250 kg N/ha

** = Significant at 1% level
* = Significant at 5% level
NS = Non Significant

Table 3. Continued.

Treatments interaction	Fresh weight of leaves per plant (gm)	Root length per plant (cm)	Diameter of root per plant (cm)	Fresh weight of root per plant (gm)	Cracked root (%)	Branched root (%)	Gross yield of root per plot (kg)	Marketable yield of root per plot (kg)	Gross yield of root (t/ha))	Marketable yield of root (t/ha)
I_0N_0	77.33	15.51	3.15	108.30	4.78	5.02	13.00	11.54	43.33	38.45
I_0N_1	119.10	16.89	5.12	135.00	7.97	6.39	16.20	13.69	54.00	45.63
I_0N_2	125.30	17.37	5.33	161.70	8.89	7.22	19.40	15.64	64.68	52.13
I_1N_0	71.84	15.33	3.05	105.80	3.86	4.56	12.70	11.52	42.33	38.41
I_1N_1	95.52	15.68	4.54	128.30	5.49	5.74	15.40	13.25	51.33	44.17
I_1N_2	110.80	16.78	4.95	133.30	7.13	6.22	16.00	13.43	53.33	44.76
I_2N_0	68.81	15.20	2.84	103.30	3.66	4.09	12.40	11.37	41.33	37.90
I_2N_1	85.17	15.62	4.47	121.70	4.84	5.26	14.60	12.97	48.68	43.23
I_2N_2	106.10	16.33	4.67	129.20	6.19	5.92	15.50	13.29	51.68	44.28
LSD $_{0.05}$	6.496	1.103	0.7799	11.20	0.8119	0.1703	1.015	0.9224	3.134	2.317
LSD $_{0.01}$	8.950	1.520	1.074	15.43	1.119	0.7034	1.399	1.271	4.318	3.192
Levels of significance	**	NS	*	*	**	*	**	*	**	**

I_0 = No intercrop
I_1 = Intercrop Red amaranth
I_2 = Intercrop Bengal spinach

N_0 = 0 kg N/ha
N_1 = 200 kg N/ha
N_2 = 250 kg N/ha

** = Significant at 1% level
* = Significant at 5% level
NS = Non Significant

4.2 Marketable return from intercrop

The highest Red amaranth yield (8.50 kg/plot or 28.33 t/h) was obtained from I_1N_2 treatment and the lowest yield (2.77 kg/plot or 9.22 t/ha) was obtained from the I_1N_0 treatment. Moreover, I_2N_2 treatment produced the highest Bengal spinach yield (6.27 kg/plot or 20.89 t/ha) and the lowest yield (2.32 kg/plot or 7.73 t/ha) came from I_2N_0 treatment combination.

Table 4. Marketable yield of red amaranth and bengal spinach as intercrop

Treatments combination	Marketable yield of intercrop			
	Red amaranth (kg/plot)	Red amaranth (t/ha)	Bengal spinach (kg/plot)	Bengal spinach (t/ha)
I_0N_0	-	-	-	-
I_0N_1	-	-	-	-
I_0N_2	-	-	-	-
I_1N_0	2.77	9.22	-	-
I_1N_1	6.23	20.77	-	-
I_1N_2	8.50	28.33	-	-
I_2N_0	-	-	2.32	7.73
I_2N_1	-	-	4.83	16.11
I_2N_2	-	-	6.27	20.89

4.3 Cost and return analysis

Material, non-material and overhead costs were recorded for all the treatments for unit plots and calculated per hectare basis (marketable yield). The price of carrot roots at the local market was also noted. The cost and return analysis were done and presented in table 5 and appendix IV.

The total cost of production ranged between Tk. 47955 to Tk. 60816 among the treatment combinations. The variation was due to the cost of different intercrops and different levels of nitrogen. The highest cost of production (Tk. 60816) was involved in the treatment combination of intercrop Bengal spinach with 250 Kg N/ha, while the lowest cost of production (Tk. 47955) was involved in the treatment of control intercrop and no nitrogen. The gross return from different treatment combinations ranged between Tk. 192250 and Tk. 294625 per hectare. Gross return was the total income through sale proceeds of both sole and inter crop carrot root, Red amaranth and Bengal spinach (marketable yield) Tk. 5000/t, 2500/t and 2500/t respectively.

The benefit cost ratio (BCR) was found to be the highest (5.22) in the treatment combination of I_1N_2, which was followed by I_0N_2 treatment combination giving BCR of 5.18. The lowest BCR (3.57) was recorded with I_2N_0 combination. Thus, it was apparent that the intercrop Red amaranth with different levels of nitrogen not only increased the total marketable yield of carrot but also gave the highest gross return (Tk. 294625), which was followed by 250 kg N/ha and Bengal spinach intercrop (Tk. 273625) treatment. On the other hand highest net return (Tk. 238169) came from I_1N_2 treatment,

Table 5: Cost and return of carrot due to intercropping and nitrogen treatments.

Treatments combination	Marketable yield of carrot (t/ha)	marketable yield of intercrop		Gross return (Tk/ha)				Total cost of production (Tk/ha)	Net return (Tk/ha)	BCR
		Red amaranth (t/ha)	Bengal spinach (t/ha)	Carrot (Tk/ha)	Red amaranth (Tk/ha)	Bengal spinach (Tk/ha)	Total (Tk/ha)			
I_0N_0	38.45	-	-	192250	-	-	192250	47955	144295	4
I_0N_1	45.63	-	-	228150	-	-	228150	49710	178440	4.59
I_0N_2	52.13	-	-	260650	-	-	260650	50320	210330	5.18
I_1N_0	38.41	9.22	-	192050	23050	-	215100	54090	161010	3.98
I_1N_1	44.17	20.77	-	220850	51925	-	272775	56070	216705	4.86
I_1N_2	44.76	28.33	-	223800	70825	-	294625	56456	238169	5.22
I_2N_0	37.90	-	7.73	189500	-	19325	208825	58450	150375	3.57
I_2N_1	43.23	-	16.11	216150	-	40275	256425	60434	195991	4.24
I_2N_2	44.28	-	20.89	221400	-	52225	273625	60816	212809	4.50

Price of Carrot @ Tk. 5000/t, Price of Red amaranth @ Tk 2500 /t, Price of Bengal spinach @ Tk. 2500/t

Gross Return = Marketable Yield x Carrot/ Red Amaranth/ Bengal Spinach

Benefit Cost Ratio (BCR) = Gross Return ÷ Total Cost of Production

I_0: No intercrop
I_1: Intercrop Red amaranth
I_2: Intercrop Bengal spinach

N_0: 0 kg N/ha
N_1: 200 kg N/ha
N_2: 250 kg N/ha

followed by I_1N_1 treatment but the lowest net return (Tk. 144295) was obtained from the treatment combination of control nitrogen with no intercrop. From economic point of view, it is apparent from the above result that Red amaranth intercrop with 250 kg N/ha was more profitable than the rest of the treatment.

Chapter 5

Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka to evaluate the effects of intercropping and levels of nitrogen on the growth and yield of carrot during October 2004 to February 2005. The experiment comprised of two different factors such as (i) three levels of intercropping viz. I_0 (control intercrop), I_1 (Red amaranth), I_2 (Bengal spinach) and (ii) three levels of nitrogen viz. N_0 (control), N_1 (200 kg N/ha) and N_2 (250 kg N/ha).

The two-factor experiment was set up in Randomized Complete Block Design (RCBD) with three replications. There were 9 treatment combinations in this trial and thus the total number of plot was 27. Each plot was 2 m long and 1.5m wide. A gap of 1.0m and 0.5m between the blocks and plots were kept respectively. The experimental plot was fertilized at the rate of 10 ton cow dung, 125 kg Triple Super phosphate and 175 kg and Muriate of potash per hectare. The carrot seed of cv. SB Kuroda were sown on 1st November 2004 and harvested on 16th February 2005. Red amaranth and Bengal spinach were used as per treatment. Data were collected from 10 randomly selected plants of each unit plot. Data on growth and yield parameters were recorded and analyzed statistically. The mean differences were adjudged by Least Significant Difference (LSD) test.

Intercropping treatments significantly influenced all the parameters assessed except diameter of root per plant. At the maximum vegetative growth of 90 DAS, the highest plant height (50.36 cm) was obtained from I_0 treatment and the lowest (45.26 cm) from I_2

treatment. The maximum number of leaves (16.20) was obtained from control intercrop treatment and the lowest (13.72) from Bengal spinach intercrop. The maximum fresh weight (107.20 gm) of leaves per plant was observed from control intercrop treatment and minimum from Bengal spinach intercrop treatment. The greatest length (16.59 cm) of root per plant was recorded from control intercrop and the shortest from the Bengal spinach intercrop. The maximum fresh weight of root per plant 135 g was found from non intercrop and the lowest fresh weight (118.10 g) of root per plant was found from Bengal spinach treatment. The highest root cracking (7.21%) was found from control intercrop treatment and the lowest (4.89%) from the Bengal spinach intercrop treatment. The maximum branching of root (6.21%) was observed from non intercrop and the lowest (5.09%) from Bengal spinach intercrop. The highest gross yield of roots (16.20 kg/plot or 54 t/ha) was recorded from non-intercrop treatment and the lowest (14.17 kg/plot or 47.22 t/ha) was observed from the Bengal spinach. The highest marketable yield of roots (13.62 kg/plot or 45.40 t/ha) was obtained from control intercrop and the lowest (12.54 kg/plot or 41.80 t/ha) was observed from the Bengal spinach intercropping treatment.

Levels of nitrogen significantly influenced all the parameters. At the maximum vegetative growth stage (90 DAS), the highest plant height (50.29 cm) was obtained from N_2 treatment and the lowest (45.44 cm) from N_0 treatment. The maximum number of leaves (16) was obtained from 250 kg N/ha treatment and the lowest (13.13) from the control treatment. The maximum fresh weight (114.10 gm) of leaves per plant was observed from 250 kg N/ha and minimum from control N dose. The highest length (16.83 cm) of root per plant was recorded from N_2 dose and the shortest from the N_0 dose. The diameter of root significantly differed for every levels of nitrogen. The maximum fresh weight of roots per plant (141.40 g) was found from 250 kg N/ha and the lowest fresh weight (105.80 g) of root from the control treatment. The highest root cracking (7.40%) was found from N_2 treatment and the lowest (4.10%) from the zero nitrogen treatment. The maximum branching of root (6.45%) was observed from 250 kg N/ha and that the lowest (4.55%) from control. The highest gross yield of roots (16.97 kg/plot or 56.56 t/ha) was recorded in N_2 treatment and the lowest (12.70 kg/plot or 42.33 t/ha) was observed in N_0 treatment. The highest marketable yield of roots (14.12 kg/plot or 47.06 t/ha) was obtained from 250 kg N/ha and the lowest (11.48 kg/plot or 38.26 t/ha) from the control treatment.

Different intercropping and nitrogen doses had significant combined effect for all the parameters except plant height at 90 DAS and root length per plant. Control intercrop and 250 kg N/ha produced the highest plant height (53.55 cm) while the lowest plant height (43.63 cm) was produced from the I_2N_0 treatment at 90 DAS. The maximum number of leaves per plant (18) was obtained from I_0N_2 treatment combination at 90 DAS and the minimum number of leaves per plant (12.46) was found in I_2N_0 treatment. The maximum fresh weight (125.30 gm) of leaves per plant was observed from control intercrop and 250 kg N/ha (I_0N_2) and minimum from Bengal spinach intercrop and control nitrogen treatment. The highest length (17.37 cm) of root per plant was recorded from I_0N_2 treatment combination and the shortest from the I_2N_0 treatment. The maximum root diameter (5.33 cm) was obtained from control intercrop and 250 kg N/ha treatment. The minimum root diameter (2.84 cm) was at I_2N_0 treatment.

The maximum fresh weight of roots per plant (161.70 g) was found from control intercrop and 250 kg N/ha and the lowest fresh weight (103.30 g) of root from Bengal spinach intercrop and control nitrogen dose. The highest root cracking (8.89%) was found from I_0N_2 treatment and the lowest (3.66%) from I_2N_0 treatment combination. Maximum-branched root (7.22%) was obtained from control intercrop and 250 kg N/ha treatment combination whereas the lowest value (4.09%) was recorded at Bengal spinach and control nitrogen treatment combination. The highest gross yield of roots (19.40 kg/plot or 64.68 t/ha) was recorded from I_0N_2 treatment and the lowest (12.40 kg/plot or 41.33 t/ha) was observed from I_2N_0 treatment. The highest marketable yield (15.64 kg/plot or 52.13 t/ha) was obtained from control intercrop and 250 kg N/ha treatment and the lowest (11.37 kg/plot or 37.90 t/ha) was from the Bengal spinach and control nitrogen treatment combination. The maximum Red amaranth yield (8.50 kg/plot or 28.33 t/ha) was obtained from I_1N_2 treatment. On other hand, the maximum Bengal spinach yield (6.27 kg/plot or 20.89 t/ha) was obtained from the Bengal spinach and 250 kg N/ha treatment.

From the economic point of view the intercrop Red amaranth with 250 kg N/ha gave the highest gross return (Tk. 294625), which was followed by (I_2N_2) Bengal spinach intercrop and 250 kg N/ha (Tk. 273625) treatment. Simultaneously highest net return (Tk. 238169) came from Red amaranth intercrop and 250 Kg N/ha treatment, which was followed by Red amaranth intercrop and 200 kg N/ha (Tk. 216705) treatment. Cost and return analysis indicated that the highest BCR (5.22) was obtained from the treatment combination of I_1N_2, which was closely followed by control intercrop with 250 kg N/ha.

From the above discussion, it may be concluded that carrot with Red amaranth intercrop and 250 kg N/ha was the best combination and a farmer may cultivate carrot with Red amaranth and 250 kg N/ha as intercropping system to get yield advantage and maximum benefit. However, further trial may be done to confirm the findings.

References

REFERENCES

Abdel Razik, A.K. (1996). Effect of nitrogen fertilizer levels and gebberelic acid concentration on carrot yield in sandy soils. *Alexandria J. Agril. Res.***41**(2): 379-388.

Abdel Razik, A.K. and El –Haris, M.K. (1997). Effect of amount of water and nitrogen levels on carrot yield under sprinkler irrigation. *Alexandria J. Agril. Res.* **42**(2): 137-147.

Ali, M.A. (1994). Interaction effects of nitrogen and potassium on the growth, yield and quality of carrot (*Daucus carrota* L.). M.S. thesis, Dept. of Hort. BAU, Mymensingh. pp.86.

Akanda, M.E. and Quayyum, M.A. (1982). Effect of intercropping soyabean, cowpea, mungbean, blackgram and groundnut with maize. *Bangladesh J. Agric. Res.* **7**(2): 66-69.

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

Balooch, A.F., Balooch, M.A. and Qayyum, S.M. (1993). Influence of phosphorus and potassium fertilizer combination with standard dose of nitrogen on the productivity of carrot (*Daucus carrota* L.). *Sarhad J. Agric.* **9**(1): 21-25.

Basso, F. (1968). A two - year trial on phosphorus and nitrogen nutriation of carrots. *Ann. Fac. Sci. Agric.* **(2)** 3: 155-177.

Batra, B.R. and Kallo. (1990). Effect of different levels of irrigation and fertilization on growth and yield of carrot for root production. *Vegetables Sci.* **17**(2): 127-139.

Bezerra, N.F., Andrade. F.V., De-Negreiros, M.Z. and Junior, J.J.D.S. (2003). Agroeconomic performance of carrot x looseleaf lettuce intercrops in two strip arrangements. *Hort- Brasileira.* **21**(4): 635-641.

Bose, T.K. and Som, M.G. (1990). Vegetable crops in India. Naya prakash, Calcutta-six, India. pp. 408-442.

Bruckner, V. (1986). Nutrient supply to carrots. Institute for Boderkunde and Pflanzcnerahrung. Geisenheim, German Federal Republic. **22**(2): 58 - 60. [Cited from Hort. Abstr., 111-112,1987].

Caetano, L.C.S., Ferreira, J.M. and De-Araujo, M. L. (1999). Productivity of carrot and lettuce in an intercropping system. *Hort-Brasileira*. (Brazil). **17**(2): 143-146.

De-Negreiros, M.Z., Neto, F.B., Porto, V.C.N. and Santos, R.H.S. (2002). Performance of lettuce cultivars with and without intercropping with carrot in Mossoro. *Hort-Brasileira*. (Brazil). **20**(2): 162-166.

Deshi, N.S., Padda, D.S. and Malik, B.S. (1964). Effect of different doses of nitrogen at two levels of potash on the development and yield of carrot. *J. Res. Ludhiana*. **1**(1): 50-55.

Evers, A.M. (1988). Effects of different fertilizer practices on growth, yield and dry matter content of carrot. *J. Agril. Sci.* (Finland). **60**(2): 135-152.

Evers, A.M. (1989a). Effect of different fertilizer practices on the glucose, fructose, sucrose, taste and texture of carrot. *J. Agril. Sci.* (Finland). **61**(2): 113-122.

Evers, A.M. (1989b). Effects of different fertilization practices on the carotene content of carrot. *J. Agil. Sci.* (Finland). **61**(1): 7-14.

FAO. (1997). Production Yearbook. Food and Agriculture Organizatio, Rome, Italy, 51:145-146.

FAO. (2000). Production Yearbook. Food and Agriculture Organizatio, Rome, Italy, 54:160-161.

Farazi, M.A. (1983). Effect of spacing and different levels of nitrogen and potash on the yield of carrot. M. Sc. thesis, Dept. of Hort. BAU, Mymensingh, Bangladesh. pp. 51-55.

Fukai, S. and Trenbath, B.R. (1993). Process determining intercrop productivity and yields of component crops. *Field Crops Res*. **34**: 247-271.

Gangasarma and Gajendra, G. (1985). Intercropping of mustard with chickpea, lentil and barley in dry lands. *Indian J. Agric.* **30** (2): 219-227.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Res. (Second edition). A. wiley-Interscience Publication. John Wiley and Sons, New York. pp. 680.

Habben, J. (1973). The effect of nitrogen and potassium fertilization on the yield and quality of carrots. *Landwirtschaftliche Forschung*. **26**(2): 156 -172. [Citedfrom Hort. Abstr., **26**(2) :551.,1973].

Hipp, B.W. (1978). Resposnse by carrots to nitrogen and assessment of nitrogen status by plant analysis. *Hort. Sci.* **13**(1): 43-44. [Cited from Hort. Abstr.,149.,1973].

Islam, M.R. (2001). Effects of mulching and levels of nitrogen and potassium on growth and yield of carrot. M. S. thesis. Dept. of Hort. BAU, Mymensingh, Bangladesh. pp. 39-40.

Jacobson, R., Kellman, J. and Menis, J. (1986). Hybrid carrots of the Nates group. *Hassadesh*. **60**(10): 1812-1813.

Konopinski, M. (1995). Effect of the biological fertilizer super fertilisant on the yield and some quality characters in carrots and beet roots. Wydzial ogradniczy, Akademia Rolinza, Lublin, Poland. pp. 683-686. [Cited from Hort. Abstr. **67**(6): 683. 1997].

Kralovic, J. and Uher, A. (1986). The relationship between nitrogen and potassium fertilization of carrot and nitrate content. Sobronik - uvtiz., Zahradnictvi, 13:2, 128-135; 17 ref. Poland. pp. 683-686. [Cited from Hort. Abstr. **13**(2): 128-135. 1988].

Kushwada, B.L. (1985). Effect of fertilizer on the yield of mustard and lentil intercropping system. *Indian J. Agron.* **30**(2): 154-157.

Michalik, H. (1987). Effect of fertilization of macro and micro elements on the dry matter, sugar and carotene content of carrot. 28: 141 -163. 683 - 686. [Cited from Hort. Abstr. **57**(7): 593-594.1988].

Midmore, D.J. (1993). Agronomic modification of resource use and intercrop productivity. *Field Crops Res.* **34**: 357-380.

Nankar J.T. (1990). Scope and prospects for intercropping of potato with sugarcane in Maharashtra state, Indian. *Field Crops Res.* **25**(1/2): 123-132.

Ogbuehi, C.R.A. (1986). Effect of relay intercropping carrot (*Daucus carota* L.) and sweet corn (*Zea mays* L) in a multiple cropping system. Dissertation – Abstracts – International, – B - science-and-Engineering. **46**(3): 2896B.

Ogbuehi,C.R.A. and Orzolek, M.D. (1987). Intercropping carrot and sweet corn in a multiple cropping system. Scientia-Hort. **31**(1/2): 17-24.

Orphanos, P.I. and Krentos, V.D. (1988). Nitrogen and phosphorus fertilizing of carrots. Technical bulletin, Agril. Res. Inst. Cyprus. pp.8.

Otani, K. (1974). Effect of nitrogen fertilizer on caroteniod content in carrot. *J. Agric. Sci.* **18**:270-273.

Patil, B.D and Gill, A.S. (1981). Response of fodder carrot to N.P.K. fertilization. *Indian J. Agron.* **26**(2): 203-204.

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

Prasad, K., Gautam, R.C. and Motha, N.K. (1985). Study on weed control in arhar and soybean as Influenced by planting pattern, intercropping and weed control method. *Indian J.Agron.* **30**(4): 434.

Ramert, B. (1996). Intercropping as a strategy for reducing damage to carrots caused by the carrot fly, *Psila rosae* (F.). *Biological Agric and Hort.* **13**(4): 359-369.

Ramert, B. and Ekbom, B. (1996). Intercropping a management strategy against carrot rust fly (Diptera: *Psilidae*): a test of enemies and resource concentration hypotheses. *Environmental Entom.* **25**(2): 1092-1100.

Rashid, M.A. (1987). Effect of intercropping cabbage and batisak at varying plant population levels.M. Sc. (Ag) thesis, BAU, Mymensingh, Bangladesh.

Rashid, M.M. (1999). Sabjibijan, 2nd Edn. Mohammad Mamunur Rashid, Rashid Publishing House, 94, Old DOHS, Dhaka. pp. 502.

Rashid, M.M. (1993). Sabjibijan, 1st Edn. Golam Moyenuddin, Director, Text Book Division, Bangla Academy, Dhaka. pp. 502-507.

Raupp, M.M. (1996). Quality investigations with products of the long-term fertilizer trial in Darmstad and in quality of plant products growth with manure and fertilizer. Proceedings of the 4th meething in Helsinki, Finland, July 6-9 [Cited from Hort. Abstr. **68**(2): 408.1998].

Sarker, M.N. (1999). Effect of different levels of nitrogen and mulching on the growth and yield of carrot. M.S. thesis, Dept. Hort. BAU, Mymensingh, Bangladesh.

Sarker, N.K. (1989). Effect of nitrogen, phosphorus and potash on the yield of carrot. M. Sc.thesis, Dept. of Hort. BAU, Mymensingh, Bangladesh.

Sharangi, A.B. and Paria, N.C. (1996). Effect of nitrogen, potassium and phosphorus on some physical attributes of Pusa Kesar carrot roots. *Env. Ecol.* (India). **8**(2): 161-164.

Sharangi, A.B. and Paria, N.C. (1995). Growth, yield and qualitative response by carrot to varying levels of nitrogen and potassium. *Hort. J.* **8**(2): 161-164.

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. (1984). Vegetable seed production technology of Japan. Vol. 1. Shinohara Authorized Agricultural consulting Engineer office, 4-7-7 N. Nishiori, Tokyo. pp. 123 –142.

Singh, K. and Sharma, U. C. (1987). Response of potato cultivars to nitrogen application under acidic soils of Meghalaya. *India. J. Agron.* **32**(4): 392-397.

Skrbic, K. (1987a). Influence of increasing amounts of nitrogen upon the growth dynamics and total nitrogen content in the roots and leaves of some carrot varieties. Agrohenija(Yugoslavia). .**6**: 383-392. [Cited from Hort. Abstr. **68** (2): 408.1998].

Skrbic, K. (1987b). Influence of increasing amounts of nitrogen upon the growth dynamics and total nitrogen content in the roots and leaves of some carrot varieties. Agrohenija (Yugoslavia). 5: 349-358. [Cited from Hort. Abstr .**60**(2): 408.1998].

Varela, O.G and Guharay, F. (1988). The use of multiple cropping (cabbage-carrot) as a component of integrated pest management of cabbage defoliators. Revista – Nicaraguense – de - Enomologia. (Nicaragua). **4**: 49-56.

Wiebe, H.J. (1987). Effects of plant densities and nitrogen supply on yield, harvest date and quality of carrots. *Acta Hort*. **198**: 191-198.

Wiech, K., Jelen, A. and Filipowicz, A. (1995). The effect of intercropping carrot with onion on theoccurrence of some phytophagours insects. Materialy ogolnopolskiej konferencji naukowej Nauka Praktyce Ogrodnicsej zokazji XXV - lecia Wydzialu Ogrodniczego Akademii Rolniczej W Lublinie.(Poland). 371-373.

Willey, R.W. (1979). Intercropping. Its importance and research needs. Part I. Competition and yield Advantage. *Field Crop Res*. **32**(1): 1-10.

Yawalkar, K.S. (1985). Vegetable crops in India. Third Edn. Mrs. Yawalkar, Agric - Horticultural Publishing House, 52, Baja Nagar. 440010. pp. 210-220.

Yildirim, E. and Guvenc, I. (2005). Intercropping based on cauliflower: more productive, profitable and highly sustainable. *European J. Agron*. **22**(1): 11-18.

APPENDICES

Appendix I. Soil analysis data of the experimental plot

Chemical analysis

Properties	Content
Organic Carbon	0.75%
Total Nitrogen	0.09%
Phosphorus	41.89%
Exchangeable K	0.18 e mol (+)/kg soil
P^H value	5.3

Mechanical analysis

Constituents	Percent
Sand	23
Silt	47
Clay	30
Textural class	Silty clay

Appendix II. Monthly records of temperature, rainfall, relative humidity, soil temperature and sunshine of the experimental site during the period from October 2004 to March 2005

Year	Month	*Air temperature (^0C)			Relative humidity (%)	Rainfall (mm)	Soil temperature at different depth (^0C)			** Sunshine (hours)
		Max.	Min.	Mean			5 cm	10cm	20 cm	
	October	30.97	23.31	75.14	75.25	208	16.90	17.20	17.30	208.90
2004	November	29.45	18.63	24.04	69.52	00	13.8	14.40	14.80	233.20
	December	26.85	16.23	21.54	70.61	00	12.60	13.60	14.00	210.50
	January	24.52	13.86	19.19	68.46	04	11.30	12.40	13.00	194.10
2005	February	28.88	17.98	23.43	61.04	03	12.90	13.70	13.80	221.50
	March	32.22	21.78	27.00	66.69	155	16.20	17.10	17.20	210.20

* Monthly Average

** Monthly Total

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1212.

Appendix III. Analysis of variance of different characters of carrot

Sources of variation	Degrees of freedom	Mean square				
		Plant height (cm)				
		30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Block	2	4.738	7.453	15.345	18.778	22.205
Factor-A (Intercropping)	2	4.090**	27.218**	145.862**	46.702**	38.891**
Factor-B (N level)	2	13.832**	42.174**	154.820**	94.705**	54.511**
Interaction (AxB)	4	1.186*	2.898*	13.888**	7.528*	4.880^{NS}
Error	16	0.349	0.938	1.947	2.390	1.600

** = Significant at 1% level

* = Significant at 5% level

NS = Non Significant

Appendix III. Contd.

Sources of variation	Degrees of freedom	Mean square				
		Number of leaves per plant				
		30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Block	2	0.088	0.637	2.141	2.006	1.925
Factor-A (Intercropping)	2	0.794*	0.887*	2.737**	5.225**	14.702**
Factor-B (N level)	2	2.613**	13.148**	9.808**	18.175**	19.732**
Interaction (AxB)	4	0.404*	0.430*	0.415*	1.445*	2.147**
Error	16	0.131	0.131	0.109	0.394	0.234

** = Significant at 1% level
* = Significant at 5% level
NS = Non Significant

Appendix III. Contd.

Sources of variation	Degrees of freedom	Mean square			
		Fresh weight of leaves per plant (gm)	Root length per plant (cm)	Diameter of root per plant (cm)	Fresh weight of root per plant (cm)
Block	2	196.333	4.594	0.243	179.111
Factor-A (Intercropping)	2	1003.201**	1.866*	0.677^{NS}	694.685**
Factor-B (N level)	2	3985.774**	4.930**	10.251**	2912.085**
Interaction (AxB)	4	129.519**	0.282^{NS}	0.661*	197.844*
Error	16	14.083	0.406	0.203	41.861

** = Significant at 1% level

* = Significant at 5% level

NS = Non Significant

Appendix III. Contd.

Sources of variation	Degrees of freedom	Mean square					
		Cracked root (%)	Branched root (%)	Gross yield of root per plot (kg)	Marketable yield of root per plot (kg)	Gross yield of root (t/ha))	Marketable yield of root (t/ha)
Block	2	3.240	1.895	4.551	10.563	53.778	11.742
Factor-A (Intercropping)	2	18.797**	4.171**	10.003**	2.992**	111.152**	33.174**
Factor-B (N level)	2	35.932**	12.057**	41.923**	16.486**	466.112**	182.923**
Interaction (AxB)	4	1.343**	0.317*	2.848**	1.321*	31.665**	14.790**
Error	16	0.220	0.087	0.344	0.284	3.278	1.792

** = Significant at 1% level
* = Significant at 5% level
NS = Non Significant

Appendix IV. Production cost of carrot per hectare

(A) Material cost (Tk.)

Treatments combination	Carrot seed (3 kg/ha)	Manures and fertilizers					Pesticide	Red amaranth seed (2 kg/ha)	Bengal spinach seed 50 kg/ha	Sub total I (A)
		Cow dung (10 t/ha)	Urea (200kg/ha)	Urea (250kg/ha)	TSP 150 kg/ha	MP 175 kg/ha				
I_0N_0	6000	4000	-	-	2400	1575	2000	-	-	15975
I_0N_1	6000	4000	1400	-	2400	1575	2000	-	-	17375
I_0N_2	6000	4000	-	1750	2400	1575	2000	-	-	17725
I_1N_0	6000	4000	-	-	2400	1575	2000	1000	-	16975
I_1N_1	6000	4000	1400	-	2400	1575	2000	1000	-	18375
I_1N_2	6000	4000	-	1750	2400	1575	2000	1000	-	18725
I_2N_0	6000	4000	-	-	2400	1575	2000	-	5000	20975
I_2N_1	6000	4000	1400	-	2400	1575	2000	-	5000	22375
I_2N_2	6000	4000	-	1750	2400	1575	2000	-	5000	22725

Carrot seed @ Tk. 2000.00/Kg.
Red amaranth seed @ Tk. 500.00/Kg
Bengal spinach seed @ Tk 100.00/Kg

Cow dung @ Tk. 0.40/kg
Urea @ Tk. 7.00/kg
TSP @ Tk. 16.00/kg
MP @ Tk. 9.00/kg

I_0: No intercrop
I_1: Intercrop Red amaranth
I_2: Intercrop Bengal spinach

N_0: 0 kg N/ha
N_1: 200 kg N/ha
N_2: 250 kg N/ha

Appendix IV. (Contd.1)
(B) Non- material Cost (Tk.)

Treatments combination	Land preparation	Manures & fertilizer application	Seed sowing	Intercultural operations	Harvesting		Sub total I (B)	Total input cost I (A)+I (B)
					Sole crop	Inter crop		
I_0N_0	7000	1120	2800	1820	8400		21140	37115
I_0N_1	7000	1120	2800	2030	8400		21350	38725
I_0N_2	7000	1120	2800	2240	8400		21560	39285
I_1N_0	7000	1120	2800	2660	8400	3500	25480	42455
I_1N_1	7000	1120	2800	3080	8400	3500	25900	44275
I_1N_2	7000	1120	2800	3080	8400	3500	25900	44625
I_2N_0	7000	1120	2800	2660	8400	3500	25480	46455
I_2N_1	7000	1120	2800	3080	8400	3500	25900	48275
I_2N_2	7000	1120	2800	3080	8400	3500	25900	48625

Labour cost @ Tk. 70/day

I_0: No intercrop
I_1: Intercrop Red amaranth
I_2: Intercrop Bengal spinach

N_0: 0 kg N/ha
N_1: 200 kg N/ha
N_2: 250 kg N/ha

Appendix IV. (Contd. 2)
(C) Overhead cost and total cost of production (Tk.)

Treatments combination	Overhead cost			Sub total (overhead cost)	Total cost of production (total input cost + overhead cost)
	Cost of lease of land	Interest on running capital for 6 months (13% of total input cost/year)	Miscellaneous cost (5% of total input cost)		
I_0N_0	7500	2412	927	10839	47955
I_0N_1	7500	2517	968	10985	49710
I_0N_2	7500	2553	982	11035	50320
I_1N_0	7500	2987	1148	11635	54090
I_1N_1	7500	3102	1193	11795	56070
I_1N_2	7500	3128	1203	11831	56456
I_2N_0	7500	3247	1248	11995	58450
I_2N_1	7500	3365	1294	12159	60434
I_2N_2	7500	3388	1303	12191	60816

I_0: No intercrop
I_1: Intercrop Red amaranth
I_2: Intercrop Bengal spinach

N_0: 0 kg N/ha
N_1: 200 kg N/ha
N_2: 250 kg N/ha