# EFFECT OF NITROGEN AND SPACING ON GROWTH AND YIELD OF LETTUCE (*Lactuca sativa* L.)


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**BY**

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# *CERTIFICATE*

This is to certify that the thesis entitled, **"Effect of Nitrogen and Spacing on Growth and Yield of Lettuce (*Lactuca sativa* L.)"** Submitted to the Department of Horticulture, 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 **A. K. M. Maroof Tahsin,** being Registration No**. 04-01411** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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*Dedicated to*

*My*

*Beloved Family*

*ACKNOWLEDGEMENT*

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***The Author***

# EFFECT OF NITROGEN AND SPACING ON GROWTH AND YIELD OF LETTUCE (*Lactuca sativa* L.)

**By**

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***ABSTRACT***

The experiment was conducted in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2009 to January, 2010. The experiment consisted of two factors. Factor A: Nitrogen (4 levels) $N_0$: 0 (Control); $N_1$: 50; $N_2$: 100 and $N_3$: 150 kg/ha respectively; and Factor B: Plant spacing (3 levels), $S_1$: 40 cm × 20 cm, $S_2$: 40 cm × 25 cm; $S_3$: 40 cm × 30 cm. The Experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In case of ntrogen the highest yield (29.99 t/ha) was recorded from $N_3$ and lowest (18.65 t/ha) from $N_0$. In case of spacing the highest yield (25.83 t/ha) was achieved from $S_2$ and lowest (23.0 t/ha) from $S_1$. For interaction effect, the highest yield (31.31 t/ha) was obtained from $N_3S_2$ and lowest (16.79 t/ha) from $N_0S_1$. The highest BCR value (3.88) was recorded from $N_3S_2$ and lowest (2.1) from $N_0S_1$. So, 150 kg/ha urea with spacing of 40 cm × 25 cm were best for growth and yield of lettuce.

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| PPM | = | Parts Per Million |
| SRDI | = | Soil Resource Development Institute |
| CGR | = | Crop Growth Rate |
| BCR | = | Benefit Cost Ratio |
| LAI | = | Leaf Area Index |
| NWFP | = | Northwest Frontier Province |
| cm | = | Centimeter |
| $^0C$ | = | Degree Celsius |
| DAT | = | Days after transplant |
| *et al.* | = | and others *(et elli)* |
| Kg | = | Kilogram |
| Kg/ha | = | Kilogram/hectare |
| mg | = | milligram (s) |
| UNDP | = | United Nations Development Programme |
| FAO | = | Food and Agriculture Organization |
| MP | = | Muriate of Potash |
| m | = | Meter |
| HPLC | = | High Performance Liquid Chromatography |
| RCBD | = | Randomized Complete Block Design |
| TSP | = | Triple Super phosphate |
| t/ha | = | ton/hectare |
| % | = | Percent |
| EU | = | European Union |
| cv. | = | Cultivar |

# CHAPTER I

## Introduction

Lettuce (*Lactuca sativa* L.*)* an annual leafy herb belongs to the family Compositae is one of the most popular salad crops and occupies the largest production area among salad crops in the world. It is popular for its delicate, crispy texture and slightly bitter taste with milky juice as fresh condition. It is the most popular amongst the salad vegetable crops (Squire *et al*. 1987). In line with investigations carried out by Stevens (1974) in USA, lettuce is ranked 26th among vegetables and fruits in terms of nutritive value and $4^{th}$ in terms of consumption rate highlighting the ever-increasing importance of this crop. The nutrient content is highest in the darker green, outer leaves. Low in calories. Each head contains 65 to 70 kilocalories.

Lettuce is rich in vitamin A and minerals like calcium and iron. It also contains protein, carbohydrate and vitamin C and in 100 g of edible portion of lettuce contains 93.4 g moisture, 2.1 g protein, 0.3 g fat, 1.2 g minerals, 0.5 g fiber, 2.5 g carbohydrates, 310 mg calcium, 80 mg phosphorus, 2.6 mg iron, 1650 I.U. vitamin A, 0.09 mg thiamine, 0.13 mg riboflavin and about 10.0 mg vitamin C (Gopalan and Balaraman, 1966). It is usually used as salad with tomato, carrot, cucumber or other salad vegetable and often served alone or with dressing. Its nutritive value is not spoiled. Moreover, it is also known as anodyne, sedative, diuretic and expectorant (Kallo, 1986). "Mixed lettuce" production includes green leaf, red leaf, butter, and romaine types. These crops are often planted alongside endive, escarole, oriental vegetables, herbs, and other leafies. Smaller operations focus on high quality produce and cater to farmer's markets, or to hotels, restaurants, and other high-end food service companies, but the volume of high quality specialty products is also increasing in main-stream retail stores.

Lettuce is mainly a cold loving crop and the best temperature for cultivation is $18^0$C to $25^0$C and the night temperature is $10^0$C to $15^0$C (Ryder, 1998). It produces a short stem early in the winter season, a cluster of leaves varying considerably in shape, character and colour in different varieties. Lettuce is originated from Southern Europe and Western Asia (Rashid, 1999). It mainly grows in temperate region and in some cases in the tropic and sub-tropic region of the world. Lettuce largely produced in greenhouse in temperate region (Lindquist, 1960).

Lettuce is getting popularity day by day but its production package is not much known to the Bangladeshi farmers. Among various factors responsible for higher yield, supply of nutrient and production technology play vital role in the production and quality of lettuce. Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). The cultivation of lettuce requires proper supply of plant nutrient. Lettuce responds greatly to major essential elements like N, P and K in respect of its growth and yield (Thompson and Kelly, 1988). Its production can be increased by adopting improved management practices.

Fertilizer plays a vital role in proper growth and development of lettuce. Fertilizer application in appropriate time, appropriate dose and proper method is the prerequisite of crop cultivation (Islam, 2003). Generally, chemical fertilizers increase the growth and yield but excessive application of chemical fertilizers in crop production causes health hazards, create problem to the environment including the pollution of soil, air and water.

This vegetable requires a high rate of nitrogen for growth and development. In Iran, farmers who applied excesses nitrogen fertilizer to increase crop yield disturbed the equilibrium balance of nutrient elements in the soil, caused pollution, decreased crop quality and thus a great part of the nation’s resources became useless (Tehrani and Malakouti 1997).

Adequate N levels are also associated with "sizing," solid heads, and earliness of maturity in lettuce. N deficient fields often result in delayed harvests, need for repeated harvests, or in failure of heads to achieve marketable size and quality. Lettuce with N deficiency appears lighter green. Corrective N applications on visually N-deficient plants are effective in the early vegetative stages but a 3-10 day delayed harvest will occur. However corrective N applications on N deficient plants during the head-formation stage will not prove helpful in increasing head size and final yields. Nitrapyrin banded at 246.9 kg/ha may help to improve normal plant were nitrogen use efficiency. Fertilizer injection through the irrigation system and increased frequency of applications may also help to improve plant nitrogen use efficiency and reduce leaching.

Plant spacing for lettuce cultivation is an important criterion for attaining maximum vegetative growth and an important aspect of crop production for maximizing the yield. Optimum plant spacing ensures judicious use of natural resources and makes the intercultural operations easier. It helps to increase the number of leaves, branches and healthy foliage. Densely planted crop obstruct the proper growth and development. On the other hand, wider spacing ensures the basic nutritional requirements but decrease the total number of plants as well as total yield. Yield may be increased for any crop up to 25% by using optimum spacing in leafy vegetable (Bansal, *et al*., 1995).
In Bangladesh like other management practices information about plant spacing to be used in lettuce cultivation is insufficient. The farmers of Bangladesh cultivate this crop according to their own choice due to the absence or unavailability of standard production technique. As a result, they do not get satisfactory yield and return from investment.

Considering the above factors, the present experiment was undertaken to study the following objectives-

i. To find out the effect of nitrogen fertilizer on the growth and yield of lettuce;

ii. To determine the effect of plant spacing on growth and yield of lettuce;
iii. To find out the suitable combination of nitrogen and plant spacing for ensuring the higher yield of lettuce.

# CHAPTER II

## Review of literature

Lettuce is one of the most important and popular salad vegetable in Bangladesh as well as in many countries of the world. The crop has conventionaly less concentration by the researchers on various aspects because it is newly introduced crop. Very few studies on the growth and yield of lettuce have been carried out in our country as well as many other countries of the world. Therefore, the research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important informative works and research findings related to nitrogen and plant spacing on lettuce so far been done at home and abroad have been reviewed in this chapter under the following headings.

## 2.1 Effect of nitrogen

Lettuce requires a high rate of nitrogen for growth and development. In Iran, farmers who applied excesses nitrogen fertilizer to increase crop yield disturbed the equilibrium balance of nutrient elements in the soil, caused pollution, decreased crop quality and thus a great part of the nation's resources became useless (Tehrani and Malakouti 1997).

The investigation carried out by Tittonell *et al*. (2003) on lettuce showed that increasing nitrogen fertilizer from 0 to 150 kg $ha^{-1}$ increased the plant height, leaf number, fresh weight and dry weight of the crop. Rincon *et al*. (1998) also reported that increasing nitrogen up to 100 kg $ha^{-1}$ increased the plant height, leaf number and yield of lettuce, reaching 53.4 t $ha^{-1}$ (total fresh matter) while the application of 150 and 200 kg $ha^{-1}$ caused a decrease in the biomass and yield index, respectively.

Gulser (2005) observed that an increase in the fertilizer nitrogen level increased the yield, stem length and leaf surface area but not the number of leaves in spinach. Demir *et al*. (1996) also reported that by increasing the nitrogen fertilizer rate the leaf area, stem length and yield of spinach increased.

Zarehie (1995) reported that by increasing the nitrogen fertilizer rate to 200 kg $ha^{-1}$ increased the plant height, leaf breadth and yield of spinach but that by increasing the nitrogen level up to 200 kg $ha^{-1}$ the corresponding increase in yield was not economical.

The investigation conducted by Mahmoudi (2005) on lettuce (cv. 'Siah Karaj') showed that by increasing the rate of nitrogen fertilizer to 300 kg $ha^{-1}$ increased plant height, number of leaves, yield and dry matter of lettuce but between 100 and 200 kg N ha$^{-1}$ was not significantly different. However, the yield response of lettuce to increasing N rate varies with different environmental variables, including weather, soil type, residual fertility, soil moisture, seasons and cultivar. This study aimed to evaluate the effect of different nitrogen levels applied as urea on the growth and productivity of two cultivars of lettuce, which can help to predict the optimal N fertilizer requirement and to improve the practice of lettuce production.

Boroujerdnia and Ansari (2007) conducted an experiment at Shahid Chamran University of Ahwaz, Iran during 2005-2006 to determine the effect of nitrogen fertilizer rates and cultivars on growth and critical yield of lettuce. The treatments included four nitrogen rates (0, 60, 120, and 180 kg N ha$^{-1}$) as the main plot and two lettuce cultivars (‘Pich Ahwazi’ and ‘Pich Varamini’) as the sub-plot. The criteria measured were plant length, fresh and dry weights of leaves, leaf area, number of leaves, crop growth rate (CGR), leaf area index (LAI) and yield. Results indicated that different levels of nitrogen fertilizer on all growth characteristics were significant at $P<0.01$. Increased plant length, fresh and dry weights of leaves, leaf area, number of leaves, crop growth rate (CGR), leaf area index (LAI) and yield were shown upto 120 kg N ha$^{-1}$. Nitrogen fertilizer caused head formation to accelerate and delayed the bolting date of lettuce. Cultivar had a significant effect on growth characteristics, on fresh and dry weights of leaves and on leaf number but not on plant length and leaf area. The highest yield was obtained with 120 kg ha$^{-1}$ treatment by ‘Pich Ahwazi’. Also, it took ‘Pich Varamini’ longer to form a head and to flower than ‘Pich Ahwazi’.

Dimitrov *et al.* (2005) conducted a field experiment in Bulgaria to study the influence of different fertilizer sources on yield and quality of lettuce on an alluvial meadow soil. The different fertilizer sources included mineral fertilizer, farmyard manure and foliar fertilizer application. The highest yield values from lettuce were obtained in the variants with mineral fertilizer application. A beneficial effect of the lettuce quality such as high values of soluble sugars and ascorbic acid content, low levels of cellulose and reduced nitrate content.

Li-Hui He *et al.* (2005) conducted a pot experiment, where the effects of application ratio of N, P, K and soil moisture on the yield and nitrate in lettuce (*Lactuca sativa* L.) leaf and stem were studied. The results indicated that the yields of lettuce (stem and leaf) had significant difference. N2P3K1 and N3P2K1 treatments had better effect on leaf and stem yield under three soil moistures. With the increment of soil moisture, the yield of lettuce increased. The ratio of yield of lettuce leaf and stem was in the order of YW25/YW15 > YW20/YW15 > YW25/YW20. The nitrate contents in lettuce leaf and stem were different under different soil moisture. When the soil moisture was increased, nitrate contents of lettuce leaf and stem in same treatment had different change. The nitrate content of lettuce leaf and stem was lower under W25 soil moisture.

Sorensen and Thorup (2003) conducted a field experiments to investigate the potential of several species of undersown legume crops to deplete soil nitrate and to accumulate nitrogen (N). A further objective was to measure the effects of the legume crops as a green manure for a succeeding early lettuce crop. In two years, different undersown legume crops were compared with a control treatment where no crop was undersown. In November, at the end of their growing season, the legume crops reduced the content of mineral nitrogen in the top 1 m of the soil to one third of what was available when no crop was undersown. The N uptake in shoots and roots was in the range of 100-160 kg $ha^{-1}$. The legume crops were incorporated at the beginning of April the succeeding year. In May, the content of soil mineral nitrogen was 3-4 fold the content in November. The main increase was seen in the top 0.25 m profile of the soils in which the legume crops had been grown. In July, the N mineralized from the incorporated legume crops and from other soil organic matter was estimated to be 36 and 38 kg $ha^{-1}$, respectively. The yield of lettuce was increased by 20-45% when grown after legume green manure crops compared with the control treatment. The yield level was comparable to that obtained in conventional horticulture.

Parente *et al.* (2006) carried out an experiment that the present work aimed to study production and accumulation of nitrate by new cultivars of lettuce in response to nitrogen doses applied to the soil. Two field trials were carried out during 1999-2000 and 2000-01 in Italy, the soil had received 30 and 64 $kg.ha^{-1}$ of N, respectively, for the two trials as a pre-transplanting treatment. The main objective was to compare a control unfertilized treatment with two nitrogen doses (75 and 150 $kg.ha^{-1}$) applied by fertigation to different cultivars of lettuce belonging to the following types: Lollo Bionda, Canasta, Lollo Rossa, and, in the second trial, Oakleaf. The Lollo Rossa cultivars produced 26 and 56% less than the Canasta type, respectively, in the first and the second year, probably due to the absence of a real head in the Lollo type. The application of nitrogen by fertigation increased yield compared with the unfertilized control. But with no difference between doses and rates of fertilizer application. On the other hand, nitrogen post-transplanting fertilization increased the nitrate content in leaves. The Lollo cultivars accumulated more nitrate than the other ones. The nitrate levels were greatly below the limit of 4.000 mg $kg^{-1}$ fw imposed by EU Regulation No. 563/2002.

Mantovani *et al.* (2005) carried out an experiment using pots under greenhouse conditions to evaluate the influence of nitrogen fertilizer application on the growth and nitrate accumulation of lettuce cultivars. Treatments consisted of five nitrogen rates (0, 141.5, 283.0, 566.0 and 1132.0 mg/pot N as urea) and five lettuce cultivars viz. Lucy Brown, Taina, Vera, Veronica and Elisa. The maximum growth was observed in the treatment using 283 mg of N/pot. The use of higher rates did not increase plant growth but raised nitrate accumulation in shoot organs. Lucy Brown and Taina accumulated more nitrate than Vera, Veronica and Elisa cultivars.

Troyanos et *al.* (2004) invistigated an experiment to know the effect of the application rate of nitrogen fertilizer on yield and nitrogen concentration of lettuce grown in a commercial vegetable field. Results showed that the optimum nitrogen application rate was 140 kg/ha. The optimum total nitrogen concentration in the above ground dried plant material was 3% (DW). This optimum nitrogen concentration was 17% less than that derived from a mathematical model developed by Greenwood. Furthermore, the optimum nitrate concentration determined in the sap derived from the base of the midrib of young leaves was 450 ppm.

Marsic and Osvald (2005) carried out a greenhouse experiment with young lettuce plants in a closed hydroponic system to monitor the N dynamics within the plant, 15N was used as a tracer. The treatments comprised: 13.0, 0.5, 0.1 and 0.0 mM NO3N. Growth of lettuce decreased progressively as the level of N supply decreased and at the lower treatment, shoot growth was more affected than root growth. In the highest treatment (13.0 mM) there was little net movement of 15N into or out of the roots, but under more deficient conditions (0.5, 0.1 and 0.0 mM) 15N increasingly accumulated in the roots.

Liao-YuLin *et al.* (2005) carried out an experiment to investigate the effects of N rates on the yield and quality, and N use efficiency of Asparagus lettuce using 15N trace technique in pot experiments. Results showed that the correlation between N rates and yield followed a regression equation, which indicated that adequate N rates could improve quality, reduce N loss and increase N use efficiency.

Kavak *et al.* (2003) conducted a field experiment to determine the effects of different nitrogen sources on yield, quality, mineral, nitrate and nitrite contents in head lettuce. N fertilizer was applied at 0, 5, 10, 15, and 20 kg/da as calcium nitrate and ammonium sulfate. Head weight, head diameter and height, number of discarded leaves, marketable head weight, number of leaves in marketable head, and total yield were determined. Calcium nitrate had a significant effect on head weight, head diameter, height, marketable head weight, and yield. Calcium nitrate at 15 kg N/da showed the highest yield (3531.4 kg/da). Moreover, ammonium sulfate had significant effect on head weight, head diameter, number of discarded leaves, number of leaves in marketable head, marketable head weight, and yield. Ammonium sulfate at 20 kg N/da showed the highest yield (3480.7 kg/da).

Chen-HongTang *et al.* (2002) carried out an experiment to investigate the effects of splitting nitrogen fertilizer on soil fertility, and on the growth, nutrient content and N composition of lettuce under plastic-covered conditions. Six splitting N fertilizer treatments were employed, including a conventional application method as the control. Lettuce was harvested 40 days after seeding. The soil was sampled after harvesting at 5 cm interval to a depth of 15 cm. The amount of nitrate-nitrogen, Bray-1 P, soluble salts and exchangeable K, Mg and Ca in the soil, and N, P, K, Cu and Zn and NO< sub>3</ sub>-N, soluble and insoluble N in the shoots and roots of lettuce were determined. No significant difference was observed in the pH, soluble salt, NO< sub>3</ sub>-N, Bray-1 P, exchangeable K, Ca and Mg in the soil. However, the nutrients in the soil accumulated to high concentrations and the NO< sub>3</ sub>-N and exchangeable K significantly increased in the topsoil (0-5 cm). No significant difference was also observed in the concentrations of N, P, K, Cu and Zn among the different treatments or in the concentrations of NO< sub>3</ sub>-N, soluble reduced N and insoluble N of the plants.

Marsic and Osvald (2002) conducted field experiment to determine the effects of different greenhouse conditions and decreasing nitrogen levels in nutrient solution on the growth and nitrate accumulation and distribution in lettuce (cv. Vanity) plants. Three successive experiments were conducted on aeroponic systems from May to August 1999. Vanity was grown in hydroponics using 13 and 5 mM NO< sub>3</ sub>-N in nutrient solution. Differences among averages of fresh shoot weight measurements were statistically significant in all three aeroponic experiments. The largest fresh shoot weights were obtained from May to June and the lettuce heads from that growing period were compact enough for marketable yield. In the second and the third experiments, elongation of stalk and puffy heads were observed in all lettuce plants irrespective of NO< sub>3</ sub>-N concentration in nutrient solution. In all three experiments, the low NO< sub>3</ sub>-N level in nutrient solution statistically diminished nitrate content in the shoots. The highest nitrate concentration was recorded in outer leaves, while the lowest nitrate concentration was recorded in inner leaves under 13 and 5 mM NO< sub>3</ sub>-N treatments.

Rincon *et al.* (2002) investigated the effect of N (25, 50, 100, 150 and 200 kg/ha), applied in fertigation, on the yield and nitrate content of iceberg lettuce (*Lactuca sativa* var. capitata) in Murcia, Spain. Crop yield increased with N levels of up to 100 kg/ha, obtaining green biomass of 53.4 t/ha and commercial lettuce heads of 33.1 t/ha. Biomass and yield index decreased with N at 150 and 200 kg/ha. The nitrate content in the soil solution increased with the 150 and 200 kg N/ha treatments, and decreased with the 25 and 50 kg N/ha treatments. Nitrate concentration remained uniform during the growth cycle when 100 kg N/ha was applied, and the availability of nitrate was balanced with the absorption by the plant. N absorption increased between the 25 and 50 kg N/ha treatments and those of the 100, 150 and 200 kg N/ha treatments. However, no significant differences were observed between the higher N treatments. The outer leaves of plants showed a nitrate concentration 3 times higher than that of the inner leaves. This concentration changed according to the quantity of N provided. At harvest, the nitrate concentration in the outer leaves ranged from 1635 to 4494 ppm, while that in the inner leaves ranged from 651 to 1508 ppm.

Soundy and Cantliffe (2001) studied with 'South Bay' lettuce (*Lactuca sativa*) seedlings and these were fertigated in floating styrofoam flats in nutrient solutions containing N at 0, 15, 30, 45, or 60 mg litre$^{-1}$. Increasing N from 0 to 60 mg litre$^{-1}$ resulted in an increase in transplant shoot and root mass. The increase in shoot mass was much greater than for root mass in response to N rate, and resulted in lower values for root: shoot ratios. Relative growth rate, specific leaf area, leaf area ratio, and leaf mass ratio increased with an increase in applied N, suggesting improved transplant growth at higher N rates. Growth responses of lettuce transplant shoots and roots to applied N were consistent, regardless of season or stage of growth. Leaf tissue N always was increased by N rate applied. Lettuce head mass in the field (Florida, USA, in 1994) at harvest was increased by pretransplant application with increased N. The heaviest heads were obtained from transplants grown with 60 mg litre$^{-1}$ in the greenhouse. This work demonstrated that at least 60 mg litre$^{-1}$ N supplied via floatation irrigation, was required for improved transplant shoot and root growth in a peat+vermiculite mix low in NO< sub>3</ sub>-N. Transplants grown with 60 mg litre$^{-1}$ N versus 15 mg litre$^{-1}$ N were bigger at transplanting and resulted in improved head mass at harvest.

D'Antuono and Neri (2001) carried out an experiment with Butterhead (Titan), romaine (Manital) and red leaf oak (Valdai) lettuces and those were grown at 0, 80 and 160 kg ha$^{-1}$ nitrogen on autumn and spring cycles at Cadriano, Bologna, Italy, during 1997 and 1998. After harvest, the heads were stored for either: 4 days at room temperature; 7 days at 4 degrees C; or 7 days at 4 degrees C+4 days at room temperature. Two nine-point descriptive scales were developed for sensory analysis of intact and cut heads, including characters such as size, colour, firmness, turgor and visual defects. The heads were evaluated at harvest and after storage, by a panel of 9 people trained in the basic use of the scales. A significant effect of nitrogen was detected on most individual traits. The first principal component extracted from the descriptive profile set was an indicator of overall quality, whereas the second was positively correlated to head size and defects. Both components showed a curvilinear response to nitrogen, with an increase from 0 to 80 kg $ha^{-1}$, but no further increase at the highest nitrogen rate. The results indicate that nitrogen-induced quality variation of lettuce can be perceived and quantitatively assessed by means of descriptive sensory profiling. There was no response of main external quality traits beyond an application of 80 kg/ha N, which was lower than that usually employed by growers, corresponding to the recommendations of the local advisory services.

Weier *et al.* (2001) investigated that although a lot is known about the nitrogen demand of vegetable crops, many farmers still determine fertilizer requirements by a 'rule of thumb'. Since no soil analysis is carried out, there is no accounting for the mineral N in the rooted layer. Nil-N-plots (where a small part of the field remains without fertilizer) offer a simple method of estimating the N< sub>min</ sub> content of the soil and a way to adapt top dressing for vegetable crops. The rest of the field receives a normal basal dressing (enough for the period of growth between planting/sowing and top dressing). The amount of top dressing is determined by the time it takes for the appearance and the intensity of N deficiency symptoms to become visible in the Nil-N-plot, compared to the rest of the field. In a 2-year (1997 and 1998) field experiment with different vegetable crops (leek cultivars Glorina and Vrizo, red cabbage cultivars Rodima and M. Lagerrot, beetroots, broccoli, kale, spinach, celeriac, kohlrabi, pepper (Capsicum annuum) and lettuce) the Nil-N-plots method was compared with the N< sub>min</ sub> method by taking soil samples and adding fertilizer up to the N< sub>min</ sub> target value. There was no decrease in yield when using Nil-N-plots method. However, when the N< sub>min</ sub> content of the soil was high at the beginning, the total fertilizer applied was higher than the N< sub>min</ sub> target value. Nevertheless Nil-N-plots are better than using 'rules of thumb'.

Marsic and Osvald (2002) experimented with lettuce plants cv. Vanity were grown aeroponically using four different amounts of nitrogen (12, 8 and 4 mM/litre) in nutrient solutions. Differences among averages of fresh shoot weights were statistically significant in all three experiments. In the first experiment, the maximum final fresh weight average was 999.0 g in treatment 8 mM. In the second experiment the largest amount of nitrogen 12 mM NO< sub>3</ sub>-N significantly ($p<0.05$) increased the fresh shoot weight of lettuce plants. The low level of nitrate in the nutrient solution (4 mM NO< sub>3</ sub>-N) significantly ($p<0.05$) increased the fresh weight of the final roots regarding the level of nitrate in standard nutrient solution (12 mM NO< sub>3</ sub>-N). The highest NO< sub>3</ sub> concentration in lettuce leaves was recorded in plants grown in nutrient solutions with the highest NO< sub>3</ sub>-N concentration (12 mM NO< sub>3</ sub>-N). The low enough NO< sub>3</ sub>-concentration was found in leaves of lettuce treated with nutrient solution with 4 mM NO< sub>3</ sub>-N in both two experiments.

Tlustos *et al.* (2002) investigated in pot experiment to know the effect of slow release N fertilizers and urea with three vegetables (radish cv. Duo, lettuce cv. Detenicka and carrot cv. Nantes) and two rates of applied N. Directly fertilized radish, subsequently grown unfertilized lettuce and third crop directly fertilized carrot were treated by urea as control treatment and by three samples of slow release fertilizers based on urea formaldehyde condensate of different solubility. Availability of N from slow release samples affected yield of growing vegetables and their nitrogen uptake. Lower availability of N caused lower yields of radish and subsequently grown lettuce mainly on treatments with lower rate of fertilizer compared with urea treatments. Carrot planted as a third vegetable and directly treated by nitrogen showed higher yield at treatments with less soluble samples due to longer growing period and continuing release of N from slow soluble samples. Yield of dry matter of individual vegetables correlated well with uptake of nitrogen determined by balance and isotope methods. Among both isotope techniques introduced, about twice lower utilization than the balance method probably caused by priming effect of N and by unsuitable conditions for plant growth at unfertilized zero treatment.

Premuzic *et al.* (2002) carried out an experiment with Lettuce cultivars Gallega and Mantecosa were grown in Buenos Aires, Argentina field during the autumn and winter seasons [date not given], to study the effects of organic and inorganic fertilizers on the production and contents of nitrates and vitamin C [ascorbic acid]. Four fertilizer treatments were applied: two organic (vermicompost and biostabilized compost) and two inorganic ones (94% Ca (NO< sub>3</ sub>)< sub>2</ sub>+6% NH< sub>4</ sub>NO< sub>3</ sub> and 74% Ca (NO< sub>3</ sub>)< sub>2</ sub>+6% NH< sub>4</ sub>NO< sub>3</ sub>+20% urea), and a control without any added fertilizer. Yield, vitamin C, nitrate and dry matter were determined at commercial maturity stage. Mantecosa showed significant differences for yield and nitrates content and no significant differences for dry matter and vitamin C among treatments. The 74-6-20 and the vermicompost treatments resulted in the largest yield. The 94-6 treatment showed the highest nitrate content; whereas, the control and the biostabilized compost had the lowest nitrate content. The mineral fertilizer treatments had a lower level of vitamin C compared to organic treatments. An opposite trend seemed to be valid for the nitrate concentration. Gallega presented two groups with significant differences for nitrates. The 94-6 treatment presented the largest concentration and vermicompost the lowest. Yield was only significant with regard to control. Vermicompost and 74-6-20 treatments obtained the largest yields. No significant differences were observed for vitamin C concentration. Comparing the two cultivars Mantecosa presented a larger nitrate concentration (2040 mg/kg fresh weight, FW). The vitamin C contents were high (23 and 19 mg/100g FW) in both cultivars. Concerning the applied fertilization, vermicompost presented the best result, i.e. a high yield, a low nitrate content and a high vitamin C content.

Kacjan *et al.* (2001) conducted a field experiments to investigate the effect of different N amounts in nutrient solution on growth, development and nitrate content in aeroponically grown lettuce cv. Vanity. The first experiment used 12.0, 17.0, 8.0 and 4.0 mM NO< sub>3</ sub> concentrations (A, B, C and D, respectively). The second experiment used 1.2, 0.5, 4.0 and 12.0 mM NO< sub>3</ sub> concentrations (A, B, C and D, respectively). In the third experiment, the concentrations of NO< sub>3</ sub> were 12.0, 0.5, 0.1 and 0.0 mM (A, B, C, and D, respectively). Differences among averages of fresh weight were statistically significant in the first experiment. The maximum final fresh weight average in treatment 8 mM was 1000 g. In the second and third experiments, the highest amount of N (12 mM) also affected the growth of lettuce. The low level of nitrate in the nutrient solution significantly increased the fresh weight of the final roots regarding the level of nitrate in standard nutrient solution (12 mM). The highest nitrate concentration in older leaves was recorded in plants grown in nutrient solutions with 8 mM and 12 mM. The low enough nitrate concentration was found in leaves treated with nutrient solution with 4 mM, in all 3 experiments.

Grazia *et al.* (2001) evaluated the effect of light radiation and temperature on the growth patterns of a leafy lettuce cultivar and their interaction with fertilizer application through trials which combined three shade levels (65, 35, and 0%) with three fertilizer application rates (0, 75 and 150 kg N/ha) in a winter sowing date. The same fertilizer application rates were applied to unshaded crops sown in the spring season. Growth rate, yield and quality traits of lettuce were measured. The results showed that radiation level was the most important factor controlling growth in lettuce, whereas the effect of N fertilizer application was only observed in those treatments in which light intensity was not a limiting factor. Results indicated that N fertilizer application rates higher than 75 kg N/ha do not provide any significant benefit to leafy lettuce crops under open field conditions neither in winter nor in spring sowing dates.

Rehman *et al.* (2001) studied the effect of sowing dates (8, 18 and 28 October and 8 November 1998) and nitrogen levels (0, 20, 40, 60 and 80 kg/ha) on the leaf yield of lettuce cv. Crinkle, an experiment was conducted at Horticulture Farm, NWFP Agricultural University Peshawar, Pakistan, during winter 1998-99. Leaves per plant, leaf area and leaf yield per hectare were significantly affected by sowing dates. Maximum leaves per plant (13.66), leaf area (73.64 cm2) and yield/ha (12.3 t) were recorded in plots sown on 18 October. Nitrogen application at the rate of 80 kg/ha significantly affected leaves per plant, leaf area, leaves weight and yield per hectare. Maximum number of leaves per plant (14.88), leaf area (83.83 cm2), leaves weight (17.19 g/plant) and yield/ha (13.6 t) were noted in plots which received nitrogen at the rate of 80 kg/ha compared to other levels of nitrogen. It is concluded that maximum leaves/plant (17.18), leaf area (91.79 cm2) and yield/ha (17.5 t) were achieved from plots sown on 18 October fertilized with 80 kg N/ha.

Premuzic *et al.* (2001) studied on Lettuce (*Lactuca sativa*) cv. Mantecosa subjected to different kinds of light supply and different N fertilization treatments was grown in the greenhouse. Three treatments were applied: two with N fertilization: (1) mineral fertilization with 94% Ca (NO< sub>3</ sub>)< sub>2</ sub> - 6% NH< sub>4</ sub>NO< sub>3</ sub>; (2) organic fertilization with biologically stabilized compost; and (3) without fertilization (control). Each treatment received two different kinds of light supply: (1) 24 h artificial light and (2) no artificial light. The yield and nitrate content, and vitamin C, were determined in plants harvested at commercial maturity. Twenty-four hours of artificial light supply improved yield and decreased nitrate content, but did not affect vitamin C content. Both fertilizer treatments resulted in the same yield level. However, mineral fertilization resulted in a higher concentration of nitrate in lettuce, whereas vitamin C content did not differ significantly between all treatments.

Matsumoto *et al.* (2001) studied on comparing the nitrogen (N) uptake of four different kinds of vegetables, i.e., pimento (*Capsicum annuum*), leaf lettuce, chingensai (a kind of Chinese cabbage, *Brassica pekinensis*), and carrot, from soil to which rapeseed cake (RC) or ammonium sulfate (AS) had been applied at the same N concentration, different N uptake responses were observed. Chingensai and carrot took up more N from the soil with applied RC than with applied AS. On the other hand, pimento and leaf lettuce grew better on the soil with applied AS than on that with applied RC. In xylem sap of chingensai grown in the soil with applied RC, a peak similar to the protein-like N compound in soil was detected on the HPLC chromatogram. Further, when chingensai, carrot, and pimento were cultivated in an N-free medium under aseptic conditions, the N uptake of chingensai and carrot increased with the addition of protein like N compound extracted from the soil. These results strongly suggest that the superior N uptake response after application of organic material by chingensai and carrot may be related to the direct uptake of organic N from the soil.

Salomez *et al.* (2001) carried out a Greenhouse studies during 1999-2000 at 8 farms in the province of West Flanders, Belgium, to monitor growth and N uptake of lettuce. Data are presented on current guideline for N fertilizer (180-N< sub>min</ sub> at 0-30 cm depth), and an adapted guideline (taking into account cultivation period and mineralization).

Simonne *et al.* (2001) carried out an experiment while nitrogen (N) form affects growth and yield of many vegetables crops, previous studies suggested that N-form may affect lettuce (*Lactuca sativa*) quality more than growth and yield. The objectives of this research (conducted in the spring of 1997, in Alabama, USA) were to evaluate the effect of the N-source used as injection material on the field performance and sensory attributes of three lettuce types. Three lettuce types, Romaine ('Parris Island'), butterhead ('Optima') and looseleaf ('Sierra'), where grown with plasticulture and sidedressed with weekly injections of calcium nitrate, potassium nitrate, or ammonium nitrate, each at a rate of 7 kg N $ha^{-1}$ $week^{-1}$. All lettuce type reached marketable size 49 days after transplanting. N-source effect on marketable yield and head number was not significant ($P>0.05$). After harvest, lettuce samples were prepared for sensory evaluation. In a quiet session, panelists (n=36) were instructed to rate each sample for bitterness, sweetness, crunchiness, and overall preference on a 9-cm Hedonic scale. Sensory ratings were similar for all three lettuce types. Panelist found that crunchiness of calcium nitrate-fed plants (4.8 cm) was significantly ($P=0.05$) higher than that of plants receiving potassium nitrate (4.4 cm) or ammonium nitrate (4.2 cm). These results suggest that while growers may use ammonium nitrate because of its cost, they should consider using calcium nitrate to enhance lettuce crunchiness.

Giletto *et al.* (2000) studied on physiological effects of high rates of N fertilizer on vegetables (including lettuce, broccoli and spinach) are discussed, and the relationships between N fertilizer, N uptake and nutritive value are described. Water pollution problems related to leaching of N fertilizers in the Mar del Plata region, Argentina, are briefly outlined.

Pascale *et al.* (2004) carried out a study on problems of growing lettuce organically, while meeting the requirements for EEC regulations 194/97 and 864/99 concerning permissible nitrate levels, are discussed in 1999 in Italy with lettuce (cultivars Ilona and Batavia), grown in tunnels. N fertilizer was applied at rates of 0, 100, 200 and 300 kg/ha, using fertigation. The highest rate increased yields by 55% (compared to the unfertilized control) and also increased water content. Nitrate levels in leaves varied during the year and were highest in lettuce grown in autumn and winter. Nitrate levels were higher in cv. Batavia than in cv. Ilona. Foliar nutrition combined with cattle slurry reduced nitrate levels, perhaps due to the rapid incorporation of amino acids into proteins (thus enabling the plant to make better use of N). Nitrate levels did not exceed permitted levels. Increasing application rates decreased the level of ascorbic acid and enhanced the level of oxalic acid.

Topcuoglu and Yalcin (1997) carried out an experiment with application of different types of nitrogen fertilizers into greenhouse soil gave variable effects on yield, and nitrate, organic fixed nitrogen, P, K, Ca and Mg contents in curly lettuce. The highest yield was obtained by urea application. In tissues of curly lettuce, relatively lower nitrate content was obtained by ammonium sulphate and amino acid nitrogen mixed liquid fertilizer applications, and higher nitrate content was obtained by calcium nitrate, ammonium chloride and urea applications. Nitrate, organic fixed nitrogen, P, K, Ca and Mg contents differed between green leaf and midrib tissues. Generally, midrib tissue has higher contents of nitrate, K and Ca while green leaf tissue has higher contents of organic fixed nitrogen, P and Mg.

Santamaria *et al.* (2000) conducted an experiment with two trials aimed at evaluating yield and nitrate content of 6 lettuce (*Lactuca sativa*) cultivars and to study the possibility of decreasing nitrate content in heads by changing nutrient solution composition near harvest, are reported. Plants were grown in a greenhouse with a soilless system (subirrigated gully). In both trials the cultivars were Alisia and Jessica (botanical variety: longifolia), Tibet and Mindoro (bot. var.: capitata), and Estilia and Carminia (bot. var.: crispa). In the second trial, the nutrient solution was changed a few days before harvest to (i) a solution with N supplied mainly as nitrate (NH< sub>4</ sub>-NO< sub>3</ sub> ratio: 20:80); (ii) a solution with N supplied mainly as ammonium (NH< sub>4</ sub>:NO< sub>3</ sub> ratio: 80:20) and (iii) only water. Yields and dry matter contents were higher in longifolia cultivars than in capitata and crispa cultivars. Nitrate content variability among cultivars was low. It was lower (<2 000 mg/kg fresh mass) than EU limits (EU Regulation n. 864/99). By changing the nutrient solution (NH< sub>4</ sub>:NO< sub>3</ sub> ratio: 20:80) 2 days before harvest to water alone or 4 days before harvest to a solution with more ammoniacal N (NH< sub>4</ sub>:NO< sub>3</ sub>: 80:20), leaf nitrate content was reduced only in longifolia cultivars.

Tei *et al.* (2000) studied in a field trial at Perugia, Italy, in 1996 Fresh and dry matter production and nitrogen uptake during growth of 2 lettuce cultivars, Audran (butterhead lettuce) and Canasta (loose leaf lettuce) involving different rates of fertilizer-N (0, 50, 100 and 200 kg N ha$^{-1}$), which were broadcast at transplanting. Both cultivars were transplanted in the field on 1 June. Plant samples were harvested weekly from 24 days after transplanting (DAT) to final harvest (52 DAT). On a dry matter basis, the relative growth rate was not strictly related to reduced-N concentration (total-N minus nitrate-N), while on a fresh weight basis, there was a linear relationship which was cultivar-specific and independent of fertilizer-N rates. This was mainly due to the effect of N availability on nitrate accumulation which has an osmotic effect on plant water content. Apparent fertilizer-N recovery declined linearly with the increase in fertilizer-N rates for both cultivars. The estimated fertilizer-N rate to obtain maximum fresh and dry weights was about 155 kg N ha$^{-1}$ for both cultivars. At that rate, the estimated N uptake was about 145 kg ha$^{-1}$ for Canasta and 131 kg ha$^{-1}$ for Audran. Considering that the N uptake with 0 kg ha$^{-1}$ of fertilizer-N was 63 kg ha$^{-1}$ for Audran and 58 kg ha$^{-1}$ for Canasta, about 80 kg ha$^{-1}$ of mineral nitrogen remained in the soil at harvest.

Staugaitis and Viskelis (2000) investigated the effect of N rates and mineral N in soil on yield and quality of head lettuce cultivated in May-October at the Lithuanian Institute of Horticulture in 1996-1998. Based on average data from 3 years and cultivation periods it was established that the highest yield and plant weight of iceberg-type lettuce were obtained by applying 135 kg N/ha. N fertilizers did not affect the contents of sugar, vitamin C and soluble solids in head lettuce, but they increased the amounts of nitrate and dry matter. The lowest levels of nitrates and dry matter were found in lettuce cultivated without N. N fertilizers increased N and reduced K content in lettuce, but had no effect on P, Ca and Mg. When 135 kg N/ha was applied the amount of N assimilated by plants was equal to that introduced by mineral fertilizers. Two thirds of the N is consumed for head production and one third for the outer leaves, which after harvesting remain in the field with other plant residues. The optimal sum of N< sub>min</ sub> and N< sub>fertilizers</ sub> for head lettuce before transplanting was 240 kg/ha, when soil samples for analysis were collected from the 0-30 cm layer, and 300 kg/ha when collected from the 0-60 cm layer.

Silva *et al.* (2000) evaluated the nutritional efficiency of nitrogen in 17 cultivars of lettuce, aiming to identify the nitrogen dose and the most adapted character for genetic studies, as well as to classify them for efficiency. The experiment was carried out in a greenhouse in polyethylene pots containing 4.5 dmsuperscript 3 of substratum (a part of sand and two of soil), in which four doses of N were used (25, 75, 125 and 200 mg N/dmsuperscript 3) in a randomized complete-block experiment with three replications. There was a genetic variability among the cultivars in the study. The doses of 75 and 125 mg N/dmsuperscript 3 were the most indicated for genetic studies. The dry and fresh matters of the aerial part were the most important characters to discriminate the cultivars as to its nutritional efficiency for N. 'Vitoria de Verao' was considered efficient for the 75 and 125 mg N/dmsuperscript 3 doses; 'Nativa' for the 75 mg N/dmsuperscript 3 dose; and 'Regina de Verao' for the 125 mg N/dmsuperscript 3 dose. Cultivars 'Grandes Lagos', 'Maravilha de Verao' and 'Grand Rapids' were inefficient for both doses.

Broadley *et al.* (2000) measured relationships between nitrogen (N) content and growth are routinely in plants. This study determined the effects of N on the separate morphological and physiological components of plant growth, to assess how N-limited growth is effected through these components. Lettuce (*Lactuca sativa*) plants were grown hydroponically under contrasting N-supply regimes, with the external N supply either maintained continuously throughout the period of study, or withdrawn for up to 14 d. Richards' growth functions, selected using an objective curve-fitting technique, accounted for 99.0 and 99.1% of the variation in plant dry weight for control and N-limited plants respectively. Sublinear relationships occurred between N and relative growth rates under restricted N-supply conditions, consistent with previous observations. There were effects of treatment on morphological and physiological components of growth. Leaf weight ratio increased over time in control plants and decreased in N-limited plants. Shoot: root ratio followed a similar pattern. On a whole-plant basis, assimilation of carbon decreased in N-limited plants, a response paralleled by differences in stomatal conductance between treatments. Changes in C assimilation, expressed as a function of stomatal conductance to water vapour, suggest that the effects of N limitation on growth did not result directly from a lack of photosynthetic enzymes. Relationships between plant N content and components of growth will depend on the availability of different N pools for remobilization and use within the plant.

Seginer *et al.* (1999) studied that limiting the supply of nitrate to winter lettuce in greenhouses ensures low nitrate levels in the marketed produce. To optimize growth under such conditions, a 2-state-variable lettuce model, originally developed to predict the nitrate concentration when the supply of nutrients is unlimited, was modified to take account of growth limited by nitrate supply. Plants respond to limited nitrate supply by replacing nitrate in the cell sap by assimilates (sugar), freeing the recovered nitrate for protein synthesis. The modified model included a balance equation for nitrate in the plant dS< sub>Nv</ sub>/dt=F< sub>Nrv</ sub>-rF< sub>Cvs</ sub>, where S< sub>Nv</ sub> is nitrate-N content, F< sub>Nrv</ sub> is nitrate-N uptake by the plant, F< sub>Cvs</ sub> is the rate of structural growth and r is the nitrogen content of the structural material. dS< sub>Nv</ sub>/dt is determined by the rate of change of the assimilate content of the cell sap, as described by the original model. If nitrate supply is abundant, its rate of uptake, namely F< sub>Nrv</ sub>, is determined as a remainder. If nitrate supply is limiting, and therefore is all taken up by the plant, it is the nitrate used for growth, rF< sub>Cvs</ sub>, that is determined by the balance. Comparison with limited experimental results produced a good agreement.

Demirer *et al.* (1999) conducted a field experiments with ammonium nitrate, ammonium sulfate, calcium ammonium nitrate and urea were applied (as fertilizers) at the rates of 50, 100, 150 or 200 kg N $ha^{-1}$, respectively, to a crop of lettuce cv. Colona. The highest yield and the lowest nitrate content were obtained with ammonium sulfate.

Nadasy (1999)  set up an experiments in 1995 and 1996 using lettuce cv. Balaton zold in pots containing 1 kg dry eroded brown forest soil with clay illuviation (0-20 cm layer) under greenhouse conditions. N was applied as NO< sub>3</ sub>-N, NH< sub>4</ sub>-N or both at a ratio of 1:1 using calcium nitrate (7.6% N), ammonium sulfate (20.2% N) and ammonium nitrate (34.7% N). N rates were 0, 40, 80, 160, 320 and 640 mg N/kg soil. Plants were harvested after 6 weeks. Leaf fresh weight was highest with 80 or 160 mg/kg N. The greatest dry matter production was found at 80 mg/kg N. The fresh and dry weights were lower after the application of calcium nitrate. Applying N in the ammonium form produced similar results to applying both nitrate and ammonium forms. Dry matter production was greatest when both N forms were applied. Increasing N rates up to 320 mg/kg gradually raised the N content of the lettuce leaves. Leaf N contents were highest when calcium nitrate was applied. The permissible nitrate concentration limit in lettuce in summer is 3500 mg NO< sub>3</ sub> per kg fresh weight in many countries. The nitrate content averaged over the 80 mg/kg N treatments was less than this.

## 2.2 Effect of spacing

Sharma *et al.* (2001) tested with twenty-four treatment combinations of six transplanting dates in lettuce cv. Alamo-1 viz., 1st Aug., 16th Aug., 1st Sept., 16th Sept., 1st Oct. and 16th October and four spacing levels viz., 30×30 cm, 45×30 cm, 45×45 cm and 60×45 cm and evaluated in a split plot design with three replications. Too early/late transplanting resulted in decreased yield and other horticultural traits. The maximum yield of 241.3 q/ha was obtained when the transplanting was done on 1st September followed by 226.5 q/ha on l6th September. In this case the plants also took less number of days to 50% maturity. The widest spacing of 60×45 cm gave the maximum fresh weight and dry weight perplant (yield/plant) but lowest per hectare. The closest spacing of 30×30 cm recorded minimum yield/plant, which did not compensate optimum yield per hectare. A plant spacing of 45×30 cm was found best for getting optimum yield per plant as well as per hectare. On the basis of overall effect of dates of planting and plant spacing on yield and its attributes, the planting date of 1st September and plant spacing of 45x30 cm proved to be the most promising for getting optimum yield in lettuce cv. Alamo-1 under Kullu valley conditions of Himachal Pradesh.

Echer *et al.* (2001) evaluated the performance of 5 lettuce cultivars (Brisa, Grande Rapida, Marisa, Vera and Veronica) in 2 spacing treatments (0.20 x 0.25 m and 0.25 x 0.25 m) from September to December 1998 in Sao Paulo, Brazil. The following parameters were evaluated: fresh matter of aerial parts per plant; number of leaves per plant; leaf fresh matter per plant; average fresh matter of one leaf; relationship between leaf fresh matter per plant and fresh matter of aerial parts per plant; and average total production per area. No significant interaction between cultivar and spacings were found. The cultivars with the best performances were Vera, Marisa and Brisa. In the small spacing (0.20 x 0.25 m) treatment, there was higher production area per plant within commercial standards than in the large spacing (0.25 x 0.25 m). A higher correlation between leaf fresh matter and fresh matter of aerial parts was observed in Vera compared to other cultivars.

Silva *et al.* (2000) carried out an experiment with lettuce cv. Great Lakes, Elisa and Baba de Verao, the effects of different plant spacings (20 x 20, 25 or 30 cm, 25 x 25 cm, 25 x 30 cm or 30 x 30 cm) on leaf yield under high temperature and ample sunlight conditions. An additional treatment of cv. Great Lakes at 20 x 20 cm under constant shading was also studied. Plant height and diameter, leaf number per plant, shoot dry matter content, leaf yield, gross and net incomes and rate of return were studied. Cv. Great Lakes had the greatest leaf yield and economic indices. Leaf yield, shoot dry matter and economic indices were greatest at a spacing of 20 x 20 cm. Leaf number per plant was highest in cv. Elisa and was unaffected by spacing.

A field experiment was conducted by Moniruzzaman (2006) with three levels of spacing (40 × 20 cm, 40 × 30 cm and 40 × 40 cm) and two levels of mulching (mulch and non-mulch) to find out the effect of plant spacing and mulching on yield and profitability of lettuce cv. ‘Green Wave’ at the Agricultural Research Station, Raikhali. Rangamati Hill District for the two consecutive years during 1999-'00 and 2000-'01. Plant spacing, mulching and their interaction showed significant effect on yield and yield components of lettuce. The highest fresh yield of lettuce was obtained from the closest spacing (40 × 20 cm) that was statistically similar to that recorded of medium spacing (40 × 30 cm) during both the years. The highest yield (25.9 t/ha in 1999-'00 and 28.3 t/ha in 2000-'01 with an average of 27.10 t/ha) was observed in the spacing of 40 × 20 cm with mulch, which was statistically at par with the spacing of 40 × 30 cm with mulch. The results also revealed that higher Gross Return (Tk. 216,800.00) was obtained from the closest spacing in combination with mulch followed by medium spacing (40 × 30 cm) with mulch (Tk. 210,160.00). The treatment combination of 40 × 30 cm spacing and mulching gave the highest benefit cost ratio (8.84). But the benefit cost ratio (4.22) from the treatment combination of 40 × 20 cm spacing and mulching was less due to the involvement of higher seedling cost.

The effects of spacing, hoeing and mulching on the yield and quality of lettuces under integrated control were determined by Petrikova and Pokluda (2004). Marketable lettuce yields reached 82-99%. Planting density, cultivar and mulching affected the quality of lettuce heads. The quality of lettuce heads were determined by the cultivar, as well as by mulching and hand hoeing. The size of lettuce heads were positively correlated with loose spacing.

A field experiment was carried out by Sodkowski and Rekowska (2003) in Szczecin, Poland during 1998-2000 to study the effects of cultivation method and mulching. The spacing between plants was 25 × 30 cm. The cultivation period was reduced by 8 days on average in the case of direct sowing, and by 3 days in plants cultivated from seedlings produced in the seedbed and the highest yield (6.50 $kg/m^2$) of crisp lettuce was obtained with this treatment.

Steingrobe and Schenk (1994) reported that seeds of lettuce cv. 'Clarion' were sown in 4 × 4 cm peat blocks and seedlings were planted out 3 weeks later at a spacing of 30 x 30 cm. Seedlings received different amounts of N fertilizer before and after planting. They found that N application increased root growth in the first 3 weeks after planting out, but had no effect on yield.

EL-Hassan, (1990) had grown lettuce cv. 'Dark Green' lettuce on experimental plot in Cairo in the winter seasons of 1987 and 1988. The effects of various planting systems and application of 20 or 40 kg N/feddan (1 feddan = 0.42 ha) on head weight, dry matter content and N content were recorded. The higher N rate and wide spacing (30 cm) gave greater head weight, % dry matter, total N (%) in dry matter and $NO_3$-N content in fresh leaf midribs. The highest total and saleable yields and the highest total dry matter content were achieved with the higher N rate, spacing at 10 cm and planting on both sides of the planting ridges.

## 2.3 Interaction effect of nitrogen and spacing

Stone (2000) conducted a field experiments where there is a need to develop sustainable nitrogen (N) management systems that minimize environmental losses by maximizing the use of efficiency of applied fertilizers, particularly with wide-row annual crops that are often poor at utilizing N. A key approach is to match nitrogen supply with crop demand using improved methods of fertilizer application and timing. One technique is to target liquid starter fertilizers close to the seed, or around the roots of transplants, and to omit or reduce conventional broadcast applications. This paper examines the effects of starter fertilizer combined with various rates of seedbed and/or top-dressed N on the growth and yield of bulb onion (*Allium cepa*), crisp lettuce (*Lactuca sativa*), forage maize (*Zea mays*) and sugarbeet (*Beta vulgaris*) at a site in the UK. Starter fertilizer improved early growth and, in combination with reduced rates of supplementary N, gave yields comparable with higher rates of base N with each crop, except sugarbeet. The use of top-dressed N was as effective as base N in supplementing starter fertilizer and had the benefit that it allowed a top-dressing requirement to be estimated accurately using a simple nitrogen balance equation. These results, taken with earlier work, show that starter fertilizers offer clear opportunities for reducing N inputs, while maintaining yield and quality of these crops.

Abu-Rayyan *et al.* (2004) conducted a field study at two locations (Jordan valley and Al-Jubeiha) with different rainfall levels, altitudes and temperature ranges. The study was established to evaluate the optimum planting density, nitrogen (N) form and irrigation level to attain the best quality of lettuce crop in terms of minimum nitrate (NO< sub>3</ sub>) content and to minimize the impact on the environment. Seeds of 'Amar' lettuce were sown 1 month before transplanting. Three forms of N fertiliser (Ca(NO< sub>3</ sub>)< sub>2</ sub>, (NH< sub>4</ sub>)< sub>2</ sub>SO< sub>4</ sub> and CO(NH< sub>2</ sub>)< sub>2</ sub>) were applied at three times at a total rate of 100 kg N ha$^{-1}$. Three in-row spacings (15, 20 and 25 cm) were assigned. Two irrigation levels were applied: level 1 had twice the amount of irrigation water as level 2, which was achieved by doubling the number of irrigation lines. The results indicated that N form significantly increased both N and NO< sub>3</ sub> contents. Ca(NO< sub>3</ sub>)< sub>2</ sub> was the most effective in increasing the N and NO< sub>3</ sub> contents in lettuce leaf tissues, followed by CO(NH< sub>2</ sub>)< sub>2</ sub> and then (NH< sub>4</ sub>)< sub>2</ sub>SO< sub>4</ sub>. The outer leaves (green colour) had about five times the NO< sub>3</ sub> content of the inner leaves (pale yellow colour). However, the effect of N form on production, total N absorption and N recovery was significant in the following order: (NH< sub>4</ sub>)< sub>2</ sub>SO< sub>4</ sub> > Ca(NO< sub>3</ sub>)< sub>2</ sub> > CO(NH< sub>2</ sub>)< sub>2</ sub>. Increasing the plant spacing resulted in a significant increase in N and NO< sub>3</ sub> contents in the lettuce leaves.

Abu-Rayyan *et al.* (2004) conducted a field study in Jordan Valley and Al-Jubeiha, Jordan, during 2000/2001 to study the optimum planting density, form of nitrogen and irrigation regime for lettuce cv. Amar. Seeds were sown one month before transplanting. A total of 100 kg pure N/ha was applied in the form of Ca(NO< sub>3</ sub>)< sub>2</ sub>, (NH< sub>4</ sub>)< sub>2</ sub>SO< sub>4</ sub>, and CO(NH< sub>2</ sub>)< sub>2</ sub>. The N fertilizer was applied at 3 different times during plant development (25 kg N/ha applied at 3 weeks after transplanting, 25 kg N/ha applied at 5 weeks after transplanting, and 50 kg N/ha applied at 7 weeks after transplanting), and in-row spacing of 15, 20 and 25 cm were used. Two irrigation regimes were evaluated in the trials, i.e. regime 1 (~40 litre m-2 week-1, which was higher by two-fold than the amount of irrigation supplied under regime 2) and regime 2. At harvesting, the vertical and horizontal diameters of the head, number of leaves, leaf area, fresh and dry weights of head, and total fresh yield were determined. The effect of N form on production and vegetative parameters of lettuce head (vertical and horizontal diameter, number of leaves, leaf area, and fresh and dry weights) followed the order (NH< sub>4</ sub>)< sub>2</ sub>SO< sub>4</ sub> > Ca(NO< sub>3</ sub>)< sub>2</ sub> > CO(NH< sub>2</ sub>)< sub>2</ sub>. Plant spacing also had a highly significant ($p<0.01$) effect on vegetative and yield components, but a spacing of 20 cm apart generally showed the highest values, followed by 25 cm then 15 cm. Regarding the effect of irrigation regime on vegetative and yield components, the amount of irrigation water had induced significant differences among the values of these parameters. The plants irrigated under regime 1 exhibited greater growth response than those irrigated under regime 2. Lettuce showed the best response under (NH< sub>4</ sub>)< sub>2</ sub>SO< sub>4</ sub> + 20 cm spacing + 1 irrigation under regime 1.

Tittonell *et al.* (2001) studied the effects of N fertilizer application (0, 75 and 150 kg/ha) and crop density (33 and 50 plants/$m^2$) on the postharvest quality of lettuce cv. Grand Rapids. Crops grown at high density were not significantly affected by N treatment. On the other hand, crops at low density showed higher yields when treated with 0 and 75 kg N/ha. However, the yield was not significantly affected by the application of 150 kg N/ha. N application decreased the dry matter but increased the nitrate N contents of the upper biomass of lettuce.

Stone (2000) studied that there is a need to develop sustainable nitrogen (N) management systems that minimize environmental losses by maximizing the use of efficiency of applied fertilizers, particularly with wide-row annual crops that are often poor at utilizing N. A key approach is to match nitrogen supply with crop demand using improved methods of fertilizer application and timing. One technique is to target liquid starter fertilizers close to the seed, or around the roots of transplants, and to omit or reduce conventional broadcast applications. This paper examines the effects of starter fertilizer combined with various rates of seedbed and/or top-dressed N on the growth and yield of bulb onion (*Allium cepa*), crisp lettuce (*Lactuca sativa*), forage maize (*Zea mays*) and sugarbeet (*Beta vulgaris*) at a site in the UK. Starter fertilizer improved early growth and, in combination with reduced rates of supplementary N, gave yields comparable with higher rates of base N with each crop, except sugarbeet. The use of top-dressed N was as effective as base N in supplementing starter fertilizer and had the benefit that it allowed a top-dressing requirement to be estimated accurately using a simple nitrogen balance equation. These results, taken with earlier work, show that starter fertilizers offer clear opportunities for reducing N inputs, while maintaining yield and quality of these crops.

# CHAPTER III

# Materials and methods

The experiment was conducted in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2009 to January 2010. The materials and methods that were used for conducting the experiment are presented under the following headings:

## 3.1 Experimental Site

The present experiment was carried out in the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^0 74^/$N latitude and $90^0 35^/$E longitude and at an elevation of 8.2 m from sea level (Anon., 1989).

## 3.2 Climate

The climate of experimental site was under the subtropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix I.

## 3.3 Characteristics of Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28. It had shallow red brown terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka and details of the recorded soil characteristics were presented in Appendix II.

## 3.4 Planting Materials

Seeds of lettuce cultivar, 'Grand Raphids' were used in the experiment and the seeds were collected from a commercial seed trader named Manik Seed Traders, Siddique Bazar, Dhaka.

### 3.5 Treatments of the experiment

The experiment was conducted to find out the effects of nitrogen and plant spacing in lettuce. The experiment consisted of two factors.

**Factor A: Nitrogen (4 levels)**

i. $N_0$: 0 kg/ha (Control)
ii. $N_1$: 50 kg/ha
iii. $N_2$: 100 kg/ha
iv. $N_3$: 150 kg/ha

**Factor B: Plant spacing (3 levels)**

i. $S_1$: 40 cm × 20 cm
ii. $S_2$: 40 cm × 25 cm
iii. $S_3$: 40 cm × 30 cm

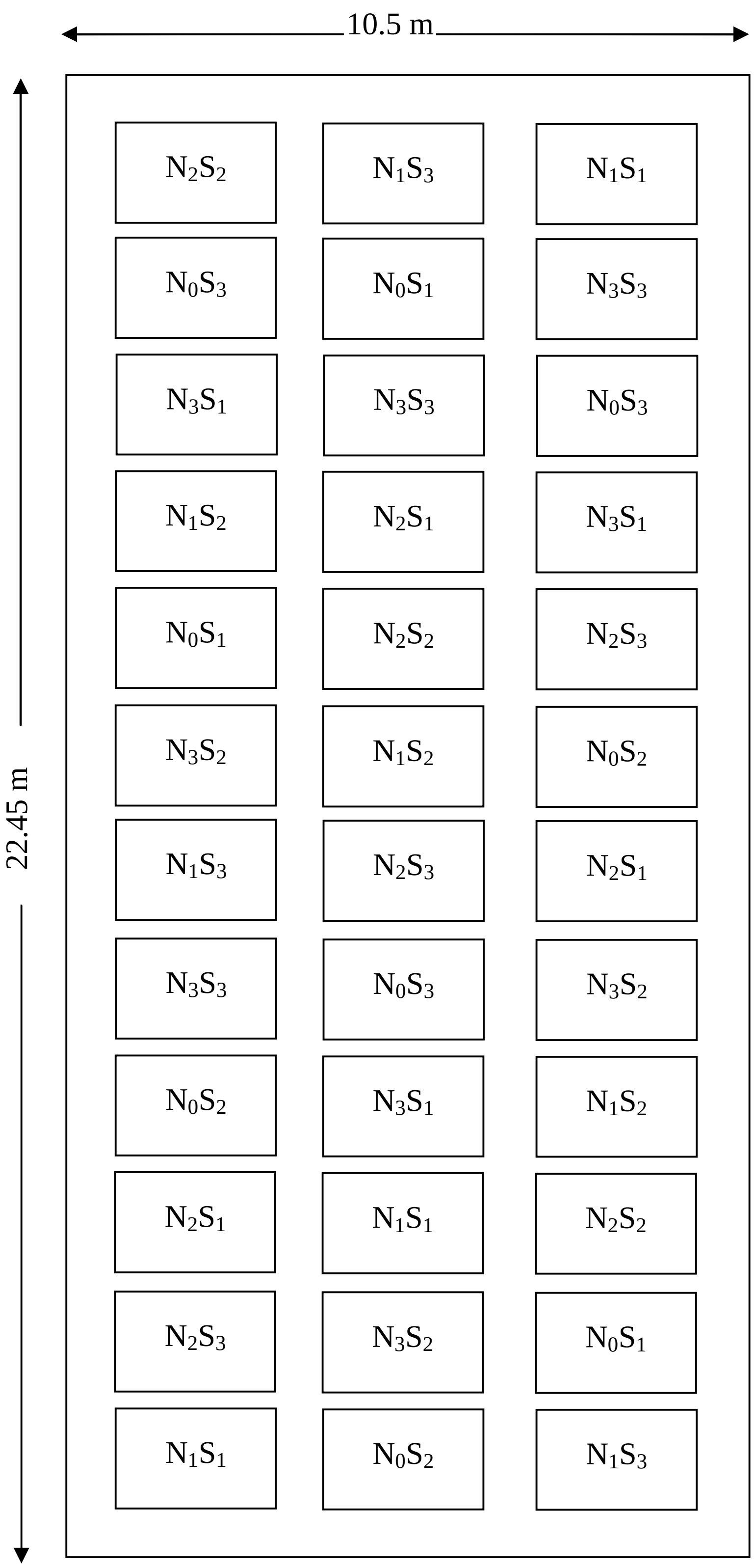
There were 12 treatment combinations such as $N_0S_1$, $N_0S_2$, $N_0S_3$, $N_1S_1$, $N_1S_2$, $N_1S_3$, $N_2S_1$, $N_2S_2$, $N_2S_3$, $N_3S_1$, $N_3S_2$ and $N_3S_3$.

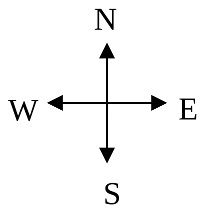
### 3.7 Raising of seedlings

The seedlings were raised at the Sher-e-Bangla Agricultural University farm, Dhaka under special care in a 3 m × 1 m size seed bed. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crops were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease cupravit fungicide was applied. Decomposed cowdung was applied to the prepared seedbed at the rate of 10 t/ha. Lettuce seed were soaked in water for 48 hours and then seeds were mixed with soil and sown in seed bed. Ten (10) grams of seeds of the lettuce variety ‘Grand Raphids’ were sown in each seedbed at ‘October 2009’.

### 3.6 Experimental design and layout

The two factors experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. An area of 22.45 m × 10.5 m was divided into three equal blocks. Each block was divided into 12 plots where 12 treatment combinations were allotted at random. There were 36 unit plots and the size of the each unit plot was 3.0 m × 1.6 m. The distance maintained between two blocks and two plots were 0.5 m and 0.25 m, respectively. The seedlings were planted with maintaining distance row to row 40 cm and plant to plant 20 cm, 25 cm and 30 cm as per plant spacing treatment. The layout of the experiment is shown in Figure 1.




Plot size: 3.0 m × 1.6 m
Plot spacing: 25 cm
Between replication: 50 cm

**Factor A: Nitrogen**

$N_0$: 0 kg/ha (control)

$N_1$: 50 kg/ha

$N_2$: 100 kg/ha

$N_3$: 150 kg/ha

**Factor B: Plant Spacing**

$S_1$: 40 cm × 20 cm

$S_2$: 40 cm × 25 cm

**Fig 1: Layout of the Experiment.**

### 3.8 Preparation of the main field

The selected experimental field was opened on 22 October 2009 with a power tiller and was exposed to the sun for a week. After 2 days 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 planting of lettuce seedlings. The experimental field was partitioned into the unit plots in accordance with the experimental design and nitrogen was applied as per treatments to each unit plot. The soil was treated with fungicide cupravit against the fungal attack.

### 3.9 Application of manure and fertilizers

The sources of N, $P_2O_5$, $K_2O$ were urea, TSP and MP, applied respectively. The entire amounts of TSP and MP were applied during the final land preparation. Urea was applied in three equal installments at 15, 30 and 45 days after seedling transplanting as per treatments. Well-rotten cowdung at 20 t/ha also applied during final land preparation. The following amount of manures and fertilizers were used which shown in tabular form as recommended by Rashid (1993).

**Table 1. Dose and method of application of fertilizers in lettuce field**

| Fertilizers | Dose | Application (%) | | | |
|---|---|---|---|---|---|
| | | Basal | 15 DAT | 30 DAT | 45 DAT |
| Cowdung | 20 tons | 100 | -- | -- | -- |
| Nitrogen | As per treatment | | | | |
| $P_2O_5$ | 60 kg/ha | 100 | -- | -- | -- |
| $K_2O$ | 200 kg/ha | 100 | -- | -- | -- |

### 3.10 Transplanting of seedlings in the main field

Healthy and uniform sized seedlings were transplanted in the main field on 19th November 2009. The seedlings were uprooted carefully from the seedbed to avoid any damage to the root system. To minimize the root damage of the seedlings, the seedbed was watered one hour before uprooting of the seedlings. Transplanting was done in the afternoon. A considerable number of seedlings were also planted in the border of the experimental plots for gap filling.

### 3.11 Intercultural operations

When the seedlings established in the beds it was always kept under careful observation. Various intercultural operations viz. irrigation and drainage, gap filling, weeding, top dressing were accomplished for better growth and development of lettuce seedlings.

#### 3.11.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after transplanting and at every alternate day in the evening upto 1$^{st}$ harvest. Further irrigation was done and when needed. Stagnant water was effectively drained out at the time of excess irrigation.

#### 3.11.2 Gap filling

Gap filling was done after 6 days of transplanting from border side transplanted plant.

#### 3.11.3 Weeding

Weeding was done to keep the plots free from weeds, easy aeration of soil, which ultimately ensured better growth and development. Mulching of the soil was done when needed.

#### 3.11.4 Top Dressing

Urea was top-dressed in 3 equal installments as per treatments. The fertilizers were applied on both sides of plant rows and mixed well with the soil by hand. Earthing up was done with the help of Nirani immediately after top-dressing of nitrogen fertilizer.

### 3.12 Plant Protection

For controlling leaf caterpillars Nogos @ 1 ml/L water was applied two times at an interval of 10 days starting soon after the appearance of infestation. No remarkable attack of disease was found in lettuce field under study.

### 3.13 Harvesting

To evaluate yield, four harvestings were done at different growth stage. First harvesting was done at 30 days after transplanting. Second, third and forth harvesting were done 40, 50 and 60 days after transplanting, respectively. Different yield contributing characters were recorded from the mean of five harvested plants which was selected from each of the specific unit plot of every harvesting stage.

### 3.14 Data collection

Data were recorded on the following parameters from the sample plants during the course of experiment. Five plants were selected from each of the unit plot for the collection of data. The plants in the outer rows and the extreme end of the middle rows were excluded from the random selection to avoid the border effect.

#### 3.14.1 Plant height

The height of plant was recorded in centimeter (cm) at 30, 40, 50 and 60 days after transplanting (DAT) in the experimental plots. The height was measured from the attachment of the ground level up to the tip of the growing point.

#### 3.14.2 Number of leaves per plant

The total number of leaves per plant was counted. Data were recorded as the average of five plants selected at random from the inner rows of each plot starting from 30 to 60 DAT at 10 days interval.

### 3.14.3 Length of leaf

The length of leaf was measured by using a meter scale. The measurement was taken from base to tip of the leaf. Average length of leaves was taken from five selected plants from inner rows of each specific plot. Data were recorded from 30 to 60 DAT at 10 days interval. Mean was expressed in centimeter (cm).

### 3.14.4 Breadth of leaf

Breadth of leaf was recorded as the average of five leaves selected at random from the plant of inner rows of each plot starting from 30 to 60 DAT at 10 days interval. Thus mean was recorded and expressed in centimeter (cm).

### 3.14.5 Yield of leaves per plant

Leaves of five randomly selected plants were detached by a sharp knife and fresh weight of leaves was recorded and expressed in gram. Data were recorded as the average of 5 randomly selected plants of inner rows of each plot starting from 30 to 60 DAT at 10 days interval.

### 3.14.6 Dry weight/plant

After harvesting selected plants were put into envelop and placed in oven and dried at $60^0$C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken. Average weight was measured in gram and expressed as dry weight per plant.

### 3.14.7 Yield per plot

Yield of lettuce per plot was recorded as the whole plant in every harvest within a plot (3.0 m × 1.6 m) and was expressed in kilogram. Yield included weight leaves at different harvested time.

### 3.14.8 Yield per hectare

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

### 3.15 Statistical Analysis

The data obtained for different parameters were statistically analyzed to find out the significance difference of nitrogen fertilization and plant spacing on yield and yield contributing characters of lettuce. The mean values of all the characters were calculated 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).

### 3.16 Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of Nitrogen and plant spacing. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 13% in simple rate. Analysis were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

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

# CHAPTER IV

## Results and discussion

The experiment was carried out to find out the effect of nitrogen and plant spacing on growth and yield of lettuce. Data on different growth parameters and yield of lettuce plant was recorded and analyzed with MSTAT program. The results have been presented and discussed, and possible interpretations are given under the following headings:

### 4.1 Plant height

#### 4.1.1 Effect of nitrogen

Plant height of lettuce did not varied significantly between $N_1$, $N_2$ and $N_3$ level of nitrogen. But plant height varied significantly at 30, 40, 50 and 60 DAT (Table 2 and Appendix III). At all the growth stages, the tallest plant (16.94, 21.85, 26.36 and 30.0 cm at 30, 40, 50 and 60 DAT respectively) was recorded from $N_3$ (150 kg N/ha) which was statistically similar (21.3 cm) to $N_2$ (100 kg N/ha) at 40 DAT. Again, the shortest plant (10.36, 13.7, 18.42 and 21.89 cm at 30, 40, 50 and 60 DAT respectively) was observed from $N_0$ (0 kg N/ha). It was revealed that with the higher doses of nitrogen level, increase plant height was observed, where no nitrogen application showed lowest plant height at all growth stages. Nitrogen fertilizer ensured favorable condition for the elongation of lettuce plant with optimum vegetative growth and the ultimate results was the tallest plant. Similar results were observed by Tittonell *et al*. (2003), Rincon *et al*. (1998) and Boroujerdnia and Ansari (2007).

#### 4.1.2 Effect of spacing

Statistically significant variation on plant height of lettuce was shown due to different plant spacing at 30, 40, 50 and 60 DAT (Table 2 and Appendix III). At different days after transplanting (DAT) the tallest plant (16.73, 22.2, 26.55

and 30.46 cm at 30, 40, 50 and 60 DAT respectively) was recorded from $S_1$ (40 cm × 20 cm). On the other hand, the shortest plant (13.3, 16.71, 21.0 and 24.21 cm at 30, 40, 50 and 60 DAT respectively) was found from $S_3$ (40 cm × 30 cm). Results under the present experiment showed that closer spacing showed higher plant height where higher plant spacing showed lower plant height because of closer spacing plant compete for light which helps to elongate plant than the wider spacing. Moniruzzaman (2006) reported similar findings from the closest spacing.

### 4.1.3 Interaction effect of nitrogen and spacing

Significant variation was observed due to interaction effect of nitrogen and plant spacing in terms of plant height of lettuce at 30, 40, 50 and 60 DAT (Table 2 and Appendix III). The tallest plant (20.0, 26.21, 31.89 and 35.01cm at 30, 40, 50 and 60 DAT, respectively) was recorded from $N_3S_1$. The combination of $N_2S_1$ also showed higher plant height but significantly different from $N_3S_1$. The shortest plant (9.71, 11.89, 17.54 and 20.11 cm at 30, 40 and 50 DAT, respectively) was found from $N_0S_{3.}$ $N_0S_2$ which also showed lower plant height but significantly different from $N_0S_3$.

Table 2: Effect of nitrogen and plant spacing on plant height at different growth stages of lettuce crop

| Treatment | Plant height (cm) | | | |
|---|---|---|---|---|
| | 30 DAT | 40 DAT | 50 DAT | 60 DAT |
| ***Main effect of nitrogen*** | | | | |
| $N_0$ | 10.36 c | 13.79 c | 18.42 c | 21.98 d |
| $N_1$ | 16.46 b | 21.05 b | 25.59 b | 28.77 c |
| $N_2$ | 16.33 b | 21.30 ab | 25.23 b | 29.07 b |
| $N_3$ | 16.94 a | 21.85 a | 26.36 a | 30.00 a |
| ***Main effect of spacing*** | | | | |
| $S_1$ | 16.73 a | 22.20 a | 26.55 a | 30.46 a |
| $S_2$ | 15.05 b | 19.58 b | 24.15 b | 27.70 b |
| $S_3$ | 13.30 c | 16.71 c | 21.00 c | 24.21 c |
| ***Interaction effect of nitrogen and spacing*** | | | | |
| $N_0S_1$ | 11.11 h | 15.89 g | 19.11 gh | 23.11 hi |
| $N_0S_2$ | 10.26 i | 13.59 h | 18.61 hi | 22.71 i |
| $N_0S_3$ | 9.71 i | 11.89 i | 17.54 i | 20.11 j |
| $N_1S_1$ | 17.61 bc | 22.91 bc | 27.61 b | 31.44 bc |
| $N_1S_2$ | 16.12 de | 20.69 de | 25.04 de | 27.99 e |
| $N_1S_3$ | 15.66 e | 19.55 e | 24.11 e | 26.89 ef |
| $N_2S_1$ | 18.10 b | 23.80 b | 27.59 b | 32.24 b |
| $N_2S_2$ | 16.59 d | 21.79 cd | 25.96 cd | 29.60 d |
| $N_2S_3$ | 14.31 f | 18.31 f | 22.16 f | 25.39 fg |
| $N_3S_1$ | 20.09 a | 26.21 a | 31.89 a | 35.05 a |
| $N_3S_2$ | 17.21 c | 22.24 c | 27.00 bc | 30.51 cd |
| $N_3S_3$ | 13.51 g | 17.10 fg | 20.20 g | 24.44 gh |
| CV(%) | 7.46 | 8.93 | 6.44 | 7.81 |

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

### 4.2 Number of leaves/plant

#### 4.2.1 Effect of nitrogen

Significant variation was recorded for number of leaves/plant of lettuce with application of different levels of nitrogen at 30, 40, 50 and 60 DAT (Table 3 and Appendix IV). At 30, 40, 50 and 60 DAT the maximum number of leaves/plant was 17.45, 24.85, 29.25 and 27.2 respectively which was obtained from $N_3$ (150 kg N/ha) and the minimum number of leaves/plant (12.65, 17.23, 22.7 and 21.45 at 30, 40, 50 and 60 DAT respectively) was found from $N_0$ (0 kg N/ha). It was revealed that the higher doses of nitrogen level showed higher number of leaves/plant where no nitrogen application showed the lowest at all growth stages. Maximum number of leaves/plant was recorded for highest level of nitrogen because nitrogenous fertilizer ensures favorable condition for the growth of lettuce. Similar findings were observed by Tittonell *et al*. (2003), Rincon *et al*. (1998) and Boroujerdnia and Ansari (2007).

#### 4.2.2 Effect of spacing

No significant variation was found for number of leaves per plant between $S_2$ and $S_3$. But Due to different plant spacing, statistically significant variation was recorded for number of leaves per plant of lettuce at 30, 40, 50 and 60 DAT (Table 3 and Appendix IV). At different days after transplanting (DAT) the maximum number of leaves per plant (16.37, 23.14, 27.39 and 25.6 at 30, 40, 50 and 60 DAT respectively) was obtained from $S_2$ (40 cm × 25 cm) which was closely followed by $S_3$ (40 cm × 30 cm). At the same condition, the minimum number of leaves/plant (14.0, 19.68, 24.31 and 22.68 at 30, 40, 50 and 60 DAT respectively) was recorded from $S_1$ (40 cm × 20 cm). It was revealed that with the increases of spacing, number of leaves per plant also increased. Enough space for vertical and horizontal expansion in the optimum spacing that leads for production of maximum number of leaves per plant than the closer spacing. Steingrobe and Schenk (1994) also reported similar results earlier.

### 4.2.3 Interaction effect of nitrogen and spacing

Interaction effect of nitrogen and plant spacing showed significant difference among the treatments in terms of number of leaves per plant of lettuce at 30, 40, 50 and 60 DAT (Table 3 and Appendix IV). The maximum number of leaves/plant (19.16, 27.1, 31.77 and 29.71 at 30, 40, 50 and 60 DAT, respectively) was found from $N_3S_2$. The treatment combination of $N_3S_3$ also showed higher number of leaves/plant but significantly different from $N_3S_2$. Again, the minimum number of leaves/plant (11.54, 15.44, 21.34 and 20.51 at 30, 40, 50 and 60 DAT respectively) was attained from $P_0S_1$. It was revealed that optimum level of nitrogen and plant spacing ensured maximum number of leaves/plant.

Table 3: Effect of nitrogen and plant spacing on number of leaves/plant at different growth stages of lettuce crop

| Treatment | Number of leaves/plant | | | |
|---|---|---|---|---|
| | 30 DAT | 40 DAT | 50 DAT | 60 DAT |
| ***Main effect of nitrogen*** | | | | |
| $N_0$ | 12.65 d | 17.23 d | 22.70 d | 21.45 c |
| $N_1$ | 15.46 c | 22.26 c | 26.10 c | 24.32 b |
| $N_2$ | 16.44 b | 23.60 b | 27.33 b | 25.34 b |
| $N_3$ | 17.45 a | 24.85 a | 29.25 a | 27.20 a |
| ***Main effect of spacing*** | | | | |
| $S_1$ | 14.03 b | 19.68 b | 24.31 b | 22.68 b |
| $S_2$ | 16.37 a | 23.14 a | 27.39 a | 25.60 a |
| $S_3$ | 16.10 a | 23.13 a | 27.33 a | 25.45 a |
| ***Interaction effect of nitrogen and spacing*** | | | | |
| $N_0S_1$ | 11.54 g | 15.44 i | 21.34 j | 20.51 h |
| $N_0S_2$ | 13.00 f | 17.81 h | 23.04 i | 21.70 gh |
| $N_0S_3$ | 13.40 ef | 18.44 h | 23.70 hi | 22.14 g |
| $N_1S_1$ | 14.54 de | 19.94 g | 24.66 gh | 23.01 fg |
| $N_1S_2$ | 15.79 b-d | 23.04 de | 26.60 e | 24.80 de |
| $N_1S_3$ | 16.04 bc | 23.79 cd | 27.06 de | 25.15 de |
| $N_2S_1$ | 14.89 cd | 21.24 f | 25.15 fg | 23.11 fg |
| $N_2S_2$ | 16.46 b | 24.60 bc | 28.14 cd | 26.20 cd |
| $N_2S_3$ | 17.99 a | 24.96 bc | 28.70 bc | 26.71 bc |
| $N_3S_1$ | 15.14 b-d | 22.11 ef | 26.11 ef | 24.09 ef |
| $N_3S_2$ | 19.16 a | 27.10 a | 31.77 a | 29.71 a |
| $N_3S_3$ | 18.04 a | 25.34 b | 29.87 b | 27.80 b |
| CV(%) | 5.48 | 7.66 | 8.14 | 7.24 |

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

### 4.3 Leaf length

#### 4.3.1 Effect of nitrogen

Application of different levels of nitrogen showed statistically significant variation for leaf length of lettuce at different days after transplanting (Table 4 and Appendix V). At 30, 40, 50 and 60 DAT the highest leaf length was 13.0, 18.0, 22.41 and 25.28 cm respectively which was achieved from $N_3$ (150 kg N/ha). Again, the lowest leaf length (9.43, 10.63, 16.76 and 17.73 cm at 30, 40, 50 and 60 DAT respectively) was found from $N_0$ (0 kg N/ha). Results showed that higher doses of nitrogen cause higher leaf length. Optimum vegetative growth was occurred due to higher amount of nitrogen fertilizer that leads for the growth of lettuce and the ultimate results was the longest leaf. The results obtained earlier by Boroujerdnia and Ansari (2007) was similar with the present study.

#### 4.3.2 Effect of spacing

Leaf length of lettuce was not significantly varied between $S_2$ and $S_3$. But leaf length was significantly influenced due to different plant spacing at 30, 40, 50 and 60 DAT (Table 4 and Appendix V). The highest leaf length (12.44, 16.44, 21.13 and 23.67 cm at 30, 40, 50 and 60 DAT respectively) was observed from $S_3$ (40 cm × 30 cm) which was statistically identical with $S_2$ (40 cm × 25 cm) and the lowest leaf length (10.51, 12.88, 18.64 and 20.66 cm) was recorded from $S_1$ (40 cm × 20 cm). It was revealed that with the increases of spacing leaf length showed increasing trend. In case of closer spacing plant compete for light and with the time being leaf length decreases. Sodkowski and Rekowska (2003) reported longest leaf from closer spacing.

### 4.3.3 Interaction effect of nitrogen and spacing

Statistically significant variation was recorded due to interaction effect of nitrogen and plant spacing in terms of leaf length of lettuce at 30, 40, 50 and 60 DAT (Table 4 and Appendix V). The highest leaf length (13.89, 19.89, 23.79 and 27.00 cm at 30, 40, 50 and 60 DAT respectively) was found from $N_3S_2$. The similar result was also observed with $N_3S_3$ at 40 and 60 DAT. The lowest leaf length (8.94, 9.0, 15.19 and 16.0 cm at 30, 40, 50 and 60 DAT respectively) was obtained from $N_0S_1$. The treatment combination of $N_0S_2$ also showed lower leaf length but significantly different from $N_3S_2$ at 40, 50 and 60 DAT. Data revealed that optimum level of nitrogen and plant spacing ensured the highest leaf length with maximum vegetative growth.

Table 4: Effect of nitrogen and plant spacing on leaf length at different growth stages of lettuce crop

| Treatment | Leaf length (cm) | | | |
|---|---|---|---|---|
| | 30 DAT | 40 DAT | 50 DAT | 60 DAT |
| ***Main effect of nitrogen*** | | | | |
| $N_0$ | 9.43 d | 10.63 d | 16.76 d | 17.73 d |
| $N_1$ | 11.68 c | 15.32 c | 20.33 c | 22.95 c |
| $N_2$ | 12.38 b | 16.60 b | 21.33 b | 24.23 b |
| $N_3$ | 13.09 a | 18.03 a | 22.41 a | 25.28 a |
| ***Main effect of spacing*** | | | | |
| $S_1$ | 10.51 b | 12.88 b | 18.64 b | 20.66 b |
| $S_2$ | 11.99 a | 16.10 a | 20.87 a | 23.32 a |
| $S_3$ | 12.44 a | 16.44 a | 21.13 a | 23.67 a |
| ***Interaction effect of nitrogen and spacing*** | | | | |
| $N_0S_1$ | 8.94 g | 9.09 i | 15.19 j | 16.09 i |
| $N_0S_2$ | 9.15 g | 10.89 h | 17.10 i | 18.00 h |
| $N_0S_3$ | 10.20 f | 11.90 gh | 18.00 h | 19.11 g |
| $N_1S_1$ | 10.64 f | 13.15 fg | 18.96 g | 21.26 f |
| $N_1S_2$ | 12.00 de | 16.10 cd | 20.90 de | 23.39 de |
| $N_1S_3$ | 12.40 cd | 16.71 cd | 21.14 de | 24.21 cd |
| $N_2S_1$ | 10.80 f | 14.00 ef | 19.89 f | 22.40 e |
| $N_2S_2$ | 12.90 bc | 17.54 bc | 21.70 cd | 24.90 bc |
| $N_2S_3$ | 13.44 ab | 18.26 b | 22.42 bc | 25.40 b |
| $N_3S_1$ | 11.66 e | 15.29 de | 20.51 ef | 22.89 e |
| $N_3S_2$ | 13.89 a | 19.89 a | 23.79 a | 27.00 a |
| $N_3S_3$ | 13.71 a | 18.90 ab | 22.94 b | 25.96 ab |
| CV(%) | 6.57 | 6.28 | 7.22 | 8.36 |

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

## 4.4 Leaf breadth

### 4.4.1 Effect of nitrogen

Application of different levels of nitrogen showed statistically significant variation for leaf breadth of lettuce at different days after transplanting (Table 5 and Appendix VI). At 30, 40, 50 and 60 DAT, the highest leaf breadth was 11.33, 15.58, 23.26 and 26.57 cm, respectively which was achieved from $N_3$ (150 kg N/ha). Again, the lowest leaf breadth (6.7, 9.63, 12.72 and 15.73 cm at 30, 40, 50 and 60 DAT respectively) was found from $N_0$ (0 kg N/ha). Results showed that higher doses of nitrogen cause higher leaf breadth. Optimum vegetative growth was occurred due to higher amount of nitrogen fertilizer that leads for the growth of lettuce and the ultimate results was the widest leaf. The results obtained earlier by Boroujerdnia and Ansari (2007) was similar with the present study.

### 4.4.2 Effect of spacing

Leaf breadth of lettuce was not significantly varied between $S_2$ and $S_3$. But leaf breadth was significantly influenced due to different plant spacing at 30, 40, 50 and 60 DAT (Table 5 and Appendix VI). The highest leaf breadth (10.45, 14.62, 21.18 and 24.69 cm at 30, 40, 50 and 60 DAT respectively) was observed from $S_3$ (40 cm × 30 cm) and the lowest leaf breadth (8.0, 11.54, 16.27 and 19.2 cm) was recorded from $S_1$ (40 cm × 20 cm). It was revealed that with the increases of spacing leaf breadth showed increasing trend. In case of closer spacing plant compete for light and with the time being leaf breadth decreases.

### 4.4.3 Interaction effect of nitrogen and spacing

Statistically significant variation was recorded due to interaction effect of nitrogen and plant spacing in terms of leaf breadth of lettuce at different growth stages (Table 5 and Appendix VI). The highest leaf breadth (12.4, 16.99, 25.0 and 28.61 cm at 30, 40, 50 and 60 DAT respectively) was found from $N_3S_3$ which was statistically identical with $N_3S_3$ at 30, 40 and 60 DAT. The lowest leaf breadth (6.1, 8.0, 11.49 and 14.25 cm at 30, 40, 50 and 60 DAT respectively) was obtained from $N_0S_1$. The combination of $N_0S_2$ and $N_0S_3$ also showed lower leaf breadth but significantly different from $N_3S_3$ at 40, 50 and 60 DAT. Data revealed that optimum level of nitrogen and plant spacing ensured the highest leaf breadth with maximum vegetative growth.

Table 5: Effect of nitrogen and plant spacing on leaf breadth at different growth stages of lettuce crop

| Treatment | Leaf breadth (cm) | | | |
|---|---|---|---|---|
| | 30 DAT | 40 DAT | 50 DAT | 60 DAT |
| ***Main effect of nitrogen*** | | | | |
| $N_0$ | 6.70 d | 9.63 d | 12.72 d | 15.73 d |
| $N_1$ | 9.78 c | 14.04 c | 19.66 c | 23.18 c |
| $N_2$ | 10.33 b | 14.28 b | 21.66 b | 25.01 b |
| $N_3$ | 11.33 a | 15.58 a | 23.26 a | 26.57 a |
| ***Main effect of spacing*** | | | | |
| $S_1$ | 8.09 c | 11.54 c | 16.27 c | 19.20 c |
| $S_2$ | 10.07 b | 13.99 b | 20.53 b | 23.99 b |
| $S_3$ | 10.45 a | 14.62 a | 21.18 a | 24.69 a |
| ***Interaction effect of nitrogen and spacing*** | | | | |
| $N_0S_1$ | 6.10 g | 8.04 i | 11.49 i | 14.25 i |
| $N_0S_2$ | 6.69 fg | 10.00 h | 12.90 h | 16.01 h |
| $N_0S_3$ | 7.31 f | 10.86 g | 13.79 h | 16.94 h |
| $N_1S_1$ | 8.14 e | 13.56 de | 15.80 g | 18.99 g |
| $N_1S_2$ | 10.39 c | 13.80 d | 21.00 de | 24.66 d |
| $N_1S_3$ | 10.80 bc | 14.75 c | 22.19 cd | 25.90 cd |
| $N_2S_1$ | 8.70 de | 11.70 f | 17.91 f | 20.86 f |
| $N_2S_2$ | 11.01 bc | 15.24 bc | 23.34 bc | 26.89 bc |
| $N_2S_3$ | 11.29 b | 15.89 b | 23.74 ab | 27.30 ab |
| $N_3S_1$ | 9.40 d | 12.84 e | 19.89 e | 22.70 e |
| $N_3S_2$ | 12.19 a | 16.90 a | 24.89 a | 28.40 a |
| $N_3S_3$ | 12.40 a | 16.99 a | 25.01 a | 28.61 a |
| CV(%) | 8.33 | 7.49 | 6.87 | 9.24 |

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

### 4.5 Fresh weight/plant

#### 4.5.1 Effect of nitrogen

Lettuce fresh weight/plant showed statistically significant variation due to the application of different levels of nitrogen at different days after transplanting (Table 6 and Appendix VII). At 30, 40, 50 and 60 DAT the maximum fresh weight/plant (87.23, 102.3, 115.3 and 126.0 g respectively) was obtained from $N_3$ (150 kg N/ha) which was significantly different from all other treatments. On the other hand, the minimum fresh weight/plant (45.0, 56.12, 67.73 and 75.79 g at 30, 40, 50 and 60 DAT respectively) was found from $N_0$ (0 kg N/ha). It was revealed that with the increase of nitrogen application, fresh weight/plant increase due to optimum vegetative growth. Nitrogen fertilizer ensures favorable condition for the growth of lettuce with optimum vegetative growth and the ultimate results was the highest fresh weight/plant. The results obtained earlier by Tittonell *et al*. (2003), Rincon *et al*. (1998) and Boroujerdnia and Ansari (2007) were similar with the present study.

#### 4.5.2 Effect of spacing

Fresh weight/plant of lettuce showed statistically significant variation due to different plant spacing at different growth stages (Table 6 and Appendix VII). At 30, 40, 50 and 60 DAT, the maximum fresh weight of plant (81.55, 94.58, 109.0 and 117.0 g at 30, 40, 50 and 60 DAT, respectively) was observed from $S_3$ (40 cm × 30 cm) while the minimum fresh weight/plant was 55.0, 65.4, 75.36 and 83.0 g respectively) was found from $S_1$ (40 cm × 20 cm). It was revealed that with the increases of spacing fresh weight of plant showed increasing trend. In case of wider spacing plant receive enough light and nutrients which leads to attain maximum fresh weight of plant. Similar result was also observed by Sharma *et al.* (2001).

### 4.5.3 Interaction effect of nitrogen and spacing

Interaction effect of different levels of nitrogen application and plant spacing showed statistically significant variation for fresh weight of lettuce plant at different growth stages (Table 6 and Appendix VII). The maximum fresh weight/plant (104.1, 120.1, 136.2 and 144.9 g at 30, 40, 50 and 60 DAT respectively) was found from $N_3S_3$ where the minimum fresh weight/plant (36.65, 44.69, 54.44 and 62.59 g) was with $N_0S_1$. It was revealed that optimum level of nitrogen and plant spacing ensured maximum vegetative growth that ensured highest fresh weight/ plant.

Table 6: Effect of nitrogen and plant spacing on fresh weight/plant at different growth stages of lettuce crop

| Treatment | Fresh weight/plant | | | |
|---|---|---|---|---|
| | 30 DAT | 40 DAT | 50 DAT | 60 DAT |
| ***Main effect of nitrogen*** | | | | |
| $N_0$ | 45.07 d | 56.12 d | 67.73 d | 75.79 d |
| $N_1$ | 66.66 c | 78.29 c | 91.77 c | 98.38 c |
| $N_2$ | 77.86 b | 89.04 b | 99.58 b | 108.90 b |
| $N_3$ | 87.23 a | 102.30 a | 115.30 a | 126.00 a |
| ***Main effect of spacing*** | | | | |
| $S_1$ | 55.06 c | 65.40 c | 75.36 c | 83.01 c |
| $S_2$ | 71.01 b | 84.34 b | 96.39 b | 106.8 b |
| $S_3$ | 81.55 a | 94.58 a | 109.00 a | 117.00 a |
| ***Interaction effect of nitrogen and spacing*** | | | | |
| $N_0S_1$ | 36.65 j | 44.69 h | 54.44 h | 62.59 h |
| $N_0S_2$ | 46.21 i | 59.55 g | 70.34 g | 79.49 g |
| $N_0S_3$ | 52.36 h | 64.11 f | 78.39 ef | 85.29 f |
| $N_1S_1$ | 54.24 h | 62.54 fg | 74.66 f | 80.11 g |
| $N_1S_2$ | 68.46 f | 80.89 d | 94.43 d | 103.50 e |
| $N_1S_3$ | 77.29 e | 91.45 c | 106.2 c | 111.50 d |
| $N_2S_1$ | 60.89 g | 71.99 e | 80.89 e | 88.11 f |
| $N_2S_2$ | 80.24 d | 92.49 c | 102.6 c | 112.20 d |
| $N_2S_3$ | 92.44 b | 102.60 b | 115.3 b | 126.40 c |
| $N_3S_1$ | 68.45 f | 82.36 d | 91.46 d | 101.20 e |
| $N_3S_2$ | 89.14 c | 104.40 b | 118.2 b | 132.00 b |
| $N_3S_3$ | 104.10 a | 120.10 a | 136.2 a | 144.90 a |
| CV(%) | 8.88 | 7.98 | 9.42 | 7.66 |

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

### 4.6 Dry weight/plant

#### 4.6.1 Effect of nitrogen

Lettuce dry weight/plant showed statistically significant variation due to the application of different levels of nitrogen at different growth stages (Table 7 and Appendix VIII). At 30, 40, 50 and 60 DAT, the maximum dry weight/plant (12.46, 14.68, 16.56 and 18.0 g, respectively) was obtained from $N_3$ (150 kg N/ha) which was significantly different from all other treatments. On the other hand, the minimum dry weight/plant (6.8, 8.23, 9.83 and 10.89 g at 30, 40, 50 and 60 DAT respectively) was found from $N_0$ (0 kg N/ha). It was revealed that with the increase of nitrogen application, dry weight/plant increase due to more availability of nutrients among the plants during vegetative growth. Similar results were also obtained by Tittonell *et al*. (2003) and Mahmoudi Kliber (2005).

#### 4.6.2 Effect of spacing

Dry weight/plant of lettuce showed statistically significant variation due to different plant spacing at different growth stages (Table 7 and Appendix VIII). At 30, 40, 50 and 60 DAT, the maximum dry weight/plant (11.83, 13.72, 15.67 and 16.81 g at 30, 40, 50 and 60 DAT respectively) was observed from $S_3$ (40 cm × 30 cm) while the minimum dry weight/plant was 8.0, 9.36, 10.84 and 10.89 g respectively was found from $S_1$ (40 cm × 20 cm). It was revealed that with the increases of spacing dry weight of plant showed increasing trend because of less competition for nutrients among the plants during growth stages. Similar result was also tested by Sharma *et al.* (2001).

### 4.6.3 Interaction effect of nitrogen and spacing

Interaction effect of different levels of nitrogen application and plant spacing showed statistically significant variation for dry weight of lettuce plant at different growth stages (Table 7 and Appendix VIII). The maximum dry weight/plant (14.94, 17.29, 19.56 and 20.8 g at 30, 40, 50 and 60 DAT, respectively) was found from $N_3S_3$ where the minimum dry weight/plant (5.84, 6.85, 7.76 and 8.99 g) was with $N_0S_1$. It was revealed that optimum level of nitrogen and plant spacing ensured maximum vegetative growth that ensured highest dry weight/plant.

Table 7: Effect of nitrogen and plant spacing on dry weight/plant at different growth stages of lettuce crop

| Treatment | Dry weight/plant | | | |
|---|---|---|---|---|
| | 30 DAT | 40 DAT | 50 DAT | 60 DAT |
| ***Main effect of nitrogen*** | | | | |
| $N_0$ | 6.80 d | 8.23 d | 9.83 d | 10.89 d |
| $N_1$ | 9.74 c | 11.08 c | 13.21 c | 14.16 c |
| $N_2$ | 11.32 b | 12.80 b | 14.32 b | 15.66 b |
| $N_3$ | 12.46 a | 14.68 a | 16.56 a | 18.05 a |
| ***Main effect of spacing*** | | | | |
| $S_1$ | 8.09 c | 9.36 c | 10.84 c | 11.89 c |
| $S_2$ | 10.31 b | 12.02 b | 13.93 b | 15.37 b |
| $S_3$ | 11.83 a | 13.72 a | 15.67 a | 16.81 a |
| ***Interaction effect of nitrogen and spacing*** | | | | |
| $N_0S_1$ | 5.84 g | 6.85 g | 7.76 g | 8.99 f |
| $N_0S_2$ | 6.86 fg | 8.19 fg | 10.46 f | 11.39 e |
| $N_0S_3$ | 7.69 ef | 9.66 ef | 11.29 f | 12.29 e |
| $N_1S_1$ | 7.95 ef | 8.40 fg | 10.79 f | 11.65 e |
| $N_1S_2$ | 9.89 d | 11.67 cd | 13.56 d | 14.88 cd |
| $N_1S_3$ | 11.39 c | 13.19 bc | 15.29 bc | 15.94 cd |
| $N_2S_1$ | 8.88 de | 10.36 de | 11.64 ef | 12.46 e |
| $N_2S_2$ | 11.75 c | 13.29 bc | 14.78 cd | 16.31 c |
| $N_2S_3$ | 13.31 b | 14.74 b | 16.54 b | 18.20 b |
| $N_3S_1$ | 9.69 d | 11.84 cd | 13.19 de | 14.45 d |
| $N_3S_2$ | 12.75 bc | 14.93 b | 16.94 b | 18.90 b |
| $N_3S_3$ | 14.94 a | 17.29 a | 19.56 a | 20.80 a |
| CV(%) | 4.68 | 7.84 | 5.23 | 6.11 |

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

### 4.7 Yield/plot

#### 4.7.1 Effect of nitrogen

Significant variation was recorded in terms of yield/plot due to the application of different levels of nitrogen at different growth stages of lettuce (Table 8 and Appendix IX). At 30, 40, 50 and 60 DAT, the highest yield/plot was 2.92, 3.42, 3.84 and 4.20 kg, respectively and that was obtained from $N_3$ (150 kg N/ha) which was statistically similar (2.4, 2.99, 3.4 and 3.66 kg at 30, 40, 50 and 60 DAT respectively) with $N_2$ (100 kg N/ha). On the other hand, the lowest yield/plot (1.45, 2.13, 2.55 and 2.83 kg at 30, 40, 50 and 60 DAT, respectively) was recorded from $N_0$ (0 kg N/ha). It was revealed that with increase of nitrogen maximizes lettuce yield because of increased nitrogen helps plant for higher vegetative growth.

#### 4.7.2 Effect of spacing

Yield/plot was statistically varied in terms of different plant spacing at different growth stages of lettuce (Table 8 and Appendix IX). At 30, 40, 50 and 60 DAT, the maximum yield/plot (2.39, 2.96, 3.37 and 3.68 kg, respectively) was obtained from $S_2$ (40 cm × 25 cm) which was closely followed by $S_3$ (40 cm × 30 cm) at all growth stages. On the other hand, the lowest yield/plot (2.0, 2.64, 3.0 and 3.33 kg at 30, 40, 50 and 60 DAT, respectively) was recorded from $S_1$ (40 cm × 25 cm). It was revealed that with the increases of spacing individual weight per plant increased. So, in spite of less population, total yield/plot may higher due to higher individual plant weight and optimum spacing ensured the highest yield with maximum vegetative growth. Moniruzzaman (2006) reported that the highest yield (25.9 t/ha in 1999-2000 and 28.3 t/ha in 2000-2001 with an average of 27.10 t/ha) was observed in the spacing of 40 × 20 cm with mulch, which was statistically at par with the spacing of 40 × 30 cm. Similar result was also tested by Sharma *et al.* (2001).

### 4.7.3 Interaction effect of nitrogen and spacing

Significant variation was observed due to interaction effect of different levels of nitrogen and plant spacing in terms of yield/plot at different growth stages of lettuce crop (Table 8 and Appendix IX). Results showed that the highest yield/plot was 3.0, 3.56, 3.99 and 4.39 kg at 30, 40, 50 and 60 DAT respectively from $N_3S_2$ which was statistically identical with $N_3S_1$ at 50 and 60 DAT but statistically similar with $N_3S_3$ and $N_3S_1$ at different DAT. The lowest yield/plot (1.36, 1.86, 2.29 and 2.59 kg at 30, 40, 50 and 60 DAT respectively) was recorded from $N_0S_1$ which was statistically identical with $N_0S_2$ at 30 DAT and statistically similar with $N_0S_3$, $N_1S_1$and $N_1S_3$ at 30 DAT. It was revealed that optimum level of nitrogen and plant spacing ensured maximum vegetative growth and the allocation of optimum number of plants that leads to produce highest yield/plot.

Table 8: Effect of nitrogen and plant spacing on yield (kg/plot) at different growth stages of lettuce crop

| Treatment | Yield (kg/plot) | | | |
|---|---|---|---|---|
| | 30 DAT | 40 DAT | 50 DAT | 60 DAT |
| ***Main effect of nitrogen*** | | | | |
| $N_0$ | 1.45 b | 2.13 c | 2.55 c | 2.83 c |
| $N_1$ | 1.98 ab | 2.70 bc | 3.07 bc | 3.35 bc |
| $N_2$ | 2.40 ab | 2.99 ab | 3.40 ab | 3.66 ab |
| $N_3$ | 2.92 a | 3.42 a | 3.84 a | 4.20 a |
| ***Main effect of spacing*** | | | | |
| $S_1$ | 2.01 b | 2.64 b | 3.05 b | 3.33 b |
| $S_2$ | 2.39 a | 2.96 a | 3.37 a | 3.68 a |
| $S_3$ | 2.16 ab | 2.84 ab | 3.22 ab | 3.51 ab |
| ***Interaction effect of nitrogen and spacing*** | | | | |
| $N_0S_1$ | 1.36 e | 1.86 j | 2.29 g | 2.56 g |
| $N_0S_2$ | 1.45 e | 2.16 i | 2.61 f | 2.89 f |
| $N_0S_3$ | 1.53 de | 2.36 hi | 2.75 ef | 3.04 ef |
| $N_1S_1$ | 1.68 de | 2.50 gh | 2.86 ef | 3.14 ef |
| $N_1S_2$ | 2.39 bc | 2.96 de | 3.36 c | 3.64 c |
| $N_1S_3$ | 1.86 de | 2.64 fg | 2.99 de | 3.26 de |
| $N_2S_1$ | 2.06 cd | 2.79 ef | 3.24 cd | 3.50 cd |
| $N_2S_2$ | 2.64 ab | 3.16 cd | 3.51 bc | 3.79 bc |
| $N_2S_3$ | 2.50 bc | 3.05 d | 3.44 bc | 3.70 c |
| $N_3S_1$ | 2.94 ab | 3.41 ab | 3.81 a | 4.16 a |
| $N_3S_2$ | 3.09 a | 3.56 a | 3.99 a | 4.39 a |
| $N_3S_3$ | 2.74 ab | 3.30 bc | 3.71 ab | 4.06 ab |
| CV(%) | 8.44 | 7.52 | 6.74 | 8.38 |

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

## 4.8 Yield/ha

### 4.8.1 Effect of nitrogen

Different levels of nitrogen application influenced yield/ha significantly at different growth stages of lettuce (Table 9 and Appendix X). At 30, 40, 50 and 60 DAT, the highest yield/ha was 6.0, 7.15, 8.0 and 8.76 t, respectively from $N_3$ (150 kg N/ha) which was statistically similar (6.58 and 7.0 t at 40 and 50 DAT respectively) with $N_2$ (100 kg N/ha). On the other hand, the lowest yield/ha (3.0, 4.43, 5.31 and 5.9 t at 30, 40, 50 and 60 DAT respectively) was recorded from $N_0$ (0 kg N/ha). It was revealed that with increase of nitrogen maximizes lettuce yield because of increased nitrogen helps plant for higher vegetative growth. The results obtained earlier by Rincon *et al.* (1998), Tittonell *et al.* (2003), Boroujerdnia and Ansari (2007) and Mahmoudi Kliber (2005) was similar with the present study.

### 4.8.2 Effect of spacing

Yield/ha of lettuce was statistically significant in terms of different plant spacing at different growth stages (Table 9 and Appendix X). At 30, 40, 50 and 60 DAT, the maximum yield/ha (4.98, 6.17, 7.03 and 7.66 t respectively) was obtained from $S_2$ (40 cm × 25 cm). On the other hand, the lowest yield/ha (4.19, 5.76, 6.35 and 6.96 t at 30, 40, 50 and 60 DAT respectively) was recorded from $S_1$ (40 cm × 25 cm). It was revealed that with the increases of spacing individual weight per plant increase. So, in spite of less population, total yield/ha may higher due to higher individual plant weight and optimum spacing ensure the highest yield with maximum vegetative growth. Similar result was also tested by Sharma *et al.* (2001).

### 4.8.3 Interaction effect of nitrogen and spacing

Significant variation was examined due to interaction effect of different levels of nitrogen and plant spacing in terms of yield/ha at different growth stages of lettuce crop (Table 9 and Appendix X). Results showed that the highest yield/ha were 6.44, 7.41, 8.31 and 9.15 t at 30, 40, 50 and 60 DAT respectively from $N_3S_2$. The lowest yield/ha (2.84, 3.89, 4.75 and 5.34 t at 30, 40, 50 and 60 DAT respectively) was recorded from $N_0S_1$ which was statistically similar with $N_0S_2$ at 30 DAT. It was revealed that optimum level of nitrogen and plant spacing ensured maximum vegetative growth and the allocation of optimum number of plants that leads to produce the highest yield/ha.

Table 9: Effect of nitrogen and plant spacing on yield (t/ha) at different growth stages of lettuce crop

| Treatment | Yield (t/ha) | | | |
|---|---|---|---|---|
| | 30 DAT | 40 DAT | 50 DAT | 60 DAT |
| ***Main effect of nitrogen*** | | | | |
| $N_0$ | 3.01 c | 4.43 c | 5.31 c | 5.90 c |
| $N_1$ | 4.11 b | 5.62 b | 6.39 b | 6.98 b |
| $N_2$ | 5.00 b | 6.58 ab | 7.08 ab | 7.63 b |
| $N_3$ | 6.08 a | 7.15 a | 8.00 a | 8.76 a |
| ***Main effect of spacing*** | | | | |
| $S_1$ | 4.19 b | 5.76 b | 6.35 c | 6.96 c |
| $S_2$ | 4.98 a | 6.17 a | 7.03 a | 7.66 a |
| $S_3$ | 4.49 b | 5.91 ab | 6.71 b | 7.33 b |
| ***Interaction effect of nitrogen and spacing*** | | | | |
| $N_0S_1$ | 2.84 i | 3.89 k | 4.75 h | 5.34 h |
| $N_0S_2$ | 3.01 hi | 4.50 j | 5.46 g | 6.01 g |
| $N_0S_3$ | 3.19 h | 4.91 i | 5.74 fg | 6.34 fg |
| $N_1S_1$ | 3.50 g | 5.21 h | 5.96 ef | 6.54 ef |
| $N_1S_2$ | 4.96 d | 6.16 f | 7.00 cd | 7.59 cd |
| $N_1S_3$ | 3.86 f | 5.50 g | 6.21 e | 6.81 e |
| $N_2S_1$ | 4.31 e | 6.79 cd | 6.75 d | 7.29 d |
| $N_2S_2$ | 5.49 c | 6.59 de | 7.34 c | 7.89 c |
| $N_2S_3$ | 5.21 d | 6.35 ef | 7.16 c | 7.71 c |
| $N_3S_1$ | 6.10 b | 7.14 b | 7.96 b | 8.66 b |
| $N_3S_2$ | 6.44 a | 7.41 a | 8.31 a | 9.15 a |
| $N_3S_3$ | 5.71 c | 6.89 bc | 7.75 b | 8.46 b |
| CV(%) | 4.53 | 6.57 | 7.28 | 8.44 |

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

## 4.9 Total yield

### 4.9.1 Effect of nitrogen

Different levels of nitrogen application influenced total yield of lettuce significantly (Table 10 and Appendix XI). It was observed that the highest yield (14.4 kg/plot or 29.99 t/ha) was obtained from $N_3$ (150 kg N/ha) where the lowest yield (8.95 kg/plot or 18.65 t/ha) was recorded from $N_0$ (0 kg N/ha). It was remarked that higher yield was achieved with higher doses of nitrogen due helping plants for higher vegetative growth. The results obtained earlier by Rincon *et al*. (1998), Tittonell *et al*. (2003), Boroujerdnia and Ansari (2007) and Mahmoudi Kliber (2005) was similar with the present study.

### 4.9.2 Effect of spacing

Total yield of lettuce was significantly influenced by different plant spacing (Table 10 and Appendix XI). Results indicated that the maximum yield (12.4 kg/plot or 25.83 t/ha) was obtained from $S_2$ (40 cm × 25 cm). On the other hand, the lowest yield (11.0 kg/plot or 23 t/ha) was recorded from $S_1$ (40 cm × 20 cm). It was said that higher spacing showed higher yield till to a certain level because of higher population is ensured with lower spacing and higher spacing provide more nutrients and less competition of nutrition for vegetative growth. Similar result was also tested by Sharma *et al.* (2001).

### 4.9.3 Interaction effect of nitrogen and spacing

Significant variation was examined due to interaction effect of different levels of nitrogen and plant spacing in terms of total yield of lettuce crop (Table 10 and Appendix XI). Results showed that the highest yield (15.0 kg/plot or 31.31 t/ha) was obtained from $N_3S_2$ where the lowest (8.0 kg/plot or 16.79 t/ha) was from $N_0S_1$. It was stated that optimum level of nitrogen and plant spacing ensured maximum vegetative growth and ultimate result is to produce the highest yield. Similar result was also achieved by Tittonell *et al.* (2001).

Table 10: Effect of nitrogen and plant spacing on total yield at different growth stages of lettuce crop

| Treatment | Total yield (kg/plot) | Total yield (t/ha) | BCR |
|---|---|---|---|
| ***Main effect of nitrogen*** | | | |
| $N_0$ | 8.95 c | 18.65 d | 2.348 c |
| $N_1$ | 11.09 b | 23.10 c | 2.890 bc |
| $N_2$ | 12.46 b | 25.96 b | 3.231 ab |
| $N_3$ | 14.40 a | 29.99 a | 3.710 a |
| ***Main effect of spacing*** | | | |
| $S_1$ | 11.04 c | 23.00 c | 2.850 b |
| $S_2$ | 12.40 a | 25.83 a | 3.222 a |
| $S_3$ | 11.74 b | 24.45 b | 3.063 ab |
| ***Interaction effect of nitrogen and spacing*** | | | |
| $N_0S_1$ | 8.06 i | 16.79 j | 2.100 h |
| $N_0S_2$ | 9.11 h | 19.00 i | 2.393 g |
| $N_0S_3$ | 9.69 gh | 20.16 hi | 2.550 fg |
| $N_1S_1$ | 10.19 fg | 21.21 gh | 2.643 ef |
| $N_1S_2$ | 12.34 d | 25.71 de | 3.213 c |
| $N_1S_3$ | 10.75 f | 22.39 fg | 2.813 e |
| $N_2S_1$ | 11.59 e | 24.14 ef | 2.993 d |
| $N_2S_2$ | 13.10 c | 27.29 cd | 3.393 c |
| $N_2S_3$ | 12.69 cd | 26.44 d | 3.307 c |
| $N_3S_1$ | 14.34 b | 29.86 ab | 3.663 b |
| $N_3S_2$ | 15.04 a | 31.31 a | 3.887 a |
| $N_3S_3$ | 13.81 b | 28.80 bc | 3.580 b |
| CV(%) | 6.58 | 7.78 | 5.66 |

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

### 4.10 Economic analysis

Different input costs for land preparation, seed, fertilizer and manure, and man power required for all the operations from transplanting of seedling to harvest of lettuce were recorded for unit plot and converted it into per hectare. Prices of lettuce for gross return 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-

#### 4.10.1 Gross return

In the combination of nitrogen fertilizer and plant spacing showed different gross return under the trial (Table 11). The highest gross return (Tk. 4,07,160.00) was obtained from $N_3S_2$ and the second highest gross return (Tk. 3,88,180.00) was obtained from $N_3S_1$ where the lowest gross return (Tk. 2,18,270.00) was obtained from $N_0S_1$.

#### 4.10.2 Net return

In case of net return different treatment combination showed different values of net return (Table 11). The highest net return (Tk. 302110.00) was obtained from $N_3S_2$ and the second highest net return (Tk. 282530.00) was obtained from $N_3S_1$. On the other hand the lowest net return (Tk. 114420.00) was obtained from $N_0S_1$.

#### 4.10.3 Benefit cost ratio (BCR)

The combination of nitrogen fertilizer and plant spacing showed different benefit cost ratio in different treatment combinations (Table 11). The highest benefit cost ratio (BCR) (3.887) was performed from $N_3S_2$ and the second BCR (3.67) was estimated from $N_3S_1$. The lowest benefit cost ratio (2.10) was obtained from $N_0S_1$. From economic point of view, it is apparent from the above results that $N_3S_2$ was the more profitable than rest of the treatment combinations for lettuce crop.

Table 11: Cost and return of lettuce cultivation as influenced by Nitrogen fertilization and plant spacing

| Treatment | Cost of production (Tk./ha) | Total yield (t/ha) | Gross return (Tk./ha) | Net return (Tk./ha) | Benefit cost ratio |
|---|---|---|---|---|---|
| $N_0S_1$ | 103850 | 16.79 | 218270 | 114420 | 2.10 |
| $N_0S_2$ | 103250 | 19.00 | 247000 | 143750 | 2.39 |
| $N_0S_3$ | 102750 | 20.17 | 262210 | 159460 | 2.55 |
| $N_1S_1$ | 104450 | 21.21 | 275730 | 171280 | 2.64 |
| $N_1S_2$ | 103850 | 25.71 | 334230 | 230380 | 3.22 |
| $N_1S_3$ | 103350 | 22.39 | 291070 | 187720 | 2.82 |
| $N_2S_1$ | 105050 | 24.14 | 313820 | 208770 | 2.99 |
| $N_2S_2$ | 104450 | 27.28 | 354640 | 250190 | 3.39 |
| $N_2S_3$ | 103950 | 26.44 | 343720 | 239770 | 3.31 |
| $N_3S_1$ | 105650 | 29.86 | 388180 | 282530 | 3.67 |
| $N_3S_2$ | 105050 | 31.32 | 407160 | 302110 | 3.88 |
| $N_3S_3$ | 104550 | 28.80 | 374400 | 269850 | 3.58 |

Market price of lettuce @ Tk. 13,000/t

# CHAPTER V

## Summary and conclusion

An experiment was conducted in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2009 to January, 2010. The experiment consisted of two factors. Factor A: Nitrogen (4 levels) $N_0$: 0 kg/ha (Control); $N_1$: 50 kg/ha; $N_2$: 100 kg/ha and $N_3$: 150 kg/ha; Factor B: Plant spacing (3 levels), $S_1$: 40 cm × 20 cm, $S_2$: 40 cm × 25 cm; $S_3$: 40 cm × 30 cm. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters and yield at different days after transplanting (DAT) were recorded.

Nitrogenous effect was considered significant under the present study. On the growth parameters; plant height, number of leaves/plant, leaf length and leaf breadth were highest with higher nitrogen doses at 150 kg/ha ($N_3$). At 30, 40, 50 and 60 DAT the tallest plant (16.94, 21.85, 26.36 and 30 cm, respectively), maximum number of leaves/plant (17.45, 24.85, 29.25 and 27.2, respectively), highest leaf length (13.09, 18.03, 22.41 and 25.28 cm, respectively) and highest leaf breadth (11.33, 15.58, 23.26 and 26.57 cm, respectively) were found from $N_3$ (150 kg N/ha). But At 30, 40, 50 and 60 DAT the shortest plant (10.36, 13.7, 18.42 and 21.89 cm, respectively), minimum number of leaves/plant (12.65, 17.23, 22.7 and 21.45, respectively), lowest leaf length (9.43, 10.63, 16.76 and 17.73 cm respectively) and lowest leaf breadth (6.7, 9.63, 12.72 and 15.73 cm, respectively) were recorded from control treatment ($N_0$). The yield contributing characters remarked as fresh weight/plant and dry weight/plant were also higher with higher nitrogen doses. At 30, 40, 50 and 60 DAT the maximum fresh weight/plant (87.23, 102.3, 115.3 and 126.0 g, respectively) and dry weight/plant (12.46, 14.68, 16.56 and 18.05 g, respectively) were obtained from $N_3$ (150 kg N/ha) where the minimum fresh weight/plant (45.07, 56.12, 67.73 and 75.79 g, respectively) and dry weight/plant (6.8, 8.23, 9.83 and 10.89 g, respectively) were recorded from $N_0$ (control treatment). Yield parameters were also significantly influenced by different doses of nitrogen application. Higher doses of nitrogen showed higher yield. At 30, 40, 50 and 60 DAT the highest yield/plot (2.92, 3.42, 3.84 and 4.20 kg, respectively) and yield/ha (6.08, 7.15, 8.0 and 8.76 t respectively) were found from $N_3$ (150 kg N/ha) where the lowest yield/plot (1.45, 2.13, 2.55 and 2.83 kg, respectively) and yield/ha (3.0, 4.43, 5.31 and 5.9 t, respectively) was recorded from $N_0$ (control). The highest total yield/plot and yield/ha (14.4 kg/plot and 29.99 t/ha, respectively) were also obtained from $N_3$ (150 kg N/ha) but the lowest (8.95 kg/plot and 18.65 t/ha, respectively) were with $N_0$ (control).

Different plant spacings had significant effect on growth, yield and yield parameters of lettuce crop under the present study. At 30, 40, 50 and 60 DAT the tallest plant (16.73, 22.2, 26.55 and 30.46 cm, respectively) was recorded from closer spacing, $S_1$ (40 cm × 20 cm) where the shortest plant (13.3, 16.71, 21.0 and 24.21 cm, respectively) was found from wider spacing, $S_3$ (40 cm × 30 cm). Again, at 30, 40, 50 and 60 DAT, the maximum number of leaves/plant (16.37, 23.14, 27.39 and 25.60, respectively) was obtained from $S_2$ (40 cm × 25 cm) and the minimum (14.03, 19.68, 24.31 and 22.68) was recorded from $S_1$ (40 cm × 20 cm), and at the same condition, the highest leaf length (12.44, 16.44, 21.13 and 23.67 cm, respectively), leaf breadth (10.45, 14.62, 21.18 and 24.69 cm respectively), fresh weight/plant (81.55, 94.58, 109.0 and 117.0 g, respectively) and dry weight/plant (11.83, 13.72, 15.67 and 16.81 g, respectively) were observed from $S_3$ (40 cm × 30 cm), where the lowest leaf length (10.51, 12.88, 18.64 and 20.66 cm, respectively), leaf breadth (8.09, 11.54, 16.27 and 19.2 cm respectively), fresh weight (55.06, 65.40, 75.36 and 83.01 g, respectively) and dry weight per plant (8.09, 9.36, 10.84 and 11.89 g, respectively) were recorded from $S_1$ (40 cm × 20 cm). In terms of yield of lettuce, at 30, 40, 50 and 60 DAT, the maximum yield/plot (2.39, 2.96, 3.37 and 3.68 kg, respectively) and yield/ha (4.98, 6.17, 7.03 and 7.66 t, respectively) was observed from $S_2$ (40 cm × 25 cm), where the lowest yield/plot (2.0, 2.64, 3.05 and 3.33 kg, respectively) and yield/ha (4.19, 5.76, 6.35 and 6.96 t, respectively) were recorded from $S_1$ (40 cm × 20 cm). The highest total yield/plot (12.40 kg) and total yield/ha (25.83 t) were also achieved from $S_2$ (40 cm × 25 cm), where the lowest total yield/plot (11.04 kg) and yield/ha (23.0 t) were recorded from $S_1$ (40 cm × 20 cm).

Interaction of nitrogen and spacing had significant effect on growth, yield and yield contributing characters of lettuce crop. Results showed that at 30, 40, 50 and 60 DAT, the tallest plant (20.09, 26.21, 31.89 and 35.0cm, respectively) was recorded from $N_3S_1$ where the shortest plant (9.71, 11.89, 17.54 and 22.71 cm, respectively) was found from $N_0S_3$. Again, at 30, 40, 50 and 60 DAT, the maximum number of leaves/plant (19.16, 27.10, 31.77 and 29.71, respectively), highest leaf length (13.89, 19.89, 23.79 and 27.00 cm, respectively), highest yield/plot (3.09, 3.56, 4.0 and 4.39 kg, respectively) and yield/ha (6.44, 7.41, 8.31 and 9.15 t, respectively), was found from $N_3S_2$, but the highest leaf breadth (12.4, 16.99, 25.01 and 28.61 cm, respectively), fresh weight/plant (104.1, 120.1, 136.2 and 144.9 g, respectively), and dry weight/plant (14.94, 17.29, 19.56 and 20.8 g, respectively) were obtained from $N_3S_3$. In terms of total yield, the highest total yield/plot (15.04 kg) and yield/ha (31.31 t) were also achieved from $N_3S_2$. On the other hand, at 30, 40, 50 and 60 DAT, the lowest number of leaves/plant (11.54, 15.44, 21.34 and 20.51, respectively), leaf length (8.94, 9.09, 15.19 and 16.09 cm respectively), leaf breadth (6.1, 8.04, 11.49 and 14.25 cm, respectively), fresh weight/plant (36.65, 44.69, 54.44 and 62.59 g, respectively), dry weight/plant (5.84, 6.85, 7.76 and 8.99 g, respectively), yield/plot (1.36, 1.86, 2.29 and 2.59 kg, respectively) and yield/ha (2.84, 3.89, 4.75 and 5.34 t, respectively), was found from $N_0S_1$. But in terms of total yield, the lowest total yield/plot (8.06 kg) and yield/ha (16.79 t) were also obtained from $N_0S_1$.

Under the present study, the ultimate goal was to achieve highest return with lettuce cultivation applying different treatment combinations and from this point of view the highest net return (Tk. 302110/ha) and BCR (3.88) were achieved from $N_3S_2$ where the lowest net return (Tk. 114420/ha) and BCR (2.1) were from $N_0S_1$.

From economic point of view, it is apparent from the above results that $N_3S_2$ was the most profitable than rest of the treatment combinations for lettuce cultivation.

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

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances.
2. Another higher level of nitrogen may be included for precise result.
3. Another spacing may also use to optimize spacing for higher yield of lettuce.

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# APPENDICES

Appendix I. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from October 2009 to March 2010

| Month | RH (%) | Max. Temp. (ºC ) | Min. Temp. ( ºC ) | Rain fall (mm) |
|---|---|---|---|---|
| October | 73.36 | 29.46 | 19.19 | Terrace |
| November | 71.15 | 26.98 | 14.88 | Terrace |
| December | 68.30 | 25.78 | 14.21 | Terrace |
| January | 69.53 | 25.00 | 13.46 | 0 |
| February | 50.31 | 29.50 | 18.49 | 0 |
| March | 44.95 | 33.80 | 20.28 | 0 |

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

Appendix II Physical characteristics and chemical composition of soil of the experimental plot.

| **Soil Characteristics** | **Analytical results** |
|---|---|
| Agrological Zone | Madhupur Tract |
| $P^H$ | 5.47 – 5.63 |
| Total N (%) | 0.43 |
| Available phosphorous | 22 ppm |
| Exchangeable K | 0.42 meq / 100 g soil |

Appendix III: Total cost of production for lettuce at different treatments.

| Treatment(s) | Material Cost (Tk./ha) | Non Material Cost (Tk./ha) | Overhead Cost (Tk./ha) | Total Cost of Production (Tk./ha) |
|---|---|---|---|---|
| $N_0S_1$ | 43350 | 15500 | 45000 | 103850 |
| $N_0S_2$ | 42750 | 15500 | 45000 | 103250 |
| $N_0S_3$ | 42250 | 15500 | 45000 | 102750 |
| $N_1S_1$ | 43950 | 15500 | 45000 | 104450 |
| $N_1S_2$ | 43350 | 15500 | 45000 | 103850 |
| $N_1S_3$ | 42850 | 15500 | 45000 | 103350 |
| $N_2S_1$ | 44550 | 15500 | 45000 | 105050 |
| $N_2S_2$ | 43950 | 15500 | 45000 | 104450 |
| $N_2S_3$ | 43450 | 15500 | 45000 | 103950 |

| | | | | |
|---|---|---|---|---|
| $N_3S_1$ | 45150 | 15500 | 45000 | 105650 |
| $N_3S_2$ | 44550 | 15500 | 45000 | 105050 |
| $N_3S_3$ | 44050 | 15500 | 45000 | 104550 |

Appendix IV: Effect of different level of nitrogen application and different plant spacing on plant height at different growth stages of lettuce crop

| Source of variation | Degrees of Freedom | Mean square | | | |
|---|---|---|---|---|---|
| | | Plant height (cm) | | | |
| | | 30 DAT | 40 DAT | 50 DAT | 60 DAT |
| Replication | 2 | 0.004 | 0.003 | 0.025 | 0.001 |
| Factor A | 3 | 8.546* | 13.22* | 12.18* | 12.53* |
| Factor B | 2 | 5.282* | 9.397* | 9.809* | 11.79* |
| AB | 6 | 4.280* | 5.371* | 15.20* | 9.293* |
| Error | 22 | 0.123 | 0.546 | 0.246 | 0.134 |

Appendix V: Effect of different level of nitrogen application and different plant spacing on number of leaves/plant at different growth stages of lettuce crop

| Source of variation | Degrees of Freedom | Mean square | | | |
|---|---|---|---|---|---|
| | | Number of leaves/plant | | | |
| | | 30DAT | 40 DAT | 50 DAT | 60 DAT |
| Replication | 2 | 0.000 | 0.001 | 0.001 | 0.002 |
| Factor A | 3 | 5.17* | 10.40* | 6.344* | 5.876* |
| Factor B | 2 | 3.96* | 7.656* | 3.128* | 3.502* |
| AB | 6 | 4.61* | 1.386* | 2.680* | 3.181* |
| Error | 22 | 0.018 | 0.1.36 | 0.245 | 1.002 |

Appendix VI: Effect of different level of nitrogen application and different plant spacing on leaf length at different growth stages of lettuce crop

| Source of variation | Degrees of Freedom | Mean square | | | |
|---|---|---|---|---|---|
| | | Leaf length (cm) | | | |
| | | 30DAT | 40 DAT | 50 DAT | 60 DAT |
| Replication | 2 | 0.006 | 0.018 | 0.002 | 0.001 |
| Factor A | 3 | 22.56* | 9.583* | 5.079* | 10.03* |
| Factor B | 2 | 12.18* | 6.347* | 7.527* | 12.54* |
| AB | 6 | 0.730** | 1.265* | 0.580** | 0.959* |
| Error | 22 | 0.018 | 0.042 | 0.036 | 0.054 |

Appendix VII: Effect of different level of nitrogen application and different plant spacing on leaf breadth at different growth stages of lettuce crop

| Source of variation | Degrees of Freedom | Mean square | | | |
|---|---|---|---|---|---|
| | | Leaf breadth (cm) | | | |
| | | 30DAT | 40 DAT | 50 DAT | 60 DAT |
| Replication | 2 | 0.016 | 0.010 | 0.024 | 0.008 |
| Factor A | 3 | 5.853* | 6.294* | 9.967* | 7.257* |
| Factor B | 2 | 9.331* | 3.846** | 8.265* | 10.15* |
| AB | 6 | 0.790** | 2.552* | 3.574* | 3.991* |
| Error | 22 | 0.024 | 0.038 | 0.102 | 0.214 |

Appendix VIII: Effect of different level of nitrogen application and different plant spacing on fresh weight/plant at different growth stages of lettuce crop

| Source of variation | Degrees of Freedom | Mean square | | | |
|---|---|---|---|---|---|
| | | Fresh weight/plant (g) | | | |
| | | 30DAT | 40 DAT | 50 DAT | 60 DAT |
| Replication | 2 | 0.001 | 0.001 | 0.008 | 0.003 |
| Factor A | 3 | 296.84* | 343.62* | 353.12* | 397.25* |
| Factor B | 2 | 213.44* | 263.56* | 347.45* | 365.89* |
| AB | 6 | 16.027* | 14.806* | 15.569* | 10.780* |
| Error | 22 | 1.001 | 2.031 | 2.014 | 1.132 |

Appendix IX: Effect of different level of nitrogen application and different plant spacing on dry weight/plant at different growth stages of lettuce crop

| Source of variation | Degrees of Freedom | Mean square | | | |
|---|---|---|---|---|---|
| | | Dry weight/plant (g) | | | |
| | | 30DAT | 40 DAT | 50 DAT | 60 DAT |
| Replication | 2 | 0.000 | 0.001 | 0.001 | 0.002 |
| Factor A | 3 | 4.280* | 6.553* | 7.672* | 8.845* |
| Factor B | 2 | 2.510* | 5.883* | 7.739* | 7.844* |
| AB | 6 | 1.679* | 1.129* | 1.075* | 1.493* |
| Error | 22 | 0.012 | 0.018 | 0.032 | 0.024 |

Appendix X: Effect of different level of nitrogen application and different plant spacing on yield/plot at different growth stages of lettuce crop

| Source of variation | Degrees of Freedom | Mean square | | | |
|---|---|---|---|---|---|
| | | Yield/plot (kg) | | | |
| | | 30DAT | 40 DAT | 50 DAT | 60 DAT |
| Replication | 2 | 0.000 | 0.000 | 0.002 | 0.004 |
| Factor A | 3 | 3.531* | 2.676* | 2.667* | 2.968* |
| Factor B | 2 | 0.443* | 0.305** | 0.306* | 0.350* |
| AB | 6 | 0.114** | 0.067** | 0.062** | 0.066** |
| Error | 22 | 0.012 | 0.032 | 0.146 | 1.112 |

Appendix XI: Effect of different level of nitrogen application and different plant spacing on yield/ha at different growth stages of lettuce crop

| Source of variation | Degrees of Freedom | Mean square | | | |
|---|---|---|---|---|---|
| | | Yield/ha (t) | | | |
| | | 30DAT | 40 DAT | 50 DAT | 60 DAT |
| Replication | 2 | 0.001 | 0.002 | 0.002 | 0.004 |
| Factor A | 3 | 5.324* | 2.687* | 3.597* | 2.918* |
| Factor B | 2 | 1.899* | 0.514* | 1.356* | 1.478* |
| AB | 6 | 0.490* | 0.454* | 0.273* | 0.283* |
| Error | 22 | 0.104 | 0.257 | 0.242 | 0.384 |

Appendix XII: Effect of different level of nitrogen application and different plant spacing on total yield of lettuce crop

| Source of variation | Degrees of Freedom | Mean square | | |
|---|---|---|---|---|
| | | Total yield | | BCR |
| | | Kg/plot | t/ha | |
| Replication | 2 | 0.002 | 0.001 | 0.000 |
| Factor A | 3 | 4.288* | 5.17* | 2.961 |
| Factor B | 2 | 5.509* | 3.96* | 0.417 |
| AB | 6 | 1.083* | 4.61* | 0.068** |
| Error | 22 | 0.486 | 0.342 | 0.064 |