EFFECT OF NITROGEN AND SPACING ON GROWTH AND YIELD OF INDIAN SPINACH (*Basella alba* L.)

BY

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*This is to certify that the thesis entitled **"Effect of Nitrogen and Spacing on Growth and Yield of Indian Spinach (Basella alba L.)"** submitted to the Department of Horticulture and Postharvest Technology, 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 **Md. Nazrul Islam**, Registration No. **00880** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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ABSTRACT

The experiment was conducted at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, during the period of April to July 2007, to find out the optimum nitrogen level and spacing on growth and yield of Indian spinach. The experiment consisted of two factors, Factor A: Four levels of nitrogen viz. N_0: 0 kg N/ha, N_1: 100 kg N/ha, N_2: 120 kg N/ha and N_3: 140 kg N/ha and factor B : Three levels of spacing viz. S_1: 60 cm × 20 cm, S_2: 60 cm × 30 cm and S_3: 60 cm × 40 cm. The experiment was laid out in Randomized Complete Block Design(RCBD) with three replications. In case of Nitrogen, N_3 performed maximum plant height (104.99 cm), number of leaves (87.59), leaf area (369.32 cm^2), dry matter content/plant (10.50%) and highest yield (22.55 t/ha) while the shortest plant height (81.91cm), number of leaves (54.78), leaf area (281.37 cm^2), dry matter content/plant (7.85%) and lowest yield (15.96 t/ha) was recorded from N_0.For spacing, S_2 performed maximum leaf area (356.24 cm^2), dry matter content/plant (10.71%) and yield (23.62 t/ha) while the minimum number of leaves/plant (73.72), dry matter content/plant (8.84%) and lowest yield (16.99 t/ha) was recorded from S_3. For combined effect the maximum plant height (107.22 cm), number of leaves (89.67), leaf area (387.25 cm^2), dry matter content/plant (12.09%) and highest yield (25.82 t/ha) was obtained from N_3S_2 while N_0S_3 contributed the lowest yield (14.71 t/ha). The highest (2.65) benefit cost ratio was recorded from N_3S_2 and the lowest benefit cost ratio (1.25) was recorded from N_0S_3. So 140kg N/ha with 60 cm × 30 cm spacing can be used to obtain higher growth and yield of Indian Spinach.

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LIST OF ABBREVIATED TERMS

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

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Indian spinach (*Basella alba* L.) commonly known as *poi*, belongs to the family Basellaceae. It is a popular summer leafy vegetable widely cultivated in Bangladesh, India, and Africa. It is a very popular vegetable in Bangladesh and it's demand is increasing day by day. Indian spinach is a fleshy annual or biennial, twining much branched herb with alternate leaves. Leaves are broadly ovate and pointed at the apex. Flowers are white or pink, small sessile in cluster on elongated thickened peduncles in an open branched inflorescence. Fruit is enclosed in fleshy perianth.

There are mainly two distinct types, *Basella alba* and *Basella rubra*, one with green petioles and stems and the other with reddish leaves, petioles and stems. Both the green and red leaved cultivers are consumed as vegetables but green-leaved cultivers are commercially cultivated. All the cultivars are trained on poles, pandals or trellis or grown on ground (Bose and Som, 1990). The fresh tender leaves and stems are consumed as leafy vegetable after cooking. As half of the water soluble substance may be lost by boiling in water, it is preferable to cook the leaves in soups and stews. Indian spinach is popular for its delicate, crispy, texture and slightly sweeter taste as fresh condition.

The nutritive value of Indian spinach is very high with a good content of minerals, vitamins and substantial amount of fibre (Ghosh and Guha, 1933). The plant is reported to contain moisture -93%, protein -1.2%, iron – 1.4%, calcium – 0.15%, vitamin A – 3250 IU/100g. In addition to these, *Basella alba* contains 16 g fluoride/100 g and nitrate content is 764 ppm on dry weight basis (Sanni, 1983). There was no loss of nitrate even after 48hrs of cold storage. Moreover, it is anadyne, sedative, diuretic and expectorant (Kallo, 1986).

The colouring matter present in the red cultivar is reported to have been used in China as a dye. The ripe fruits also contain a deep violet colouring matter which is also used in colouring food. On account of the presence of mucilagenous substances in the leaves and stems, it is used as poultice.The juice of leaves is prescribed in cases of constipation, particularly for children and pregnant woman (Burkill, 1935). The crop grows in well manured sandy loam soil provided it is well drained and well aerated. Adequate moisture and partial shade result in better growth of the plant and formation of bigger succulent leaves. Cultivation of the crop should be avoided in regions affected by frost. The crop is usually grown during warm and moist seasons.

Indian spinach as a leafy vegetable responds greatly to major essential elements like N, P and K in respect of its growth and yield (Thompson and Kelly, 1988). Generally, a large amount of nitrogen is required for the growth of the leaf and stem of Indian spinach (Opena *et al*., 1988). It plays a vital role as a constituent of protein, nucleic acid and chlorophyll. It is also the most different element to manage in a fertilization system such that an adequate, but not excessive amount of nitrogen is available during the entire growing season (Anon., 1972). Nitrogen progressively increases the marketable yield (Obreza and Vavrina, 1993) but an adequate supply of nitrogen is essential for vegetative growth, and desirable yield (Yoshizawa *et al*., 1981). Excessive application of nitrogen on the other hand is not only uneconomical but also induces physiological disorder.

Plant spacing had a marked effect on growth and development of crops (Mittel and Srivastava, 1964). It is 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 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 requirements but decrease the total number of plants as well as total yield. Yield may be increased upto 25% by using optimum spacing (Bansal, *et al.*, 1995). In Bangladesh like other management practices information about spacing to be used in Indian Spinach cultivation is scanty. 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. Still to day there is few research works conducted focusing on the effects of nitrogen and plant spacing on the growth and yield of Indian spinach in Bangladesh.

Considering above facts, the present study was undertaken with the following objectives:

- To findout the optimum level of nitrogen for Indian spinach production.
- To find out the suitable plant spacing with view to attaining the maximum yield.
- To find out the suitable combination between level of nitrogen and plant spacing for ensuring the higher yield as well as economic production of Indian spinach.
- To find out the benefit cost ratio for the production of Indian spinach by using different level of nitrogen and plant spacing.

Chapter 2
Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Indian spinach (*Basella alba* L.) is one of the most popular leafy vegetable in Bangladesh. Like many other vegetables such as root and tuber crops as well as spices, the growth and yield of *Basella alba* are influenced by different factors like sowing time, temperature, soil moisture, plant spacing, organic and inorganic fertilizer etc.The crop has received less attention of the researchers on its various aspects because normally it grows with less care or management practices. For that a very few studies on growth, yield and development of Indian Spinach have been carried out in our country as well as in many other countries of the world. Hence, the research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important works and researches related to the nitrogen and plant spacing so far done at home and abroad on some leafy vegetable crops production including Indian Spinach has been reviewed in this chapter under the following headings-

2.1 Effect of nitrogen on growth and yield

Rashid *et al.* (1981) studied the acclimatization, adaptability and performance of Kang Kong (*Ipomoea aquatica*) and reported that the yield was significantly increased by increasing the application of nitrogen levels up to a certain limit. Tindal (1983) reported that Kang Kong responded to nitrogen fertilizers applied either before planting or as subsequent top dressing.

Rai (1981) also reported that nitrogen increases the vegetative growth and produces good quality foliage and promotes carbohydrate synthesis. Like Spinach, Kang Kong also responds to the application of nitrogen. The general recommendation of nitrogen for Kang Kong under Bangladesh conditions is 150 kg urea per hectare (Anonymous, 1980; Hossain, 1980). They suggested to apply 50% should be applied in three equal installments as top dressing 1st after seven days of germination, 2nd and 3rd after 1st and 2nd harvest of the corp.

Islam *et al.* (1984) obtained the experimental results at the Bangladesh Agricultural University, Mymensingh revealed that application of nitrogen increased the yield and quality of Kang Kong. The influence of nitrogen was distinct at the second and third harvest. Application of 160 kg N/ha was found to be the best for seed propagated plants, while for the vegetatively propagated plants the use of nitrogenous fertilizer appeared to be economic only upto the level of 80 kg N/ha. In addition to increased yield, the added nitrogen also improves the edible quality of the vegetable, particularly at the later harvests.

Rahman *et al.* (1985) studied Indian Spinach and reported that the highest yield of greens (62.89 t/ha) was obtained from the closest spacing when the highest dose of nitrogenous fertilizer was applied. Due to the application of N at different levels, all the characters differed significantly. However, the maximum number of shoots (88) was produced from the highest dose of N (82.8 kg/ha).

Hamid *et al.* (1986) conducted an experiment to observe the effect of nitrogenous fertilizer on the growth and yield of India Spinach and found significant variations among the different nitrogen treatments in respect of the number of shoot/plant, number of leaves/plant, shoot length, leaf length and breadth and yield. The highest yield (79.34 t/ha) was obtained by applying the highest dose of nitrogen (250 kg N/ha).

Dhillon *et al.*(1987) conducted an experiment to observe the effect of different levels of nitrogen on the yield of Spinach (*Ipomoea oleracea*) and they reported that in field trials over two years with cv. Punjab selection N was applied as urea @ 0-90 kg/ha. The average leaf yield rose with increasing N rate from 20.4 t/ha at zero kg N to 41.2 t/ha at the highest N rate.

Nitrogen was reported to be the most important fertilizer to increase plant growth and yield of Batisak (Anonymous, 1984). Miah (1987) reported that yield of Batisak increased with an increase in nitrogen level from 80 kg to 172 kg per hectare under Mymensingh condition.

An experiment was carried out at IPSA, Salna, Gazipur during Kharif season of 1989 to study the effect of four manuring doses (0, 10, 30 and 60 t/ha of cowdung) and harvest frequency (17, 21 and 25 days) on growth and yield of Gimakalmi. The total yield was highest (68.82 t/ha) at 25 days harvest frequency which was statistically similar to that (65.82 t/ha) produced by 17 days harvest frequency. Although 25 days harvest frequency produced the highest yield, most of the foliage became fibrous and unfit for consumption (Awal, 1989).

Rubeiz *et al.* (1992) mentioned that the lack of significant response in Indian spinach yield was due to sufficient levels of soil NO_3-N and available P in the untreated soil. Manure or fertilizer application had no effect on soil EC, pH or available P. Soil NO_3-N at harvest was significantly increased only by NH_4NO_3. Leaf PO_4-P concentration was not affected by treatments, but leaf NO_3-N at heading was significantly increased by all treatments.

Park *et al.* (1993) conducted an experiment on the effect of fertilizer level on the growth of water Spinach (*Ipomoea aquatica*) and reported that application of N fertilizer at 30 kg per 10 acres increased yield more than lower rates.

Etman (1993) observed that increasing soil application of nitrogen from 50 to 100 kg urea/feddan (1 feddan=0.42 ha) increased yield of Spinach. Application of 50 kg/feddan to the soil plus 25 kg/feddan as a foliar spray increased leaf area, number of leaves per plant and shoot weight and length ultimately resulted in the highest yield.

Zhu *et al.* (1994) studied plants grown in solution culture and the effects of N supply (1-15 mmol NO_3/litre) and light intensity on nitrate accumulation, nitrate reductase activity (NRA), and metabolic pool size (MPS) of nitrate reduction in the leaves. MPS and NRA in situ increased with increasing NO_3 concentration in the nutrient solution. When the NO_3 concentration was >10 mmol/litre, MPS was only slightly increased but the NO_3 accumulation in the vacuoles was increased. Under low light intensity, NO_3 accumulation in the leaves was increased; it was mostly stored in the vacuoles, as the NO_3 in the metabolic pool was not affected. Under low light intensity, the soluble sugar content of the leaves was significantly reduced. Accumulation of NO_3 in the vacuoles may be involved in osmoregulation.

Aditya *et al.* (1995) conducted an experiment on the effect of different levels of nitrogen on the production of Pak choi (*Brassica chinensis L.*) cv. Batishak at the Horticultural Farm of BAU, Mymensingh. They reported that application of nitrogen significantly influenced the growth and yield of Batisak. The yield was increased with increasing levels of nitrogen, and maximum yield per hectare in both fresh and dry weight basis was obtained with 200 kg N/ha.

Abdel (1996) carried out two experiments at the Experiment Station Farm of Agriculture and Veterinary Medicine College, King Saud University, Saudi Arabia, in the winter of 1991-92 and 1992-93. Seeds of the lettuce cv. White Paris were sown in a nursery in October 1991 and 1992. Seedlings were transplanted in December. N as ammonium sulphate (20.5%N) was applied at 0, 100, 200 and 300 kg/ha in 3 equal doses 3, 5 and 7 weeks after transplanting. Increasing N concentration resulted in increases in all measured parameters. Head fresh weight and total yield both increased with increasing applications of N. It was concluded that to maximise lettuce yields the optimum N application should be 200 kg/ha.

Anez and Pino (1997) evaluated the methods and timing for the application of nitrogen fertilizer to lettuce (leafy vegetable) Great Lakes. Ten nitrogen treatments (side dressing of 100 kg N/ha at transplantation or 15, 30, 45 and 60 days after transplanting (DAT), side dressing of 50 kg N/ha plus 50 kg N/ha applied or foliar fertilizer applied at transplantation or 15, 30, 45 and 60 DAT; control (without nitrogen fertilizer) were tested on a sandy-loam soil in Merida, Venezuela. Significant differences were found between methods of application and the control when 100 kg N/ha were applied at 45 DAT. No significant differences were observed between the treatments and the control when 100 kg N/ha was applied after 45 DAT.

Kowalska (1997) conducted green house trials in two winter-spring seasons, N fertilizer in the form of urea, ammonium or nitrate was applied once before planting to pot grown plants Indian spinach cv. Alka in peat or a soil-based mixture (peat: sand: mineral soil, 1:1:1). The average fresh weight and dry matter yield of plants grown in peat was considerably higher than that of plants grown in the soil mixture. Application of fertilizer with reduced nitrogen forms increased the ammonium content of plants, where as nitrate-N increased nitrate accumulation. It was concluded that application of reduced forms of N significantly improved the quality of the vegetable by reducing the accumulation of nitrates especially in plants grown in peat which has a slower rate of nitrification.

Vidigal *et al.* (1997) mentioned that dried pig manure gave the highest yields in Indian spinach at 65 days after sowing (54.4 t/ha), an increase of 33.3% above those supplied with NPK, with similar results in a succeeding crop planted on the same ground in late September (a 39.4% increase over NPK). Napier grass + coffee straw + pig slurry was the best mixture, increasing yields 10.8% and 17.6% above those produced by NPK in 1st and 2nd crops, respectively.

Zarate *et al.* (1997) observed that the interaction between rate and method of application was significant in *B.alba.* In the absence of incorporated manure, surface application of 14 t manure/ha gave significantly higher yields (17.8 t fresh matter/ha) than other rates. When 7 t/ha was incorporated, the rate of surface application had no significant effect on yields (13.3-17.1 t/ha), whereas when 14 t/ha was incorporated, surface application of 7 t manure/ha gave significantly highest yield (20.0 t fresh matter/ha).

Zhong *et al.* (1997) conducted an experiment in Hanghou, China using a cropping system with amaranth, onion, cabbage, taro and cauliflower to investigate the effect of different potassium fertilizers (sulfate of potash and/or muriate of potash) on the yield and quality of vegetable crops. Market yield of all those vegetables increased significantly with potassium fertilization. Sulphate of potash was more effective in terms of yield and quality compared to muriate of potash.

Rodrigues and Casali (1999) observed that the highest estimated yields of Indian spinach 119.5, 119.4 and 153.9 g/plant were obtained with 37.7 t organic compost/ha with no mineral fertilizer application, 18.9 t organic compost/ha with half the recommended mineral fertilizer rate and 13 t organic compost/ha with the recommended mineral fertilizer rate. Organic compost application resulted in lower foliar N and Ca concentrations and higher foliar P, K and Na concentrations compared with mineral fertilizer application.

Bastelaere (1999) stated that nitrogen fertilizer application (250 kg/ha) in Indian spinach during the autumn on well-leached soils resulted in glassiness and rib blight. However, after soil disinfection, an application of 225 kg/ha was sometimes necessary. Greater application rates resulted in stagnated growth and lower crop weight.

Tisselli (1999) reported that maximum rates of organic manure (usually poultry manure) and NPK were recommended in 1998 for use in lettuce crops in Emilia-Romagna and Italy.

Trials showed that a combination of organic and mineral fertilizers gave higher yields of marketable heads, fewer rejects and a better average weight/head than mineral fertilizer alone.

Brahma *et al.* (2002) conducted a field experiment for two years at Assam Agricultural University in India during Rabi season to study the effect of nitrogen, phosphorous and potassium on the growth and yield. Treatments for potassium fertilizer comprised of five levels of potassium (0, 20, 40, 60 and 80 kg/ha, respectively). They found that growth and yield was highly improved with the increasing level of potassium.

Linkui *et al.* (2002) carried out an experiment in Shanghi, China to investigate the effect of different bio-organic fertilizers on the yield and quality of 3-coloured amaranth. Fertilizers applied at the rate of 1.9 kg/plot. Amaranth receiving bio-fertilizers showed a yield increase of 15-38% compared to those receiving exclusive vegetable fertilizers.

Thapa and Maity (2002) carried out a field experiment in the sandy loam of West Bengal, India during the summer seasons of 1998 and 1999 to study the effect of different N @ 50, 100 and 150 kg/ha and K_2O @ 40 and 60 kg/ha on the growth and yield of Amaranthus sp. cv. local. The response in terms of growth components such as plant height, number of leaves, and number of branches, leaf area index, yield and dry matter production was highest at the highest nutrient levels. The highest yields of 100.75, 101.5 and 112.47 q/ha was obtained from treatments with N at 150, P_2O_5 at 60 kg K_2O /ha, respectively.

Ayodele *et al.* (2002) conducted a field experiment to evaluate the effect of N fertilizer @ 0, 50, 100 and 200 kg/ha on growth and yield of Amaranthus. Plant height, number of leaves produced, fresh and dry weights of plant parts increased with increased nitrogenous fertilizer application within a certain range. Application of fertilizer at 200 kg N/ha increased leaf production upto 75%, and the yield increased upto 114%. The unfertilized plants had yellowish green coloration as compared to the brighter green color observed in fertilized plants.

Islam (2003) reported that fertilizer doses at the rate of 200, 100 and 200 kg/ha of urea, triple super phosphate and muriate of potash respectively and maintaining other agricultural practices properly the average yield of amaranth can be raised upto 45 to 50 t/ha.

Santos *et al.* (2003) carried out a field trial in South Florida, United States, between 1996 and 1999 to determine the extent of yield reductions under two P fertility regimes. Phosphorus was applied in two ways likely broadcast at 250 kg P/ha and banded at 125 kg/ha. When P was broadcasted, yield reductions were observed approximately 20% in no weeding condition whereas 24% reductions were occurred in banded condition. Maximum yield was recorded from 250 kg P/ha treatment.

Rana and Rameshwar (2003) conducted an experiment in Sangla, Kinnaur, Himachal Pradesh, India during the summer seasons of 2000 and 2001 to find out the response to phosphorus fertilizer at 20, 40 and 60 P_2O_5 kg/ha rate under irrigated conditions on amaranth. Yield and yield contributing characters increased significantly with the increase in the rate of fertilizer. But maximum net returns and benefit cost ratio were obtained from the phosphorous fertilizer application @ 40 kg P_2O_5 per hectare under irrigated conditions.

Santos *et al.* (2004) conducted A field trial to investigate the influence of P application method on the critical period of amaranth with phosphorus fertilizer at rates of 125 or 250 kg ha^{-1}, respectively. Significant differences in respect of marketable yield, fresh yield and stem diameter were recorded at harvest. Fresh yield was 20% higher in 250 kg ha^{-1} compare with 125 kg/ha P in the method of broadcasting application.

Effect of a compound NPK mineral fertilizer on the growth response of amaranths resulting from inorganic nutrient sources was investigated by Agele *et al.* (2004) in sandy clay loam soil condition. The application rate of N 150 kg/ha from NPK fertilizer resulted with highest maximum yield as well as economic return. A higher proportion of the N present appeared to be resistant to microbial degradation and was thus unavailable for plant uptake.

A field experiment was conducted by Rathore *et al.* (2004) in Rajasthan, India during the winter seasons of 1997-1998 and 1998-1999 to identify the optimum doses of nitrogen for green amaranth cultivar. The crop was supplied with 0, 30, 60 and 90 kg N/ha in the growing period. Of those 90 kg/ha N fertilizer gave significantly higher yield, better growth and higher values for yield components compare to other doses. Application of N enhanced the growth and yield attributes significantly, whereas harvest index remained unaffected for using nitrogen fertilizer.

2.2 Effect of plant spacing on growth and yield

Davey (1965) observed maximum head size in cabbage with a spacing of 25-40 cm in row. However, closer spacing resulted in higher yields per hectare with greater variability in head size. Somos (1954) reported that wider spacing resulted in better growth and rapid development than closer spacing.

Koay and Chua (1979) conducted an experiment to study the effect of appropriate planting method and density for economical production of Pak-choi (*Brassica chinensis* L.) in Singapore. The treatment compared were direct seeding, bare root transplanting or ball root transplanting in rows 30 cm apart with inter plant spacing of 10 cm, 20 cm, 30 cm. The highest yield (50 t/ha) was obtained from the transplanted plants at the closest spacing. Lee (1983) studied the effects of plant densities on some leafy vegetables including Pak-choi. Four plant densities viz. 10 cm × 10 cm, 15 cm × 15 cm, 20 cm × 20 cm and 30 cm × 30 cm were included in the study. The highest yield was obtained in 15 cm × 15 cm spacing but had no significant difference with 10 cm × 10 cm spacing.

Rahman *et al.* (1985) conducted an experiment to see the effect of spacing and harvesting interval on the growth and yield of Indian spinach (Puisak) at the Central Research Station of BARI at Joydevpur. They reported that the highest number of shoots per plant was obtained from the quicker harvesting (8 days interval) and this was reflected as the highest yield (41.11 t/ha), while yield per hectare decreased with the increase of harvesting interval.

Vogel and Paschold (1989) conducted an experiment in Germany on Pak-choi (*Brassica chinesis* L.) in relation to different spacing and dates of planting. A crop density of 160,000 plants per hectare with spacings of 25 cm × 25 cm gave the highest yields and high proportion of plant weighing 200-600 g.

In an experiment conducted by Hill (1990) at Manjimup Research Station, Australia on a sandy loam over clay at 60 cm, Chinese cabbage cv. Early Jade Pagoda was grown at spacing of 25 × 25, 30 × 30, 35 × 35 or 40 × 40 cm with 0, 50, 100, 200, 300 or 400 kg N/ha. The highest marketable yields, 126.6 and 123.6 t/ha, were produced at the closest spacing, marketable yield for this spacing increased as N rate increased from 0 to 200 kg/ha, and remained constant from 200 to 300 kg/ha but decreased when the N rate was increased to 400 kg/ha. The yield potential of Chinese cabbage was higher at closer spacing than at the wider.

Kler *et al.* (1992) conducted a field trial at Ludhiana, Indian Punjab in 1988-1990, Chinese cabbage seedling were sown with 30 cm spacing between N-S rows, or with bidirectional sowing with 30 cm between N-S and E-W rows, or with 30 cm row spacing between N-S rows and 45 cm between E-W rows. Crops received 60, 90 or 120 kg N/ha. Seed yield was increased by cross-sowing and by increasing N rate from 60 to 90 kg/ha. Correlation coefficients between different yield components were calculated. Seed yield was positively correlated with plant height, days to maturity and harvest index. These parameters, and seed yield, were all positively correlated with light interception.

Plant spacing is an important factor which affects the growth and yield of Gimakalmi. Park *et al.* (1993) conducted an experiment on plant spacing. From their findings it was clear that 30 cm × 30 cm was better than 15 cm × 15 cm or 45 cm × 45 cm in consideration of growth and yield of the crop.

Two field experiments were conducted by Norman and Shongwe (1993) on a sandy clay loam soil during the summer seasons of 1990-1991 and 1991-1992. Seeds were sown in for the 1st experiment with 4 spacings (60 × 45, 60 × 60, 90 × 45 and 90 × 60, cm) and in the second experiment with 5 spacings (45 × 45, 60 × 45, 60 × 60, 90 × 45, 90 × 60). These spacings recorded no significant improvement in shoot, leaf or stem quality.

Damrong and Krung (1994) conducted an experiment with Chinese cabbage 2 varieties, ASVEG no.1 and commercial cultivar Elephant brand which were planted under different spacing of 40×40, 40×30, 40×25, 30×30, 30×25 cm during July to September 1987 at Kasetsart University Kamphaengsaen Nakhon Pathom. They found that closer spacing had more number of plants per unit area. Increasing of plant population did not produce better yield because the percent of non-heading plant was increased and consequently their mean head weight. The most suitable spacing between plant for growing Chinese cabbage variety ASVEG no.1 was 40 cm. The commercial cultivar Elephant brand gave very low yield only 4-11 t/ha while ASVEG no.1 produced 26-28 t/ha.

Bansal *et al.* (1995) reported from an experiment that closer inter row (40 cm) and intra row spacing (10 cm) significantly reduced the dry matter accumulation, number of functional leaves and hence yield/plant. An experiment was conducted by Quasem and Hossain (1995) to evaluate 16 germplasms of local stem amaranth in summer. Spacing was maintained at 30 × 15 cm. Plant height at last harvest was found to be the maximum in SAT 0034 (88.3 cm) and minimum in SAT 0062 (13.4 cm). The highest yield was recorded in SAT 0054 (54 t/ha) and lowest in SAT 0024 (15.5 t/ha).

Gupta and Arvind (1995) carried out a field study in 1990-1991 at Pantnagar, Naintal and noted that seed and oil yields of *B. campestris* were highest with spacing 30 × 15 cm and harvest index was highest with spacing at 40 × 10 cm. Gupta and Panda (1995) reported from field trial in winter 1989-1990 at Pantnagar, Uttar Pradesh that *B. campestris* (var. toria cv. PT 303) was line sown or broadcast at various spacings to give 160000-500000 plants/ha. Seed yield was higher with broadcasting than line sowing and was highest at a density of 220 000 plants/ha (30 x 15 cm spacing).

Jehangir *et al.* (1999) conducted an experiment to study the response of different varieties to row spacing on a silty clay-loam soil of Shalimar (Kashmir) during rabi, [winter] 1993-1994. Cabbage Cv. KS-101 gave seed yield 8.4, 18.2 and 20.2% higher than KS-103, KS-102 and KOS-1, respectively. The row spacing of 30 × 10 cm recorded a significant increase of 11.9 and 19.2% in seed yield over 15 × 10 cm and 45 × 10 cm row spacing, respectively.

Das and Ghosh (1999) conducted an experiment from March to August 1999 in Salna, Gazipur, Bangladesh to evaluate the seed yield potential of 3 amaranths cultivars (Drutaraj, Bashpata and Sureshsari) grown under 5 different spacing levels (30 × 10, 30 × 15, 30 × 20, 30 × 25 and 30 × 30 cm). Spacing had pronounced effect on the seed yield and yield contributing characters. Plants grown at the widest spacing of 30 × 30 cm produced the longest stem (95.25 cm), maximum seed yield per plant (24.24 g) and had germination of 80.60%. However, plants grown at a spacing of 30 × 20 cm recorded the highest seed yield/ha (3.64 t/ha).

A field experiment was conducted by Bali *et al.*, (2000) in Jammu and Kashmir, India, during the rabi seasons of 1995-1996 and 1996-1997, to study the effect of planting density and different N and P fertilizer rates on cabbage cultivar KS 101. Plants were sown at 25, 33 and 50 per square m, and at 40 × 10, 30 × 10 and 20 × 10, respectively. N was applied at 30, 60 and 90 kg/ha, while P was applied @ 30, 45 and 60 kg/ha. Seed yield was highest at 33 plants per square m and at 30 × 10 cm spacing. Seed yield increased with increasing N rates up to 60 kg/ha, and also increased with increasing P rates. N at 60 kg/ha gave the highest return and cost benefit ratio.

Field trials were conducted in South Florida, United States, between 1996 and 1999 by Santos *et al.* (2003) to determine the extent of yield reduction due to population densities of stem amaranth. They recorded that yield reductions reached 24% with densities higher than 8 plants/6 m row planting. Missinga and Currie (2002) conducted an experiment to assess the impact of plant densities of amaranth on yield and yield contributing characters and reported that spacing didn't affect the individual plant yield but the yield per hectare was greatly influenced due to plant spacing.

A field experiment was conducted to determine the effect of crop densities (10, 20 and 40 plants m^{-1}) of amaranth by Abbasdokht *et al.* (2003) in Iran. Yield and yield contributing characters were statistically significant in different density. The density with 40 plants m^{-1} gave the minimum yield, whereas 10 plants m^{-1} gave the highest single plant yield but the lowest yield was found when yield in hectare was considered.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

Indian spinach (*Basella alba)* is being grown in a very large scale in Bangladesh. A good deal of interest has been generated for raising this crop due to it's present popularity and demand.. As a leafy vegetable nitrogen and plant spacing affects the growth, development and yield. In this chapter, the details of different materials used and methodologies followed during the experiment are described.

3.1 Experimental Site

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from April to July 2007. The experimental site was previously used as vegetable garden and recently developed for research work. The location of the site is 23°74´N latitude and 90° 35´E longitude with an elevation of 8.2 meter from sea level (Anon., 1989).

3.2 Climate

The climate of the experimental site is sub-tropical, characterized by rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). The average monthly maximum and minimum temperatures were 34.7°C and 12.4°C repectively during the experimental period. Kharif season is characterized by plenty of sunshine. The maximum and minimum temperature, humidity rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department (Climate and Weather Division) and have been presented in Appendix I.

3.3 Characteristics of Soil

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

3.4 Sowing materials

In this research work, Indian Spinach seed was used as the planting material and the seeds were collected from Siddique Bazar, Gulistan, Dhaka. Seeds were used @ 600 g/ha.

3.5 Treatments of the experiment

Factor A : Level of nitrogen (four levels):

i. N_0: 0 kg N/ha

ii. N_1: 100 kg N/ha

iii. N_2: 120 kg N/ha

iv. N_3: 140 kg N/ha

Factor B : Plant spacing (three levels) :

i. S_1: 60 cm × 20 cm

ii. S_2: 60 cm × 30 cm

iii. S_3: 60 cm × 40 cm

Treatment combination : 4 × 3 = 12 (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).

3.6 Experimental design and layout

The experiment was in two factors and laidout out Randomized Complete Block Design (RCBD) with three replications. Each block consisted of 12 plots, where 12 treatments were alloted at random. Thus the total number of plots was 36. The size of unit plot was 2.4 m × 1.8 m.= 4.32 m^2. The distance between the plots and the blocks were 50 cm and 75 cm, respectively. The total area of experiment was 31 m × 10.2 m = 316.2 m^2. The layout of the experiment was given in Figure 1.

3.7 Land preparation

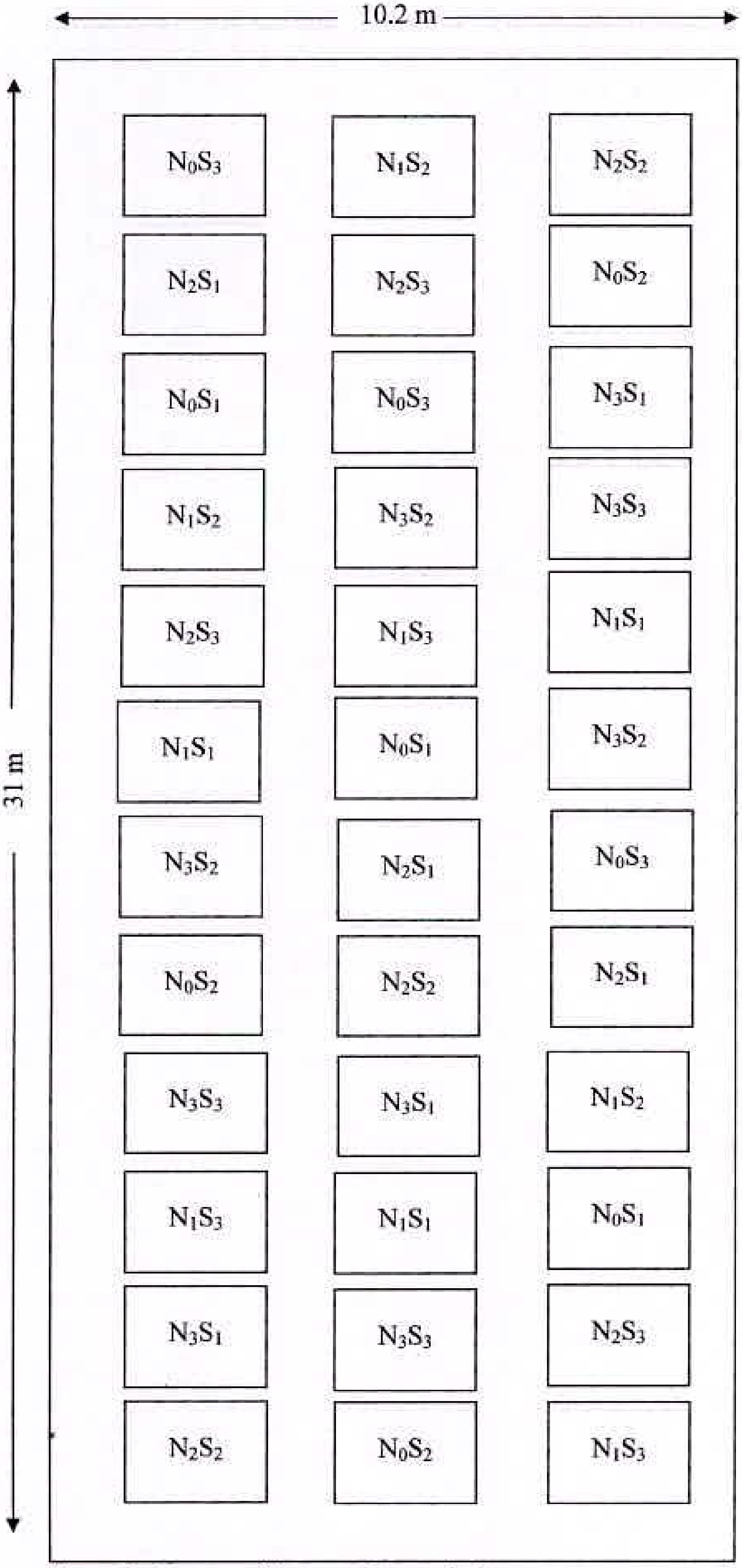
The land which was selected to conduct the experiment was opened on 24 April 2007 with the help of a power tiller and then it was kept open for 5 days prior to further ploughing. Afterwards it was prepared by ploughing and cross ploughing followed by laddering. Deep ploughing was done to have good tilth which was necessary for getting better yield of the crop. The weeds and stubbles were removed after each laddering. Simultaneously the clods were broken and the soil was pulverized for good tilth.

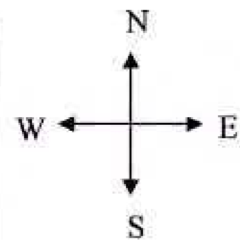
3.8 Application of manures and fertilizers

Manures and fertilizers were applied according to the treatments considering the recommended dose for Indian spinach according to Rashid (1994).

Table 1. Dose and method of application of fertilizers in Indian spinach field

Fertilizers	Dose/ha	Application (%)			
		Basal	15 DAS	30 DAS	45 DAS
Cowdung	20 tonnes	100	--	--	--
N (as urea)	As per treatment	--	33.33	33.33	33.33
P_2O_5 (as TSP)	120 kg	100	--	--	--
K_2O (as MP)	180 kg	100	--	--	--





Plot size = 2.4 m × 1.8 m
Plot spacing = 50 cm
Between replication = 0.75 m

Factors A:

Level of nitrogen (four levels):

N_0: 0 kg N/ha
N_1: 100 kg N/ha
N_2: 120 kg N/ha
N_3: 140 kg N/ha

Factor B

Plant spacing (three levels) :

S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

Figure 1. Layout of the experimental plot

3.9 Seed sowing

Seed sowing were done on 30 April, 2007 as per design of the experiment. Light irrigation was provided in the evening after sowing of seeds. Some seeds also sown in boder area for gap filling or replacement of weak seedlings.

3.10 Intercultural operation

3.10.1 Gap filling

Dead, injured and weak seedlings were replaced by healthy seedlings from boarder line.

3.10.2 Weeding

Some weeds were found in the experimental plot. Weeding was done time to time in the plots to keep it clean.

3.10.3 Irrigation

Light irrigation was given just after the sowing of seeds. The plots were irrigated more frequently for better establishment of the plants.

3.10.4 Insects and Diseases

In early stage some insect was noticed. This was controlled by using systemic insecticides. There was no incidence of diseases.

3.11 Harvesting

Randomly selected 4 plants were harvested from each plot for data collection. First, second, third and final harvests were done at 30, 45, 60 and 75 DAS.

3.12 Data collection

Data were recorded on the following parameters from the sample plants. During the course of experiment 4 plants were sampled randomly from each unit plot for data collection.

3.12.1 Plant height

Plant height was measured in centimeter (cm) by a meter scale at 30, 45, 60 and 75 days after seed sowing (DAS) from the point of attachment of the leaves to the ground level up to the tip of the plant.

3.12.2 Number of leaves per plant

Number of leaves of 4 randomly chosen plants were counted at 30, 45, 60 and 75 days after seed sowing (DAS). All the leaves of each plant were counted seperately. Only the smallest young leaves at the growing point of the plant were excluded from counting. The average number of leaves of 4 plants gave the number of leaves per plant.

3.12.3 Leaf area per plant

The selected leaves of 4 randomly chosen plants were measured at 30, 45, 60 and 75 days after seed sowing (DAS). Only the largest young leaves of the plant were measured. The average leaf area of the 4 plants gave leaf area per plant (cm^2).

3.12.4 Number of branches per plant

Number of branches of 4 randomly chosen plants were counted at 30, 45, 60 and 75 days after seed sowing (DAS). Only the smallest young branches at the growing point of the plant were excluded from counting. The average number of branches of 4 plants gave number of branches per plant.

3.12.5 Fresh weight per plant

Leaves and twigs of 4 randomly selected plants at 30, 45, 60 and 75 days after seed sowing were detached by a sharp knife and average fresh weight per plant was recorded in gram (g).

3.12.6 Dry matter of plant

One hundred grams of leaf and twigs sample previously cut into thin pieces were sun dried, after that samples were placed in envelop, weighed and placed in an oven maintained at 70^0C for 72 hours until these reached a constant weight. The sample then was transferred into a desiccator and allowed to cool down to room temperature. The dry weight of the sample was taken at 30, 45, 60 and 75 days after seed sowing (DAS). The dry matter contents were computed by simple calculation from the weight by the following formula.

$$\text{Dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.12.7 Yield per plot

The yield of Indian spinach per hectare was calculated form every harvest of leaves and twigs per plot at 30, 45, 60 and 75 days after sowing (DAS). The yield per plot was expressed in kg.

3.12.8 Yield per hectare

It consisted of leaf and twigs of Indian spinach weighed and then converted into ton per hectare. The yield per plot was expressed in tonnes.

3.13 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the nitrogen and plant spacing on yield and yield contributing characters of Indian spinach. The analysis of variance was performed by using MSTAT Program. The significance of the difference among the treatment combination means was estimated by DMRT (Duncan's Multiple Range Test) at 5% level of probability (Gomez and Gomez, 1984).

3.14 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% for six months. The market price of Indian spinach was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

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

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Chapter 4

Results and Discussion

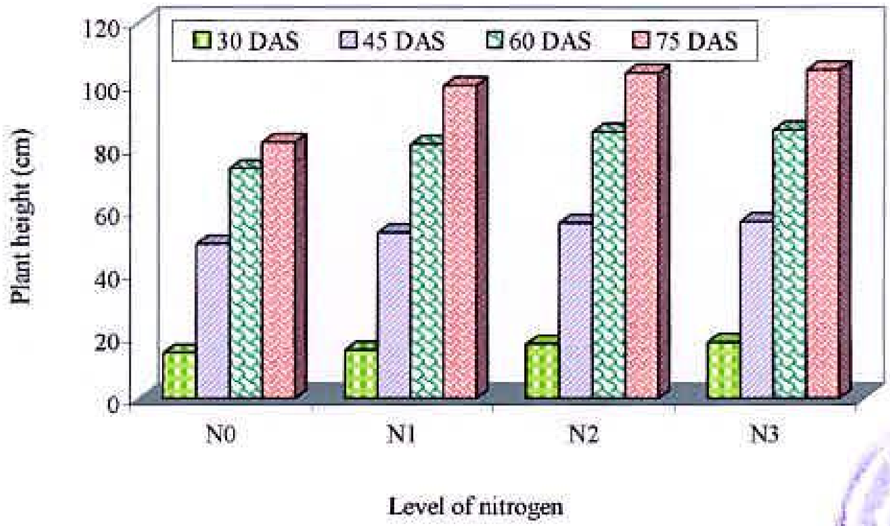
CHAPTER IV

RESULTS AND DISCUSSION

To determine the effect of different level of nitrogen and plant spacing on growth and yield of Indian spinach the present study was conducted. Data on different yield contributing characters and yield at different days after sowing (DAS) were recorded. The analysis of variance (ANOVA) of the data on different yield contributing characters and yield of Indian spinach are given in Appendix III-VI. The results have been presented and discussed, and possible interpretations given under the following headings:

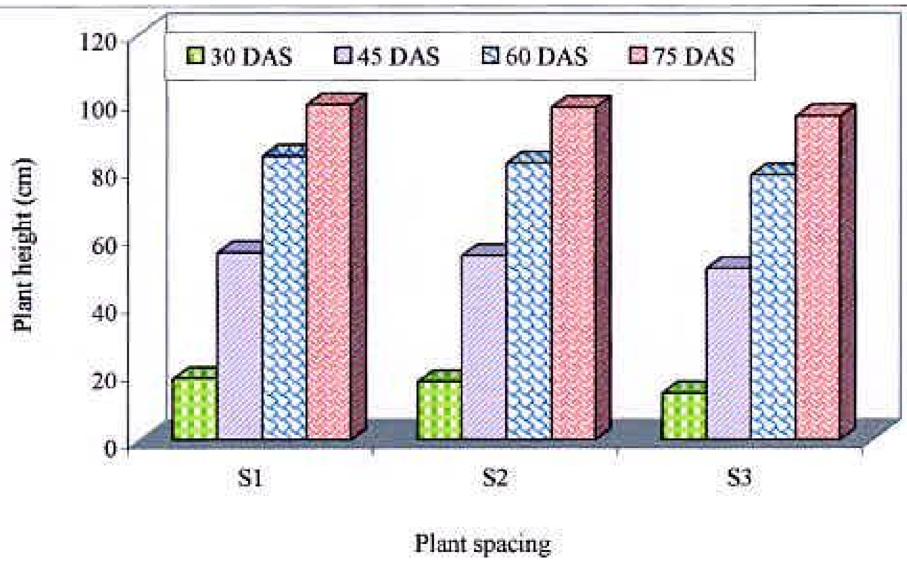
4.1 Plant height

Statistically significant variation was recorded due to different levels of nitrogen on plant height of Indian spinach at 30, 45, 60 and 75 DAS (Appendix III). At 30 DAS, the longest (17.95 cm) plant was recorded from N_3 (140 kg N/ha) which was statistically similar (17.43 cm) to N_2 (120 kg N/ha), while the shortest (14.65 cm) plant was recorded from N_0 (0 kg N/ha) which was statistically identical (15.56 cm) to N_1 (100 kg N/ha). The longest (56.39 cm) plant was found from N_3 which was statistically similar (55.92 cm) to N_2, while the shortest (49.39 cm) plant was recorded from N_0 which was closely followed (52.93 cm) by N_1 at 45 DAS. At 60 DAS, the longest (85.73 cm) plant was recorded from N_3 which was statistically similar (85.17 cm) to N_2 and the shortest (73.50 cm) plant was recorded from N_0 which was closely followed (81.16 cm) by N_1. The longest (104.99 cm) plant was recorded from N_3 which was statistically similar (104.01 cm) to N_2, while the shortest (81.91 cm) plant was observed from N_0 which was closely followed (99.77 cm) by N_1 at 75 DAS (Figure 2). Nitrogen influenced the vegetative growth of plant and the ultimate results was the longest plant as compared to control. Hamid *et al.* (1986) reported for highest plant (85.25 cm) by applying the highest dose of nitrogen (250 kg N/ha).



N_0 : 0 kg N/ha
N_1 : 100 kg N/ha
N_2 : 120 kg N/ha
N_3 : 140 kg N/ha

Figure 2. Effect of nitrogen on plant height of Indian spinach



S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

Figure 3. Effect of plant spacing on plant height of Indian spinach

Plant height varied significantly due to the different plant spacing at 30, 45, 60 and 75 DAS (Appendix III). At 30 DAS, the longest (18.13 cm) plant was found from S_1 (60 cm × 20 cm) which was statistically identical (17.25 cm) to S_2 (60 cm × 30 cm) and the shortest (13.81 cm) plant was recorded from S_3 (60 cm × 40 cm). The longest (55.53 cm) plant was recorded from S_1 which was statistically identical (54.57 cm) to S_2 and the shortest (50.87 cm) plant was recorded from S_3 at 45 DAS. At 60 DAS, the longest (83.92 cm) plant was recorded from S_1 which was statistically identical (81.84 cm) to S_2 and the shortest (78.41 cm) plant was observed from S_3. The longest (99.06 cm) plant was found from S_1 which was statistically identical (98.29 cm) to S_2 and the shortest (95.66 cm) plant was recorded from S_3 at 75 DAS (Figure 3). Park *et al.* (1993) reported that that 30 cm × 30 cm was better than 15 cm × 15 cm or 45 cm × 45 cm in consideration of growth and yield of the crop.

Combined effect between nitrogen and plant spacing on plant height showed significant differences at 30, 45, 60 and 75 DAS (Appendix III). At 30 DAS, the longest (19.98 cm) plant was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_1S_3 (100 kg N/ha + 60 cm × 40 cm) gave the shortest (13.38 cm) plant. The longest (59.09 cm) plant was observed from N_3S_1 (120 kg N/ha + 60 cm × 20 cm), while N_0S_2 (0 kg N/ha + 60 cm × 30 cm) gave the shortest (48.07 cm) plant at 45 DAS. At 60 DAS, the longest (88.11 cm) plant was recorded from N_3S_1 (120 kg N/ha + 60 cm × 20 cm), while N_1S_3 gave the shortest (78.68 cm) plant. The longest (107.22 cm) plant was found from N_3S_2, while N_0S_2 gave the shortest (78.18 cm) plant at 75 DAS (Table 2). Rahman *et al.* (1985) studied Indian Spinach and reported from their experiment that the longest plant (89.55 cm) was from the closest spacing when the highest dose of nitrogenous fertilizer was applied.

Table 2. Combined effect of nitrogen and plant spacing on plant height and number of leaves per plant of Indian spinach

Treatment Combinations	Plant height (cm) at 30 DAS	45 DAS	60 DAS	75 DAS	Number of leaf per plant at 30 DAS	45 DAS	60 DAS	75 DATS
N_0S_1	16.92 c	50.56 cde	77.82 d	82.94 c	12.00 ef	26.00 c	50.00 g	59.67 e
N_0S_2	13.53 e	48.07 e	70.15 e	78.18 d	10.67 f	21.00 d	44.44 h	50.44 g
N_0S_3	13.50 e	49.54 e	72.53 e	84.60 c	11.11 ef	26.33 c	44.11 h	54.22 f
N_1S_1	17.34 bc	54.51 bc	82.59 bcd	100.58 b	13.89 bcde	30.89 b	56.44 ef	76.11 c
N_1S_2	15.96 cd	53.87 cd	82.22 cd	100.79 b	13.44 cdef	29.55 b	55.00 f	76.33 c
N_1S_3	13.38 e	50.39 de	78.68 d	97.93 b	11.33 ef	26.22 c	50.56 g	72.00 d
N_2S_1	19.18 ab	57.95 ab	87.17 abc	105.98 a	15.67 abcd	33.11 a	60.11 bc	86.67 ab
N_2S_2	19.55 a	57.88 ab	87.10 abc	106.97 a	16.00 abc	33.11 a	61.11 ab	88.44 a
N_2S_3	13.57 e	51.93 cde	81.24 d	99.07 b	12.33 ef	30.56 b	57.67 de	84.11 b
N_3S_1	19.07 ab	59.09 a	88.11 a	106.74 a	16.44 ab	33.89 a	61.45 ab	88.56 a
N_3S_2	19.98 a	58.45 a	87.89 ab	107.22 a	16.88 a	34.11 a	62.33 a	89.67 a
N_3S_3	14.79 de	51.61 cde	81.20 d	101.03 b	13.22 def	30.89 b	59.00 cd	84.56 b
$LSD_{(0.05)}$	1.825	3.629	4.915	4.719	2.484	1.850	2.001	3.103
Level of significance	0.01	0.05	0.05	0.01	0.05	0.01	0.01	0.01
CV(%)	6.57	10.99	8.57	7.85	10.80	6.69	12.14	9.41

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

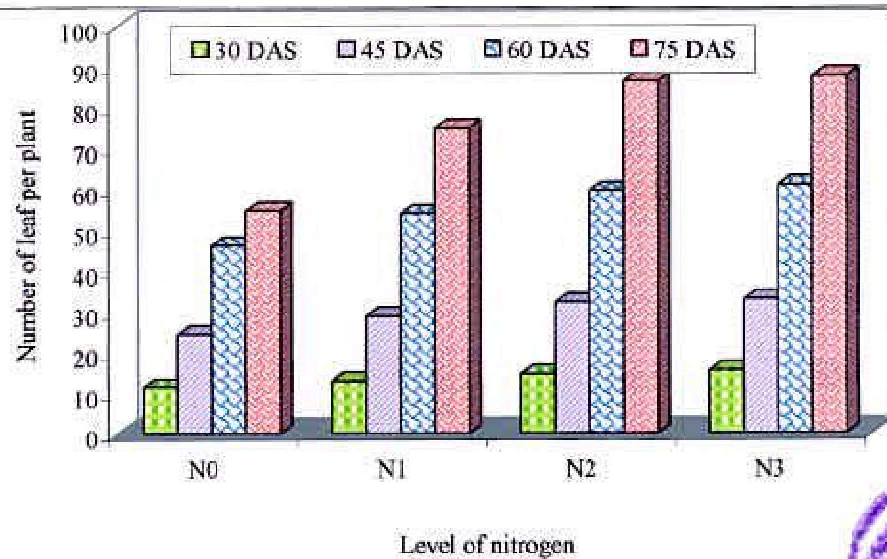
N_0: 0 kg N/ha
N_1: 100 kg N/ha
N_2: 120 kg N/ha
N_3: 140 kg N/ha

S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

4.2 Number of leaves per plant

Number of leaves per plant of Indian spinach varied significantly due to different level of nitrogen at 30, 45, 60 and 75 DAS (Appendix III). At 30 DAS, the maximum (15.51) number of leaves per plant was recorded from N_3 (140 kg N/ha) which was statistically similar (14.67) to N_2 (120 kg N/ha), while the minimum (11.26) number of leaves per plant was found from N_0 (0 kg N/ha) which was closely followed (12.89) by N_1 (100 kg N/ha). The maximum (32.96) number of leaves per plant was recorded from N_3 which was statistically similar (32.26) to N_2, while the minimum (24.45) number of leaves per plant was recorded from N_0 which was closely followed (28.89) by N_1 at 45 DAS. At 60 DAS, the maximum (60.93) number of leaves per plant was recorded from N_3 which was closely followed (59.63) by N_2 and the minimum (46.18) number of leaves per plant was observed from N_0 which was closely followed (54.00) by N_1. The maximum (87.59) number of leaves per plant was recorded from N_3 which was statistically similar (83.41) to N_2, while the minimum (54.78) number of leaves per plant was recorded from N_0 which was closely followed (74.81) by N_1 at 75 DAS (Figure 4). Hamid *et al.* (1986) reported that nitrogen increased number of leaves/plant.

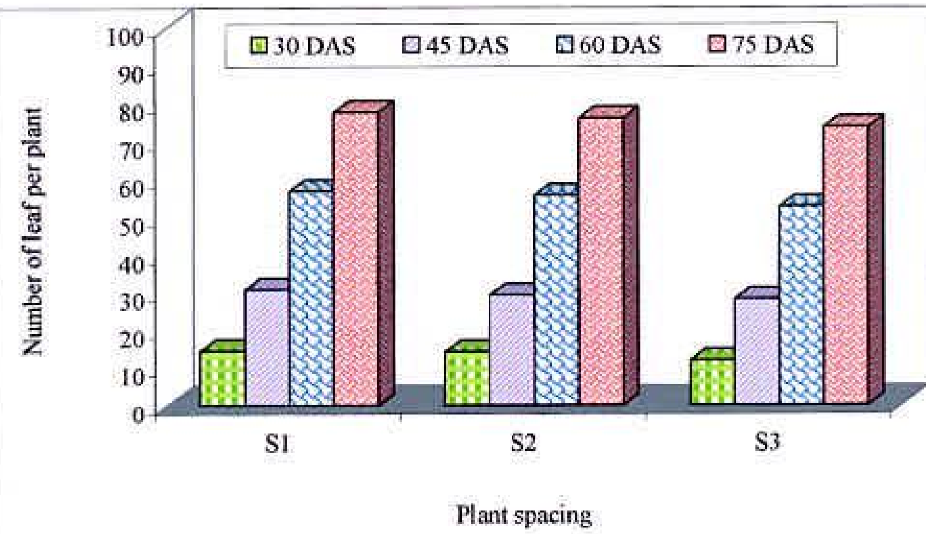
Number of leaves per plant differed significantly due to the different plant spacing at 30, 45, 60 and 75 DAS (Appendix III). At 30 DAS, the maximum (14.50) number of leaves per plant was recorded from S_1 (60 cm × 20 cm) which was statistically similar (14.25) to S_2 (60 cm × 30 cm) and the minimum (12.00) number of leaves per plant was recorded from S_3 (60 cm × 40 cm). The maximum (30.97) number of leaves per plant was recorded from S_1 which was closely followed by S_2 (29.45) and the minimum (28.50) number of leaves per plant was recorded from S_3 at 45 DAS. At 60 DAS, the maximum (57.00) number of leaves per plant was recorded from S_1 which was closely



N_0 : 0 kg N/ha N_1 : 100 kg N/ha

N_2 : 120 kg N/ha N_3 : 140 kg N/ha

Figure 4. Effect of nitrogen on number of leaf per plant of Indian spinach



S_1: 60 cm × 20 cm S_2: 60 cm × 30 cm

S_3: 60 cm × 40 cm

Figure 5. Effect of plant spacing on number of leaf per plant of Indian spinach

followed by S_2 (55.72) and the minimum (52.83) number of leaves per plant was recorded from S_3. The maximum (77.75) number of leaves per plant was found from S_1 which was statistically identical to S_2 (76.22) and the minimum (73.72) number of leaves per plant was recorded from S_3 at 75 DAS (Figure 5).

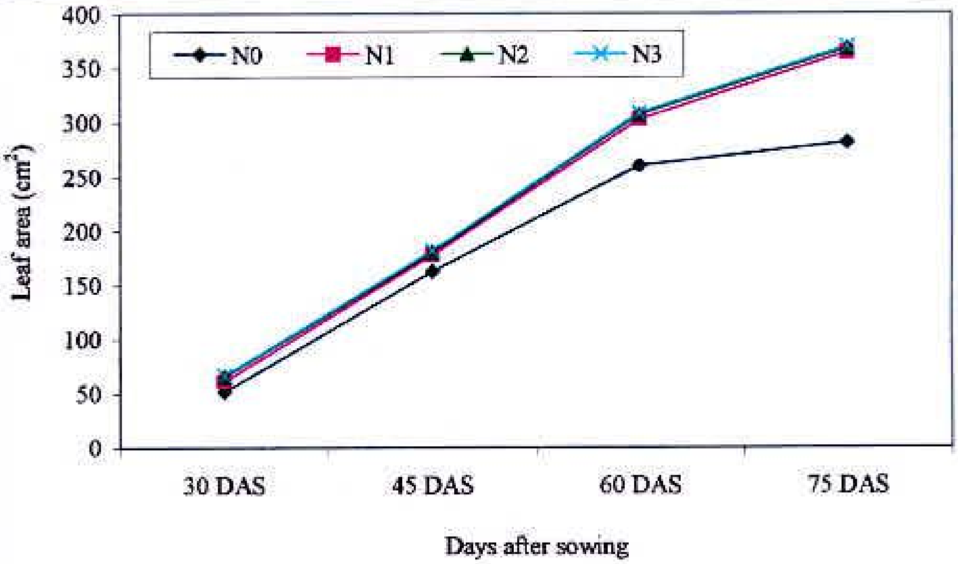
Significant differences was recorded for the combined effect between nitrogen and plant spacing on number of leaves per plant showed at 30, 45, 60 and 75 DAS (Appendix III). At 30 DAS, the maximum (16.88) number of leaves per plant was found from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_2 (0 kg N/ha + 60 cm × 30 cm) gave the minimum (10.67) number of leaves per plant. The maximum (34.11) number of leaves per plant was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_2 gave the minimum (21.00) number of leaves per plant at 45 DAS. At 60 DAS, the maximum (62.33) number of leaves per plant was observed from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_3 gave the minimum (44.11) number of leaves per plant. The maximum (89.67) number of leaves per plant was recorded from N_3S_2, while N_0S_2 gave the minimum (50.44) number of leaves per plant at 75 DAS (Table 2).

4.3 Leaf area per plant

A statistically significant variation was found due to different levels of nitrogen on leaf area per plant of Indian spinach at 30, 45, 60 and 75 DAS (Appendix IV). At 30 DAS, the maximum (67.06 cm^2) leaf area was recorded from N_3 (140 kg N/ha) which was statistically similar (65.44 cm^2) to N_2 (120 kg N/ha), while the minimum (51.73 cm^2) leaf area was recorded from N_0 (0 kg N/ha) which was closely followed (61.30 cm^2) by N_1 (100 kg N/ha). The maximum (181.93 cm^2) leaf area was recorded from N_3 which was statistically similar (180.52 cm^2) to N_2, while the minimum (162.48 cm^2) leaf area was found from N_0 which was closely followed (177.76 cm^2) by N_1 at 45 DAS. At 60 DAS, the maximum (308.56 cm^2) leaf area was recorded from N_3 which was statistically similar to N_2 (307.19 cm^2) and N_1 (303.12 cm^2) and the minimum (260.27 cm^2) leaf area was recorded from N_0 (54.00). The maximum (369.32 cm^2) leaf area was recorded from N_3 which was statistically similar to N_2 (368.03 cm^2) and N_1 (364.00 cm^2), while the minimum (281.37 cm^2) leaf area was observed from N_0 at 75 DAS (Figure 6). Etman (1993) reported that application of 50 kg/feddan to the soil plus 25 kg/feddan as a foliar spray increased leaf area.

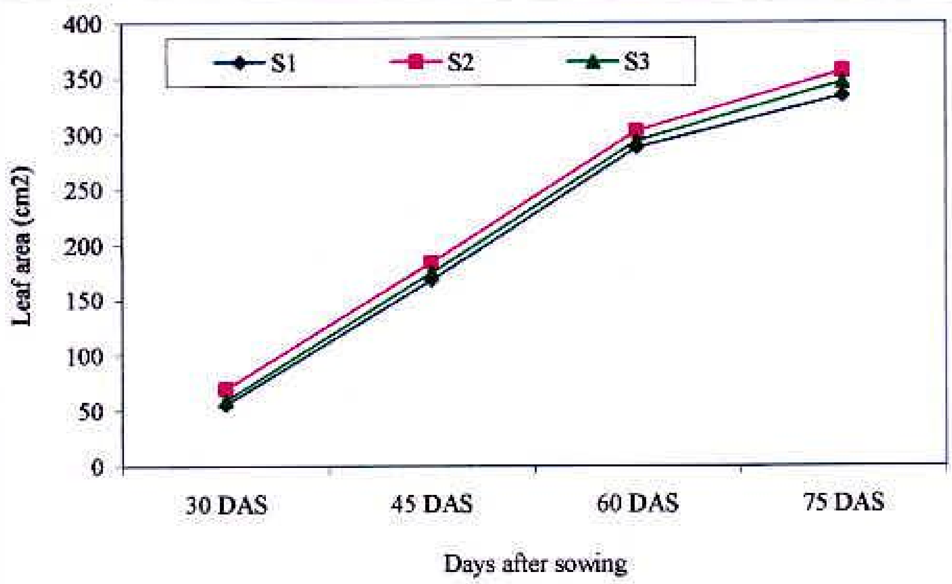
Leaf area per plant varied significantly for the different plant spacing at 30, 45, 60 and 75 DAS (Appendix IV). At 30 DAS, the maximum (69.63 cm^2) leaf area was recorded from S_2 (60 cm × 30 cm) which was closely followed (59.19 cm^2) by S_3 (60 cm × 40 cm) and the minimum (55.33 cm^2) leaf area was found from S_1 (60 cm × 20 cm). The maximum (184.35 cm^2) leaf area was recorded from S_2 which was closely followed (174.76 cm^2) by S_3 and the minimum (167.35 cm^2) leaf area was recorded from S_1 at 45 DAS. At 60 DAS, the maximum (302.85 cm^2) leaf area was recorded from S_2 which was closely followed (293.81 cm^2) by S_3 and the minimum (287.69 cm^2) leaf area was recorded from S_1. The maximum (356.24 cm^2) leaf area was found from S_2 which was closely followed by S_3 (346.75 cm^2) and the minimum (334.05 cm^2) leaf area was recorded from S_1 at 75 DAS (Figure 7). Park *et al.* (1993) reported that that 30 cm × 30 cm was better than 15 cm × 15 cm or 45 cm × 45 cm in consideration of growth and yield of the crop.

Combined effect between nitrogen and plant spacing on leaf area per plant showed significant variation at 30, 45, 60 and 75 DAS (Appendix IV). At 30 DAS, the maximum (78.73 cm^2) leaf area was found from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_1 (0 kg N/ha + 60 cm × 20 cm) gave the minimum (47.78 cm^2) leaf area.



N_0 : 0 kg N/ha
N_1 : 100 kg N/ha
N_2 : 120 kg N/ha
N_3 : 140 kg N/ha

Figure 6. Effect of nitrogen on leaf area of Indian spinach



S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

Figure 7. Effect of plant spacing on leaf area of Indian spinach

Table 3. Combined effect of nitrogen and plant spacing on leaf area and number of branches per plant of Indian spinach

Treatment combinations	Leaf area (cm^2) at				Number of branches per plant			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
N_0S_1	47.78 f	154.66 d	261.52 d	272.50 e	0.44 b	2.78 de	3.78 d	7.56 g
N_0S_2	51.31 ef	162.39 cd	254.88 d	272.60 e	0.78 ab	2.45 e	4.00 d	8.22 fg
N_0S_3	56.10 cde	170.39 bc	264.41 d	299.02 d	0.56 ab	3.89 cd	6.78 c	9.78 ef
N_1S_1	54.75 de	170.49 bc	293.04 c	352.26 c	0.56 ab	3.78 cde	6.78 c	11.23 de
N_1S_2	71.16 b	187.74 a	312.79 ab	379.35 ab	0.89 ab	6.22 b	9.67 ab	14.56 c
N_1S_3	57.98 cde	175.05 b	303.53 bc	360.39 c	0.78 ab	4.11 cd	7.89 c	14.45 c
N_2S_1	58.63 cd	172.57 b	296.84 c	354.58 c	0.56 ab	4.11 cd	7.11 c	12.45 d
N_2S_2	77.30 ab	192.55 a	321.04 a	385.76 a	1.22 ab	7.44 ab	11.00 a	18.45 a
N_2S_3	60.38 cd	176.44 b	303.68 bc	363.75 bc	1.33 ab	4.33 c	8.34 bc	16.11 bc
N_3S_1	60.15 cd	173.93 b	299.36 c	356.86 c	0.78 ab	4.22 c	7.00 c	12.56 d
N_3S_2	78.73 a	194.73 a	322.70 a	387.25 a	1.67 a	7.56 a	11.22 a	18.67 a
N_3S_3	62.29 c	177.14 b	303.61 bc	363.84 bc	1.22 ab	4.88 c	8.22 bc	16.56 b
$LSD_{(0.05)}$	6.515	9.210	9.962	16.42	0.9786	1.269	1.506	1.723
Level of significance	0.01	0.05	0.01	0.01	0.05	0.01	0.01	0.01
CV(%)	6.27	7.10	9.00	11.80	14.32	16.13	11.63	7.60

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

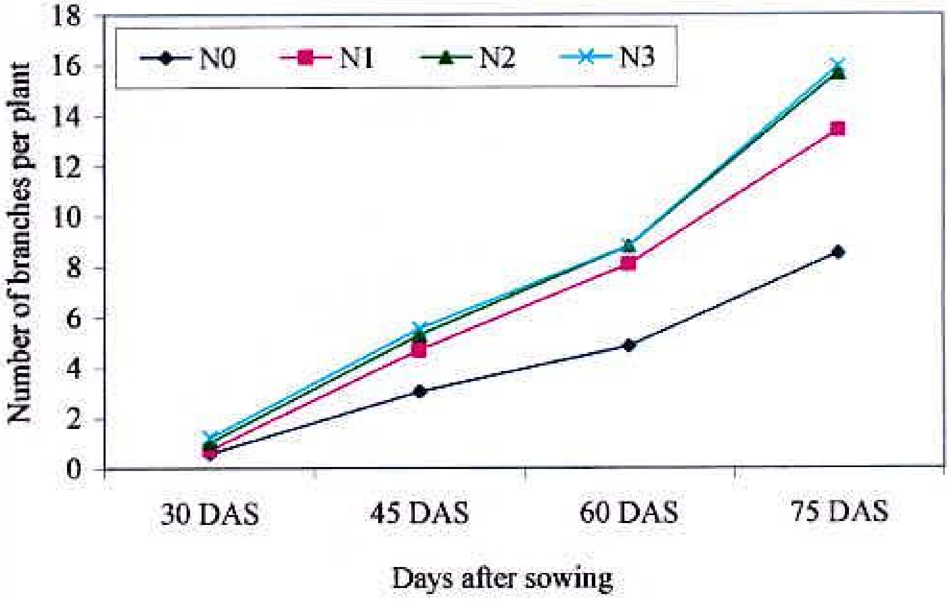
N_0: 0 kg N/ha
N_1: 100 kg N/ha
N_2: 120 kg N/ha
N_3: 140 kg N/ha

S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

The maximum (194.73 cm^2) leaf area was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_1 gave the minimum (154.66 cm^2) leaf area at 45 DAS. At 60 DAS, the maximum (322.70 cm^2) leaf area was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_2 gave the minimum (254.88 cm^2) leaf area. The maximum (387.25 cm^2) leaf area was observed from N_3S_2, while N_0S_1 gave the minimum (272.50 cm^2) leaf area at 75 DAS (Table 3).

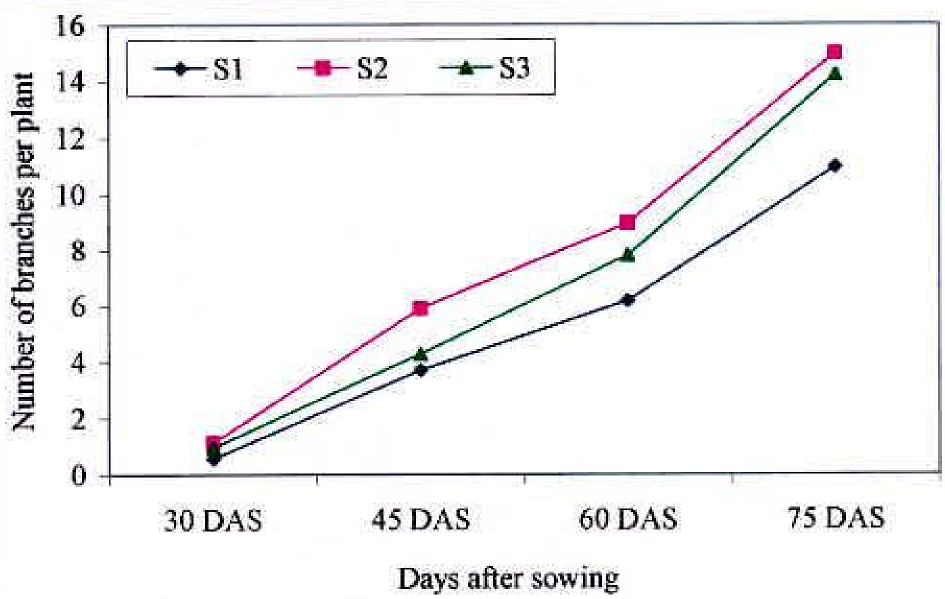
4.4 Number of branches per plant

A statistically significant difference was recorded due to different levels of nitrogen on number of branches per plant of Indian spinach at 30, 45, 60 and 75 DAS (Appendix IV). At 30 DAS, the maximum (1.22) number of branches per plant was recorded from N_3 (140 kg N/ha) which was statistically similar (1.04) to N_2 (120 kg N/ha), while the minimum (0.53) number of branches per plant was observed from N_0 (0 kg N/ha) which was closely followed (0.59) by N_1 (100 kg N/ha). The maximum (5.55) number of branches per plant was recorded from N_3 which was statistically similar (5.29) to N_2, while the minimum (3.04) number of branches per plant was recorded from N_0 which was closely followed (4.70) by N_1 at 45 DAS. At 60 DAS, the maximum (8.82) number of branches per plant was recorded from N_3 and N_2 which was statistically similar (8.11) to N_1 and the minimum (4.85) number of branches per plant was recorded from N_0. The maximum (15.93) number of branches per plant was found from N_3 which was statistically similar (15.67) to N_2, while the minimum (8.52) number of branches per plant was recorded from N_0 which was closely followed (13.41) by N_1 at 75 DAS (Figure 8).



N_0 : 0 kg N/ha N_1 : 100 kg N/ha
N_2 : 120 kg N/ha N_3 : 140 kg N/ha

Figure 8. Effect of nitrogen on number of branches per plant of Indian spinach



S_1: 60 cm × 20 cm S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

Figure 9. Effect of plant spacing on number of branches per plant of Indian spinach

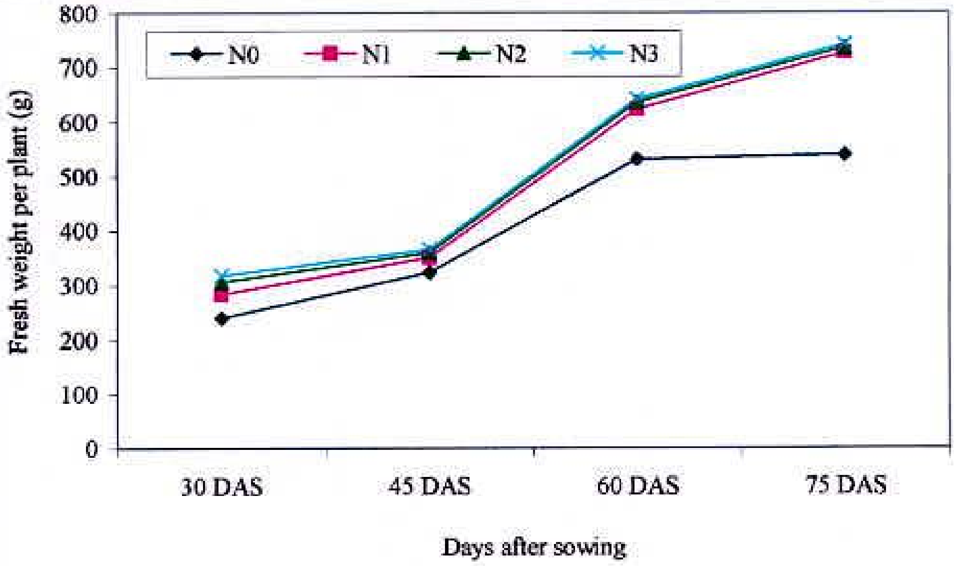
Number of branches per plant differed significantly due to the different plant spacing at 30, 45, 60 and 75 DAS (Appendix IV). At 30 DAS, the maximum (1.14) number of branches per plant was recorded from S_1 (60 cm × 20 cm) which was statistically similar (0.97) to S_2 (60 cm × 30 cm) and the minimum (0.58) number of branches per plant was observed from S_3 (60 cm × 40 cm). The maximum (5.92) number of branches per plant was recorded from S_2 which was closely followed by S_3 (4.30) and the minimum (3.72) number of branches per plant was recorded from S_1 at 45 DAS. At 60 DAS, the maximum (8.97) number of branches per plant was recorded from S_2 which was closely followed by S_3 (7.81) and the minimum (6.17) number of branches per plant was recorded from S_1. The maximum (14.97) number of branches per plant was found from S_2 which was statistically identical to S_3 (14.22) and the minimum (10.95) number of branches per plant was recorded from S_1 at 75 DAS (Figure 9).

Combined effect between nitrogen and plant spacing on number of branches per plant showed significant differences at 30, 45, 60 and 75 DAS (Appendix IV). At 30 DAS, the maximum (1.67) number of branches per plant was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_1 (0 kg N/ha + 60 cm × 20 cm) gave the minimum (0.44) number of branches per plant. The maximum (7.56) number of branches per plant was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_2 gave the minimum (2.45) number of branches per plant at 45 DAS. At 60 DAS, the maximum (11.22) number of branches per plant was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_1 gave the minimum (3.78) number of branches per plant. The maximum (18.67) number of branches per plant was recorded from N_3S_2, while N_0S_1 gave the minimum (7.56) number of branches per plant at 75 DAS (Table 3).

4.5 Fresh weight per plant

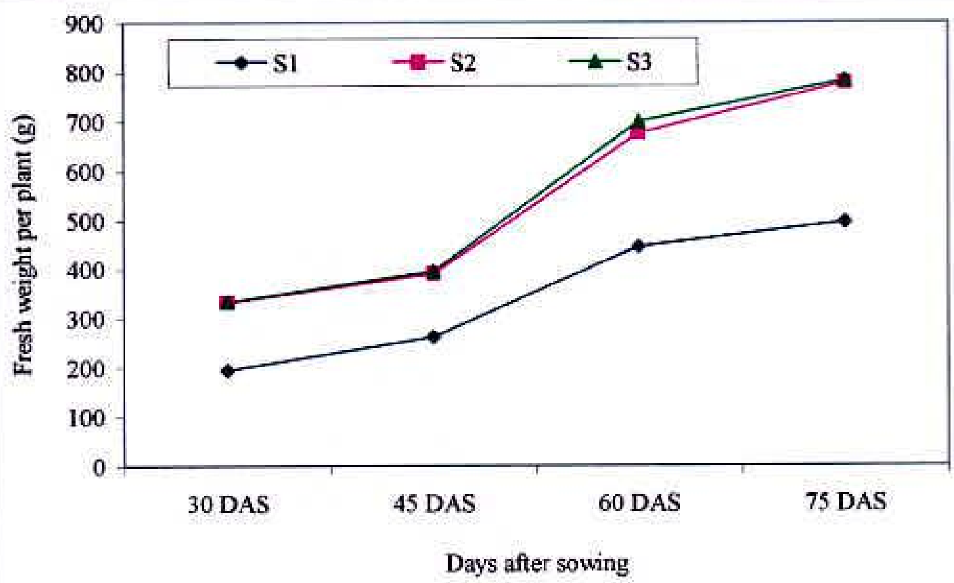
A statistically significant variation was recorded due to different level of nitrogen on fresh weight per plant of Indian spinach at 30, 45, 60 and 75 DAS (Appendix V). At 30 DAS, the highest (318.30 g) fresh weight per plant was recorded from N_3 (140 kg N/ha) which was statistically similar (306.22 g) to N_2 (120 kg N/ha), while the lowest (239.43 g) fresh weight per plant was found from N_0 (0 kg N/ha) which was closely followed (284.08 g) by N_1 (100 kg N/ha). The highest (365.75 g) fresh weight per plant was recorded from N_3 which was statistically similar (359.73 g) to N_2, while the lowest (323.19 g) was recorded from N_0 which was closely followed (350.73 g) by N_1 at 45 DAS. At 60 DAS, the highest (641.51 g) fresh weight per plant was recorded from N_3 which was statistically similar (636.18 g) to N_2 and the lowest (531.68 g) was recorded from N_0. The highest (741.87 g) fresh weight per plant was recorded from N_3 which was statistically similar to N_2 (735.74 g) and N_1 (725.98 g), while the lowest (539.32 g) was recorded from N_0 at 75 DAS (Figure 10).

Fresh weight per plant varied significantly due to the different plant spacing at 30, 45, 60 and 75 DAS (Appendix V). At 30 DAS, the highest (334.13 g) fresh weight per plant was observed from S_3 (60 cm × 40 cm) which was statistically similar (332.81 g) to S_2 (60 cm × 30 cm) and the lowest (194.09 g) fresh weight per plant was recorded from S_1 (60 cm × 20 cm). The highest (396.48 g) fresh weight per plant was recorded from S_3 which was statistically identical (391.50 g) to S_2 and the lowest (261.57 g) was recorded from S_1 at 45 DAS. At 60 DAS, the highest (700.65 g) fresh weight per plant was recorded from S_3 which was closely followed (677.28 g) by S_2 and the lowest (446.70 g) fresh weight per plant was recorded from S_1. The highest (783.12 g) fresh weight per plant was found from S_3 which was statistically identical (777.56 g) to S_2 and the lowest (496.50 g) was recorded from S_1 at 75 DAS (Figure 11). Park *et al.* (1993) reported that 30 cm × 30 cm was better than 15 cm × 15 cm or 45 cm × 45 cm in consideration of growth and yield of the crop.



N_0 : 0 kg N/ha
N_1 : 100 kg N/ha
N_2 : 120 kg N/ha
N_3 : 140 kg N/ha

Figure 10. Effect of nitrogen on fresh weight per plant of Indian spinach



S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

Figure 11. Effect of plant spacing on fresh weight per plant of Indian spinach

Combined effect between nitrogen and plant spacing on fresh weight per plant showed significant variation at 30, 45, 60 and 75 DAS (Appendix V). At 30 DAS, the highest (381.56 g) fresh weight per plant was observed from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_1 (0 kg N/ha + 60 cm × 20 cm) gave the lowest (155.84 g) fresh weight per plant. The highest (413.62 g) fresh weight per plant was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_1 gave the lowest (232.22 g) fresh weight per plant at 45 DAS. At 60 DAS, the highest (724.22 g) fresh weight per plant was recorded from the treatment combination of N_3S_3 (140 kg N/ha + 60 cm × 40 cm), while N_0S_1 gave the lowest (389.88 g) fresh weight per plant. The highest (849.91 g) fresh weight per plant was found from N_3S_3, while N_0S_1 gave the lowest (353.79 g) fresh weight per plant at 75 DAS (Table 4).

4.6 Dry matter content of plant

Statistically significant variation was recorded due to different level of nitrogen on dry matter content per plant of Indian spinach at 30, 45, 60 and 75 DAS (Appendix V). At 30 DAS, the highest (6.27%) dry matter content per plant was found from N_3 (140 kg N/ha) which was statistically similar (6.01%) to N_2 (120 kg N/ha) and N_1 (5.52%), while the lowest (4.07%) dry matter content per plant was recorded from N_0 (0 kg N/ha). The highest (7.35%) dry matter content per plant was recorded from N_3 which was statistically similar to N_2 (6.92%), while the lowest (5.05%) dry matter content per plant was recorded from N_0 which was closely followed by N_1 (6.36%) at 45 DAS. At 60 DAS, the highest (8.37%) dry matter content per plant was recorded from N_2 which was statistically similar to N_3(8.26%) and the lowest (6.10%) dry matter content per plant was observed from N_0. The highest (10.50%) dry matter content per plant was recorded from N_3 which was statistically similar to N_2 (10.15%), while the lowest (7.85%) dry matter content per plant was recorded from N_0 at 75 DAS (Figure 12).

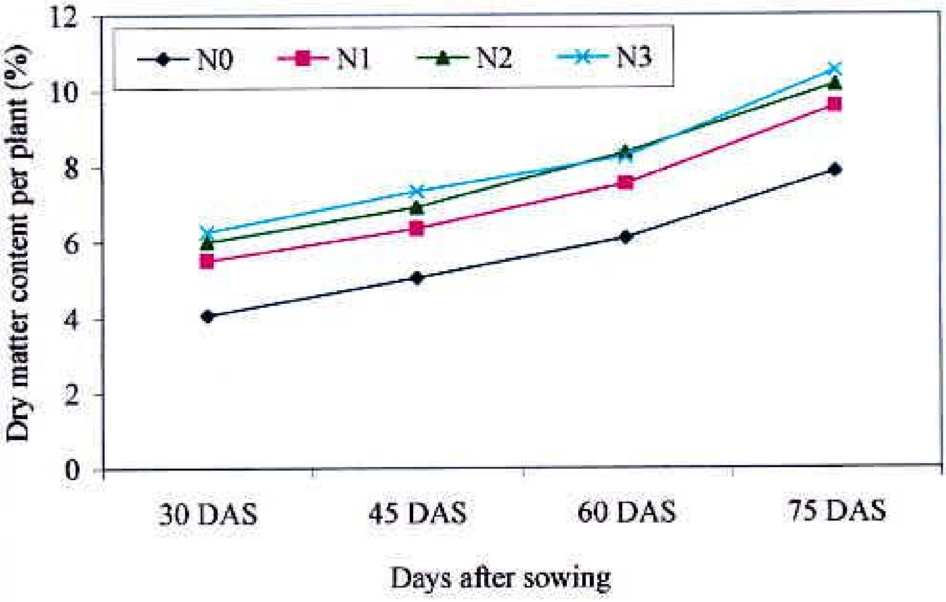
Table 4. Combined effect of nitrogen and plant spacing on yield per plant and dry matter content per plant of Indian spinach

Treatment Combinations	Fresh weight per plant (g)				Dry matter content per plant (%) at			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
N_0S_1	155.84 f	232.22 f	389.88 g	353.79 c	4.07 de	4.94 ef	6.03 de	7.73 d
N_0S_2	240.74 d	349.40 c	568.91 d	586.35 c	3.66 e	4.70 f	5.55 e	7.51 d
N_0S_3	321.72 c	387.94 b	636.24 c	677.83 b	4.49 cde	5.51 def	6.72 cde	8.30 cd
N_1S_1	186.01 ef	259.22 e	452.66 f	532.99 d	4.96 cde	5.79 def	6.81 cde	9.12 cd
N_1S_2	339.45 bc	397.10 ab	699.77 b	834.09 a	6.68 ab	7.75 bc	8.81 ab	11.00 ab
N_1S_3	326.80 c	395.87 ab	718.00 ab	810.85 a	4.93 cde	5.53 def	6.99 cde	8.60 cd
N_2S_1	210.71 de	274.34 de	467.58 ef	546.78 d	5.13 cd	6.28 de	7.57 bcd	9.40 c
N_2S_2	369.48 ab	405.88 ab	716.82 ab	839.89 a	7.35 a	8.84 ab	10.23 a	12.25 a
N_2S_3	338.48 bc	398.98 ab	724.14 a	820.56 a	5.55 bc	5.64 def	7.32 bcd	8.80 cd
N_3S_1	223.80 de	280.50 d	476.68 e	552.43 cd	5.60 bc	6.72 cd	7.65 bc	9.73 bc
N_3S_2	381.56 a	413.62 a	723.64 a	849.91 a	7.78 a	9.13 a	10.03 a	12.09 a
N_3S_3	349.54 abc	403.14 ab	724.22 a	823.26 a	5.42 bcd	6.20 de	7.11 cde	9.68 bc
$LSD_{(0.05)}$	36.03	19.70	19.26	37.02	1.275	1.293	1.394	1.440
Level of significance	0.01	0.05	0.01	0.01	0.05	0.05	0.01	0.01
CV(%)	7.41	9.33	11.87	5.19	13.77	11.90	10.88	8.93

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

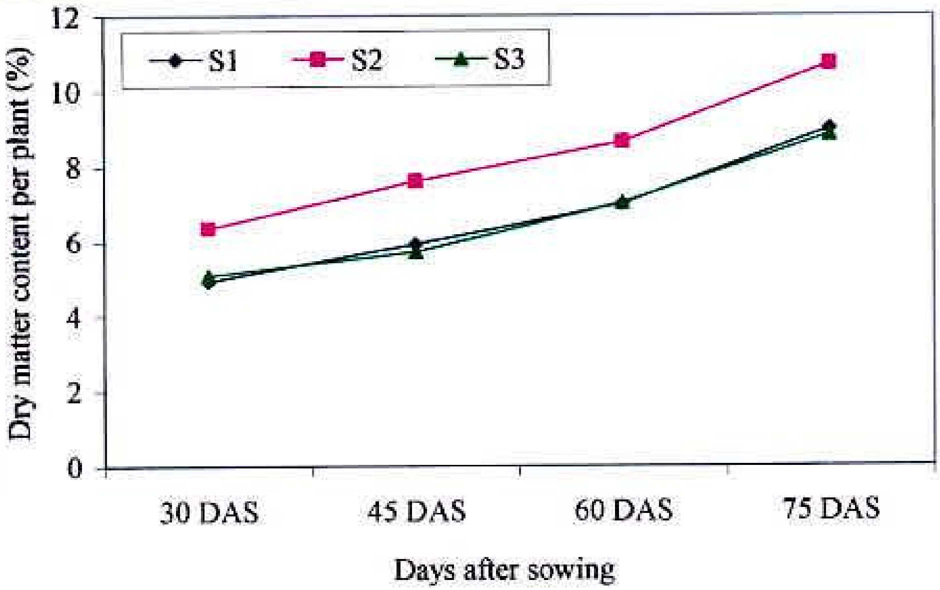
N_0: 0 kg N/ha
N_1: 100 kg N/ha
N_2: 120 kg N/ha
N_3: 140 kg N/ha

S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm



N_0 : 0 kg N/ha N_1 : 100 kg N/ha
N_2 : 120 kg N/ha N_3 : 140 kg N/ha

Figure 12. Effect of nitrogen on dry matter content per plant of Indian spinach



S_1: 60 cm × 20 cm S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

Figure 13. Effect of plant spacing on dry matter content per plant of Indian spinach

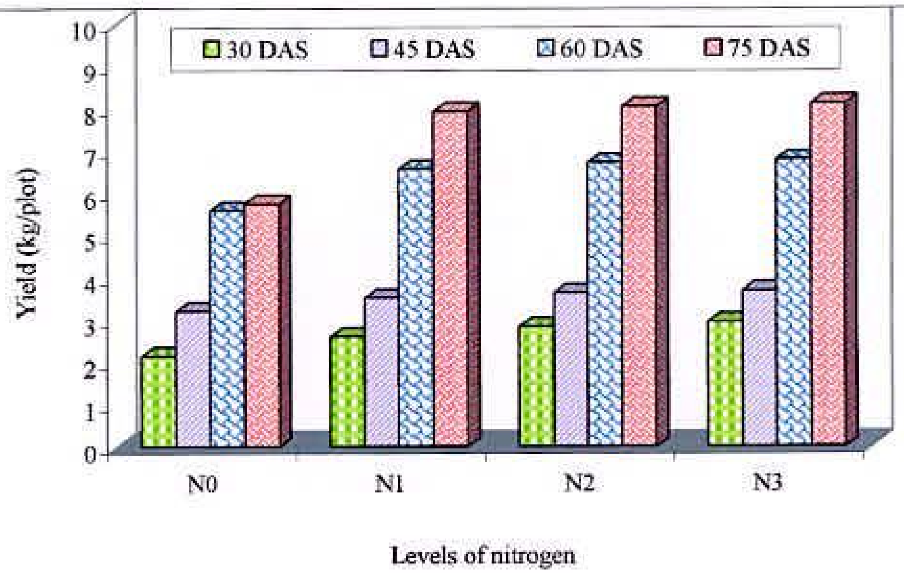
Dry matter content per plant varied significantly due to the different plant spacing at 30, 45, 60 and 75 DAS under the trial (Appendix V). At 30 DAS, the highest (6.37%) dry matter content per plant was recorded from S_2 (60 cm × 30 cm) which was closely followed (5.09%) by S_3 (60 cm × 40 cm) and the lowest (4.94%) dry matter content per plant was found from S_1 (60 cm × 20 cm). The highest (7.61%) dry matter content per plant was recorded from S_2 which was closely followed by S_1 (5.93%) and the lowest (5.72%) dry matter content per plant was observed from S_3 at 45 DAS. At 60 DAS, the highest (8.66%) dry matter content per plant was recorded from S_2 which was closely followed by S_3 (7.04%) and the lowest (7.01%) dry matter content per plant was recorded from S_1. The highest (10.71%) dry matter content per plant was recorded from S_2 which was closely followed by S_1 (9.00%) and the lowest (8.84%) dry matter content per plant was recorded from S_3 at 75 DAS (Figure 13).

Combined effect between nitrogen and plant spacing for dry matter content per plant showed significant differences at 30, 45, 60 and 75 DAS (Appendix V). At 30 DAS, the highest (7.78%) dry matter content per plant was found from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_2 (0 kg N/ha + 60 cm × 20 cm) gave the lowest (3.66%) dry matter content per plant. The highest (9.13%) dry matter content per plant was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_2 gave the lowest (4.70%) dry matter content per plant at 45 DAS. At 60 DAS, the highest (10.03%) dry matter content per plant was recorded from the treatment combination of N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_2 gave the lowest (5.55%) dry matter content per plant. The highest (12.25%) dry matter content per plant was observed from N_2S_2, while N_0S_2 gave the lowest (7.73%) dry matter content per plant at 75 DAS (Table 4).

4.7 Yield per plot

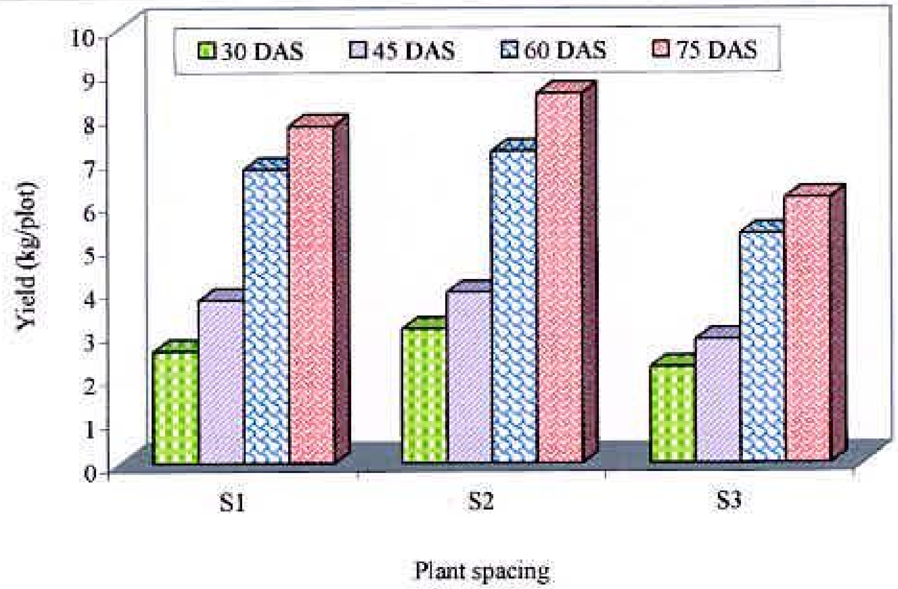
A statistically significant difference was observed due to different levels of nitrogen on yield per plot of Indian spinach at 30, 45, 60 and 75 DAS (Appendix VI). At 30 DAS, the highest (2.95 kg) yield per plot was found from N_3 (140 kg N/ha) which was statistically similar (2.83 kg) to N_2 (120 kg N/ha), while the lowest (2.15 kg) yield per plot was recorded from N_0 (0 kg N/ha) which was closely followed (2.60 kg) by N_1 (100 kg N/ha). The highest (3.69 kg) yield per plot was found from N_3 which was statistically similar to N_2 (3.63 kg), while the lowest (3.21 kg) yield per plot was recorded from N_0 which was closely followed by N_1 (3.52 kg) at 45 DAS. At 60 DAS, the highest (6.79 kg) yield per plot was recorded from N_3 which was statistically similar to N_2 (6.72 kg) and the lowest (5.59 kg) yield per plot was observed from N_0. The highest (8.12 kg) yield per plot was recorded from N_3 which was statistically similar to N_2 (8.05 kg) and N_1 (7.93 kg), while the lowest (5.75 kg) yield per plot was obtained from N_0 at 75 DAS (Figure 14).

Yield per plot differed significantly due to the different plot spacing at 30, 45, 60 and 75 DAS (Appendix VI). At 30 DAS, the highest (3.09 kg) yield per plot was recorded from S_2 (60 cm × 30 cm) which was closely followed (2.58 kg) by S_1 (60 cm × 20 cm) and the lowest (2.22 kg) yield per plot was observed from S_3 (60 cm × 40 cm). The highest (3.93 kg) yield per plot was recorded from S_2 which was closely followed by S_1 (3.75 kg) and the lowest (2.85 kg) yield per plot was recorded from S_3 at 45 DAS. At 60 DAS, the highest (7.18 kg) yield per plot was obtained from S_2 which was closely followed by S_1 (6.77 kg) and the lowest (5.31 kg) yield per plot was recorded from S_3. The highest (8.50 kg) yield per plot was found from S_2 which was closely followed by S_1 (7.76 kg) and the lowest (6.12 kg) yield per plot was recorded from S_3 at 75 DAS (Figure 15).



N_0 : 0 kg N/ha
N_1 : 100 kg N/ha
N_2 : 120 kg N/ha
N_3 : 140 kg N/ha

Figure 14. Effect of nitrogen on yield per plot of Indian spinach



S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

Figure 15. Effect of plant spacing on yield per plot of Indian spinach

Combined effect between nitrogen and plot spacing for yield per plot varied significantly at 30, 45, 60 and 75 DAS (Appendix VI). At 30 DAS, the highest (3.55 kg) yield per plot was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_1 (0 kg N/ha + 60 cm × 20 cm) gave the lowest (2.07 kg) yield per plot. The highest (4.16 kg) yield per plot was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_3 gave the lowest (2.78 kg) at 45 DAS. At 60 DAS, the highest (7.67 kg) yield per plot was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_3 performed the lowest (4.82 kg) yield per plot. The highest (9.30 kg) yield per plot was recorded from N_3S_2, while N_0S_3 gave the lowest (5.30 kg) at 75 DAS (Table 5).

4.8 Yield per hectare

A statistically significant difference was recorded due to different levels of nitrogen on yield per hectare of Indian spinach at 30, 45, 60 and 75 DAS (Appendix VI). At 30 DAS, the highest (8.18 ton) yield per hectare was found from N_3 (140 kg N/ha) which was statistically similar (7.85 ton) to N_2 (120 kg N/ha), while the lowest (5.96 ton) was recorded from N_0 (0 kg N/ha) which was closely followed (7.22 ton) by N_1 (100 kg N/ha). The highest (10.26 ton) yield per hectare was recorded from N_3 which was statistically similar (10.07 ton) to N_2, while the lowest (8.92 ton) yield per hectare was recorded from N_0 which was closely followed by N_1 (9.77 ton) at 45 DAS. At 60 DAS, the highest (18.68 ton) yield per hectare was observed from N_3 which was statistically identical to N_2 (18.68 ton) and the lowest (15.52 ton) yield per hectare was recorded from N_0. The highest (22.55 ton) yield per hectare was recorded from N_3 which was statistically similar to N_2 (22.35 ton) and N_1 (22.02 ton), while the lowest (15.96 ton) was recorded from N_0 at 75 DAS (Figure 14). Hamid *et al.* (1986) reported that highest yield (79.34 t/ha) was obtained by applying the highest dose of nitrogen (250 kg N/ha).

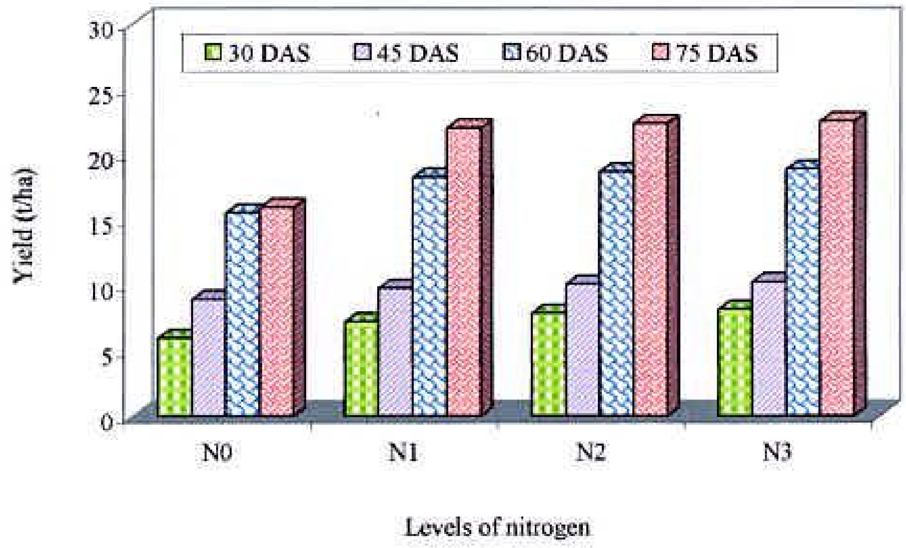
Table 5. Combined effect of nitrogen and plant spacing on yield per plot and per hectare of Indian spinach

Treatment Combinations	Yield (kg/plot) at				Yield (t/ha) at			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
N_0S_1	2.07 e	3.33 d	5.91 f	5.53 d	5.75 e	9.26 d	16.41 f	15.36 d
N_0S_2	2.24 e	3.51 d	6.03 f	6.41 c	6.21 e	9.75 d	16.76 f	17.81 c
N_0S_3	2.14 e	2.78 e	4.82 h	5.30 d	5.93 e	7.73 e	13.39 h	14.71 d
N_1S_1	2.47 de	3.72 c	6.86 e	8.33 b	6.86 de	10.34 c	19.05 e	23.13 b
N_1S_2	3.15 bc	3.99 ab	7.42 bc	9.12 a	8.76 bc	11.08 ab	20.62 bc	25.34 a
N_1S_3	2.17 e	2.84 e	5.44 g	6.33 c	6.03 e	7.89 e	15.11 g	17.60 c
N_2S_1	2.80 cd	3.94 b	7.08 de	8.54 b	7.77 cd	10.94 b	19.68 de	23.73 b
N_2S_2	3.43 ab	4.08 ab	7.60 ab	9.19 a	9.54 ab	11.33a b	21.12 ab	25.52 a
N_2S_3	2.25 e	2.86 e	5.49 g	6.41 c	6.24 e	7.95 e	15.24 g	17.81 c
N_3S_1	2.97 c	4.03 ab	7.22 cd	8.63 b	8.25 c	11.18 ab	20.06 cd	23.98 b
N_3S_2	3.55 a	4.16 a	7.67 a	9.30 a	9.85 a	11.54 a	21.32 a	25.82 a
N_3S_3	2.32 e	2.89 e	5.49 g	6.43 c	6.44 e	8.04 e	15.24 g	17.87 c
$LSD_{(0.05)}$	0.3592	0.1931	0.2395	0.4250	1.002	0.5434	0.6645	1.180
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	8.10	5.29	8.20	10.36	8.10	5.29	8.20	10.36

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

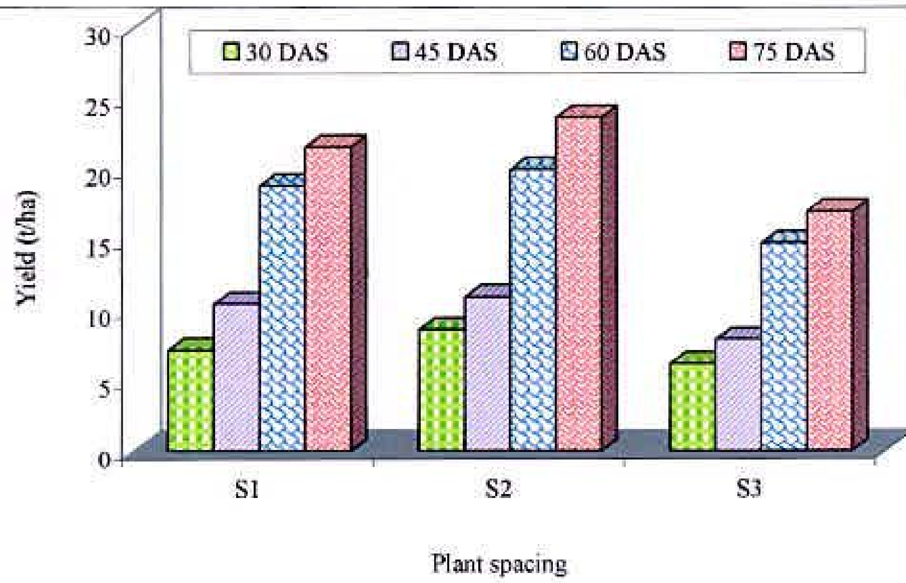
N_0: 0 kg N/ha
N_1: 100 kg N/ha
N_2: 120 kg N/ha
N_3: 140 kg N/ha

S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm



N_0 : 0 kg N/ha N_1 : 100 kg N/ha
N_2 : 120 kg N/ha N_3 : 140 kg N/ha

Figure 16. Effect of nitrogen on yield per hectare of Indian spinach



S_1: 60 cm × 20 cm S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

Figure 17. Effect of plant spacing on yield per hectare of Indian spinach

Yield per hectare varied significantly due to the different plant spacings at 30, 45, 60 and 75 DAS (Appendix VI). At 30 DAS, the highest (8.59 ton) yield per hectare was found from S_2 (60 cm × 30 cm) which was closely followed (7.19 ton) by S_1 (60 cm × 20 cm) and the lowest (6.16 ton) yield per hectare was recorded from S_3 (60 cm × 40 cm). The highest (10.93 ton) yield per hectare was recorded from S_2 which was closely followed by S_1 (10.43 ton) and the lowest (7.90 ton) yield per hectare was recorded from S_3 at 45 DAS. At 60 DAS, the highest (19.95 ton) yield per hectare was recorded from S_2 which was closely followed by S_1 (18.80 ton) and the lowest (14.74 ton) yield per hectare was recorded from S_3. The highest (23.62 ton) yield per hectare was recorded from S_2 which was closely followed by S_1 (21.55 ton) and the lowest (16.99 ton) yield per hectare was recorded from S_3 at 75 DAS (Figure 15). Park *et al.* (1993) reported that 30 cm × 30 cm was better than 15 cm × 15 cm or 45 cm × 45 cm in consideration of growth and yield of the crop.

Combined effect between nitrogen and plant spacing on yield per hectare showed significant differences at 30, 45, 60 and 75 DAS (Appendix VI). At 30 DAS, the highest (9.85 ton) yield per hectare was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_1 (0 kg N/ha + 60 cm × 20 cm) gave the lowest (5.75 ton) yield per hectare. The highest (11.54 ton) yield per hectare was observed from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_3 gave the lowest (7.73 ton) yield per hectare at 45 DAS. At 60 DAS, the highest (21.32 ton) yield per hectare was recorded from N_3S_2 (140 kg N/ha + 60 cm × 30 cm), while N_0S_3 gave the lowest (13.39 ton) yield per hectare. The highest (25.82 ton) yield per hectare was recorded from N_3S_2, while N_0S_3 gave the lowest (14.71 ton) yield per hectare at 75 DAS (Table 5). Rahman *et al.* (1985) studied Indian Spinach and reported that the highest yield of greens (62.89 t/ha) was obtained from the closest spacing when the highest dose of nitrogenous fertilizer was applied.

4.9 Economic analysis

Input costs for land preparation, seed cost, fertilizer, irrigation and man power required for all the operations of Indian spinach were recorded for unit plot and converted into cost per hectare. Prices of Indian spinach were considered from the market of Agargaon, Dhaka. 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-

4.9.1 Gross return

Combination of nitrogen and plant spacing showed different gross return under the trial (Table 6). The highest gross return (Tk. 411,180/ha) was noted from N_3S_2 (140 kg N/ha + 60 cm × 30 cm) and the second highest gross return (Tk. 405,060/ha) was recorded from N_2S_2 (120 kg N/ha + 60 cm × 30 cm). The lowest gross return (Tk.250,560/ha) was recorded from N_0S_3 (0 kg N/ha + 60 cm × 40 cm).

4.9.2 Net return

Different treatment combinations showed different amount of net returns. The highest net return (Tk. 298,490/ha) was obtained from N_3S_2 and the second highest net return (Tk. 292,679/ha) was recorded from N_2S_2. The lowest net return (Tk. 139.413/ha) was found from N_0S_3 (Table 6).

4.9.3 Benefit cost ratio

The combination of nitrogen and plant spacing for benefit cost ratio was different for treatment combination (Table 6). The highest (2.65) benefit cost ratio was recorded from N_3S_2 and the second highest benefit cost ratio (2.60) was recorded from N_2S_2. The lowest benefit cost ratio (1.25) was recorded from N_0S_3. From economic point of view, it was apparent from the above results that the treatment combination of N_3S_2 was more profitable as compared to other treatments.

Table 6. Cost and return of Indian Spinach cultivation as influenced by nitrogen and plant spacing

Treatment Combinations	Cost of production (Tk./ha)	Yield at harvest (ton) at				Gross return	Net return (Tk./ha)	Benefit cost ratio
		30 DAS	45 DAS	60 DAS	75 DAS			
N_0S_1	111,147	5.75	9.26	16.41	15.36	280,680	169,533	1.53
N_0S_2	111,147	6.21	9.75	16.76	17.81	303,180	192,033	1.73
N_0S_3	111,147	5.93	7.73	13.39	14.71	250,560	139,413	1.25
N_1S_1	112,086	6.86	10.34	19.05	23.13	356,280	244,194	2.18
N_1S_2	112,086	8.76	11.08	20.62	25.34	394,800	282,714	2.52
N_1S_3	112,086	6.03	7.89	15.11	17.60	279,780	167,694	1.50
N_2S_1	112,381	7.77	10.94	19.68	23.73	372,720	260,339	2.32
N_2S_2	112,381	9.54	11.33	21.12	25.52	405,060	292,679	2.60
N_2S_3	112,381	6.24	7.95	15.24	17.81	283,440	171,059	1.52
N_3S_1	112,690	8.25	11.18	20.06	23.98	380,820	268,130	2.38
N_3S_2	112,690	9.85	11.54	21.32	25.82	411,180	298,490	2.65
N_3S_3	112,690	6.44	8.04	15.24	17.87	285,540	172,850	1.53

Price of Indian spinach @ Tk. 7 per Kg.

N_0: 0 kg N/ha
N_1: 100 kg N/ha
N_2: 120 kg N/ha
N_3: 140 kg N/ha

S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from April to July 2007 to find out optimum level of nitrogen and spacing that would be suitable combination for growing Indian spinach. The experiment consisted of two factors. Factor A: Level of nitrogen (four levels)-N_0: 0 kg N/ha, N_1: 100 kg N/ha, N_2: 120 kg N/ha and N_3: 140 kg N/ha and factor B : Spacing (three levels) : S_1: 60 cm × 20 cm, S_2: 60 cm × 30 cm and S_3: 60 cm × 40 cm. There were 12 (4 ×3) treatments combination and the experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters and yield were recorded.

Significant variation was recorded on different yield contributing characters and yield of Indian spinach due to the application of different levels of nitrogen. At 75 DAS, the longest (104.99 cm) plant height was obtained from N_3, while the shortest (81.91 cm) plant height was recorded from N_0. The maximum (87.59) number of leaves per plant was recorded from N_3 and the minimum (54.78) number of leaves per plant was recorded from N_0. The maximum (369.32 cm^2) leaf area was recorded from N_3 and the minimum (281.37 cm^2) leaf area was recorded from N_0. The maximum (15.93) number of branches per plant was found from N_3 while the minimum (8.52) number of branches per plant was recorded from N_0. The highest (741.87 g) fresh weight per plant was recorded from N_3, while the lowest (539.32 g) fresh weight per plant was recorded from N_0. The highest (10.50%) dry matter content per plant was obtained from N_3 while the lowest (7.85%) dry matter content per plant was found from N_0. The highest (8.12 kg) yield per plot was recorded from N_3, while the lowest (5.75 kg) yield per plot was recorded from N_0. The highest (22.55 ton) yield per hectare was recorded from N_3, while the lowest (15.96 ton) yield per hectare was recorded from N_0.

In case of different yield contributing characters and yield of Indian spinach significant variation was recorded due to different plant spacing. At 75 DAS, longest (99.06 cm) plant height was recorded from S_1 and the shortest (95.66 cm) plant height was recorded from S_3 at 75 DAS. The maximum (77.75) number of leaves per plant was recorded from S_1 and the minimum (73.72) number of leaves per plant was recorded from S_3. The maximum (356.24 cm^2) leaf area was obtained from S_2 and the minimum (334.05 cm^2) leaf area was recorded from S_1. The maximum (14.97) number of branches per plant was recorded from S_2 and the minimum (10.95) number of branches per plant was recorded from S_1. The highest (783.12 g) fresh weight per plant was recorded from S_3 and the lowest (496.50 g) fresh weight per plant was found from S_1. The highest (10.71%) dry matter content per plant was recorded from S_2 and the lowest (8.84%) dry matter content per plant was recorded from S_3. The highest (8.50 kg) yield per plot was recorded from S_2 and the lowest (6.12 kg) yield per plot was recorded from S_3. The highest (23.62 ton) yield per hectare was recorded from S_2 and the lowest (16.99 ton) yield per hectare was recorded from S_3.

Combination of different level of nitrogen and plant spacing also showed significant differences for different yield contributing characters and yield of Indian spinach. At 75 DAS the longest (107.22 cm) plant height was recorded from N_3S_2, while N_0S_2 gave the shortest (78.18 cm) plant height. The maximum (89.67) number of leaves per plant was recorded from N_3S_2, while N_0S_2 gave the minimum (50.44) number of leaves per plant. The maximum (387.25 cm^2) leaf area was recorded from N_3S_2, while N_0S_1 gave the minimum (272.50 cm^2) leaf area. The maximum (18.67) number of branches per plant was recorded from N_3S_2, while N_0S_1 gave the minimum (7.56) number of branches per plant. The highest (849.91 g) fresh weight per plant was recorded from N_3S_3, while N_0S_1 gave the lowest (353.79 g) fresh weight per plant. The highest (12.25%) dry matter content per plant was recorded from N_2S_2, while N_0S_2 gave the lowest (7.73%) dry matter content per plant. The highest (9.30 kg) yield per plot was recorded from N_3S_2, while N_0S_3 gave the lowest (5.30 kg) yield per plot. The highest (25.82 ton) yield per hectare was recorded from N_3S_2, while N_0S_3 gave the lowest (14.71 ton) yield per hectare.

The highest gross return (Tk. 411,180/ha) was found from N_3S_2 and the lowest (Tk.250,560/ha) was recorded from N_0S_3. The highest net return (Tk. 298,490/ha) was recorded from N_3S_2 and the lowest (Tk. 139.413/ha) was recorded from N_0S_3. The highest (2.65) benefit cost ratio was obtained from N_3S_2 and the lowest (1.25) was recorded from N_0S_3. From economic point of view, it was apparent from the above results that the treatment combination of N_3S_2 was more profitable as compared to other treatments.

CONCLUSION:

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

1. Another levels of nitrogen and spacing may be included for drawing conclusion.
2. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance before final recommendations can be made.

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Appendices

APPENDICES

Appendix I. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from April to July 2007

Month	*Air temperature (°c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
April, 2007	33.6	23.6	69	163	6.4
May, 2007	34.7	25.9	70	185	7.8
June, 2007	32.4	25.5	81	628	5.7
July, 2007	33.5	26.4	85	845	5.8

* Monthly average.

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan. Dhaka - 1207

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

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

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

* **Source:** SRDI

Appendix III. Analysis of variance of the data on plant height and number of leaves per plant of Indian spinach as influenced by nitrogen and plant spacing

Source of variation	Degrees of freedom	Mean square							
		Plant height (cm) at				Number of leaves per plant at			
		30 DAT	45 DAT	60 DAT	75 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	0.445	1.943	11.452	1.117	0.038	0.755	1.002	4.615
Nitrogen (A)	3	21.681**	93.867**	286.341**	272.974**	32.348**	136.366**	350.736**	123.741**
Plant spacing (B)	2	62.575**	72.701**	92.859**	38.156**	22.723**	18.652**	54.681**	49.584**
Interaction (A×B)	6	5.131**	11.380*	16.102*	31.304**	2.856*	13.885**	8.256**	22.887**
Error	22	1.162	4.593	8.425	7.768	2.152	1.193	1.396	3.359

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

Appendix IV. Analysis of variance of the data on leaf area and number of branches per plant of Indian spinach as influenced by nitrogen and plant spacing

Source of variation	Degrees of freedom	Mean square							
		Leaf area (cm^2) at				Number of branches per plant at			
		30 DAT	45 DAT	60 DAT	75 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	10.257	9.901	15.616	52.148	0.705	0.227	0.003	0.150
Nitrogen (A)	3	425.441**	723.149**	342.854**	441.083**	0.728*	11.511**	32.283**	106.050**
Plant spacing (B)	2	656.569**	818.499**	355.329**	348.554**	0.976*	15.547**	23.813**	55.010**
Interaction (A×B)	6	83.903**	106.585*	198.999**	441.075**	0.107*	3.744**	5.644**	5.311**
Error	22	14.802	29.585	34.609	11.702	0.334	0.562	0.791	1.035

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

Appendix V. Analysis of variance of the data on yield per plant and dry matter content in plant of Indian spinach as influenced by nitrogen and plant spacing

Source of variation	Degrees of freedom	Mean square							
		Fresh weight per plant (g)				Dry matter content in plant (%)			
		30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	47.376	33.837	69.976	229.329	0.221	0.204	0.307	2.043
Nitrogen (A)	3	568.993**	742.864**	800.631**	796.770**	8.619**	9.008**	9.875**	12.420**
Plant spacing (B)	2	582.760**	330.307**	236.414**	207.151**	7.372**	12.787**	10.645**	12.910**
Interaction (A×B)	6	340.052**	412.557*	518.522**	433.612**	1.845*	2.689*	3.054**	2.747**
Error	22	21.030	21.954	22.221	36.134	0.567	0.583	0.678	0.723

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

Appendix VI. Analysis of variance of the data on yield per plot and hectare of Indian spinach as influenced by nitrogen and plant spacing

Source of variation	Degrees of freedom	Mean square							
		Yield (kg/plot)				Yield (t/ha)			
		30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.035	0.014	0.014	0.093	0.269	0.110	0.110	0.719
Nitrogen (A)	3	1.116**	0.411**	2.851**	11.815**	8.614**	3.172**	21.997**	91.167**
Plant spacing (B)	2	2.320**	4.085**	11.643**	17.882**	17.904**	31.520**	89.838**	137.977**
Interaction (A×B)	6	0.217**	0.067**	0.160**	0.809**	1.677**	0.516**	1.232**	6.240**
Error	22	0.045	0.013	0.020	0.063	0.350	0.103	0.154	0.486

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

Appendix VII. Cost of production for Indian spinach cultivation as influenced by nitrogen and plant spacing

Treatment Combination	Labour cost	Ploughing cost	Seed cost (Tk)	Irrigation Cost	Weeding cost	Pesticides	Manure and fertilizers				Sub Total (A)
							Cowdung	Urea	TSP	MP	
N_0S_1	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	0.00	2,160.00	2,700.00	56,060
N_0S_2	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	0.00	2,160.00	2,700.00	56,060
N_0S_3	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	0.00	2,160.00	2,700.00	56,060
N_1S_1	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	840.00	2,160.00	2,700.00	56,900
N_1S_2	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	840.00	2,160.00	2,700.00	56,900
N_1S_3	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	840.00	2,160.00	2,700.00	56,900
N_2S_1	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	1,104.00	2,160.00	2,700.00	57,164
N_2S_2	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	1,104.00	2,160.00	2,700.00	57,164
N_2S_3	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	1,104.00	2,160.00	2,700.00	57,164
N_3S_1	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	1,380.00	2,160.00	2,700.00	57,440
N_3S_2	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	1,380.00	2,160.00	2,700.00	57,440
N_3S_3	12,000.00	5,000.00	1,200.00	5,000.00	5,000.00	3,000.00	20,000.00	1,380.00	2,160.00	2,700.00	57,440

N_0: 0 kg N/ha
N_1: 100 kg N/ha
N_2: 120 kg N/ha
N_3: 140 kg N/ha

S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm

Appendix VII. Contd.

B. Overhead cost (Tk./ha)

Treatment Combination	Cost of lease of land for 6 months (13% of value of land Tk. 7,00000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 13% of cost/year	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
N_0S_1	45,500	2,803	6,784	55,087	111,147
N_0S_2	45,500	2,803	6,784	55,087	111,147
N_0S_3	45,500	2,803	6,784	55,087	111,147
N_1S_1	45,500	2,845	6,841	55,186	112,086
N_1S_2	45,500	2,845	6,841	55,186	112,086
N_1S_3	45,500	2,845	6,841	55,186	112,086
N_2S_1	45,500	2,858	6,859	55,217	112,381
N_2S_2	45,500	2,858	6,859	55,217	112,381
N_2S_3	45,500	2,858	6,859	55,217	112,381
N_3S_1	45,500	2,872	6,878	55,250	112,690
N_3S_2	45,500	2,872	6,878	55,250	112,690
N_3S_3	45,500	2,872	6,878	55,250	112,690

N_0: 0 kg N/ha
N_1: 100 kg N/ha
N_2: 120 kg N/ha
N_3: 140 kg N/ha

S_1: 60 cm × 20 cm
S_2: 60 cm × 30 cm
S_3: 60 cm × 40 cm