PERFORMANCE OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND YIELD OF INDIAN SPINACH (*Basella alba* L.) ON ROOF TOP GARDEN

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CERTIFICATE

*This is to certify that the thesis entitled “**“PERFORMANCE OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND YIELD OF INDIAN SPINACH (Basella alba L.) ON ROOF TOP GARDEN”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Agroforestry and Environmental Science**, embodies the result of a piece of bona fide research work carried out by **NILIMA ROY**, Registration number:* **12-04831** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: . . . .

Prof. Dr. Md. Forhad Hossain
Supervisor

Place: Dhaka, Bangladesh

DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The experiment was conducted on the roof top of Biotechnology Department of Sher-e-Bangla Agricultural University, Dhaka, during the period from September 2016 to January 2017 to optimizing the appropriate levels of nitrogen (N) from urea and phosphorus (P_2O_5) from TSP on growth and yield of Indian Spinach. The experiment was laid out in Completely Randomized Design (CRD) with three replications having two factors viz., Factor A: Three levels of nitrogen (N) i.e. N_0 (0 kg N ha^{-1} or Control), N_1 (120 kg N ha^{-1}), N_2 (180 kg N ha^{-1}); and Factor B: Three levels of phosphorus (P_2O_5) i.e. P_0 (0 kg P_2O_5 ha^{-1} or Control), P_1 (120 kg P_2O_5 ha^{-1}), P_2 (140 kg P_2O_5 ha^{-1}). The seeds of Indian Spinach (BARI Puishak -2) were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. A statistically significant variation was observed in respect of all characters at different days after sowing (DAS) in relation with different levels of nitrogen and phosphorous application. The doses of N_2 treatment showed the maximum plant height (96.62 cm), number of branches per plant (17.97), number of leaves per plant (93.21), leaf area (254.49 cm^2), yield per plot (947.81g $plot^{-1}$), yield per hectare (20.43 ton), while the control treatment gave the lowest values. The doses of P_2 treatment showed the maximum plant height (84.58 cm), number of branches per plant (16.27), number of leaves per plant (84.23), leaf area (216.43 cm^2), yield per plot (887.87 g $plot^{-1}$), yield per hectare (19.06 ton), while the control treatment gave the lowest values. The combined effect also showed significant differences. Among the treatment combinations, N_2P_2 (180 kg N ha^{-1} + 140 kg P_2O_5 ha^{-1}) showed the maximum plant height (98.21 cm), number of branches per plant (18.75), number of leaves per plant (95.56), leaf area (266.56 cm^2), yield per plot (970.22 g $plot^{-1}$), yield per hectare (20.9 ton), while the control treatment gave the lowest value. The over all result suggests that N_2 treatment and P_2 treatment can be applied to boost up the production of Indian Spinach.

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List of Abbreviated Terms

Agro-Ecological Zone	AEZ
Analysis of variance	*ANNOVA*
and others	*el al.*
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Centimetre	cm
Completely Randomized Design	CRD
Days after sowing	DAS
Degree Celsius	°C
df	Degree of freedom
Dhaka City Corporation	DCC
Dhaka North City Corporation	DNCC
Dhaka South City corporation	DSCC
ed est (means That is)	i.e.
Etcetera	etc.
Exempli gratia (by way of example)	e.g.
Food and Agriculture Organization	FAO
Gram	g
Hectare	ha
Hour	hr
Hydrogen ion conc.	p^H
Kilogram	kg
Least Significant Difference	LSD
Meter	m
Millimetre	mm
Microsoft Excel	MS Excel
Percent	%
Rajdhani Unnayan Kartripakkha	RAJUK
Randomized Complete Block Design	RCBD
Relative Prevalence	RP
Roof Top Garden	RTG
Sher-e-Bangla Agricultural University	SAU
Square Metre	m^2
Standard Deviation	SD
Standard Error	S.E
Statistical Package for Social Science	SPSS
United Nations	UN
United Nations Development Program	UNDP
United Nations Development Program	UNDP

CHAPTER I

INTRODUCTION

Dhaka, the capital city of Bangladesh has experienced a higher rate of urban growth in recent years and emerged as the world's fastest growing mega city. Due to unrestrained urban growth, it will be the fourth largest urban agglomeration of the world with a population of 162.9 million by 2018 (Worldometer, 2018). So, the city is facing incredible problem to provide adequate nutrition support to its people. The loss of plant diversity has been a common concern of mankind and a threat for our agriculture, environment, and forest also poses long term humanity problem. Several of the global hotspots of biodiversity are at the same time areas where human population density has increased tremendously, which has contributed to current global species extinction levels paralleling to previous mass extinction events (Myers *et al.,* 2001). To solve this severe problem, rooftop gardening may be a solution and natural habitats to conserve some diversity (Kindt *et al*., 2005) in Dhaka city.

Roof top gardens (RTG) are man-made green spaces on the topmost levels of industrial, commercial, and residential structures. They may be designed to produce, provide play space, give shade and shelter, or simply be there as a living, green area. Plants are grown for a variety of utilitarian and non-utilitarian purposes (Sajjaduzzaman *et al.,* 2005). Rooftop garden can supplement the diets of the community it feeds with fresh produce and provide a tangible benefits tie to food production. Plant species diversity is a resource, property and the characteristic of plant kingdom. We depend on it for our security and health; it strongly affects our social relations and gives us freedom and choice. In this case, RTG can be an effective method to rich biodiversity which is important in maintaining the balance of nature (Hoggerbrugge and Fresco, 1993).

Roof top garden can be one of the best solutions for cultivating vegetables in the cities. City's gardeners and agriculturists, however, cite yet another reason why more house owners getting keen having a patch of greenery on their roofs, which is, they want vegetables and fruits fresh and free from poisonous chemicals. So, the objectives of the research are to study Indian Spinach cultivation in rooftop garden in Dhaka city and to explore the performance of Nitrogen and Phosphorous on the growth and yield of the Indian Spinach. The finding of the research will be directly beneficial to the rooftop garden owners as they get feedback from the research findings. The findings will also useful to all garden owners that fall in similar ecological zones to get idea for the adoption of new alternatives as roof top gardening or improving the existing practices.

Indian spinach *(Basella alba* L.) belongs to the family Basellaceae. It is a popular summer leafy vegetable widely cultivated in Bangladesh, India, in Tropical Asia and Africa. Indian spinach is a fleshy annual or biennial, twining much branched herb with alternate leaves.

The nutritive value of Indian spinach is very high with a good content of minerals and a moderate storage of vitamins to the human diet plus substantial amount of fibre and water. The plant is reported to contain moisture - 93%, protein -1.2%, iron - 1.4%, calcium - 0.15%, vitamin A - 3250 IU/l00g. In addition to these, *Basella alba* contains 16g fluoride/100g and nitrate content is 764 ppm on dry weight basis (Sanni, 1983).

Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). Indian spinach responds greatly to major essential elements like N and P in respect of its growth and yield (Mital, 1975). 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. Nitrogen progressively increases the marketable yield but an adequate supply of nitrogen is essential for vegetative growth, and desirable yield (Yoshizawa *et al.*, 1981).

Phosphorus is also one of the important essential macro elements for growth and development of plant. The Phosphorus requirements vary depending upon the nutrient content of the soil (Bose and Som, 1990). It helps photosynthesis by maintaining iron supply and increases the body substrates. Phosphorus improves root system of Indian spinach, so that the roots can absorb the minerals and irons from soil solution efficiently, resulting with higher yield. Considering the above mentioned facts this experiment will satisfy the following objectives:

1. To find out the optimum dose of nitrogen and phosphorus for growth and maximum yield of Indian spinach; and
2. To investigate the combined effect of nitrogen and phosphorus for obtaining desirable yield.

CHAPTER II

REVIEW OF LITERATURE

The aim of this chapter is to describe the review of the past research conducted in line of the major focus of the study. The literature review chapter consists of three sections. The first section illustrates the rooftop gardening, its history, role and importance, rooftop garden in terms of intensive and extensive green roof, present situation in Bangladesh while discussions about Indian Spinach will come next and last of all fertilizer (Nitrogen and Phosphorous) effect will be illustrated. Literatures related of rooftop gardens, Indian Spinach and fertilizers which were collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented in this chapter under the following headings-

2.1.1 Rooftop gardens and green roofs

Rooftop gardening is a particular form of urban greening that uses the rooftops of buildings for growing plants. The word 'roof' in this context refers to any continuous surface designed for the protection of inhabitants from the climatic elements, whether open or closed on the sides. They are a powerful tool in combating the adverse impacts of land development and the loss of open space. The vegetated space may be below, at or above grade; located on a podium deck, a 'sky garden' on an intermediate floor level, or at the very top level of the building; but in all cases the plants are not planted in the ground (Hossain, 2009).

There are two main forms, green roofs and rooftop gardens, as described below. While both are of interest to urban areas, this research focuses on the later. A roof garden is an area that is generally used for recreation, entertaining, and as an additional outdoor living space for the building's resident(s). It may include planters, plants, dining and lounging furniture, outdoor structures such as pergolas and sheds, and automated irrigation and lighting systems. A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems (Hossain *et al.*, 2009).

A rooftop garden is a garden on the roof of a building. Besides the decorative benefit, roof plantings may provide food, temperature control, hydrological benefits, architectural enhancement, habitats or corridors for wildlife, recreational opportunities, and in large scale it may even have ecological benefits (Kallo,1986). Rooftop farming is usually done using green roof, hydroponics, aeroponics or air-dyponics systems of container gardens. A lot of various plants can grow in a rooftop garden depending on the weather conditions in that particular region. Rooftop gardening is very fun and can provide a yearly income through the vegetables and fruits growing in it. Rooftop gardens are a tremendously easy, cathartic, accessible way to grow plants and vegetables and they come with a number of benefits (Khandaker *et al.,* 2004).

Hodgon *et al*. (2011) reported that urban agriculture is much more than private gardens and community gardens, and many communities are beginning to see the promise of other forms of urban agriculture.

Moustier (2007) provides an extensive summary of the importance of urban agriculture in 14 African and Asian cities.

Islam (2001) has published an article named “Roof gardening as a strategy of urban agriculture for food security: the case of Dhaka city, Bangladesh.” He has reported that urban agriculture in the cities of developing countries are growing rapidly which also means the number of low-income consumers is increasing. Because of food insecurity in these cities is increasing. Urban agriculture (UA) contributes to food security by increasing the supply of food and by enhancing the quality of perishable foods reaching urban consumers.

Kamrujjaman (2015), wrote a Book name “Green Banking” regarding the Rooftop Gardening. The book describes the thermal benefits of roof gardens and the overall techniques and farming procedures of vegetables, fruits, flowers/ ornamental plants and multipurpose use of Roof garden.

Orsini *et al*. (2014) was carried out a study of addressing the quantification of the potential of rooftop vegetable production in the city of Bologna (Italy) as related to its citizen's needs. The potential benefits to urban biodiversity and ecosystem service provision were estimated. RTGs could provide more than 12,000 t year-1 vegetables to Bologna, satisfying 77 % of the inhabitants' requirements.

Rashid and Ahmed (2009) experimented the thermal performance of rooftop garden in a six storied building established in 2003. It found that the temperature of this building was 3°C lower than other surrounding buildings and this Green application can reduce the indoor air temperature 6.8°C from outdoor during the hottest summer Period.

Lundholm and Oberndorfer (2007) demonstrated that easily measured plant traits (height, individual leaf area, specific leaf area, and leaf dry matter content) can be used to select species to optimize green roof performance across multiple key services.

2.1.2 History of Roof Gardens:

Roof gardens, the precursors of contemporary green roofs, have ancient roots. The earliest documented roof gardens were the hanging gardens of Semiramis or Hanging garden of Babylon, what is now in Syria, considered one of the seven wonders of the ancient world.

The standard construction practices of roof greening in many countries have started a hundred years ago. Ornamental roof gardens developed initially by the ancient Mesopotamian civilizations of the Tigris and Euphrates River valleys (the Hanging

Garden of Babylon) and by the Romans. Until the mid20th century, green roofs have been a feature of the vernacular architecture notably of Scandinavia and Kurdistan region. Traditional Scandinavian turf roof (combination of mud and grass on flat roof) helped to reduce heat loss during the long, dark winters. Scandinavian immigrants to the United States and Canada took the idea with them, and grass roofs were used on settler cabins. Traditional Kurdish turf roofs serve to keep heat in winter and keep out the burning sun in summer (Millat-e-Mustafa, 1997).

Traditionally sod (also called turf) roofs have been used in Scandinavia as an anti-fire protective measure by covering the roof with fire resistant soil. Grass develops over time to create a sod roof. Modern green roofs were first used in Switzerland in the 1960s as storm water management and spread to Germany in the late 1970s. Today they are broadly used and are, in some parts, required by law as a means to preserve a certain degree of green space . Besides Germany, Austria (Linz city) has developed a rooftop garden project since 1983, as well as the Swiss began to intensively develop rooftop garden since 1990. In the UK, London and Sheffield city government has even made special policies regarding the development of the roof garden. Development of the roof garden is also popular in the U.S. although not as intensive as in Europe. In America the roof garden concept was first developed in Chicago and then became popular in Atlanta, Portland, Washington, and New York (Wikipedia, 2008). Green roofs are most widely used in Germany, where approximately 14% of all flat roofs are green (VanWoert *et al.*, 2005). The first modern green roofs in Sweden arrived in the early 1990s and have only become commonly used in occasional projects or as part of new housing areas with an

2.1.3 Roof gardens as Ecosystem

Green roofs and roof gardens represent an opportunity to increase the coverage of living ecosystems in cities. However, the extent on which roof gardens can be justified to compensate for the ground-level ecosystems and the extent on which roof gardens serve as a complementary solution needs to be studied, as their structure and many functions differ profoundly from ground-level ecosystems. Both the green roofs and rooftop gardens represent a class of technology that can be considered bioengineering or bio mimicry: the ecosystem created by a roof garden's interacting components mimics several key properties of ground-level vegetation that are absent from a conventional roof (Khandaker *et al.,* 2004). Green roofs and Rooftop gardens, like other constructed ecosystems (e.g., sewage treatment wetlands, bio swales for storm-water management, or living walls), mimic natural ecosystems to provide ecosystem services. Ecosystem diagrams use symbols to describe flows of energy, materials and information to, from and within an ecosystem.

Rooftop Gardens may reduce a city's Ecological Footprint (EF) by reduction of pollution and noise, the absorption of CO^2 emissions and the control of the Urban Heat Island (UHI) effect by shading. (Rees and Wackernagel, 1996). Thus, RTGs can reduce the expense of heating and cooling and at the same time improve urban air quality (Peck, 2003). Furthermore, RTGs, while being aesthetically appealing, can contribute to biodiversity in the urban environment, achieve more sustainable conditions, including those necessary for the production of food and improve the overall quality of urban life (Bennett, 2003; Khandaker *et al.*, 2004; Maas *et al.*, 2006).

2.1.4 Roof Gardening overview in Bangladesh

Although rooftop gardening is a new practice in Bangladesh, This concept has spread during 1990s with the pioneer works of Urban Agriculture Network supported by the UNDP

• The direct or indirect stakeholder departments which are responsible of Urban Greening and Roof Top Gardening are- City Corporations (Dhaka North, Dhaka South, Gazipur, Narayangonj) and the Rajdhani Unnayan artripakkha (RAJUK)

• With DCC and RAJUK, a number of state bodies, autonomous bodies, private organizations, NGOs, different societies are involved with greening activities in and around Dhaka city.

• Of them, the key state and autonomous authorities are Department of Environment (DOE), Local Government and Engineering Department (LGED), Bangladesh Forest Department (BFD), Dhaka Urban Transport Project (DUTP), and Dhaka Transport Coordination Board (DTCB), Department of Archeology, etc.

• Apart from these, some NGOs like ASHA, PROSIKA, different financial organization, donor agencies such as ADB, World Bank are also taking part in greening activities in Dhaka city

• Some social organizations like Society of Arboriculture, Bangladesh National Nursery Consortium (NNC) are "Green savers" also contributing their efforts for promoting greening activities. Recently, the mayors of DNCC and DSCC have been declared that, 10% building tax reduction will be granted for the resident buildings with RTGs to inspire and increase the number of RTGs in Dhaka city. Moreover Mayor Anisul Haque has been launched a project named "Green Dhaka Project" aimed for increasing greeneries in Dhaka city by utilizing free space such as over bridges, bare rooftops and so on.

2.2.1 Indian Spinach

Indian spinach is one of the most popular leafy vegetable in Bangladesh. It is native of Indo-Chinese region (Laxman *et al.,* 1990). It is popular due to its high nutritive value. 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 (Laxman *et al.,* 1990).

2.2.2 Scientific Recognition and ingredients of Indian Spinach

Basella alba commonly known as poi belongs to the family Basellaceae genus *Basella,* species *alba* and with Chromosome number 2n=18 B. alba is a fast growing vegetable, native to tropical Asia (India or Indonesia) and extremely heat tolerant (Grubben and Denton, 2004). It is commonly known as Malabar, Ceylon, EastIndian, Surinam and Chinese spinach. It is fast growing perennial plant but it is sometimes cultivated as an annual for home gardens and as a cash crop. It is an easy growing plant propagated by seed, root or long tip cuttings. *B. alba* is commonly grown for its leaves and young shoots, which are high in Vitamin A, B9, C, iron and calcium (Grubben and Denton, 2004). Due to its mucilaginous nature of leaves and stems, the juice of leaves has been prescribed against constipation especially for children and pregnant women (Duke and Ayensu, 1985). Its thick, semi succulent, heart-shaped leaves have a mild flavour and mucilaginous texture. Daily consumption of Indian spinach has been shown to provide vitamin A especially in populations at high risk of vitamin A deficiency (Haskell *et al.*, 2004).

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 cultivars are consumed as vegetables but green-leaved cultivars 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 in fresh condition. The nutritive value of Indian spinach is very high with a good content of minerals and a moderate storage of vitamins to the human diet plus substantial amount of fibre and water (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/l00g. In addition to these, *Basella alba* contains 16g fluoride/100g 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).

Basella alba is also known to be a heavy absorber of soil moisture which should be ensured through proper water management such as irrigation. There is a little or no combined research work to the effect of organic and inorganic fertilizer on growth and yield of *Basella alba* in Bangladesh. The literature related to the present study are reviewed in this chapter.

Miura *et al*. (1997) carried out an experiment with individual seeds of Malabar spinach (*Basella alba*) were sown in plastic cells of flats in a commercial potting mixture (Shinkenbyokun type 140) with 3 different water regimes. The moisture levels were adjusted by adding 16, 52 and 100 g of water to 500 g of potting mixture. It was suggested that optimal emergence of *B. alba* seeds could be obtained by sowing in a potting mixture with a moisture content equivalent to 52 g water/500 g mixture (water content of 41- 45%), and chilling at 15°C for 10 days.

Rosu *et al*. (2004) suggests that the vitamin A equivalency of beta-carotene from plant sources is lower than previously the effect of 60 d of daily supplementation with 750 microgram retinol equivalents (RE) of either cooked, pureed sweet potatoes; cooked, pureed Indian spinach (*Basella alba*), or synthetic sources of vitamin A or beta-carotene on total- body vitamin A stores in men.

Smith (2004) carried out a pot experiments where seedlings emerging from doses higher than 0.33 kg (ai ha^{-1}) were significantly stunted, dark-green, mottled and produced shrunken, deformed, thickened and brittle leaves.

Busuioc *et al.* (1998) respiration and the activity of catalase and peroxidases were determined in leaves of *B. alba* and *B. rubra*, collected in June-September from plants grown in the field or in the greenhouse in Romania. Differences were found between field and greenhouse cultivated plants, and between species. In all cases, respiration was highest during August and was higher in field-grown plants. Peroxidase and catalase activities tended to be the lowest in August, and higher in field-grown plants.

El-Karamany *et al*. (2000) reported that biological fertilization of plants by N_2 fixing bacteria gained importance in the last years. The significant effect of bio-fertilizers may be due to the effect of different strain groups such as nitrogen fixer, nutrient mobilization microorganisms which help in increasing the availability of minerals and their forms in the composted materials and increase levels of extractable of macro or micronutrients.

Fatma Rizk and Shafeek (2000) Biogein has high amounts of symbiotic and non symbiotic bacteria responsible for atmospheric nitrogen fixation. Application of Biogein reduced the required mineral nitrogen by 25%, increased the availability of various nutrients, enhances the resistance of plants to root disease and reduces the environmental pollution from chemical fertilizer application.

Glassgen *et al.* (1993) were identified betanidin monoglucoside, gomphrenin I (15S-betanidin 6-O-betaglucoside), and its 4-coumaroyl and feruloyl derivatives, gomphrenin II (15S-betanidin 6-0-(6'-0-(4-coumaroyl)-beta-glucoside)), isogomphrenin I and II, and gomphrenin III (15S-betanidin 6-0-(6'-0-feruloylbeta-glucoside)), from the juice of fresh B. rubra fruits. Their structures were elucidated from spectral analyses.

Banerjee *et al.* (1992) observed that *B. rubra*, known as poi, is used in the treatment of constipation in children and pregnant women, and urticaria. Palmitic, oleic, linoleic, linolenic and arachidonic acids were present in the fatty oil (10.7%) from seeds (collected locally), while the proteins (3.3%) included lysine, theonine, valine, methionine and leucine.

Demidov *et al.* (1991) with *B. rubra* [*B. alba*] in greenhouse container trials was conducted by the vegetatively propagated plants were grown in 3 different substrates viz. (1) natural zeolite, (2) zeolite + 5% chernozem and (3) a 1:1 mixture of leaf compost and river sand. All substrates had a similar nutrient content and 4-kg containers were used. The plants were grown in 30/20°C day/night temperatures at 65.5% RH and 50 or 70 W/m2 PAR, under a daily 12-h illumination. The foliage was cut at 15 cm above the substrate level 3 times per week. *B. alba* was found a promising salad crop giving a high yield per unit area.

2.3 Fertilizers

Effects of fertilizers has a great impact on crop as well as vegetable production. In case of Indian Spinach fertilizer plays an important role for the growing up of the plants. In this research we wanted to see the effect of two fertilizer namely Nitrogen and phosphorous. A brief discussion on them and their effects has been mentioned bellow:

2.3.1 Nitrogen

Nitrogen fertilizers are made from ammonia (NH_3), which is sometimes injected into the ground directly. The ammonia is produced by the Haber-Bosch process. In this energy-intensive process, natural gas (CH_4) usually supplies the hydrogen, and the nitrogen (N_2) is derived from the air. This ammonia is used as a feedstock for all other nitrogen fertilizers, such as anhydrous ammonium nitrate (NH_4NO_3) and urea ($CO(NH_2)_2$).

Deposits of sodium nitrate ($NaNO_3$) (Chilean saltpeter) are also found in the Atacama desert in Chile and was one of the original nitrogen-rich fertilizers used. It is still mined for fertilizer.

2.3.2 Phosphorous

The fertilizer containing phosphorous in named as phosphate fertilizer. All phosphate fertilizers are obtained by extraction from minerals containing the anion PO_4^{3-}. In rare cases, fields are treated with the crushed mineral, but most often more soluble salts are produced by chemical treatment of phosphate minerals. The most popular phosphate-containing minerals are referred to collectively as phosphate rock. The minerals are flour apetite $Ca_5(PO_4)_3F$ CFA andd hydroxyapatite $Ca_5(PO_4)_3OH$. These minerals are converted to water-soluble phosphate salts by treatment with sulfuric (H_2SO_4) or phosphoric acids (H_3PO_4). The large production of sulfuric acid as an industrial chemical is primarily due to its use as cheap acid in processing phosphate rock into phosphate fertilizer. The global primary uses for both sulphur and phosphorous compounds relate to this basic process.

In the nitrophosphate process or Odda process, phosphate rock with up to a 20% phosphorus (P) content is dissolved with nitric acid (HNO_3) to produce a mixture of phosphoric acid (H_3PO_4) and calcium nitrate ($Ca(NO_3)_2$). This mixture can be combined with a potassium fertilizer to produce a compound fertilizer with the three macronutrients N, P and K in easily dissolved form.

2.3.3 Effect of fertilizers (Nitrogen and Phosphorous):

Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). The cultivation of *Basella alba* requires proper supply of plant nutrient. This requirement can be provided by applying inorganic fertilizer or organic manure or both. In this research work we would discuss about the effect of inorganic fertilizer Nitrogen and phosphorous only. The associated literature for this fertilizers have been studied here.

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.

Bastelaere (1999) stated that fertilizer application (12.5 $kgha^{-1}$) in Indian spinach the autumn on well-leached soils resulted in glassiness and rib blight. However, after soil disinfection, an application of 25 kg ha^{-1} was sometimes necessary. Greater application rates resulted in stagnated growth and lower crop weight.

Kowalska (1997) conducted Greenhouse 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 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.

El-Shinawy *el al.* (1999) reported that the highest in the control treatment, followed by poultry manure, pigeon manure and finally buffalo manure. Mineral composition of Indian spinach plants was influenced by treatment. The results suggested that poultry manure, with some modifications, could be used as an organic source under the nutrient film technique system.

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^{-1} with half the recommended mineral fertilizer rate and 13 t organic compost ha^{-1} 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.

Tisselli (1999) reported that maximum rates of organic manure (usually poultry manure) and NPK 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.

Rubeiz *et al.* (1992) mentioned that the lack of significant response in Indian spinach yield was due to sufficient levels of soil NO3-N and available P in the untreated soil. Manure or fertilizer application had no effect on soil EC, pH or available P. Soil NO3-N at harvest was significantly increased only by NH4NO3. Leaf PO4-P concentration was not affected by treatments, but leaf NO3-N at heading was significantly increased by all treatments.

Vidigal *et al.* (1997) mentioned that dried pig manure gave the highest yields in Indian spinach at 65 days after sowing (54.4 tha^{-1}), 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. 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 matterha^{-1}) than other rates. When 7 t/ha was incorporated, the rate of surface application had no significant effect on yields (13.3-17.1 tha^{-1}), whereas when 14 t/ha was incorporated, surface application of 7 t manure/ha gave the significantly highest yield (20.0 t fresh matterha^{-1}).

CHAPTER III

MATERIALS AND METHODS

Indian Spinach (*Basella alba*) locally known as Pui shak, is highly nutritious green leafy vegetable crop. It is being grown in a very large scale in Bangladesh, a good deal of interest has been generated for raising this crop due to its demand. It is necessary to explore the possibilities of growing Indian spinach in order to raise its yield level, fertilizer effects on growth, development and yield. So, this experiment was undertaken to find out optimum doses of fertilizer effective for yield of this crops.

3.1 Location of the experiment field

The experiment was conducted at the roof of third floor of Biotechnology Department of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka during the period from September 2016 to January 2017. The location of the experimental site was at 23°75′ N latitude and 90°34′ E longitudes with an elevation of 8.45 meter from sea level (Anon, 1989).

3.2 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). The total rainfall of the experimental site was 25 mm during the study period. The average monthly maximum and minimum temperatures were 32.2 ºC and 21.6 ºC, respectively, during the experimental period. Rabi season is characterized by plenty of sunshine. The maximum and minimum temperature, humidity rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department (Climate Division) and have been presented in Appendix I.

3.3 Soil

The soil of the experimental site was collected from outside of Dhaka city, which was sandy clay. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resource Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and presented in Appendix I.

3.4 Plant materials collection

Variety: BARI Puishak -2 (*Basella alb*a-Green)

Source: The seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Treatment of the Experiment

The experiment considered two factors. Details are presented below:

Factor A: Levels of nitrogen (3 levels)

i. N_0: 0 kg N ha^{-1} (Control)

ii. N_1: 120 kg N ha^{-1}

iii. N_2: 180 kg N ha^{-1}

Factor B: Levels of phosphorus (3 levels)

i. P_0: 0 Kg P_20_5 ha^{-1} (Control)

ii. P_1: 120 Kg P_20_5 ha^{-1}

iii. P_2: 140 Kg P_20_5 ha^{-1}

So, there were 9 treatment combinations such as N_0P_0, N_0P_1, N_0P_2, N_1P_0, N_1P_1, N_1P_2, N_2P_0, N_2P_1 and N_2P_2 .

3.6 Layout of the Experiment

The two factors experiment was laid out following Completely Randomized Design (CRD) with three replications. An area of 9 m x 4 m was divided into three equal blocks. Each block was consists of 9 plots where 9 treatment combinations were allotted at random. There were 27 unit plots altogether in the experiment. The size of each plot was 1 m x 1 m, which accommodated 4 plants at a spacing 0.3 m x 0.3 m. The distance between two blocks and two plots were kept 0. 5 m and 0.25 m, respectively. The layout of the experiment is shown in Figure 1.

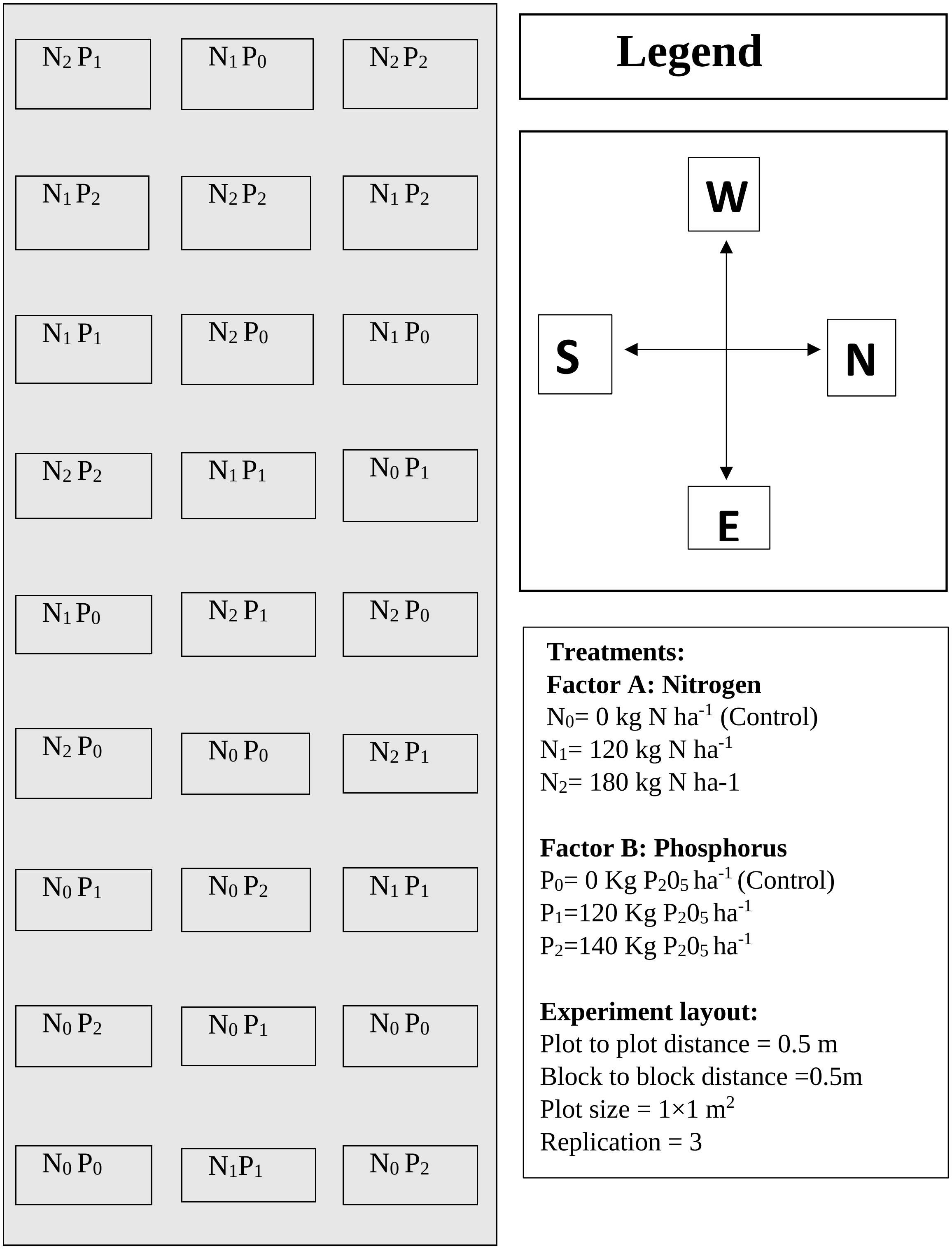


Figure 1. Layout of the experimental field

3.7. Land preparation

Before starting the experiment a concrete structure called block using brick and sand was prepared measuring 9 m × 5 m on the roof top of the third floor of Biotechnology Department (SAU). After that each block was fill with soil. The sandy loam soil was prepared and good tilth ensured for commercial crop production on 3rd September 2017. The land were spaded and larger clods were broken into smaller pieces. After spading all the stubbles and uprooted weeds were removed and finally obtained a desirable tilth of soil for sowing of Indian spinach seeds. The experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in Figure 1. Recommended doses of well decomposed cow-dung manure and chemical fertilizers as indicated below were mixed with the soil of each unit plot.

3.8. Manure and fertilizers and its methods of application

Urea, triple super phosphate (TSP) and muriate of potash (MP) were applied as the source of nitrogen, phosphorus and potassium, respectively as per treatment in each plot. The entire amount of well-rotten cow-dung 20 ton ha^{-1}, TSP and MP were applied as basal during land preparation. Those were mixed with the soil of the individual plot 4 days before seed sowing. Urea was applied in three equal instalments at 15, 30 and 45 days after seed sowing (DAS) of Indian spinach. The following amount of manures and fertilizers were used which shown as tabular form recommended by Uddin *et al.* (2012) from Fertilizer recommendation guide:

Table 1. Doses and method of application of fertilizers in Indian Spinach field

Manures and fertilizers	Dose per hectare	Application (%)			
		Basal	15 DAS	30 DAS	45 DAS
Cow dung	20 tons	100	-	-	-
Nitrogen	As treatment	-	33.33	33.33	33.33
$P_2 0_5$ (as TSP)	As treatment	100	-	-	-
$K_2 0$ (as MP)	120 kg	100	-	-	-

3.9 Seed sowing

Seeds were sown in field in the first week of September with maintaining the distance between plant to plant and row to row.

3.10 Intercultural operation

When the seedlings started to emerge in the beds it was always kept under careful observation. After emergence of seedlings, various intercultural operations irrigation, thinning, weeding, top dressing was accomplished for better growth and development of the Indian spinach seedlings.

3.10.1 Irrigation

Over-head irrigation was provided with a watering cane to the plots once immediately after germination and the irrigation was done at four times as per treatment for proper growth and development of plants.

3.10.2 Gap filling

When the seedlings were well established, the soil around the base of each seedling was pulverized. A few gap filling was done by healthy seedlings of the same stock where initial planted seedling failed to survive.

3.10.3 Thinning

The seedlings were first thinned from all of the plots after 10 days after sowing and were continued at 7 days interval for proper growth and development of spinach seedlings.

3.10.4 Weeding

Weeding was done to keep the plots free from weeds, easy aeration of soil, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully after complete emergence of spinach seedlings whenever it is necessary. Generally three weeding were done at 15 days interval. Breaking the crust of the soil was done when needed.

3.10.5 Top Dressing

After basal dose, the remaining doses of urea were top-dressed in 3 equal instalments. The fertilizers were applied on both sides of plant rows and mixed well with the soil. Earthling up operation was done immediately after top- dressing of nitrogenous fertilizer.

3.10.6 Insects and Diseases

In early stage ant was attacked. This was controlled by using systemic insecticides. There was no remarkable attack of disease.

3.11 Harvesting

To evaluate yield, three times harvesting were done at different growth stages. First harvesting was done at 30 days after sowing. Second and third harvesting were done 45 and 60 days after sowing, respectively.

3.12 Data collection

Data were recorded on the following parameters from the sample plants. During the course of experiment, 3 plants were sampled randomly from each unit plot for data collection in such a way that the border effect could be avoided for the highest precision. Data on the following parameters were recorded from the sample plants during the course of experiment.

3.12.1 Plant height (cm)

Plant height was measured in centimetre (cm) by a meter scale at 15, 30, 45 and 60 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 3 randomly selected plants were counted at 15, 30, 45 and 60 days after seed sowing (DAS). All the leaves of each plant were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting. The average number of leaves of 3 plants gave the number of leaves per plant.

3.12.3 Leaf area per plant (cm^2)

The selected leaves of 3 randomly selected plants were measured at 15, 30, 45 and 60 days after seed sowing (DAS). Only the largest young leaves of the plant were measured. The average leaf area of the 3 plants gave leaf area per plant (cm^2).

3.12.4 Number of branches per plant

Number of branches of 4 randomly selected plants were counted at 15, 30, 45 and 60 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 3 plants gave number of branches per plant.

3.12.5 Dry matter of stems

After harvesting 100 g of stem sample previously sliced into very thin pieces were put into envelop and placed in oven and dried at 60°C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken. The dry matter contents of stems were computed by simple calculation from the weight recorded by the following formula.

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

3.12.6 Dry matter of leaves

After harvesting, randomly selected 100 g of leaf sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60°C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature. The final weight of the sample was taken. The dry matter contents of leaves were computed by simple calculation from the weight recorded by the following formula

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

3.12.7 Gross yield (g plot^{-1})

An electric balance was used to measure the weight of leaves and twigs per plot. The total yield of each unit plot measured separately during the harvest period and was expressed in gram (g).

3.12.8 Total yield (t ha^{-1})

It consisted of leaf and twigs of Indian spinach weighed and then converted into ton.

3.12.9 Light measurement

Light was measured by Lux meter on each vegetable crop rows. It was done to determine the availability of light and expressed as lux. Light intensities were measured above the canopy of vegetable crops at 9.00- 10.00 am, 1.00- 2.00 pm and 4.00- 5.00 pm using Lux meter at three times per month.

3.12.10 Soil moisture measurement

Soil moisture was measured by Soil Moisture Meter on each vegetable crop rows. It was expressed as percentage (%). Soil moisture was measured at 10 cm depth of soil adjacent to main root of vegetable crop rows at 9.00- 10.00 am, 1.00- 2.00 pm and 4.00- 5.00 pm in 3 times per month.

3.12.11 Soil temperature measurement

Soil temperature was measured by Soil Temperature Meter on each vegetable crop rows. It was expressed as degree centigrade (˚C). Soil temperature was measured at 10 cm deep soil adjacent to main root of vegetable crop rows at 9.00- 10.00 am, 1.00- 2.00 pm and 4.00- 5.00 pm in 3 times per month.

3.13 Statistical analysis

The recorded data on different parameters were statistically analysed by using SPSS software to find out the significance of variation resulting from the experimental treatments. The mean values for all the treatments were accomplished by Dancan test. The significance of difference between pair of means was tested at 5% and 1% level of probability.

Plate 1. Land preparation

Plate 2. Prepared land

Plate 3. Seed sowing

Plate 4. Emergence of seedlings

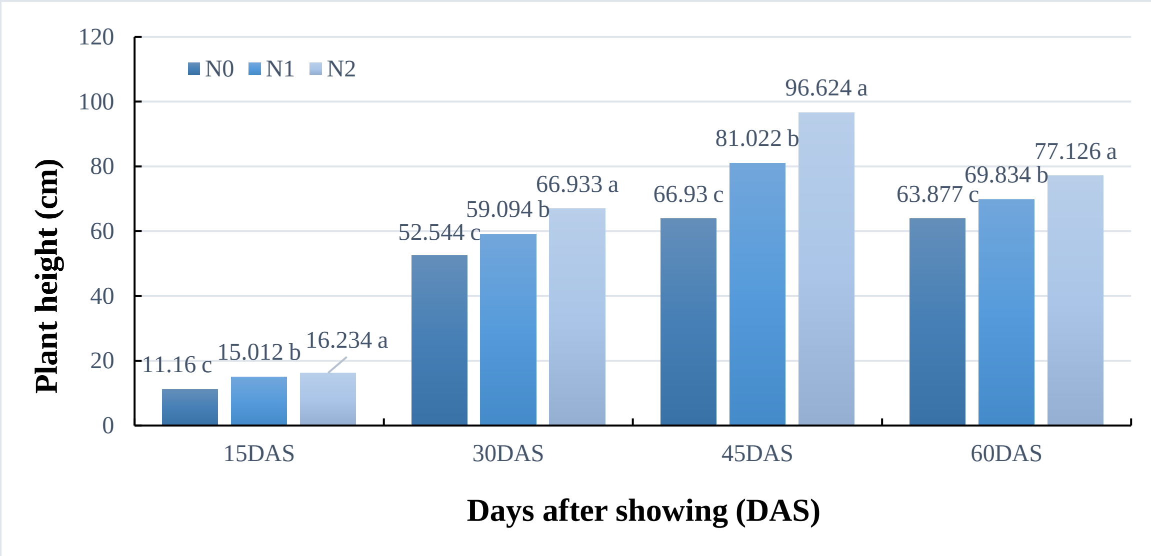
CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to investigate the effect of different levels of nitrogen and phosphorus on the growth and yield of Indian Spinach. The analysis of variances for different characters has been presented in Appendix **III.** Data on different parameters were analysed statistically and the results have been presented in the Table 1 to 16 and Figures 2 to 7. The results of the present study have been presented and discussed in this chapter under the following headings:

4.1 Plant Height

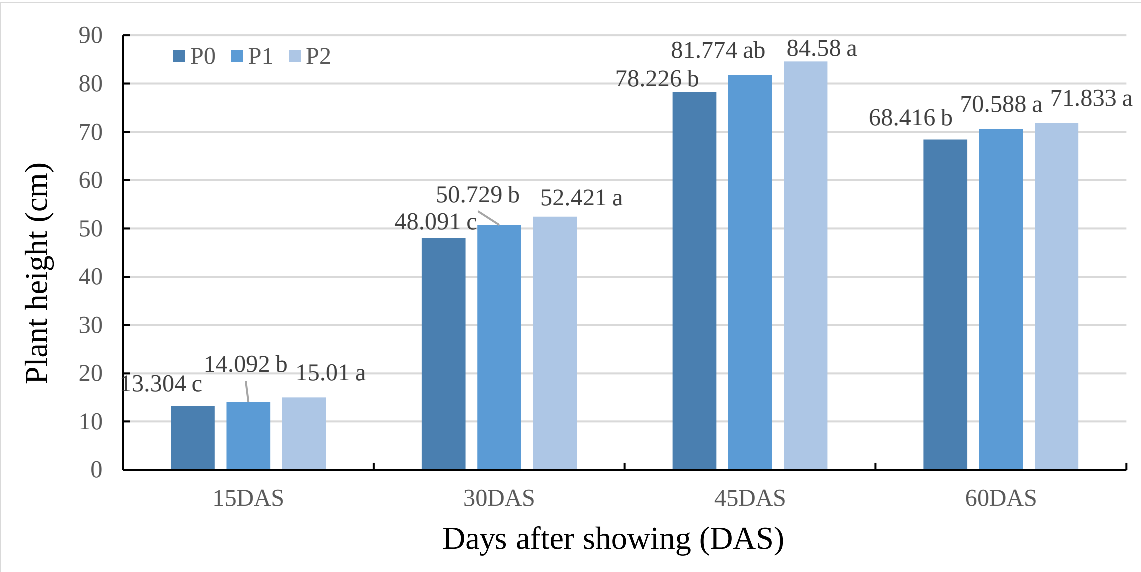
Effect of Nitrogen: Plant height of Indian spinach was significantly influenced by different doses of nitrogen at all day after sowing (DAS). At 45 DAS, the tallest plant height (96.624 cm per plant) of spinach was observed from N_2 treatment (180 kg N ha^{-1}) and the lowest plant height (66.93 cm per plant) was observed from control treatment (0 kg N ha^{-1}). In case of 60 DAS, the tallest plant height (77.126 cm per plant) was observed from N_2 treatment (180 kg N ha^{-1}) and the lowest plant height (63.87 cm per plant) was observed from control treatment (0 kg N ha^{-1}). So, N_2 treatment was more effective which concluded that nitrogen had a positive impact on the growth of Indian Spinach (Figure 2). Similar results were found by Majeeduddin *et al.* (2015) they reported that plant height increased with the increasing levels of nitrogen application. Qamar-uz-Zaman *et al. (*2018) also agreed with this result. This experiment revealed that there was no remarkable difference in plant hight of indian spinach compare to roof top and open field.



Here, N_0=0 kg N ha-1 (Control), N_1= 120 kg N ha-1, N_2=180 kg N ha-1

Figure 2. Effect of nitrogen on the plant height of Indian spinach at different days after sowing (DAS)

Effect of Phosphorus: Plant height of Indian spinach was significantly influenced by different doses of phosphorus at all day after sowing (DAS). At 45 DAS, the tallest plant height (84.58 cm per plant) of spinach was observed from P_2 treatment (140 kg P_2O_5 ha^{-1}) which was statistically significant with P_1 treatment (120 kg P_2O_5 ha^{-1}) and the lowest plant height (78.226 cm per plant) was observed from control treatment (0 kg P_2O_5 ha^{-1}). In case of 60 DAS, the tallest plant height (71.83 cm per plant) was observed from P_2 treatment (180 kg P_2O_5 ha^{-1}) and the lowest plant height (68.41 cm per plant) was observed from control treatment (0 kg P_2O_5 ha^{-1}). So, P_2 treatment was more effective which concluded that phosphorus had a positive impact on the growth of Indian Spinach (Figure 3). Similar results were found by Majeeduddin *et al.* (2015) they reported that plant height increased with the increasing levels of phosphorus application. Qamar-uz-Zaman *et al.* (2018) also ageed with this result.



Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 ha$^{-1.}$

Figure 3. Effect of Phosphorus on the plant height of Indian spinach at different days after sowing (DAS)

Combined effect (Nitrogen and phosphorus): The combined effect of nitrogen and phosphorous was also significant (Appendix III) in terms of plant height (cm) at different days after sowing (Table 2). At 45 DAS, maximum plant height (98.207cm per plant) was recorded in N_2P_2 (180 kg N ha^{-1} + 140 kg P_2O_5 ha^{-1}) treatment and minimum plant height (64.293 cm per plant) was recorded in N_0P_0 (0 kg N ha^{-1} + 0 kg P_2O_5 ha^{-1}) treatment. At 60 DAS, maximum plant height (78.46 cm per plant) was recorded in N_2P_2 (180 kg N ha^{-1} + 140 kg P_2O_5 ha^{-1}) treatment and minimum plant height (61.26 cm per plant) was recorded in N_0P_0 (0 kg N ha^{-1} + 0 kg P_2O_5 ha^{-1}) treatment. An increasing trend was found in with the change of treatment from N_0P_0 to N_2P_2 which clearly showed that the combined effect of nitrogen and phosphorous was strong influence on plant height for Indian Spinach. Qamar-uz-Zaman *et al.* (2018) reported that combined effect of nitrogen and phosphorus 150-100 kg ha^{-1} increased spinach yield.

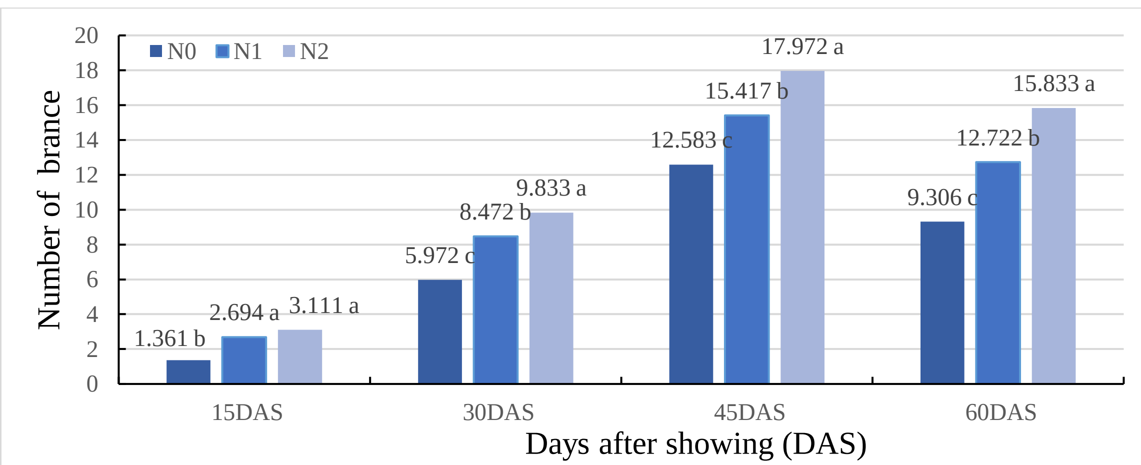
Table 2. Combined effect of nitrogen and phosphorus on plant height at different days after sowing (DAS)

Treatment	Plant height (cm) at different DAS			
	15DAS	30DAS	45DAS	60DAS
N_0P_0	9.680 f	37.263 f	64.293 f	61.260 f
N_0P_1	10.967 e	38.583 f	66.880 f	64.360 ef
N_0P_2	12.833 d	42.960 e	69.627 de	66.010 cd
N_1P_0	14.380 c	49.250 d	75.827 cd	67.830 bc
N_1P_1	15.027 bc	54.130 c	81.333 bc	70.643 b
N_1P_2	15.630 ab	54.253 c	85.907 b	71.030 b
N_2P_0	15.853 ab	57.760 b	94.557 a	76.157 a
N_2P_1	16.283 a	59.473 ab	97.110 a	76.760 a
N_2P_2	16.567 a	60.050 a	98.207 a	78.460 a
S.E	0.46433	1.64940	2.55918	1.14135

In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.
Here, N_0=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}
P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

4.2 Number of branches per plant

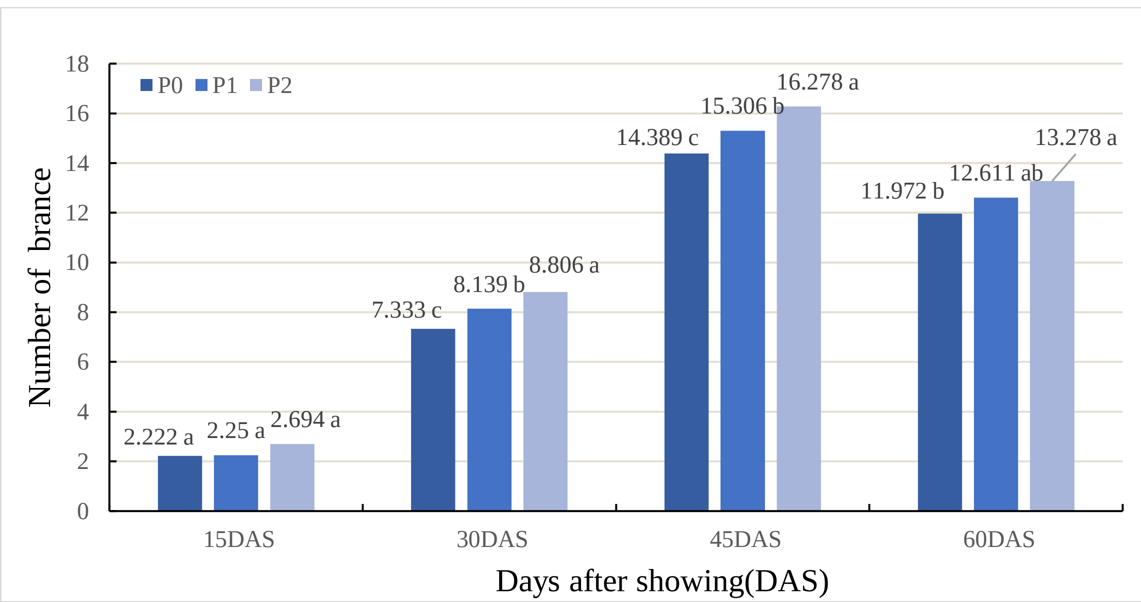
Effect of Nitrogen: Number of branches at different days after sowing was significantly influenced by the different doses of nitrogen (Figure 4). At 45 DAS, maximum number of branches (17.97 per plant) of spinach was observed from N_2 treatment (180 kg N ha^{-1}) and minimum number of branches (12.58 per plant) was observed from control treatment (0 kg N ha^{-1}). In case of 60 DAS, maximum number of branches (15.83 per plant) of spinach was observed from N_2 treatment (180 kg N ha^{-1}) and minimum number of branches (9.306 per plant) was observed from control treatment (0 kg N ha^{-1}). So, N_2 treatment was more effective which concluded that nitrogen was a positive impact on the number of branches of Indian Spinach. As data shown, N fertilization increased number of branches which were in agreement with findings of Rubeiz *et al.* (1992). Likewise, Qamar-uz-Zaman *et al.* (2018) also observed the same results in spinach.



Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Figure 4. Effect of nitrogen on Number of Branch of Indian spinach at different days after sowing (DAS)

Effect of Phosphorus: Number of branches at different days after sowing was significantly influenced by the different doses of nitrogen (Figure 5). At 45 DAS, maximum number of branches (16.278 per plant) of spinach was observed from P_2 treatment (140 kg P_2O_5 ha^{-1}) and minimum number of branches (14.398 per plant) was observed from control treatment (0 kg P_2O_5 ha^{-1}). In case of 60 DAS, maximum number of branches (13.278 per plant) was observed from P_2 treatment (180 kg P_2O_5 ha^{-1}) and minimum number of branches (11.972 per plant) was observed from control treatment (0 kg P_2O_5 ha^{-1}). So, we can concluded that the effect of phosphorous had a positive influence in the number of branches of Indian Spinach. As data shown, P fertilization increased number of branches which were in agreement with findings of Rubeiz *et al.* (1992).



Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 ha^{-1}.

Figure 5. Effect of phosphorus on Number of Branch of Indian spinach at different days after sowing (DAS)

Combined effect (Nitrogen and phosphorus): The combined effect of nitrogen and phosphorous significantly influence on number of branches in Indian Spinach at different days (Table 3). At 45 DAS, maximum number of branches (18.75 per plant) was recorded at N_2P_2 treatment (180 kg N ha^{-1} + 140 kg P_2O_5 ha^{-1}) while minimum number of branches (11.583 per plant) was recorded at control treatment (0 kg N ha^{-1} + 0 kg P_2O_5 ha^{-1}). In 60 DAS, maximum number of branches (16.417 per plant) was recorded at N_2P_2 treatment while minimum number of branches (8.75 per plant) was recorded at control treatment. So, we may conclude that combined effect was positively influenced on number of branches of Indian Spinach. The experiment revealed that there was no remarkable difference in number of branch compare to rooftop and open field. Likewise, Qamar-uz-Zaman *et al.* (2018) also observed the same results in spinach.

Table 3. Combined effect of nitrogen and phosphorus on Number of Branch at different days after sowing (DAS)

Treatment	Number of Branch at different DAS			
	15DAS	**30DAS**	**45DAS**	**60DAS**
N_0P_0	.833 d	5.000 c	11.583 g	8.750 d
N_0P_1	1.417 cd	5.667 c	12.333 fg	9.333 d
N_0P_2	1.833 bcd	7.250 d	13.833 ef	9.833 d
N_1P_0	2.333 bcd	7.667 d	14.500 de	11.750 c
N_1P_1	2.750 abc	8.833 c	15.500 cd	12.833 bc
N_1P_2	3.000 abc	8.917 bc	16.250 c	13.583 b
N_2P_0	3.500 a	9.333 abc	17.083 bc	15.417 a
N_2P_1	2.583 abc	9.917 ab	18.083 ab	15.667 a
N_2P_2	3.250 ab	10.250 a	18.750 a	16.417 a
S.E	0.21281	0.35258	0.48109	0.55796

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

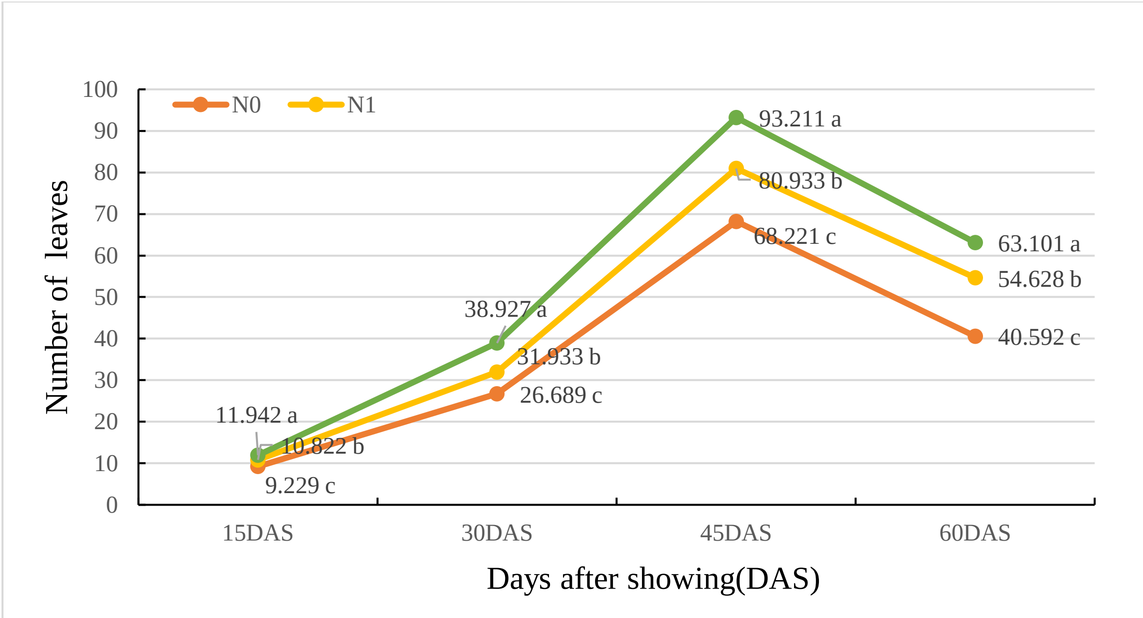
P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

4.3 Number of leaves per plant

Effect of nitrogen: Different doses of nitrogen showed statistically significant variation in terms of number of leaves (Appendix III). Maximum number of leaves (93.21 per plant) was observed from treatment N_2 (180 kg N ha^{-1}) and minimum number of leaves (68.221 per plant) was observed from control treatment (0 kg N ha^{-1}) at 45 DAS (Figure 6). At 60 DAS, maximum number of leaves (63.101 per plant) was recorded from the treatment of N_2 and minimum number of leaves

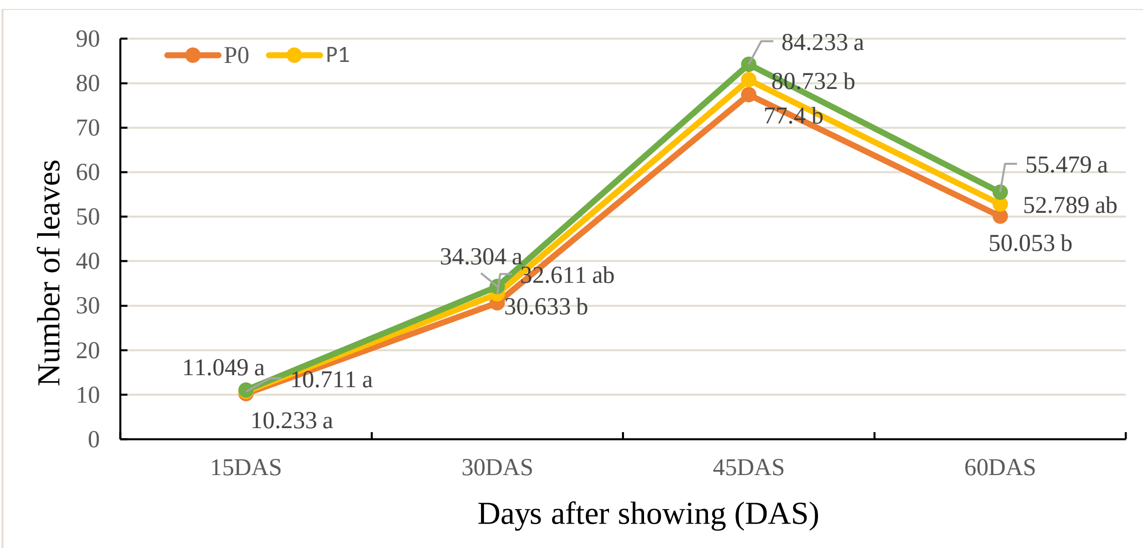
(40.592 per plant) was observed from the control treatment. At 30 DAS, maximum number of leaves (38.927per plant) was recorded from the treatment of N_2 and minimum number of leaves (26.689 per plant) was observed from the control treatment. The results of this study agreed with the study of Majeeduddin *et al.* (2015), who reported that number of leaves per plant increased with the increasing levels of nitrogen.

Effect of phosphorus: Different doses of phosphorous showed a statistically significant variation in consideration of number of leaves (Appendix III). At 45 DAS, maximum number of leaves (84.233 per plant) was recorded from P_2 treatment (140kg P_2O_5 ha^{-1}) and minimum number of leaves (77.4 per plant) was recorded from control condition (0kg P_2O_5 ha^{-1}) which was statistically similar with P_1 (120kg P_2O_5 ha^{-1}) treatment (80.732 per plant). At 60 DAS, maximum number of leaves (55.479 per plant) at harvest was recorded from P_2 treatment which was statistically similar with P_1 (52.789 per plant) treatment and minimum (50.053 per plant) was recorded from control condition. At 30 DAS, the maximum number of leaves (34.304 per plant) at harvest was recorded from P_2 treatment which was statistically similar with P_1 (32.611 per plant) treatment and minimum (30.633 per plant) was recorded from control condition. As data shown, P fertilization increased number of leaves which were in agreement with findings of Rubeiz *et al.* (1992).



Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Figure 6. Effect of nitrogen on number of leaves of Indian spinach at different days after sowing (DAS)



Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 ha$^{-1.}$

Figure 7. Effect of phosphorus on number of leaves of Indian spinach at different days after sowing (DAS)

Combined effect (Nitrogen and phosphorus): The combined effect of nitrogen and phosphorous was also significant in terms of number of leaves per plant at different days after sowing (Appendix III). At 45 DAS, maximum number of leaves (95.56 per plant) during harvest was recorded from N_2P_2 treatment (180 kg N ha^{-1}+ 140 kg P_2O_5 ha^{-1}) and minimum (65.467 per plant) number of leaves was obtained from control treatment (0 kg N ha^{-1}+ 0 kg P_2O_5 ha^{-1}) (Table 4). Maximum number of leaves (40.84 per plant) was recorded from the treatment combination of N_2P_2 and minimum (25.06 per plant) was obtained from the control treatment at 30 DAS. At 60 DAS, maximum number of leaves (64.737 per plant) was recorded from the treatment combination of N_2P_2 and minimum (37.67 per plant) was recorded from the control treatment. Hamid *et al*. (1989) found in an experiment that the maximum number of leaves per plant at 49 DAS ranged from 72.3 to 162.

Table 4. Combined effect of nitrogen and phosphorus on number of leaves at different days after sowing (DAS)

Treatment	Number of leaves at different DAS			
	15DAS	30DAS	45DAS	60DAS
N_0P_0	8.767 e	25.067 e	65.467 e	37.677 e
N_0P_1	9.333 de	27.167 de	67.997 e	40.467 e
N_0P_2	9.587 cde	27.833 de	71.200 de	43.633 e
N_1P_0	10.467 bcd	29.833 cde	77.000 cd	50.883 d
N_1P_1	10.800 abcd	31.733 cd	79.867 c	54.933 cd
N_1P_2	11.200 abc	34.233 bc	85.933 b	58.067 bc
N_2P_0	11.467 ab	37.000 ab	89.733 ab	61.600 ab
N_2P_1	12.000 ab	38.933 ab	94.333 a	62.967 ab
N_2P_2	12.360 a	40.847 a	95.567 a	64.737 a
S.E	0.26827	1.12976	2.15557	1.95103

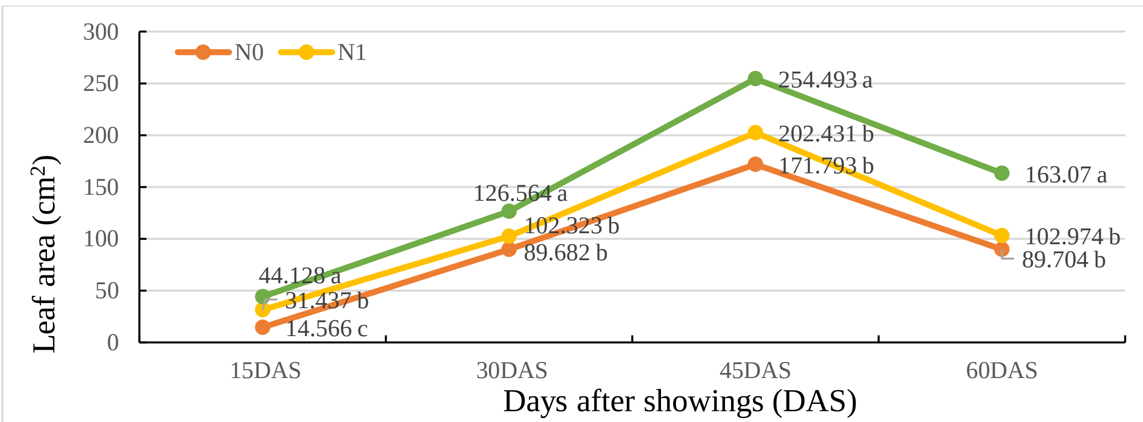
In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.
Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}
P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

4.4 Leaf area

Effect of nitrogen: The leaf area of indian spinach was significantly influenced by different doses of nitrogen fertilizers at different days after sowing (Figure 8). The result revealed that maximum leaf area (254.49 cm^2) was recorded from N_2 treatment (180 kg N ha^{-1}) and minimum leaf area (171.79 cm^2) was recorded from control treatment (0 kg N ha^{-1}) which was statistically similar with (202.43 cm^2) N_1 treatment (120 kg N ha^{-1}) at 45 DAS. At 30 DAS, maximum leaf area (126.56 cm^2) was recorded from N_2 treatment and minimum leaf area (89.68 cm^2) was recorded from control treatment which was statistically similar (102.32 cm^2) with N_1 treatment at 30 DAS. At 60 DAS, maximum leaf area (163.07 cm^2) was recorded from N_2 treatment and minimum leaf area (89.70 cm^2) was recorded from control treatment which was statistically similar (102.97 cm^2) with N_1 treatment at 60 DAS. As data shown, N fertilization increased the leaf area which were in agreement with findings of Rubeiz *et al.* (1992).

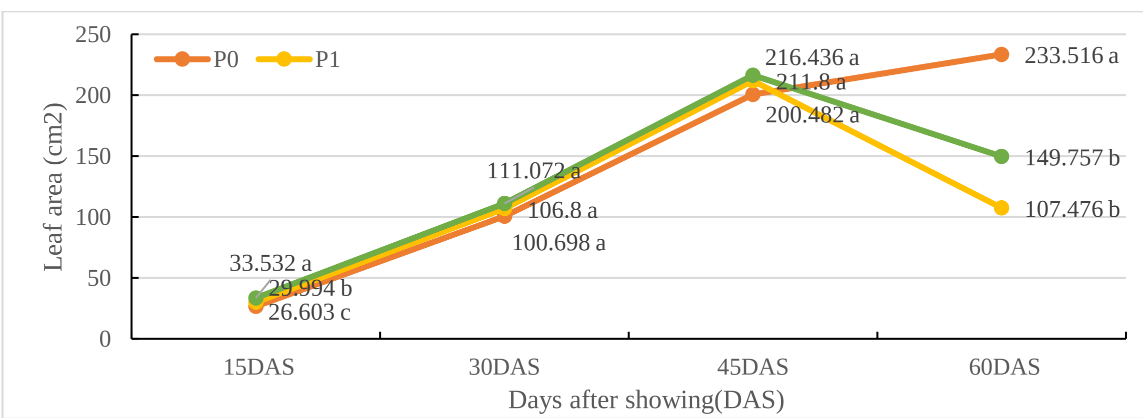
Effect of phosphorus: The analysis of variance demonstrated that differences in the leaf area of spinach under different doses of Phosphorus was slightly varied at 15, 30, 45 and 60 DAS (Figure 9). The result represented that maximum leaf area (216.43 cm^2) was recorded from P_2 treatment (140 kg P_2O_5 ha^{-1} and minimum (200.48 cm^2) was recorded from control treatment (0 kg P_2O_5 ha^{-1}) which was statistically similar with (211.80 cm^2) P_1 treatment (120 kg P_2O_5 ha^{-1}) at 45 DAS. At 30 DAS, maximum leaf area (111.07 cm^2) was recorded from P_2 treatment and minimum (100.69 cm^2) was recorded from control treatment which was statistically similar (106.80 cm^2) with P_1 treatment at 30 DAS. At 60 DAS, the maximum leaf area (233.51 cm^2) was recorded from controlled treatment and the minimum (107.47 cm^2) was recorded from P_1 treatment which was statistically similar (149.75 cm^2) with P_2 treatment at 60 DAS. Similar result was found by Boroujerdnia (2007).

Combined effect (Nitrogen and phosphorus): Interaction effect of Nitrogen and phosphorus fertilizer for leaf area at different days after sowing showed significant differences (Appendix II). At 45 DAS, maximum leaf area (266.5 cm^2) was recorded from N_2P_2 treatment (180 kg N ha^{-1}+ 140 kg P_2O_5 ha^{-1}) and minimum leaf area (160.79 cm^2) was obtained from control treatment (0 kg N ha^{-1}+ 0 kg P_2O_5 ha^{-1}) (Table 5). At 30 DAS, maximum leaf area (132.89 cm^2) was recorded from N_2P_2 treatment and minimum leaf area (86.79 cm^2) was recorded from control treatment. At 60 DAS, the maximum leaf area (129.27 cm^2) was recorded from N_2P_1 treatment and the minimum leaf area (86.51 cm^2) was recorded from control treatment.



Here, No=0 kg N ha^{-1} (Control), N_1= 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Figure 8. Effect of nitrogen on Leaf Area of Indian spinach at different days after sowing (DAS)



Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 ha^{-1}.

Figure 9. Effect of phosphorus on Leaf Area of Indian spinach at different days after sowing (DAS)

Table 5. Combined effect of nitrogen and phosphorus on Leaf Area at different days after sowing (DAS)

Treatment	Leaf area (cm^2) at different DAS			
	15DAS	30DAS	45DAS	60DAS
N_0P_0	12.947 f	86.793 d	160.793 d	86.515 a
N_0P_1	14.167 f	89.063 cd	169.730 d	89.407 a
N_0P_2	16.583 f	93.190 cd	184.857 d	93.190 a
N_1P_0	25.047 e	95.770 cd	197.670 cd	95.837 a
N_1P_1	31.750 d	104.067 bcd	211.733 bcd	103.750 a
N_1P_2	37.513 c	107.133 bc	197.890 cd	109.337 a
N_2P_0	41.817 b	119.530 ab	242.983 abc	118.197 a
N_2P_1	44.067 ab	127.270 a	253.937 ab	129.270 a
N_2P_2	46.500 a	132.893 a	266.560 a	126.743 a
S.E	2.48766	3.51639	8.34880	4.86611

In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.

Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

4.5 Dry weight of leaf

Effect of nitrogen: The effect of nitrogen on dry weight of leaf of Indian Spinach was shown in table 6. Dry weight of leaf was maximum for treatment N_2 (180 kg N ha^{-1}) which was 3.399g and minimum dry weight (3.2 g) happened for treatment N_1 (120 kg N ha^{-1}) and the control treatment (0 kg N ha^{-1}) had the dry weight of 3.353g. The standard error for the effect of nitrogen on dry weight of leaf of Indian Spinach was .0782 which measures the significance of the effect of nitrogen on dry weight of leaf.

Table 6. Effect of nitrogen on Dry Weight of Leaf of Indian spinach

Treatment	Dry Weight of Leaf (g)
N_0	3.353 a
N_1	3.200 a
N_2	3.399 a
S.E	0.07820

In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.

Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Effect of phosphorus: The table 7 showed the effect of phosphorous on dry weight of leaf on Indian Spinach. Treatment P_2 (140 kg P_2O_5 ha^{-1}) showed maximum dry weight of leaf was 3.63 g while minimum dry weight of 3.117g was shown by control treatment (0 kg P_2O_5 ha^{-1}) and the treatment P_1 (120 kg P_2O_5 ha^{-1}) showed the dry weight of leaf was 3.206 g. The value of standard error .0782 measures the significance of the effect of phosphorous on dry weight leaf.

Table 7. Effect of phosphorus on Dry Weight of Leaf of Indian spinach

Treatment	Dry Weight Of Leaf (g)
P_0	3.117 b
P_1	3.206 b
P_2	3.630 a
S.E	0.07820

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

Combined effect (Nitrogen and phosphorus): From table 8, it was evident that the combined effect of nitrogen and phosphorous was high (3.873 g) for the treatment N_1P_2 (120 kg N ha^{-1} + 140 kg P_2O_5 ha^{-1}) and low (2.747 g) for the treatment N_1P_1 (120 kg N ha^{-1}+ 120 kg P_2O_5 ha^{-1}). The standard error .0782 showed the significance of the effect. Among all the treatment N_0P_2 (0 kg N ha^{-1} + 140 kg P_2O_5 ha^{-1}) had the highest significance dry weight of leaf.

Table 8. Combined effect of nitrogen and phosphorus on Dry Weight of Leaf of Indian spinach

Treatment	Dry Weight Of Leaf (g)
N_0P_0	3.097 cde
N_0P_1	3.587 abc
N_0P_2	3.377 abcd
N_1P_0	2.980 dc
N_1P_1	2.747 e
N_1P_2	3.873 a
N_2P_0	3.273 bcd
N_2P_1	3.283 bcd
N_2P_2	3.640 ab
S.E	0.07820

In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.

Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

4.6 Dry weight of stem

Effect of nitrogen: From table 9, maximum dry weight of stem (3.741g) was recorded at N_1 (120 kg N ha^{-1}) treatment while minimum dry weight of stem was 3.669 g recorded at control (0 kg N ha^{-1}) treatment and the treatment N_2 (120 kg N ha^{-1}) was 3.703 g dry weight of stem. The value of standard error measured the significance of the effect on dry weight of stem of Indian Spinach.

Table 9. Effect of nitrogen on Dry weight of stem of Indian spinach

Treatment	Dry Weight of Stem (g)
N_0	3.669
N_1	3.741
N_2	3.703
S.E	0.06532

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.
Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Effect of phosphorus: Table 10 showed the effect of phosphorous on dry weight of stem of indian spinach. It was found that maximum dry weight of stem (4.007 g) of Indian Spinach was recorded in control treatment (0 kg P_2O_5 ha^{-1}) while the minimum dry weight of stem (3.501g) was recorded for the treatment P_1 (120 kg P_2O_5 ha^{-1}) which was statistically significant with treatment P_2 (140 kg P_2O_5 ha^{-1}). The standard error 0.06532 measures the significance of the effect of phosphorous on dry weight of stem.

Table 10. Effect of phosphorus on Dry Weight of Stem of Indian spinach

Treatment	Dry Weight Of Stem (g)
P_0	4.007 a
P_1	3.501 b
P_2	3.606 b
S.E	0.06532

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 ha^{-1}

Combined effect (Nitrogen and phosphorus): Table 11 showed the combined effect of nitrogen and phosphorous on dry weight of stem of Indian Spinach. It was found from the table that the highest dry weight of stem (4.267 g) of indian spinach was recorded from treatment N_1P_0 (120 kg N ha^{-1} + 0 kg P_2O_5 ha^{-1}) and lowest dry weight of stem (3.220 g) of indian spinach was recorded from treatment N_1P_1 (120 kg N ha^{-1} + 120 kg P_2O_5 ha^{-1}) which was statistically significant with N_0P_2 (0 kg N ha^{-1} + 140 kg P_2O_5 ha^{-1}). The standard error measures the significance of the combined effect of nitrogen and phosphorous on dry weight of stem of Indian Spinach.

Table 11. Combined effect of nitrogen and phosphorus on Dry Weight of Stem of Indian spinach

Treatment	Dry Weight Of Stem (g)
N_0P_0	3.973 b
N_0P_1	3.780 b
N_0P_2	3.253 d
N_1P_0	4.267 a
N_1P_1	3.220 d
N_1P_2	3.737 b
N_2P_0	3.780 b
N_2P_1	3.503 c
N_2P_2	3.827 b
S.E	0.06532

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.
Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}
P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

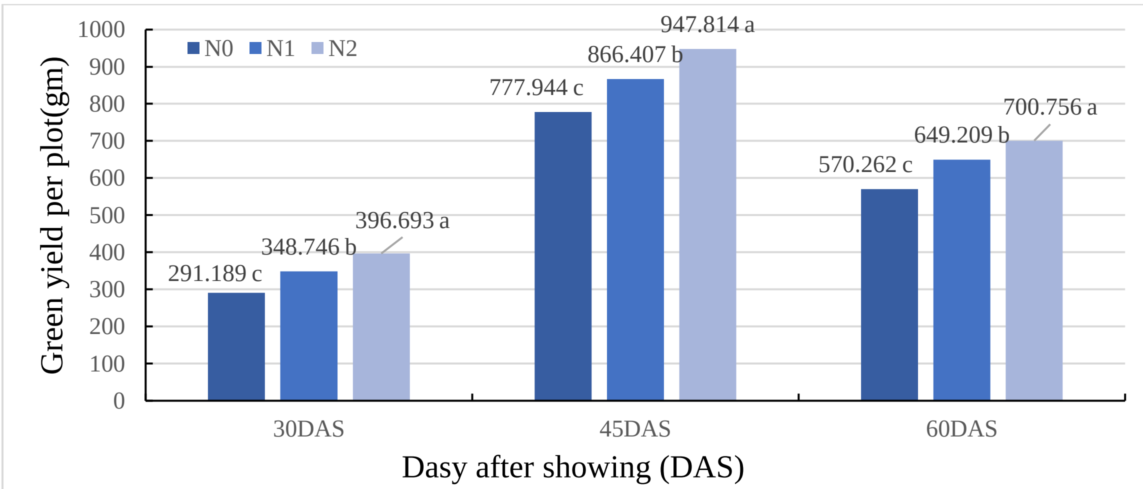
4.7 Yield per plot

Effect of nitrogen: Significant variation was observed among the different doses of nitrogen in respect of green yield per plot at different days of observation (Appendix III). The highest yield per plot was observed in N_2 treatment (180 kg N ha^{-1}) at different stages of harvesting i.e. 30, 45 and 60 DAS, while the control treatment gave the lowest. During the first observation the highest yield per plot (396.69 g) was observed from N_2 treatment and the lowest yield per plot was obtained (291.18 g) from the control treatment at 30DAS. At 45 DAS, the highest yield per plot was recorded (947.81 g) from N_2 treatment and the lowest was found

(777.94 g) from the control treatment. The highest yield per plot (700.75 g) was observed from N_2 treatment and the lowest yield per plot (570.26 g) was recorded from the control treatment at 60 DAS (Figure 10).

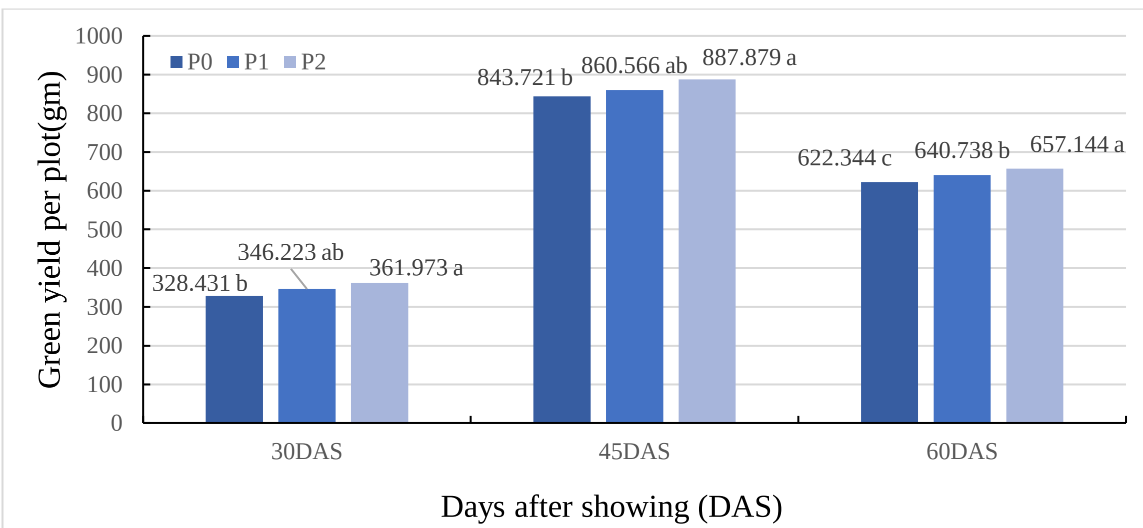
Effect of phosphorus: It was observed that various level of phosphorus exhibited significant effect on the green yield per plot at 30, 45 and 60 DAS (Figure 11). The highest yield per plot was observed in P_2 (140 kg N ha^{-1}) at different stages of harvesting, while the control (0 kg N ha^{-1}) treatment gave the lowest. The highest yield per plot (361.97 g) was observed from P_2 treatment and the lowest yield per plot was obtained (328.43 g) from the control treatment at 30DAS. At 45 DAS, the highest yield per plot was recorded (887.87 g) from P_2 treatment and the lowest was found (843.72 g) from the control treatment. The highest yield per plot (657.14 g) was observed from P_2 treatment and the lowest yield per plot (622.34 g) was recorded from the control treatment at 60 DAS (Figure 11).

Combined effect (Nitrogen and phosphorus): Yield per plot varied statistically due to the combined effect of nitrogen and phosphorus at 30, 45 and 60 DAS (Appendix III). At 30 DAS, maximum yield (409.07 g $plot^{-1}$) was recorded from the treatment combination of N_2P_2 (180 kg N ha^{-1} + 140 kg P_20_5 ha^{-1}), while the control treatment i.e. N_0P_0 (0 kg N ha^{-1}+ 0 kg P_20_5 ha^{-1}) gave the minimum yield (273.92 g $plot^{-1}$) (Table 12). At 45 DAS, the maximum yield (970.22 g $plot^{-1}$) was observed from the treatment combination of N_2P_2 whereas the minimum (755.04 g $plot^{-1}$) was recorded from control. At 60 DAS, the maximum yield (713.60 g $plot^{-1}$) was recorded from the treatment combination of N_2P_2 and the minimum yield (549.56 g plot^{-1}) was recorded from the control. These results agree with the findings of Majeeduddin *et al*. (2015) who obtained the maximum fruits per plant at higher rate of nitrogen and phosphorus.



Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Figure 10. Effect of nitrogen on Yield of Indian spinach at different days after sowing (DAS)



Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 ha^{-1}

Figure 11. Effect of phosphorus on Yield of Indian spinach at different days after sowing (DAS)

Table 12. Combined effect of nitrogen and phosphorus on Yield at different days after sowing (DAS)

Treatment	Green yield per plot (g) at different DAS		
	30DAS	**45DAS**	**60DAS**
N_0P_0	273.927 f	755.043 f	549.560 g
N_0P_1	290.597 ef	774.487 ef	571.473 f
N_0P_2	309.043 def	804.303 e	589.753 e
N_1P_0	329.733 cde	846.523 d	631.257 d
N_1P_1	348.700 bcd	863.590 cd	648.293 d
N_1P_2	367.803 abc	889.107 c	668.077 c
N_2P_0	381.633 ab	929.597 b	686.217 b
N_2P_1	399.373 a	943.620 ab	702.447 ab
N_2P_2	409.073 a	970.227 a	713.603 a
S.E	9.57407	14.49854	11.01718

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

4.8 Total Yield of Indian spinach per hectare

Effect of nitrogen: The total yield of spinach varied significantly varied due to the application of different doses of nitrogen (Appendix II). The highest yield (20.43 t ha^{-1}) was observed in treatment N_2 (180 kg N ha^{-1}). On the other hand, the lowest yield recorded 16.39 t ha^{-1} from the control treatment (Table 13).

Effect of phosphorus: The effect of phosphorus on the yield (ton ha^{-1}) of spinach are presented in Table 14. The yield of spinach significantly influenced by different level of phosphorus. Among the different doses of phosphorus P_2 (140 kg N ha^{-1}) showed the highest yield (19.06 t ha^{-1}). On the other hand the lowest yield (17.93 t ha^{-1}) was observed in the control treatment (Table 14).

Table 13. Effect of nitrogen on Total Yield of Indian spinach

Treatment	Total Yield (t ha^{-1})
N_0	16.39 c
N_1	18.63 b
N_2	20.43 a
S.E	0.03434

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.
Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Table 14. Effect of phosphorus on Total Yield of Indian spinach

Treatment	Total Yield (t ha^{-1})
P_0	17.93 c
P_1	18.47 b
P_2	19.06 a
S.E	0.03434

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.
Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

Combined effect (Nitrogen and phosphorus): Due to the combined effect of nitrogen and phosphorus yield hectare varied statistically. The highest yield (20.90 t ha^{-1}) was observed in N_2 P_2 (180 kg N ha^{-1} +140 kg N ha^{-1}) which was statistically similar with N_2P_1. On the other hand, the lowest yield was obtained (15.77 t ha^{-1}) from the control treatment which was statistically similar with N_0P_1 (Table 15). The experiment revealed that there was no remarkable difference in the yield of indian spinach compare to rooftop and open field.

Table 15. Combined effect of nitrogen and phosphorus on Total Yield of Indian spinach

Treatment	Total Yield (t ha^{-1})
N_0P_0	15.77 f
N_0P_1	16.37 ef
N_0P_2	17.03 e
N_1P_0	18.07 d
N_1P_1	18.60 cd
N_1P_2	19.23 c
N_2P_0	19.97 b
N_2P_1	20.43 ab
N_2P_2	20.90 a
S.E	0.03434

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

4.9 Light Availability

In the spinach field light availability was measured at 15 days interval over the growing season (Table 16). Significant variation of light intensity was recorded when spinach cultivation on different DAS. The highest light intensity was observed (22.700 k.lux) from N_1P_1 treatment. The lowest light intensity was recorded (19.100 k.lux) from N_1P_2 treatment which was also statistically similar with N_0P_0 & N_2P_0 treatment. In the experiment there was no remarkable variation found in light intensity on the rooftop which affect the growth and yield of indian spinach.

4.10 Soil moisture

The soil moisture (%) availability over the time (days after measurement) in the field was observed (Table 16) at 15 days interval. The significant variation of soil moisture was observed and the highest moisture recorded 23.473 % in N_0P_1 plot which was also statistically similar with the plot of N_1P_2 treatment and the lowest moisture was recorded 22.227 % in the plot of N_2P_1 treatment which was also statistically similar with N_1P_0 treatment. In the experiment there was no remarkable variation found in soil moisture on the rooftop which affect the growth and yield of indian spinach.

4.11 Soil Temperature

In the spinach field the significant variation of soil temperature was observed (Table 16). The highest soil temperature was observed (31.433 ^{0}C) from N_0P_2 treatment which was also statistically similar with N_0P_0 treatment. The lowest soil temperature was recorded (30.773 ^{0}C) in the plot of N_1P_0 treatment done which was also statistically similar with N_2P_2 treatment. Soil temperature is an important factor for crop production. It was found that mulching decreased the soil temperature and increased soil moisture which helped to increase spinach production. In the experiment there was no remarkable variation found in soil temperature on the rooftop which affect the growth and yield of indian spinach.

Table 16. Availability of light intensity, soil moisture and soil temperature

Treatment	Light Intensity	Soil Moisture	Soil Temperature
N_0P_0	19.167 d	22.890 b	31.210 ab
N_0P_1	20.617 c	23.473 a	30.903 b
N_0P_2	21.227 b	22.563 bc	31.433 a
N_1P_0	21.127 b	22.497 c	30.773 c
N_1P_1	22.700 a	22.690 b	30.937 b
N_1P_2	19.100 d	23.263 ab	31.200 ab
N_2P_0	19.980 cd	23.177 ab	30.367
N_2P_1	21.483 b	22.227 c	30.833 c
N_2P_2	20.303 c	23.323 a	30.840 c

In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.

Here, No=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

Plate 6. Data collection

Plate 7. Vegetative growth of Indian spinach

Plate 8. Total view of the rooftop garden

Plate 9. Yield of Indian spinach

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

The experiment was conducted at roof of the third floor of Biotechnology Department of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from September 2016 to January 2017 to study the effect of different levels of nitrogen and phosphorus on growth and yield of Indian Spinach. The experiment was laid out in Completely Randomized Design (CRD) having two factors with three replications viz., Factor A: Three levels of nitrogen (N) i.e. N_0 (0 kg N ha^{-1} or Control), N_1 (120 kg N ha^{-1}), N_2 (180 kg N ha^{-1}) and Factor B: Three levels of Phosphorus (P_2O_5) i.e. P_0 (0 kg P_2O_5 ha^{-1} or Control), P_1 (120 kg P_2O_5 ha^{-1}), P_2 (140 kg P_2O_5 ha^{-1}). The seeds of Indian Spinach were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. There were altogether 9 (3x3) treatment combinations. After emergence of seedlings, various intercultural operations were accomplished for better growth and development of the Indian spinach. Data were collected in respect of the plant growth characters and green yield of spinach at different days after sowing. The data recorded from different characters were statistically analysed to find out the significance of difference of different levels of nitrogen and phosphorus on yield and yield contributing characters of spinach.

The tallest plant (96.62 cm) during harvesting period was recorded in N_2 and the shortest (66.93 cm) was recorded in the plot with control treatment. The highest number of branch per plant was recorded at N_2 which was 17.97 and the lowest one is recoded at no nitrogen fertilizer which was 12.58 at 45 DAS. Maximum number of leaves per plant at harvest (93.21) was recorded in N_2 and minimum (68.22) was recorded in the plot with no nitrogen fertilizer. Maximum leaf area at harvest (254.49 cm^2) was recorded in N_2 and minimum leaf area at harvest (171.79 cm^2) was recorded in the plot with control treatment. The highest green yield per plot (947.81 gm) was recorded in N_2 and the lowest yield per plot (777.94 gm) was recorded in the plot with no nitrogen fertilizer. The highest total yield per plot at final harvest (20.43 t ha^{-1}) was recorded in N_2 and lowest (16.39 t ha^{-1}) was recorded in the plot with control treatment.

Application of different level of phosphorus showed statistically significant variation on growth and yield of Indian spinach. The tallest plant (84.58 cm) during harvesting period was recorded in P_2 which was statistically similar with N_1 and the shortest (78.226 cm) was recorded in the plot with control treatment. The highest number of branch per plant was recorded at P_2 which was 16.28 and the lowest one was recoded at control treatment which was 14.38 at 45 DAS. Maximum number of leaves per plant at harvest (84.23) was recorded in P_2 and minimum (77.4) was recorded in the plot with no phosphorus fertilizer. Maximum leaf area at harvest (216.43 cm^2) was recorded in P_2 and minimum leaf area at harvest (200.48 cm^2) was recorded in the plot with control treatment. The highest green yield per plot (887.87 gm) was recorded in P_2 which was statistically similar with P_1 and the lowest yield per plot (843.72 gm) was recorded in the plot with control treatment. The highest total yield per plot at final harvest (19.06 t ha^{-1}) was recorded in P_2 and lowest (17.93 t ha^{-1}) was recorded in the plot with control treatment.

Combined effect of nitrogen and phosphorus had significant effect on growth, yield and yield contributing characters of Indian spinach crop. The maximum growth and development and yield was attained with the combination of N_2P_2 treatment and the minimum was attained in control condition. The highest yield per plot (20.9 t ha^{-1}) was observed in N_2P_2 and the lowest (15.77 t ha^{-1}) was attained in control condition.

5.2 Conclusion

Considering the above result of this experiment the following conclusions can be drawn:

1. It may be suggested that Nitrogen level at 180 kg ha^{-1} and Phosphorous level at 140 kg ha^{-1} can be used to obtain higher growth and higher yield for successful production of Indian Spinach.
2. It may also be suggested that collecting yield after 45 days of sowing can results in maximum production.
3. The results clearly showed that rooftop is suitable for vegetables production and the total yield per hectare was increased with the using of Nitrogen and phosphorous at the rooftop garden.

5.3 Recommendations

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

1. Another fertilizers with different levels for both organic and inorganic may be included in the future program.
2. Another higher level of nitrogen and phosphorus may be included for precise result.
3. Similar study is needed in wide range with variety of crops.
4. Similar experiment can be conducted in Balcony, Kitchen and Container for Hydroponics, aeroponics and Geoponics farming in the roof top.
5. DAE can provided the basic demands of incentives for the gardening activities but adequate training, motivation and sustainable management are required to encourage the city people in practicing roof top garden to increase the production.

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APPENDICES

Appendix I. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	27
Silt	43
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix II: List of necessary tables for result and discussion.

Table 1. Effect of nitrogen on the plant height of Indian spinach at different days after sowing (DAS).

Treatment	Plant height (cm) at different DAS			
	15DAS	30DAS	45DAS	60DAS
N_0	11.160 c	52.544 c	63.877 c	63.877 c
N_1	15.012 b	59.094 b	81.022 b	69.834 b
N_2	16.234 a	66.933 a	96.624 a	77.126 a
S.E	0.46433	1.64940	2.55918	1.14135

In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.

Here, N_0=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Table 2. Effect of phosphorus on the plant height of Indian spinach at different days after sowing (DAS).

Treatment Combination	Plant height (cm) at different DAS			
	15DAS	30DAS	45DAS	60DAS
P_0	13.304 c	48.091 c	78.226 b	68.416 b
P_1	14.092 b	50.729 b	81.774 ab	70.588 a
P_2	15.010 a	52.421 a	84.580 a	71.833 a
S.E	.46433	1.64940	2.55918	1.14135

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

Table no 3. Effect of nitrogen on Number of Branch of Indian spinach at different days after sowing (DAS).

Treatment	Number of Branch at different DAS			
	15DAS	30DAS	45DAS	60DAS
N_0	1.361 b	5.972 c	12.583 c	9.306 c
N_1	2.694 a	8.472 b	15.417 b	12.722 b
N_2	3.111 a	9.833 a	17.972 a	15.833 a
S.E	.21281	.35258	.48109	.55796

In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.

Here, N_0=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Table 4. Effect of phosphorus on Number of Branch of Indian spinach at different days after sowing (DAS).

Treatment	Number of Branch at different DAS			
	15DAS	30DAS	45DAS	60DAS
P_0	2.222 a	7.333 c	14.389 c	11.972 b
P_1	2.250 a	8.139 b	15.306 b	12.611 ab
P_2	2.694 a	8.806 a	16.278 a	13.278 a
S.E	.21281	.35258	.48109	.55796

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 ha$^{-1.}$

Table 5. Effect of nitrogen on Number of leaves of Indian spinach at different days after sowing (DAS)

Treatment	Number of leaves at different DAS			
	15DAS	30DAS	45DAS	60DAS
N_0	9.229 a	26.689 c	68.221 c	40.592 c
N_1	10.822 b	31.933 b	80.933 b	54.628 b
N_2	11.942 a	38.927 a	93.211 a	63.101 a
S.E	.26827	1.12976	2.15557	1.95103

In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.

Here, N_0=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Table 6. Effect of phosphorus on Number of leaves of Indian spinach at different days after sowing (DAS).

Treatment	Number of leaves at different DAS			
	15DAS	30DAS	45DAS	60DAS
P_0	10.233 a	30.633 b	77.400 b	50.053 b
P_1	10.711 a	32.611 ab	80.732 b	52.789 ab
P_2	11.049 a	34.304 a	84.233 a	55.479 a
S.E	.26827	1.12976	2.15557	1.95103

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 ha$^{-1.}$

Table 7. Effect of nitrogen on Leaf Area of Indian spinach at different days after sowing (DAS).

Treatment	Leaf area (cm^2) at different DAS			
	15DAS	30DAS	45DAS	60DAS
N_0	14.566 c	89.682 c	171.793 c	89.704 a
N_1	31.437 b	102.323 b	202.431 b	102.974 a
N_2	44.128 a	126.564 a	254.493 a	1639.070 a
S.E	2.48766	3.51639	8.34880	460.86611

In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.

Here, N_0=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Table 8. Effect of phosphorus on Leaf Area of Indian spinach at different days after sowing (DAS).

Treatment	Leaf area (cm^2) at different DAS			
	15DAS	30DAS	45DAS	60DAS
P_0	26.603 c	100.698 a	200.482 a	233.516 a
P_1	29.994 b	106.800 a	211.800 a	107.476 a
P_2	33.532 a	111.072 a	216.436 a	1490.757 a
S.E	2.48766	3.51639	8.34880	460.86611

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 $ha^{-1.}$

Table 9. Effect of nitrogen on Yield of Indian spinach at different days after sowing (DAS).

Treatment	Green yield per plot (g) at different DAS		
	30DAS	45DAS	60DAS
N_0	291.189 c	777.944 c	570.262 c
N_1	348.746 b	866.407 b	649.209 b
N_2	396.693 a	947.814 a	700.756 a
S.E	9.57407	14.49854	11.01718

In a column means having similar letter (s) are statistically similar and those having dissimiliar letter (s) differ significantly.

Here, N_0=0 kg N ha^{-1} (Control), $N_{1=}$ 120 kg N ha^{-1}, N_2=180 kg N ha^{-1}

Table 10. Effect of phosphorus on Yield of Indian spinach at different days after sowing (DAS).

Treatment	Green yield per plot (g) at different DAS		
	30DAS	45DAS	60DAS
P_0	328.431 b	843.721 b	622.344 c
P_1	346.223 ab	860.566 ab	640.738 b
P_2	361.973 a	887.879 a	657.144 a
S.E	9.57407	14.49854	11.01718

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Here, P_0=0 Kg P_20_5 ha^{-1} (Control), P_1=120 Kg P_20_5 ha^{-1}, P_2=140 Kg P_20_5 ha$^{-1.}$

Appendix III: Analysis of variance tables

Table 1. Analysis of variance on plant height at 15 DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	126.250	2	63.125	60.349	.000
Phosphorus	13.115	2	6.558	1.139	.337
Nitrogen × Phosphorus	144.452	8	18.057	47.092	.000

Table 2. Analysis of variance on plant height at 30 DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	1771.051	2	885.526	153.156	.000
Phosphorus	85.711	2	42.856	.564	.576
Nitrogen × Phosphorus	1881.776	8	235.222	151.001	.000

Table 3. Analysis of variance on plant height at 45 DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	3970.465	2	1985.232	75.964	.000
Phosphorus	182.534	2	91.267	.496	.615
Nitrogen × Phosphorus	4187.034	8	523.379	22.942	.000

Table no 4. Analysis of variance on plant height at 60 DAS

S. V	**SS**	**d.f**	**MS**	**F-value**	**Significance**
Nitrogen	792.565	2	396.283	78.015	.000
Phosphorus	53.853	2	26.927	.751	.483
Nitrogen × Phosphorus	854.324	8	106.791	31.957	.000

Table 5. Analysis of variance on Number of branch at 15DAS

S. V	**SS**	**d.f**	**MS**	**F-value**	**Significance**
Nitrogen	15.042	2	7.521	10.776	.000
Phosphorus	1.264	2	.632	.497	.615
Nitrogen × Phosphorus	18.583	8	2.323	3.166	.020

Table 6. Analysis of variance on Number of branch at 30DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	69.032	2	34.516	45.426	.000
Phosphorus	9.782	2	4.891	1.515	.240
Nitrogen × Phosphorus	81.269	8	10.159	30.476	.000

Table no 7. Analysis of variance on Number of branch at 45DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	130.796	2	65.398	49.543	.000
Phosphorus	16.060	2	8.030	1.316	.287
Nitrogen × Phosphorus	147.519	8	18.440	22.189	.000

Table 8. Analysis of variance on Number of branch at 60DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	191.894	2	95.947	86.397	.000
Phosphorus	7.671	2	3.836	.437	.651
Nitrogen × Phosphorus	200.380	8	25.047	24.818	.000

Table 9. Analysis of variance on Number of leaves at 15DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	33.466	2	16.733	23.545	.000
Phosphorus	3.022	2	1.511	.764	.477
Nitrogen × Phosphorus	36.545	8	4.568	5.883	.001

Table 10. Analysis of variance on Number of leaves at 30DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	678.522	2	339.261	37.438	.000
Phosphorus	60.768	2	30.384	.873	.431
Nitrogen × Phosphorus	742.447	8	92.806	10.878	.000

Table 11. Analysis of variance on Number of leaves at 45DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	2810.534	2	1405.267	74.731	.000
Phosphorus	210.168	2	105.084	.826	.450
Nitrogen × Phosphorus	3041.602	8	380.200	31.074	.000

Table 12. Analysis of variance on Number of leaves at 60DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	2326.333	2	1163.166	80.720	.000
Phosphorus	132.468	2	66.234	.626	.543
Nitrogen × Phosphorus	2472.286	8	309.036	27.830	.000

Table 13. Analysis of variance on Leaf area 15DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	3958.871	2	1979.436	123.257	.000
Phosphorus	216.075	2	108.038	.628	.542
Nitrogen × Phosphorus	4245.911	8	530.739	97.101	.000

Table 14. Analysis of variance on Leaf area 30DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	6323.182	2	3161.591	32.192	.000
Phosphorus	489.354	2	244.677	.717	.498
Nitrogen × Phosphorus	6863.755	8	857.969	8.502	.000

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Table 15. Analysis of variance on Leaf area 45DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	31465.315	2	15732.658	21.618	.000
Phosphorus	1212.268	2	606.134	.305	.740
Nitrogen × Phosphorus	33577.686	8	4197.211	4.921	.002

Table 16. Analysis of variance on Leaf area 60DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	14280903.029	2	7140451.515	1.271	.299
Phosphorus	10530020.006	2	5265010.003	.912	.415
Nitrogen × Phosphorus	45650132.110	8	5706266.514	.993	.474

Table 17. Analysis of variance on Dry weight of leaf

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	.195	2	.098	.572	.572
Phosphorus	1.355	2	.677	5.533	.011
Nitrogen × Phosphorus	2.942	8	.368	4.899	.002

Table no 18. Analysis of variance on Dry weight of stem

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	.023	2	.012	.095	.910
Phosphorus	1.282	2	.641	8.980	.001
Nitrogen × Phosphorus	2.683	8	.335	19.338	.000

Table 19. Analysis of variance on Yield 30DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	50228.841	2	25114.421	42.692	.000
Phosphorus	5069.119	2	2534.560	1.026	.374
Nitrogen × Phosphorus	55415.938	8	6926.992	13.960	.000

Table 20. Analysis of variance on Yield 45DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	129925.824	2	64962.912	88.385	.000
Phosphorus	8938.988	2	4469.494	.774	.472
Nitrogen × Phosphorus	138930.525	8	17366.316	36.200	.000

Table 21. Analysis of variance on Yield 60DAS

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	77754.435	2	38877.218	125.190	.000
Phosphorus	5455.600	2	2727.800	.821	.452
Nitrogen × Phosphorus	83359.546	8	10419.943	101.495	.000

Table 22. Analysis of variance on Total Yield

S. V	SS	d.f	MS	F-value	Significance
Nitrogen	0.739	2	.370	99.772	.000
Phosphorus	0.057	2	.028	.883	.427
Nitrogen × Phosphorus	0.797	8	.100	57.330	.000