EFFECT OF N AND P ON THE PERFORMANCE OF SPINACH (*Spinacia oleracea*) IN ROOFTOP AND FARM

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CERTIFICATE

This is to certify that the thesis enlightens, **"EFFECT OF N AND P ON THE PERFORMANCE OF SPINACH (*Spinacia oleracea*) IN ROOFTOP AND FARM"** 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 conducted by **MST. FATEMA TUJ JOHRA**, Registration no. **19-10357** under my supervision and guidance. No part of this 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 study has been dully acknowledged.

Dated: December, 2021
Dhaka, Bangladesh

Dr. Md. Forhad Hossain
Professor
Supervisor

Dedicated

to

My Beloved Parents, Brother

&

Husband

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The Author

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Abstract

The experiment was conducted at the rooftop of Soil Science Department and research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from October 2020 to December 2020 to study the performance of spinach in the rooftop and farm. The experiments were laid out in RCBD design with three replications. The study consists of two factors. Factor A: Three levels of nitrogen N_0 (control), N_1 (56 kg ha^{-1}), and N_2 (84 kg ha^{-1}), and Factor 2: Three levels of phosphorus P_0 (control), P_1 (36 kg P_2O_5 ha^{-1}) and P_2 (57.5 kg P_2O_5 ha^{-1}). Haldibari, local variety seed was used in this experiment. Different growth and yield contributing parameters were recorded to determine the optimum dose of N and P for growing on rooftop and farm. The result reveals that N_1 (56 kg ha^{-1}) is optimum dose for growing spinach on both rooftop and farm whereas, P_1 (36 kg P_2O_5 ha^{-1}) and P_2 (57.5 kg P_2O_5 ha^{-1}) are optimum dose for rooftop for farm condition respectively. Among the treatment combination, N_1P_1 (56 kg/ha N + 36 kg/ha P_2O_5) seems to be more suitable for getting higher yield in both rooftop and farm.

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AEZ = Agro-Ecological Zone

BARI = Bangladesh Agricultural Research Institute

BAU = Bangladesh Agricultural University

BADC = Bangladesh Agricultural Development Corporation

BBS = Bangladesh Bureau of Statistics

CV% = Percentage of coefficient of variance

DAE = Department of Agricultural Extension

DAS = Days after sowing

EC = Electrical Conductivity

et al. =And others

FAO = Food and Agriculture Organization

g = gram

plant $^{-1}$= Per plant

ha $^{-1}$= Per hectare

kg = Kilogram

LSD = Least Significant Difference

Max = Maximum

mg = milligram

Min = Minimum

MoP = Muriate of Potash

N = Nitrogen

No. = Number

NS = Not significant

SAU = Sher-e-Bangla Agricultural University

SRDI = Soil Resources and Development Institute

TSP = Triple Super Phosphate

wt. = Weight

% = Percent

^{o}C = Degree Cel

CHAPTER 1

INTRODUCTION

Spinach (*Spinacia oleracea*) is a winter seasonal leafy green vegetable which is well-known for its nutritive values and is considered one of the most popular vegetable in Bangladesh. Spinach belongs to the member of the family Amaranthaceae, and Sub-family Chenopodioideae and it is believed to have originated from Persia, where the earliest references to spinach occurred between 200 and 600 A.D., and was transported to India and Asia and later to the Mediterranean countries and Europe (Wright, 2001). Its leaves are a popular culinary vegetable that can be eaten fresh or after being preserved through canning, freezing, or dehydration and the high oxalate content may be reduced by steaming. However, it is an annual winter season flowering plant that produces a rosette of leaves during its vegetative growth stage (rarely biennial), growing up to 30 cm (1ft). By weight, spinach contains 91.4% water, 3.6% carbs and protein 2.9%. There are 23 calories in 100 grams of spinach leaves. Above all, spinach is a rich source of vitamins A, C, E, and K, as well as a source of folate, fiber, magnesium, and several important antioxidants and has long been valued nutritionally. However, its reputation as a rich source of iron (Bender and Bender, 2005).

Fertilizer application to the spinach crop greatly influence their growth, production and plant nutrients constituents. Nitrogen strongly stimulates growth, expansion of the crop canopy and interception of solar radiation (Milford *et al*., 2000). Nitrogen is an essential macronutrient needed by all plants for proper growth. It is an important component of main structural, genetic as well as metabolic compounds in plant cells. Increasing the doses of nitrogen during the vegetative stage can strengthen and support plant roots, helps plants to take in more water and nutrients; and allows a plant to grow more rapidly and produce large amounts of succulent and green foliage, which ultimately can generate higher yields, tastier vegetables, and a crop that is more resistant to diseases, pests, and other adverse conditions (Eckert *et al*., 2010). Similarly, phosphorus (P) is an essential nutritional element that functions as a catalyst in the conversion of multiple critical biochemical activities in plants as well as a component of several key plant structure components. Moreover, it stimulates root development, increases stem strength, improves flower formation and seed production, more uniform and earlier crop maturity (Dinesh kumar, 2008).

As a result of urbanization fresh, healthy produce can be expensive and inaccessible to some people. So utilizing the normally unused rooftops for farming can provide a solution to these issues (Rabin, 2021). Currently, in this urban planet, 54 percentage of the world's population are living in urban areas and the share is expected to enhance to 66 percentages by 2050 (United Nations, 2014). Rooftop farming in the buildings in urban areas is usually done by using green roof, hydroponics, aeroponics, organic, or container gardens (Asad and Roy, 2014)**.** Islam (2004) has published an article named "Roof gardening as a strategy of urban agriculture for food security': the case of Dhaka city, Bangladesh." He has concluded that in the cities of developing countries urban agriculture is growing rapidly which also indicates the number of low-income consumers is increasing. It leads to food security by increasing the food supply and enhancing the quality of perishable foods reaching urban consumers.

For improving crop quality, and increased resistance to plant diseases phosphorus application is essential (Griffith et al., 2010). Leafy vegetables, especially, the spinach is highly responsive to fertilization (Cantliffe *et al*., 1992) and oxalates which are the key quality indicator due to a very efficient absorption system and inefficient reductive systems (Jaworska et al., 2005. Adequate supply of fertilizers can improve plant growth and increase crop production, but excessive and inappropriate use of chemical fertilizers may cause accumulation of compounds in the consumable products which have a detrimental impact on human health, causing environmental pollution and economical losses (Wang et al., 2002). El-Fadaly (Fadaly *et al*., 2000) observed that N increased the yield and enhanced the accumulation of N and P in leaves of spinach. Luyen (Luyen et al., 2004) found that spinach is a vegetable with a high potential to convert the nitrogen into urea efficiently into edible biomass with high nitrogen content. (Assiouty et al., 2005) concluded that use of 40 kg N + 150 kg P_2O_5 increased plant fresh yield by 27.2 and 42.3% and 16.3 and 10.4% in seed yield of spinach over the control in the first and second seasons, respectively. (Boroujerdnia *et al*., 2007) observed that the maximum yield with 120 kg N ha^{-1}. (Odueso *et al*., 2011) reported that NPK 20-10-10 were observed to be efficient for the growth and yield performance of spinach (Zikalala *et al*. 2017)

In Bangladesh spinach covers 24500 acres with an annual production of 61850 ton (BBS, 2021). To compare with other countries this production is much lower. So, to increase the spinach production it is important to improve the crop management through advanced technologies. Moreover, optimum application of both N and P in spinach is crucial for better growth and yield. Dhaka is one of the world's fastest growing mega cities where the open and cultivable land has been converting to built-up area indiscriminately, as a result, agricultural land has been decreased at an alarming rate (Islam and Ahmed, 2011). Due spinach production practice on rooftop garden, the production will be increased which will meet the demand of the urban people and also reduce the costs of transport as well as encourage the varieties of vegetables production in the urban area than field (Abdul-Soud, 2015).

The present study was carried out to determine the effect of different nitrogen and phosphorus levels on the growth and yield of spinach in rooftop and farm condition with the following objectives.

1. To determine the optimum doses of nitrogen for maximizing growth and yield of spinach in rooftop and farm.
2. To determine the optimum doses of phosphorus for higher yield and yield contributing characters in rooftop and farm.
3. To determine the combined dose of nitrogen and phosphorus for better growth and maximum yield of spinach in rooftop and farm condition.

CHAPTER 2

REVIEW OF LITERATURE

Spinach is a popular and demanding winter vegetable in Bangladesh. It contains tons of nutrients with a low calorie package. Such dark, leafy greens like spinach are essential for skin, hair, and bone health. It also provides iron, protein, vitamins, and minerals. The possible health benefits of spinach uptake include improving blood glucose control in people who have diabetes, lowering the risk of cancer diseases, and bone health improvement, and supplying minerals and vitamins as well. Since it is a cheap and easy to prepare vegetable it can be simply incorporated into any diet. In Bangladesh there are a few research on the finding out the performance of spinach in both rooftop and farm condition under same fertilizer and management practices. Despite that, available literature and research findings regarding to the proposed study have been presented in this chapter:

2.1 Spinach cultivation

Ambia et al. (2016) conducted a field experiment at the farm of Department of Horticulture, BSMRAU, Salna, Gazipur-1706 with six spinach (Beta vulgaris var. bengalensis Hort) genotypes to study the seed production potentiality and to record the quality of produced spinach seeds. The seeds of cultivar BRAC kopi palong performed the best in quality tests. It showed the highest germination percentage and lowest value in conductivity test. Conversely, the seeds of Debgiri cultivar had the lowest quality among all the cultivars showing the lowest germination percentage and highest value in conductivity and tests. Finally, the relationship between the seed yield and seed quality were observed to be appreciating, since high seed producing variety possessed good quality of seed.

Syed, A. U. A., Khan, Z. A., Chattha, S. H., Shaikh, I. A., Ali, M. N. H. A., Dahri, S. H., & Buriro, G. B. (2021) conducted an experiment with the goal to find a substitute for conventional farming practices that could conserve water, fertilizer and generate more sustainable food vertically and horizontally. Two treatments were performed, each with two replications. The treatments included hydroponic (soil-less) and geoponic (soil) spinach seed cultivation. The seed was initially grown in a seedling tray before being transferred onto a prepared plot and a hydroponic model, respectively. All the standard materials (made of plastic) needed for a perfect low-cost hydroponic model, obtained from local markets, were combined accordingly to achieve the results of set goals. A total of 9680.00 PKR was the approximate expense of the manually manufactured hydroponic model. The field under geoponic cultivation was maintained equal to the manufactured hydroponic model (4'x 4'). Full-Spectrum Light-emitting diode (LED) grow light was used to meet the plants' light requirements. The stock solution (a combination of water and nutrients) was used to feed the transplanted plants during hydroponic cultivation. On average, relative to water use under geoponic agriculture, the hydroponic model's productivity was 97.42 percent. The growth efficiency of the hydroponic spinach crop was much higher than that of geoponic cultivation. On average, the leaf area was 24 percent, height 25 percent, and steam scale 24 percent greater than geoponic. Statistically, there was a substantial ($p<0.05$) variation in the leaf area, height, and steam scale of plants, suggesting that hydroponic technology could also increase crop yields by up to 25 percent. It is inferred from this analysis that hydroponic cultivation is successful in saving water and fertilizer and increasing crop yields at the desirable limit. To enhance yield, the hydroponic model should be equipped with sensors and artificial intelligence technologies to handle difficulties related with food supplies. The hydroponic growing technology should be introduced to cities. At the time, such as when challenged with Covid-19 and the locust attack.

Both, A. J., Leed, A. R., Goto, E., Albright, L. D., & Langhans, R. W. (1996) conducted an experiment on spinach (Spinacia oleracea L., cv. Nordic) production in greenhouse in a NFT system. Primed spinach seed was started in rockwool slabs in a growth room for eight days before the seedlings were transplanted into a controlled environment greenhouse equipped with five identical, but separate, NFT systems. The day and night temperatures in the greenhouse were maintained at 24 and 18°C, respectively, with the daytime starting at 06:00 and ending at 22:00 hr. A photoperiod of 16 hrs was maintained, to prevent early bolting, and different target daily integrated light levels (PPF, in mol m-2 d-1) were studied to observe dry weight production. HPS lamps were used as the supplemental light source. Thirty-three days after seeding a final harvest was performed. Using the expolinear growth equation, dry weight production can be predicted based solely on target daily integrated light levels. Total chlorine residuals in the nutrient solution higher than 1 ppm were observed to be toxic. Root disease (rot) in the plant crown was found to be caused by Fusarium. Several remedies, including three bio fungicides and potassium silicate, were tried but none proved to be consistently successful.

2.2 Effect of fertilizer doses on spinach

Zaki et al. (2016) carry out an experiment in the farm of the faculty of agriculture Moshtohor Quliubia governorate during the winter seasons of 2013/2014 and 2014/2015 to find out the effect of nitrogen fertilizer at the rate of 0, 25, 50 and 75 kg N/fed and spraying the plants with salicylic acid at 1g/l ,amino acids at 0.5ml/l and seaweed extract at 5 ml/l and biogen bio fertilizer as a soil addition at 800 g/fed as well as their combinations in addition to the control treatment on flowering behavior ,seed yield and its quality of spinach plant, cv. Saloniki. The results showed that increasing nitrogen doses up to the highest levels (50 or 75 kg N/fed) provided the highest values of number of female plants. Therefore, it could be recommended to add nitrogen fertilizer at 50 or 75 kg N/fed combination with soil addition of biogen at 800g/fed to get the highest seed yield with best quality.

Solangi et al. (2015) conducted an experiment to evaluate the effect of different levels of nitrogen and phosphorus fertilizers on the growth and yield of spinach. Spinach that receives lower nitrogen and phosphorus doses (75-70, 50-60, 25-50 kg ha-1) and control showed lower performance than the higher N-P levels, but the decrease in the performance was dose dependent. The values for almost all the spinach characters studied observed similarity ($P>0.05$) under N-P levels of 150-100 kg and 125-90 kg/ha and concluded that N-P application beyond 125-90 kg/ha was uneconomical; and 125-90 kg/ha was considered as an optimum N-P level.

Assiouty et al. (2005) studied an experiment during two successive winter seasons (2002-2003 & 2003-2004) at Kaha Vegetable Farm, Horticulture *Research* Institute, ARC. It involved the effect of bio-fertilizers (*Azotobacter chroccocum* & phosphorein) singly or in combination with different rates of nitrogen and phosphorus chemical fertilizers on growth, yield, sex ratio, seeds yield & seed quality of spinach plants cv. Dokki.

Shormin et al. (2018) conducted a study on the effects of N from different inorganic fertilizers on growth and yield of Indian spinach (*Basella alba* L.). There were six treatments comprising of control, N @ 130 kg/ha from urea ammonium fertilizers. The results concluded that application of nitrogen from urea was the most effective compared to other sources of nitrogen on the growth and yield characters of Indian spinach.

Wahocho et al. (2016) reported that nitrogen is one of the most critical nutrients for plant growth and yield. Hence its optimum use in crop cultivation is a prerequisite for sustainable agriculture. A field trial was carried out during the growing season of 2014-15 to evaluate the response of nitrogen on the growth and productivity of spinach. The experiment was laid out according to randomized complete block design with three replicates. Five N doses i.e. 0, 35, 70, 105 and 140 kg/ha were applied to see the growth and yield of spinach. The results revealed that various nitrogen levels had significant (P0.05) was observed between N levels 140 kg ha-1 and 105 kg ha-1 for all the observed growth and yield related parameters. Hence, 105 kg ha-1 was considered an optimum dose for better growth and production of spinach.

Abgad et al. (2015) conducted study on the effect of P and K levels on yield and quality of spinach during Rabi season 2012-13 at College Garden, Department of Horticulture, College of Agriculture, Nagpur. The treatments were three levels of phosphorus viz., 0 kg (P0), 10 kg (P_1), 20 kg (P2) and potassium viz., 0 kg (K0), 15 kg (K1), 30 kg (K2) accordingly. The experiment was also laid out in RCBD with three replications. The output were found in treatment which received phosphorus @ 20 kg ha-1 and potassium @ 30 kg ha-1, respectively at harvesting.Marvi and Mahdi (2009) showed that Lettuce (*Lactuca sativa*) and Spinach (*Spinacea oleracea*) were used as a case study crop to compare models for determining fertilizer use efficiency based on nitrogen and phosphorous and nitrate concentration. Field studies were carried out to measure yield, nitrate, fertilizer use efficiency, response to applied nitrogen and phosphorous fertilizer in two plants. It predicted the fertilizer use efficiency that help to agricultural management practice so that nitrogen and phosphorous fertilizers are used in proper doses and avoid leaching of nitrogen in lettuce culture.

Kaminishi et al. (2006) reported that reduction of nitrate and oxalate content in spinach (*Spinacia oleracea* L.). The main objectives of this study were 1) to find out the seasonal change in nitrate and oxalate concentrations 2) to determine the relationship between growth rate and concentration of nitrate and oxalate in spinach crop the result revealed that, the fast-growing cultivars contained higher nitrate and lower oxalate, whereas slow-growing cultivars contained lower nitrate and higher oxalate.

Ali et al. (2013) were studied during the two seasons of 2010 and 2011 at the experimental station of National Research Centre, Beheira Governorate (North of Egypt) to evaluate the effect of bio and chemical fertilizer (NPK) at different rates for influence plant growth, total yield and chemical properties of spinach crop. The findings of the study are: 1) addition of high rate of bio fertilizer (2 kg/ha) resulted in a significant increase in most growth characters, i.e. number of leaves/plant, fresh and dry weight of whole plant, leaf area/plant and total chlorophyll contents and total yield of leaves (ton/ha). Also gave the maximum percentage of protein, N, P, K and NO_3 content in ppm. 2) addition of 70 % of recommended rate (RR) of chemical fertilizer resulted in the tallest and the heaviest fresh and dry weight of spinach plants and its different organs, as well as the heaviest total leaves yield (ton/ha) and its nutritional values. 3) the combined treatments resulted that using high rate of bio fertilizer (2 kg/ha) with the 70% of (RR) of chemical fertilizer resulted the superiority in plant growth characters as well as the best total yield (ton/fed.) and its content of protein, P, K and NO_3.

Morshed M.T et al. (2019) carried out a survey work in Bogura sadar upazilla , Rajshahi, Bangladesh, to evaluate the status of rooftop and homestead gardening. He conducted the study on behalf of the department of Horticulture, Bangladesh Agriculture University, Mymensingh-2202. The study showed that 66% rooftop gardeners and 70% homestead gardeners preferred rooftop farming for production of healthy-fresh food. Regarding the survey there were about 80 type of plants in rooftop gardens and 87 types in homestead gardens found. These plants involved fruits (97%), flowers (64%), vegetables (86%), spices (72%), medicinal plants (64%), ornamental plants (23%) and plantation crops (12%). Among the vegetable crops spinach variety noticeably grown in rooftop gardens whereas eggplant, papaya, bottle gourd, water spinach and some medicinal plants like neem and American life plant were grown in the homestead gardens.

2.3 Effect of variety on the performance of spinach

Kunicki, E., Grabowska, A., Sękara, A., & Wojciechowska, R. (2010) carried out an experiment to investigate the influence of spraying with Aminoplant on the yield of two spinach cultivars in the spring and autumn cultivations. The experiment was carried out in 2008 and 2009 in the experimental station of the University of Agriculture in Krakow, Poland. Three factors were taken into consideration: (1) cultivar: ‘Rembrandt

F1' and 'Spiros F1'; (2) time of cultivation: spring and autumn; (3) dose of Aminoplant: control (without Aminoplant), 1.5 dm3 ha-1 and 3.0 dm3 ha-1. The spinach yield was dependent on the time of production and cultivar type, and ranged between 18.6-44.8 t ha-1. Both cultivars yielded better in autumn cultivation. Spraying with Aminoplant had no effect on spinach yield. Dry matter content in spinach leaves was between 6.3-11.2 g 100 g-1. Spinach grown in the autumn had a greater content of dry matter in comparison to the spring cultivation. In 2009, 'Rembrant F1' was characterized by greater dry matter content than 'Spiros F1'. Aminoplant in a dose of 3.0 dm3 ha-1 lowered dry matter content in spinach leaves as compared to the control. The nitrate content in spinach was differentiated (558-3506 mg NO3 kg-1 f.m.) and depended on the time of cultivation, the cultivar, and the Aminoplant dose.

Pavlovic, R., Petrovíc, S., & Stevanovíc, D. (1997) carried out an experiment to study the effect of cultivar - hybrid and that of higher nitrogen amounts (850–200 kg/ha) on yield and accumulation of nitrate nitrogen in edible spinach parts (leaf and petiole), was studied. Spinach was grown under open field conditions over spring cycle on the soil of hard mechanical composition of smonitza type. The domestic cultivar and newly-introduced hybrids, for whose introduction into large-scale production yield and nitrates concentration play an important part, were studied. The results obtained clearly show that in all treatments with usage of higher nitrogen amounts the yield is higher on the average by 27–86%, compared with the control variety. Accordingly, the concentration of nitrate nitrogen was increased in the leaf and even more in the petiole. The highest yields were achieved by the hybrids Vivat (on average 57,0 t/ha) and Triathlon (on average 48,2 t/ha). However, with respect to nitrate nitrogen content the Triathlon hybrid had the highest concentration, i.e. this hybrid is highly prone to nitrate accumulation in edible parts. The Vivat hybrid achieved the highest yields in all experimental treatments, maximally 78,0 t/ha (treatment 4). In addition to extremely high yields, the lowest nitrate concentration was established in edible parts of this hybrid so that it can be recommended for introduction into large-scale production.

2.4 Urban agriculture

Urban agriculture decreases the heat island effect of urban which is the elevated temperatures of urban areas. It enhances the quality of air in cities by removing particulates from the air (Unger & Wooten, 2006).

The long and rich history of urban gardening movements in America is feeding the current urban agriculture movement. The leaders, citizens, gardeners, planners, designers, and activists of new generation are finding sustainable ways to support the rapid growing urban population (Roehr and Kunigk, 2009).

In 2009, the city of Vancouver, British Columbia, established a "multi-disciplinary taskforce representing various government offices and tasked it with developing recommendations for urban agriculture across the city" (Mukherji and Morales, 2010).

Urban agriculture is a key component to a sustainable community food system and can reduce the diseases related to diet associated with food deserts. This is because healthy foods are not available at reasonable prices (Cano, 2011). Urban agriculture provides with ecological habitats (Cosier, 2011).

Urban agriculture is the practice of growing, processing, and supplying food in or around a City, town, or village. It can also involve aquaculture, animal husbandry, agroforestry, and urban beekeeping as well as horticulture. These practices may be found in peri urban areas as well as urban areas (FAO, 2013).

Urban agriculture minimizes greenhouse gas emissions by selecting the right crops in the United Kingdom, a life cycle analysis resulted that the alteration of 26 hectares of vacant land to community farming could decreases greenhouse gas emissions by 881 tons of carbon dioxide equivalent per acre (Kulak et al., 2013).

Conventional method of for growing vegetables and fruits are energy intensive. Moreover they need to transport the produce to the smaller markets by heavy good vehicles, ships, and planes (Kulak et al., 2013). Urban agriculture can reduce these difficulties when the foods will be grown and sold locally.

Hough (1995) considers architecture from an urban design point of view, appreciating the natural cycles that must be incorporated into urban spaces and city plans. One example is the use of normally unused urban places, such as building rooftops.

McDonough (2005) is concerned with the overall construction of urban landscapes, especially rooftop gardens, their varied varieties, methodologies, and loading capacities. This was useful when recognizing the various challenges associated with rooftop gardens. Furthermore, the use of effective practices can assist minimize difficulties caused by global warming as well as opportunity costs when developing in varied habitats and climates.

2.5 Rooftop Agriculture

Rani et al. (2016) studied on urban agriculture that was conducted in selected urban areas of Hyderabad City. Fifty respondents who were practicing gardening in rooftop were selected for the study. Vegetables, flowers and fruits were the commonly grown plants observed in those rooftop gardens. Study showed that majority of the practitioners were growing these plants organically and were able to meet their household requirements to a great extent except during the summer season. However, limited access to technical advice, non-availability of services and quality inputs materials at reasonable price, potential leakages, lack of training and follow-up etc. were the major chalanges found in sustaining the practice.

Shuvo (2000), projected for a theoretical skeleton on the basis on a mandatory on-site revision to 'long-term greening' and explained how this framework should allow a sustainable mainstreaming of the violated constructions ensuring fiscal reimbursement for RAJUK, edifice owner and the 'green industry' identical.

Islam (2001), studied that urban inhabitants in the cities of rising countries are growing fast which also indicates the quantity of consumers of low-income. Due to the fact, for insecurity in these cities is enhancing. Urban agriculture ensures food security by boosting the supply of food and by enhancing the quality of fragile foods attainment urban consumers. In this research, he tried to recognize the potential for and barriers to UA with orientation to rooftop gardening and to observe the strategies to encourage food security in Dhaka city.

Kamron (2006), published an article naming 'Adoption of roof gardening at Mirpur-10 area under Dhaka city'. She revealed the preferred distinctiveness of the respondents, family size, roof gardening knowledge, approach towards roof gardening, use of information sources, and familiarities of rooftop gardening had encouraging consequence of relationship with their acceptance of rooftop gardening. There were other characteristics, namely: age, family education and family earnings did not show any significant relationship with the respondent's adoption of rooftop gardening.

Lundholm and oberndorfer (2007), verified that without difficulty measured plant traits (height, individual leaf area, specific leaf area, and leaf dry matter content) can be used to select the species to optimize green roof performance throughout the manifold key services.

Moustier (2007), provides a comprehensive summary of the significance of urban agriculture in 14 African and Asian cities. Among the consequences they observed that 90% of all vegetables consumed in Dares Salaam (Jacobi et al., 2000) and 60% of vegetables consumed in Dakar create from urban agriculture. Rooftops are worldwide underutilized components of this urban landscape. With the advancements in technology, desire for increased green space in a time of economic turmoil, and the public and political will to support urban gardens, the scope for rooftop food production has never been greater (Burros, 2009).

Rashid and Ahmed (2009), recorded the thermal performance of rooftop garden in a six storied building established in 2003. He observed that the temperature of this construction building is 3°C lower than the other surrounding buildings. This green appliance can reduce the interior air temperature 6.8°C from open-air throughout the hottest summer Period. Some benefits of rooftop gardening over growing fruits and vegetables on the field areas that contamination can be controlled, soil composition can be managed, and the growth of excessive weeds are less likely to grow (Urban Design Lab, 2012).

Sharmin (2013), has performed in a case study on green roof and revealed that it is an innovative way to obtain environmental sustainability and thermal comfort in Dhaka city. She observed that green areas (like gardens, parks, vegetation, playing fields) in cities and urban areas are being replaced with concrete surfaces that results from the extreme urbanization. It ultimately cause a broad and devastating ecological degradations in urban. She focused on this paper about the potential of widespread over deep exhaustive green roof in conservation the urban built environment. It boosts environmental sustainability and the local thermal comfort level in impenetrable urban areas of Dhaka city.

Mostafa et al., (2013); established in his study the current status of rooftop gardening in Sylhet City Corporation, Bangladesh that each gardener was paying attention in growing of rooftop garden as they think that home gardens could facilitate them to earnings and keep money. Its stistical representation is likewise 29.8% respondents were occupied in gardening for monetary point, 54.9% respondents for green amelioration, 95.3% was involved for mental happiness and refreshment, aesthetic value (82.5%) and for activity in relaxation time (87.8%). Orsini et al., (2014); conducted an experiment to study the intensity of the prospective rooftop vegetable production in the city of Bologna (Italy) as based on the necessities of its citizen. The prospective advantages to urban biodiversity and ecosystem service some prerequisite were determined. RTGs could afford above 12,000 ton year−1 vegetables to Bologna, meeting 77 % of the inhabitants' need.

Kamrujjaman (2017), wrote a book naming "Green Banking" related to the rooftop farming. The book includes seven chapters that describes the thermal profit of rooftop gardens and the overall methodology and farming procedures of fruits, vegetables, flowers/ornamental plants and multipurpose use of roof gardening.

Niachou et al. (2001) concluded in his study that the indoor temperature in the building with green roof are lower during the day. They measured the roof temperatures in non-insulated buildings with and without green roof and recorded the evaluation.

Orsini et al. (2014) carried out a study of appreatiating the effectiveness of the potential of rooftop vegetable production in the city of Bologna (Italy) as related to its citizen's needs. The potential benefits of urban biodiversity and ecosystem service provision were evaluated. RTGs could give more than 12,000 ton/year vegetables to Bologna, meeting 77 % of the inhabitants' requirements.

2.6 Performance of Spinach in rooftop and farm condition

Zaman et al. (2018) carried out an experiment at PARC National Tea and High Value Crops Research Institute Shinkiari, Mansehra, (Pakistan) during the period 2016-17. He worked with the spinach crop to determine the optimum fertilizer doses for getting maximum spinach production. His study revealed that nitrogen and phosphorus @ 125-90 and 150-100 NP kg/ha are optimum dose for getting maximum production from spinach.

Stagnari et al. (2007) studied an experimental on department of food science (TE, Italy) in 2004 and 2005 to evaluate the effects of genotypes, different N forms and N rates on yield, safety and nutritional characteristics of spinach. This research work results differences among spinach genotypes in terms of efficiency in nitrogen use and oxalate and nitrate accumulation. Spinach accumulated much more nitrate in petioles and much more oxalate in blades which indicates that nitrate and oxalate might play a counter role to each other. Fertilizers that contains nitrogen in forms not readily available to the crop, accumulate less than fast N-release fertilizers, but their effect on yield was limited.

Bostanci and Ülger conducted an experiment where, the objective was to find out the effect of glasshouse and outdoor conditions on the growth of spinach plants in floating hydroponic culture and soil. In the floating hydroponic culture, the plants were grown in a plastic tank (120x50x30 cm) with a volume of 80 L in a glasshouse and open field. There was no significant difference in EC values measured in the glasshouse and outside, and the pH value of the solutions in the outdoor environment was higher (except in late December) than those in the glasshouse. The earliest and late harvests were made in floating hydroponic culture in the glasshouse and outdoor cultivation at 64 and 97 days. The highest yield was 1.54 kg/m^2 in open field cultivation, it was followed by 1.45 kg m^2 in the greenhouse and 1.32 kg m^2 in the open field in floating hydroponic culture, respectively. Despite the high yield that can be obtained from floating hydroponic culture cultivation in the glasshouse and outside, the fact that there is a less marketable amount that is a negative aspect. Howsoever, the floating hydroponic results better than the soil cultivation due to many advantages such as production 2-3 times a year, low labor costs, and less pesticide use. Spinach cultivation in the open field does not have any problems in terms of nitrate, but nitrate accumulation can be a problem in hydroponic culture.

Chapter 3

MATERIALS AND METHODS

An experiment was conducted in order to achieve the stated objectives of this study and the materials and methods used are outlined in this chapter under the following headings:

3.1 Location of the experimental site

The experiments were carried out at both rooftop and farm. The rooftop of Soil Science Department building and farm of Sher-e-Bangla Agriculture University, Dhaka was used. According to Geography, the experimental site is on 90.2^{o} N and 23.5^{o} E Latitude and altitude of 8.25 m above the sea level. The experiment was conducted during Rabi season from October 2020 to December 2020. There maintained same treatments, replications and management practices for both rooftop and farm.

3.2 Climatic condition

The experimental area had a subtropical climate characterized by high temperatures, high humidity, and heavy precipitation with occasional gusty winds from April to September, but meager rainfall and moderately low temperatures prevailed from October 2020 to March 2021. A detailed meteorological data of air temperature, relative humidity, rainfall, and sunshine hour recorded by the meteorology center of Dhaka was included in Appendix III during the experiment period.

3.3 Soil

The soil for the experiment was sandy loam that was collected from outside of Dhaka city. The analytical data of this soil was determined in Soil Resource Development Institution (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and presented in Appendix I.

3.4 Details of experiment

3.4.1 Collection of Planting Material

Variety: Holdibari seed

Source: The seeds were collected from a seed shop in Agargaon, Dhaka.

3.4.2 Treatment of Experiment

The experiment was conducted in two conditions, rooftop condition and farm condition.

Factor A: Three levels of Nitrogen

- $N_0 = 0$ kg N_2 ha^{-1}
- $N_1 = 56$ kg N_2 ha^{-1}
- $N_2 = 84$ kg N_2 ha^{-1}

Factor B: Three levels of Phosphorus

- $P_0 = 0$ kg P_2O_5 ha^{-1}
- $P_1 = 36.8$ kg P_2O_5 ha^{-1}
- $P_2 = 57.5$ kg P_2O_5 ha^{-1}

There were total 9 (3×3) treatment combination, 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.

3.4.3 Layout and Design

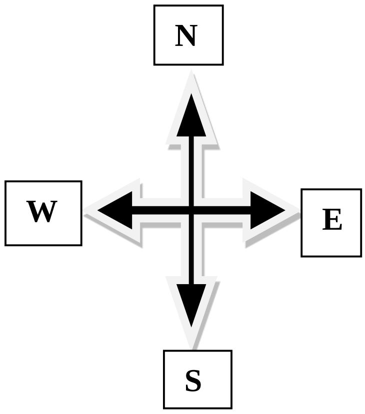
The layout of the experiment was designed using Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot were 12 m x 5 m, that is equivalent to 35.7 m^2 or 1 decimal. The plot is consists of three equal blocks. Each block area was 12 m x 1m which comprises 9 equal plots. So, there are twenty seven unit plot in total. The size of the unit plot is 1 m x 1.10 m and drain or the spaces between unit plots is 0.25 m. Plant to plant distance is 10 cm so the number of plant in each unit plot is 110. The layout of the experiment is shown in Figure 1.

3.5 Field operation details

3.5.1 Land Preparation

The land preparation in the rooftop was started on 13 October 2020. I had selected rooftop of the Soil Science Department, (SAU). There is a pre-built structure for rooftop farming with a measurement of 12 m long and 5 m width. Three block made with concrete were filled with soil. The land was spaded to break the larger clods and uprooted weeds. After that I obtained my desired tilt of soil for sowing my Spinach seed. The recommended doses of manures, cow-dung, and fertilizers were applied in the soil. Then after leveling the soil uniformly, pulverization of soil particle was done

R1	R2	R3
N_0P_0	N_1P_0	N_1P_1
N_0P_1	N_1P_1	N_0P_0
N_0P_2	N_2P_0	N_1P_2
N_1P_0	N_2P_2	N_0P_1
N_1P_1	N_2P_1	N_2P_2
N_1P_2	N_0P_0	N_0P_2
N_2P_0	N_0P_2	N_2P_1
N_2P_1	N_1P_2	N_1P_0
N_2P_2	N_0P_1	N_2P_0



Total length = 12.2 m
Total width = 5 m
Unit plot size =
1.10 m x 1m
Distance between
Two blocks = 0.5 m
Distance between
Two plots = 0.25 m
Total area = 35.7 m²

Figure 3.2 Layout of the experimental design for both rooftop and farm condition

finally. The blocks were divided into unit plots according to the design of experiment shown in figure 1.

3.5.2 Sowing of seed

Seeds were soaked in water for about 24 hours for better germination. Then seeds were sown in the rooftop on 12 October 2020 in line sowing maintaining 10 cm plant to plant distance. In the similar manner seed sowing is done in the farm land on 20 October 2020.

3.5.3 Manure and fertilizer application

Manure / fertilizer	Dose/ha	Application
Cow dung	10 ton	All applied during final land preparation
N (as Urea)	N_0 = 0 kg N_1= 120 kg N_2= 180 kg	As per treatment
P_2O_5 (as TSP)	P_0 = 0 kg P_1 = 80 kg P_2 = 125 kg	As per treatment
MOP	125 kg	At three installment; 10, 30, and 45 days accordingly after sowing

Source: Krishi Projukti Hatboi (9th Edition)

3.5.4 Seed germination

Seeds started germinating within almost 7 days after sowing. Gradually, all fields appeared to germinate.

3.6 Intercultural operation

With the establishment of seedling intercultural operations were started operating for better growth and development.

3.6.1 Irrigation and drainage

Irrigation was provided three times during the crop growth stage. And drainage was done in case of heavy rainfall.

3.6.2 Thinning and gap filling

Thinning and gap filling was done at twelve days after sowing (DAS).

3.6.3 Weeding

Three times during the crop's growth stage, weeding was done. The first weeding was done 15 days after sowing (DAS), followed by the second and third weddings at 30 and 45 DAS.

3.6.4 Stalking

Stalking was done to keep the plants erect with bamboo stalk. It helped to protect the plants from damage by heavy wind.

3.6.5 Plant protection

For protecting the crop from ant attack Furadan was applied.

3.6.7 Harvesting

Crop was harvested manually by uprooting plants by hand both on rooftop and farm. On the rooftop, harvesting was done on the 26th November 2020 at 45 DAS (days after sowing). Similarly, on 3rd December 2020 harvesting was completed at 45 DAS. On both condition, crop was harvested plot-wise.

3.7 Data collection

Data was collected and recorded on the following parameters on 20 DAS and at harvesting on 45 DAS (days after sowing). For collecting data five plants were selected randomly from each unit plots.

Here are the parameters on which data collection was done. The mean value of the data collected from the randomly selected five plants was calculated.

i. Germination percentage
ii. Germination index
iii. Plant height (cm)
iv. Number of leaves plant $^{-1}$
v. Leaf length (cm)
vi. Leaf breadth (cm)
vii. Shoot length (cm)
viii. Root length (cm)
ix. Fresh weight plant^{-1} (gm)

x. Dry weight $plant^{-1}$ (gm)

xi. Yield $plant^{-1}$ (kg)

xii. Yield ha^{-1} (ton)

3.7.1 Total germination percentage (TG %)

Total germination (TG) was estimated as the number of seeds germinated within 15 days as a proportion of number of seeds sown in each treatment plot, which was expressed as a percentage (Othman et al., 2006).

$$TG\ (\%) = \frac{\text{number of germinated seeds}}{\text{total number of seeds set for germination}} \times 100$$

3.7.2 Germination index (GI)

Germination index (GI) was estimated using the following formula as mentioned below-

Germination index = (No. of germinating seeds/ Days of first count) + …. + (No. of germinating seeds/Days of final count).

3.7.3 Plant height (cm)

Height of the plants were measured by a meter scale from the ground level to the tip of the leaves from randomly selected five plants from each plot and the mean value was calculated.

3.7.4 Number of leaves per plant

Number of leaves per plant was counted and recorded from the randomly selected five plots. Finally, the average value was calculated.

3.7.5 Leaf length (cm)

The length of leaves were recorded from each of the leaves of the five selected plants per plot and the mean value was calculated.

3.7.6 Leaf Breadth (cm)

The leaf breadth was also measured in the similar way of leaf length. The average value of the leaf breadth was recorded from the randomly selected five plants from each plot.

3.7.7 Shoot length (cm)

Five plants were selected randomly from each treatment plot and the cotyledon were removed. Then the shoot length was measured with a measuring tape and averaged.

3.7.8 Root length (cm)

The root length of the randomly selected five plants in each plot was measured after 45 days after sowing (DAS). The length was measured in centimeters and the mean value was calculated.

3.7.9 Fresh weight plant^{-1} (gm)

During harvesting, fresh weight of five plants plot^{-1} was weighed by electrical balance and their mean value was estimated while the fresh weight was expressed in gram.

3.7.10 Dry weight plant^{-1} (gm)

Ten plants were cut down and collected from each plot and oven dried at a temperature of 60 °C for 72 hours to remove the outer moisture. Then it was weighed by an electrical balance in gram and averaged.

3.7.11 Yield plot^{-1} (kg)

For yield measurement, a balance was used to weigh the harvested crop per plot. Yield from the each unit plots was recorded in kg (kilogram).

3.7.12 Yield ha^{-1} (ton)

The yield per plot (kg plot^{-1}) was converted into yield per hectare.

3.8 Statistical data analysis

After data collection, the data was statistically analyzed using Statistix 10 computer software program to determine the significant difference of farm and rooftop cultivation on yield and yield contributing characters. All the parameters' mean value was computed and at 5% level of significance, the mean differences were tested by using Least Significance Difference (LSD) test (Gomez and Gomez, 1984).

Chapter 4

RESULT AND DISCUSSION

The experiment was carried out at the rooftop of soil Science department and agronomy farm of Sher-e-Bangla Agriculture University, Dhaka, Bangladesh. It was conducted during the period of October 2020 to December 2020 to determine the performance of Spinach cultivated on rooftop and farm condition. The outcome of the experiment has been presented in this chapter and discussed under the following headings.

4.1 Total germination percentage (%)

4.1.1 Effect of nitrogen

Total germination percentage of spinach was significantly varied in rooftop due to various doses of nitrogen (Fig.4.1). The maximum germination percentage (87.57) was recorded from the N_2 (84 kg/ha N) treatment which was statistically significant from others (Table 1.), whereas the minimum germination percentage (78.05) was observed due to N_0 (control) treatment.

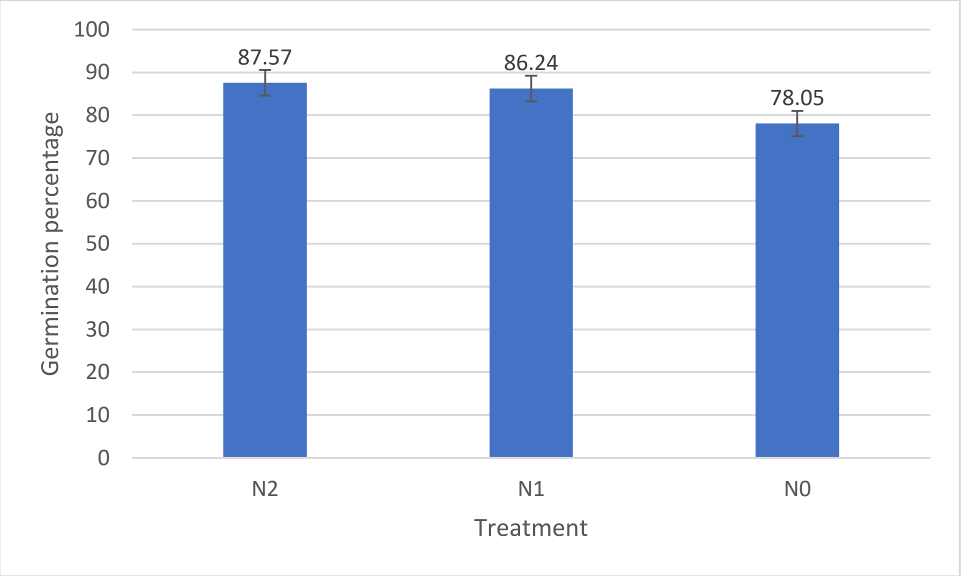


Figure 4.1 Effect of nitrogen on germination percentage of spinach in rooftop

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

On the other hand, in the farm, the highest germination percentage (78.29) was found as a result of N_1 (56 kg ha^{-1} N) treatment (Figure 4.2) which is statistically different from others. The lowest germination percentage (72.27) was observed due to N_0 (control) treatment. Zaki et al. (2016) reported that seed quality and yield of spinach were improved due to the increasing rate of nitrogen doses.

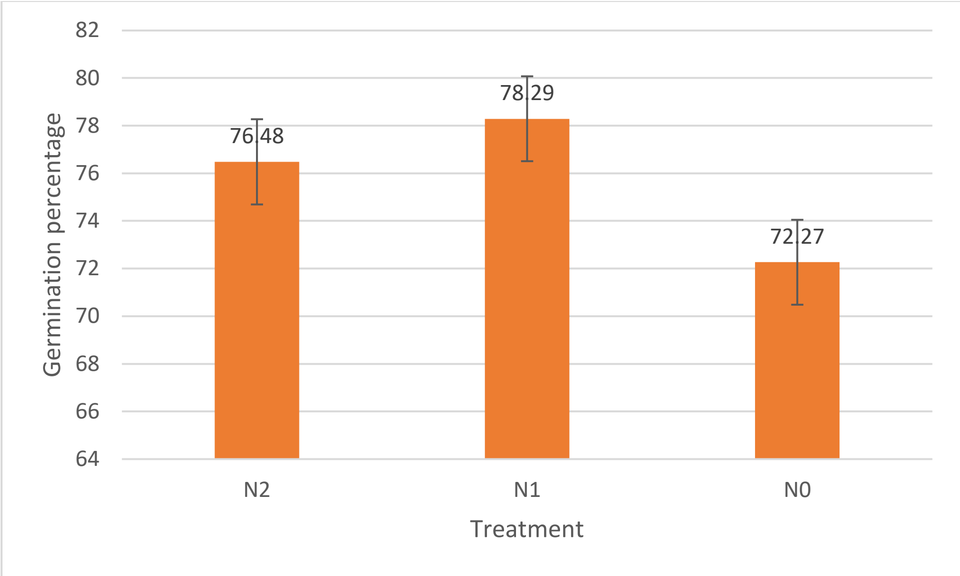


Figure 4.2 Effect of nitrogen on germination percentage of spinach in farm

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

4.1.2 Effect of phosphorus

A significant variation was recorded on germination percentage of spinach due to the single effect of phosphorus in rooftop (Figure 4.3). The maximum germination

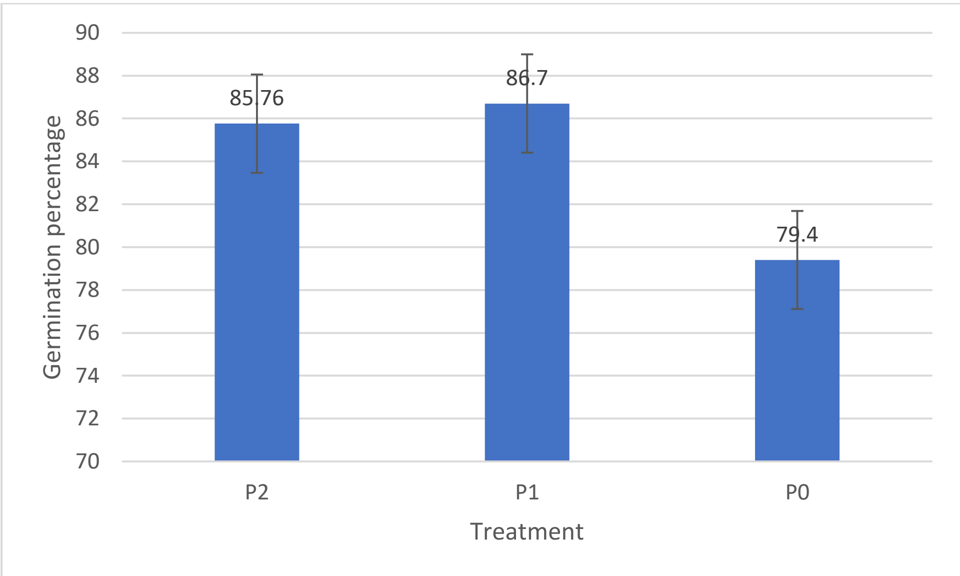


Figure 4.3 Effect of phosphorus on germination percentage of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

percentage (86.70) was observed owing to the application of P_1 (36.8 kg ha^{-1} P_2O_5) fertilizer dose (Figure 4.4) and it is statistically significant from other treatments.

Meanwhile the minimum germination percentage (79.4) was found due to the effect of P_0 (control) treatment.

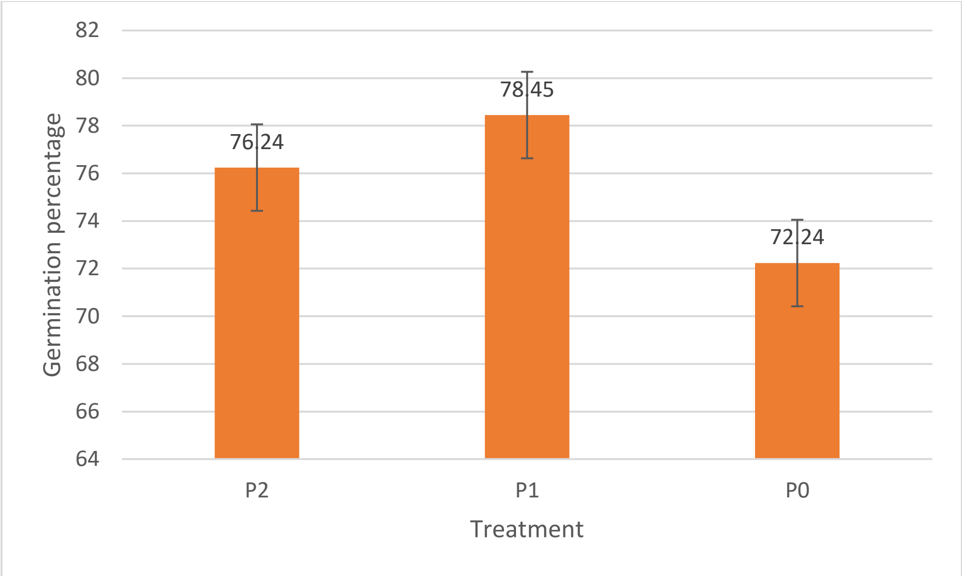


Figure 4.4 Effect of phosphorus on germination percentage of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

At the same time, the highest germination percentage (76.24) was recorded in farm condition due to the use of P_1 (36.8 kg ha^{-1} P_2O_5) treatment which is significantly different from other treatment. The lowest germination percentage (72.24) was seen due to P_0 (control) treatment

4.1.3 Combined effect of nitrogen and phosphorus

The combined effect of nitrogen and phosphorus doses had significant influence on germination percentage of spinach in rooftop. The maximum germination percentage (91.37) was recorded in the treatment combination of N_1P_1 (56 kg/ha N + 36.8 kg ha^{-1} P) in rooftop condition which was statistically identical to N_2P_1 (84 kg ha^{-1} N + 36.8 kg ha^{-1} P) that resulted 90.60 germination percentage. On the other hand, the minimum germination percentage (72.33) was recorded in the N_0P_0 (control) treatment. Accordingly, the the highest germination percentage (82.58) seen to occur in farm due to N_1P_1 (56 kg ha^{-1} N + 36.8 kg ha^{-1} P) which was significantly different from one another. And the lowest result (68.51) was due to N_0P_0 (control) treatment.

4.2 Germination index

4.2.1 Effect of nitrogen

In rooftop, significant variation was recorded for germination index due to different nitrogen doses. However, the highest germination index (21.79) was found from the treatment N_2 (84 kg ha^{-1} N) which was statistically identical to N_1 (56 kg ha^{-1} N) treatment. The lowest germination index (16.63) was recorded from the N_0 (control) treatment.

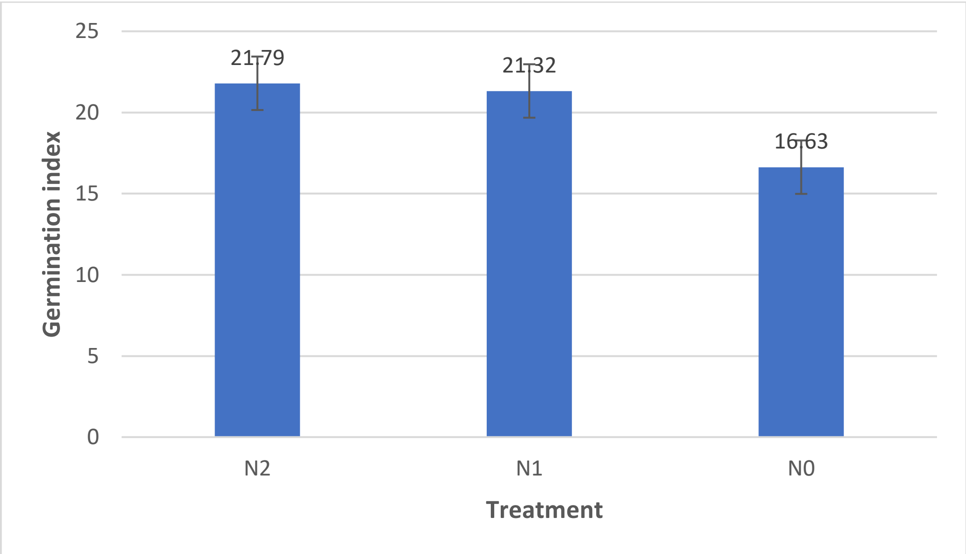


Figure 4.5 Effect of nitrogen on germination index of spinach in rooftop

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

Accordingly, in the farm, the highest germination index (18.99) was found due to N_1 (56 kg ha^{-1} N) application and the lowest germination index (14.92) was recorded from the N_0 (control) treatment. Here, significance variation was also seen due to different phosphorus doses.

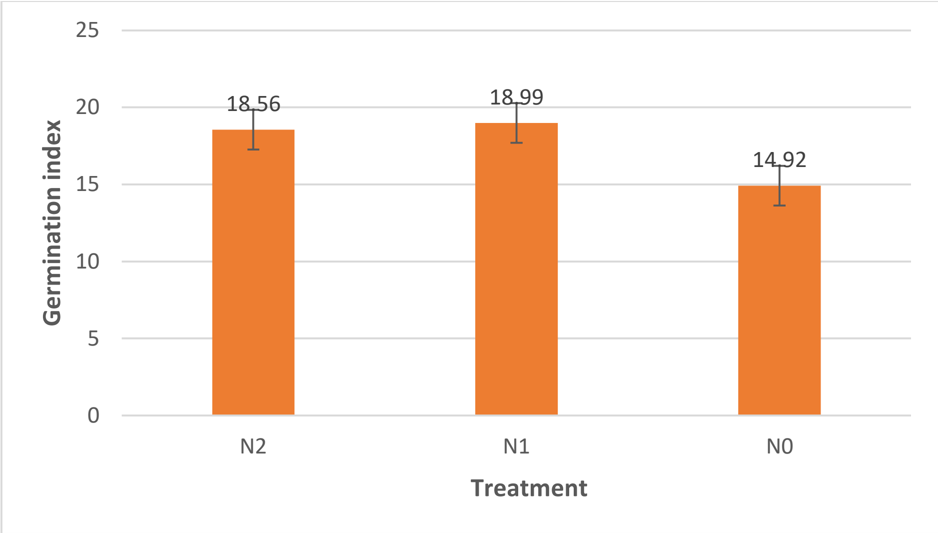


Figure 4.6 Effect of nitrogen on germination index of spinach in farm

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

4.2.2 Effect of phosphorus

Germination index was found to vary due to application of various doses of phosphorus (Figure 4.7). The maximum germination index (21.07) was recorded in P_2 (57.5 kg/ha P_2O_5) treatment which is statistically identical P_1 (36.8 kg ha^{-1} P_2O_5). The minimum (17.60) germination index was observed in P_0 (control) treatment (Figure 4.7).

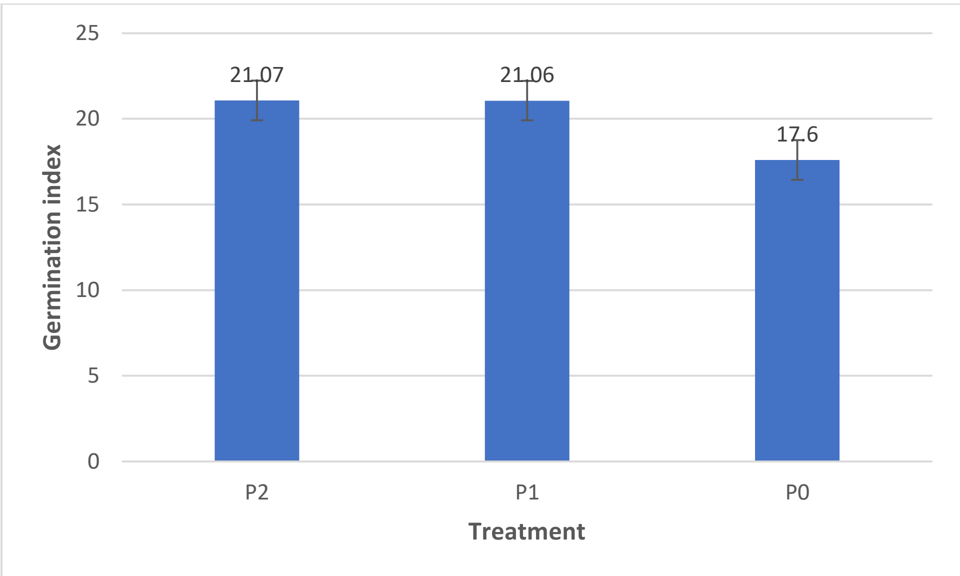


Figure 4.7 Effect of phosphorus on germination index of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36.8 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

On the other hand, in farm, the single effect of phosphorus fertilizer greatly affect in spinach. The highest germination index (19.04) was revealed due to P_1 (36.8 kg ha^{-1})

which was significantly different from one another. The lowest index was found in P_0 (control) treatment.

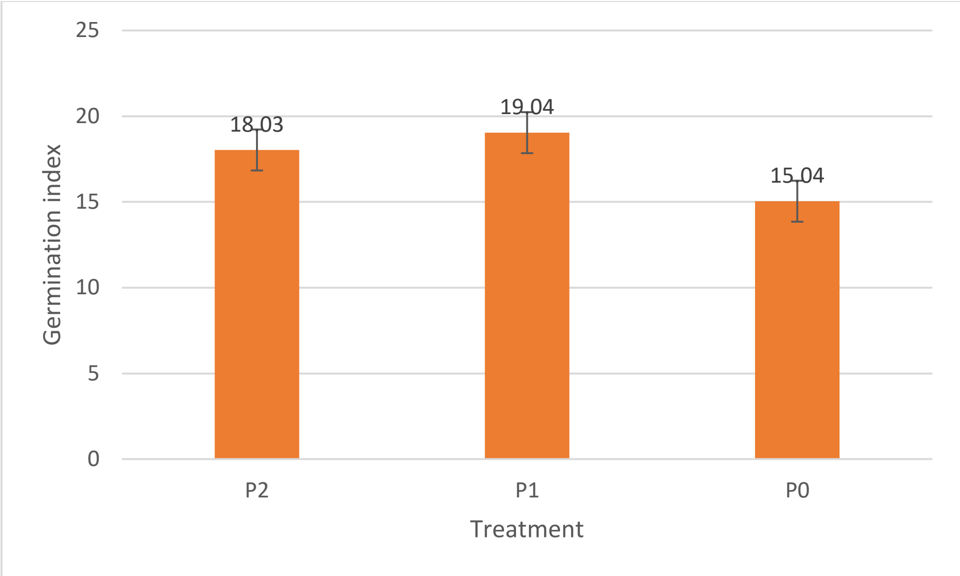


Figure 4.8 Effect of phosphorus on germination index of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36.8 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

4.2.3 Combined effect of nitrogen and phosphorus on germination index

The combination effect of nitrogen and phosphorus was observed in germination index of spinach in rooftop (Table. 1). The highest germination index (23.42) was recorded owing to the application of N_1P_1 (56 kg/ha N + 36.8 kg/ha P) which is statistically identical to N_2P_1 (84 kg/ha N + 36.8 kg/ha P). On the other hand, the lowest germination index (13.17) was noticed at N_0P_0 (control) treatment combination. Similarly, in farm condition the maximum germination index (21.50) was also recorded due to the application of N_1P_1 (56 kg/ha N + 36.8 kg/ha P) which is statistically significant and the minimum index (12.93) was observed in N_0P_0 (control) treatment.

4.3 Plant height (cm)

4.3.1 Effect of nitrogen

The plant height varied significantly in rooftop due to different doses of nitrogen (Table 1). The highest plant height (21.45 cm) of spinach was found due to N_2 (84 kg ha^{-1} N) (Fig 4.9) and the lowest plant height (13.01 cm) was observed in N_0 (0 kg ha^{-1} N) control condition**.**

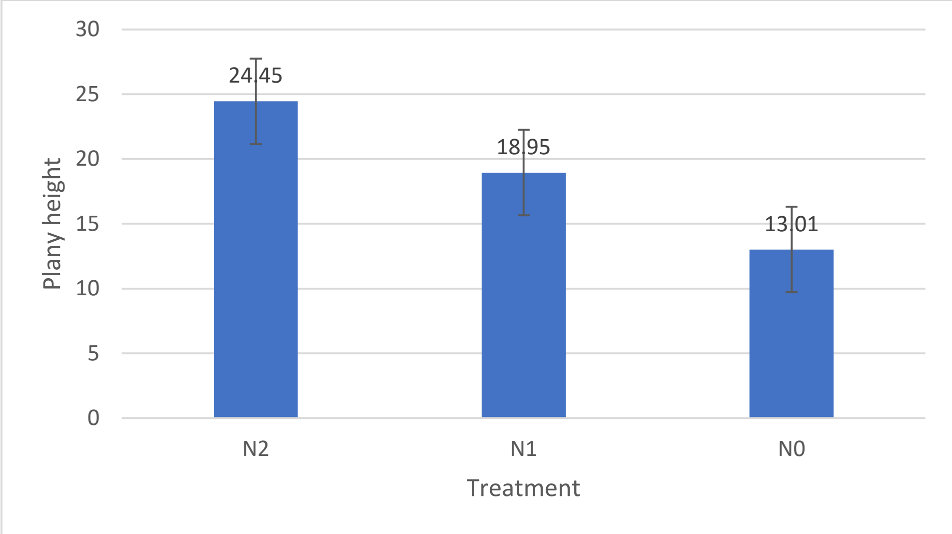


Fig 4.9 Effect of nitrogen on plant height (cm) of spinach in farm

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N ha^{-1}; N_2= 84 kg N ha^{-1}

On the other hand, in farm, it was observed that the maximum plant height (18.62 cm) was due to N_2 (84 kg ha^{-1} N) fertilizer dose and minimum height (9.02 cm) was for N_0 (control) treatment**.** So, it reveals that plant height of spinach enhanced with the

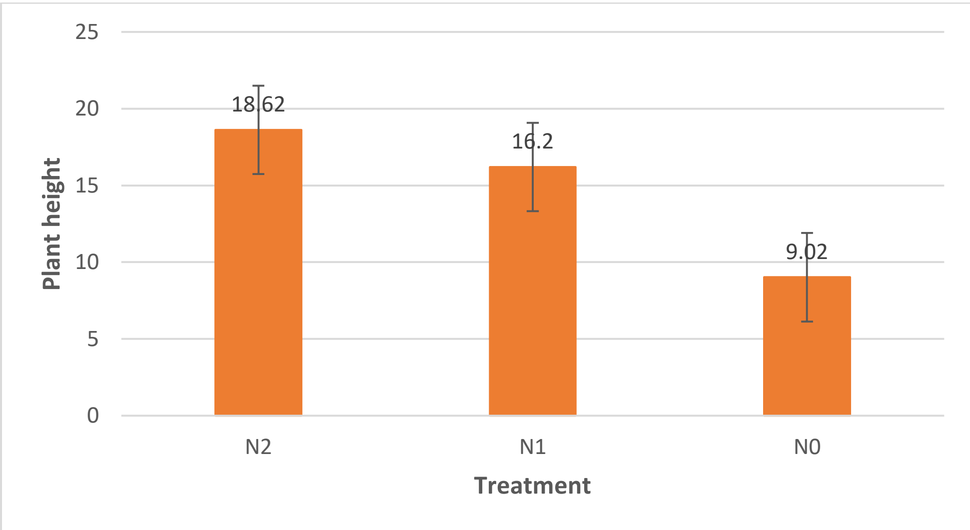


Fig 4.10 Effect of nitrogen on plant height (cm) of spinach in farm

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N ha^{-1}; N_2= 84 kg N ha^{-1}

increasing of nitrogen doses up to N_2 (84 kg ha^{-1}) dose. Similar findings were also reported by Wahocho, et al. (2016).

4.3.2 Effect of phosphorus

Statistically significant difference was found on plant height of spinach due to the application of various doses of phosphorus (Figure 4.11). Among different levels of phosphorus, P_2 (57.5 kg ha^{-1} P_2O_5) was seen to provide the highest plant height (19.87 cm) of spinach in rooftop and the lowest plant height (15.09 cm) was observed due to (control) treatment.

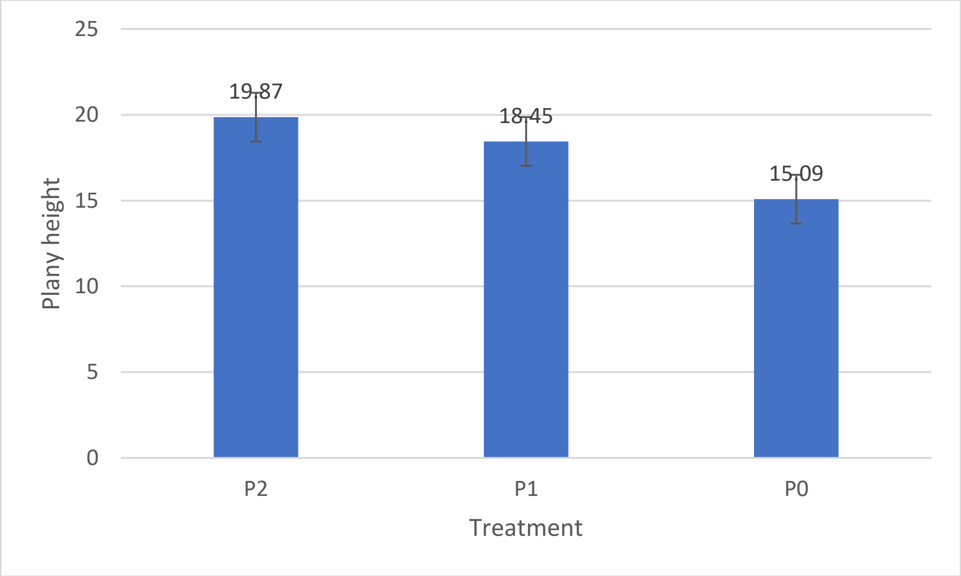


Figure 4.11 Effect of phosphorus on plant height (cm) of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

Conversely, the largest plant height (16.72 cm) was observed in the farm owing to the application of P_2 (57.5 kg ha^{-1} P_2O_5). And P_0 (control) treatment showed the lowest height. So, it revealed that for highest plant height of spinach P_2 (57.5 kg ha^{-1} P_2O_5) is optimum dose of phosphorus.

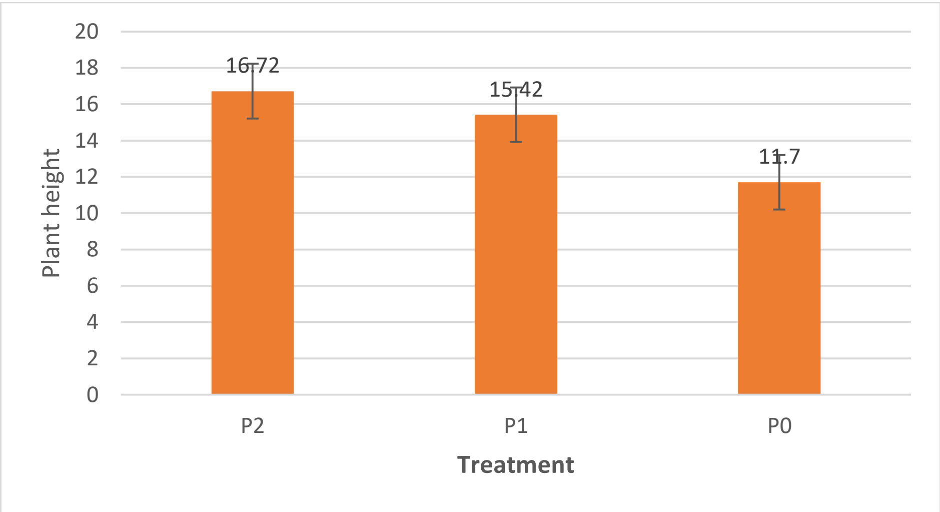


Figure 4.12 Effect of phosphorus on plant height (cm) of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

4.3.3 Combined effect of nitrogen and phosphorous

Plant height was significantly influenced in rooftop and farm conditions under the present experiment. The interactive effect of nitrogen and phosphorus doses had significant influence on the plant heights in spinach in both rooftop and farm condition (Table. 1). The highest plant height (23.86 cm) was recorded in rooftop due to the combination treatment of N_2P_2 **(**180 kg ha^{-1} + 80 kg ha^{-1}). Moreover, the lowest plant height (10.74) was found in N_0P_0 (control) treatment. Accordingly, the maximum plant height (20.94 cm) was recorded in farm for the treatment combination of N_2P_2 **(**180 kg ha^{-1} + 80 kg ha^{-1}) which is statistically significant from one another. The lowest height (6.20 cm) was observed due to N_0P_0 (control) treatment. This result revealed that, increased doses of phosphorus results increased plant height that follow the findings by Patel et al. (2021)

4.4 Number of leaves per plant

4.4.1 Effect of nitrogen

Due to the effect of nitrogen doses, leaf production varied significantly. The highest number of leaves (21.07) was recorded in rooftop condition for N_1 (56 kg ha^{-1}N) treatment and the lowest leaf number (13.78) was seen in N_0 (control) treatment.

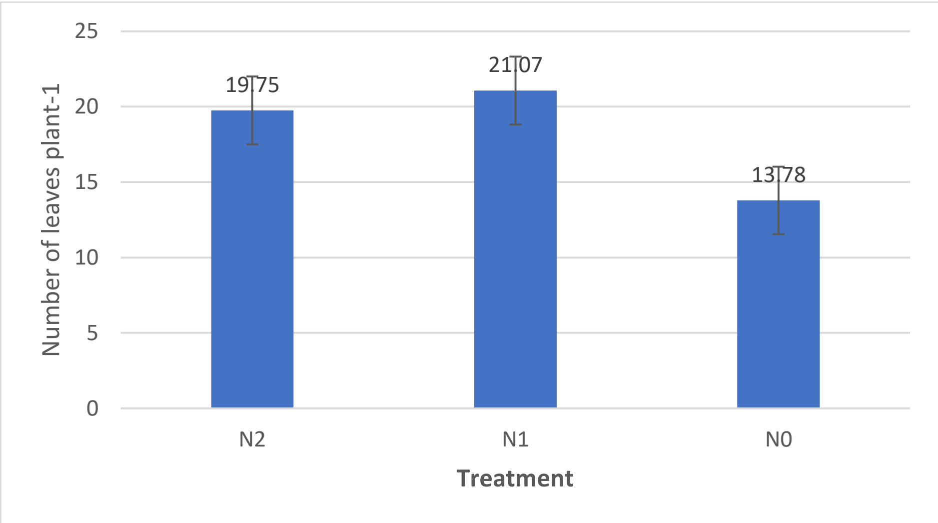


Figure 4.13 Effect of nitrogen on number of leaves of spinach in rooftop

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N ha^{-1}; N_2= 84 kg N ha^{-1}

While on the other hand, N_1 (56 kg N ha^{-1}) produced the maximum number of leaves per plant (12.30) at farm condition (Figure 4.14) the minimum number of leaves per plant (8.12) was found in N_0 (control) treatment. From this research work it was found that the highest number of leaves per plant was increased due to the increase in vegetative growth of spinach plants. This result revealed that N_1 (56 kg N ha^{-1}) leads to increase in number of leaves per plant similar to the report by Zhang, et al. (2014).

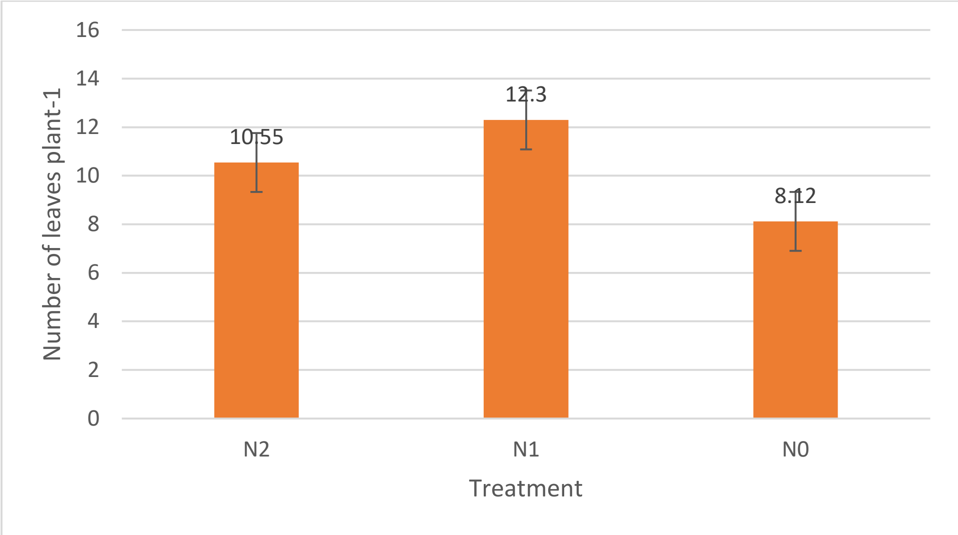


Figure 4.14 Effect of nitrogen on number of leaves of spinach in farm

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N ha^{-1}; N_2= 84 kg N ha^{-1}

4.4.2 Effect of phosphorus

Significant variation was noticed on number of leaves per plant of spinach due to the application of phosphorus at different levels. Among the different phosphorus doses P_2 (57.5 kg P_2O_5 ha^{-1}) produced the maximum number (20.43) of leaves per plant in

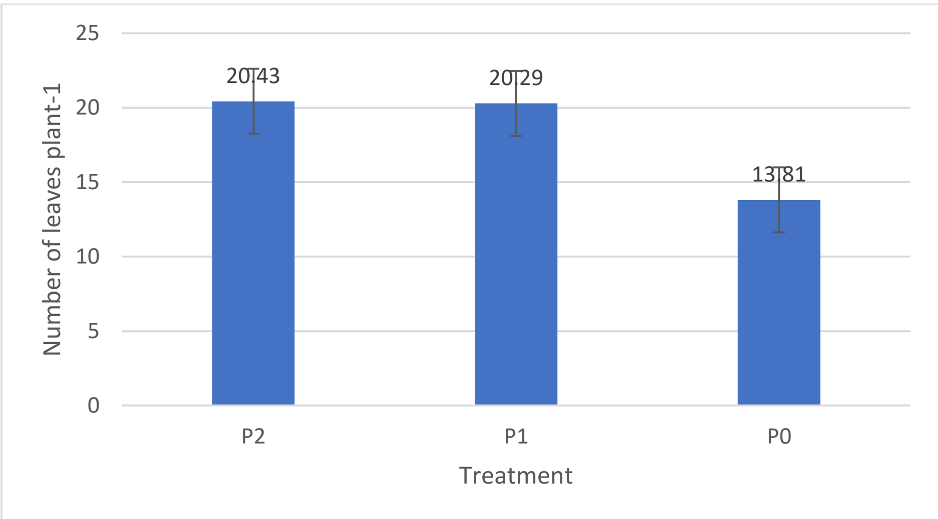


Figure 4.15 Effect of phosphorus on number of leaves $plant^{-1}$ of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

rooftop which is statistically identical to P_1 (36.8 kg P_2O_5 ha^{-1}) and the lowest number of leaves per plant was 13.81 which was found due to the application of treatment, P_0 (control) treatment.

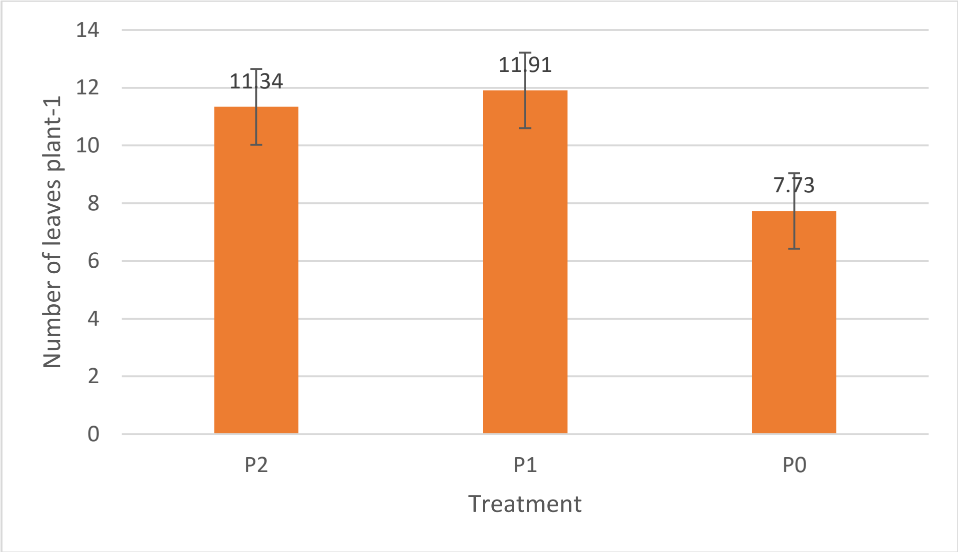


Figure 4.16 Effect of phosphorus on number of leaves plant^{-1} of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

Similarly in farm the highest leaf number (11.34) was recorded due to also P_2 (57.5 kg P_2O_5 ha^{-1}) and least leaf number (7.73) was found in P_0 (control) treatment. So it revealed that, P_2 (57.5 kg P_2O_5 ha^{-1}) is the single optimum dose of phosphorus for getting maximum spinach leaf number, that also follow the findings by Ambia, (2016).

4.4.3 Combined effect of nitrogen and phosphorus

The combined effect of different application doses of nitrogen and phosphorus showed statistically significant influence on number of leaves per plant of spinach (Table 1). The highest number of leaves per plant (25.42) in rooftop was found in N_1P_1 (56 kg ha^{-1} N + 36.8 kg ha^{-1} P_2O_5) that is statistically identical to N_1P_2 (56 kg ha^{-1} N + 57.5 kg ha^{-1} P_2O_5) treatment. The similar increasing trend was also observed in N_2P_1 (84 kg ha^{-1} N + 80 kg ha^{-1} P_2O_5) and N_2P_2 (84 kg ha^{-1} N + 57.5 kg ha^{-1} P_2O_5) respectively. On the other hand, the lowest number of leaves per plant (5.81) was recorded in N_0P_0 (control) treatment. Accordingly, in the farm, the highest number of leaves per plant (14.95) was found in N_1P_1 (56 kg ha^{-1} N + 36.8 kg ha^{-1} P_2O_5) that is statistically identical to N_1P_2 (56 kg ha^{-1} N + 57.5 kg ha^{-1} P_2O_5) and N_2P_1 (84 kg ha^{-1} N + 80 kg ha^{-1} P_2O_5) treatment. The similar increasing trend was also observed in N_2P_2 (84 kg ha^{-1} N + 57.5 kg ha^{-1}

P_2O_5) respectively. The minimum leave number (5.81) was found in N_0P_0 (control) treatment.

This result revealed that the combination application of nitrogen and phosphorus leads to a linear increase in the number of leaves per plant on spinach. The number of leaves per plant is the principal yield contributing factor of spinach. The optimum level of N and P might have enhanced availability and absorption of plant nutrients. The photosynthesis and other physiological processes of spinach relies on combined nitrogen and phosphorus application that results a better performance of the crop and at the end produce more leaves per plant. Ambia et al. (2016) also marked the similar result in her study.

4.5 Leaf Length

4.5.1 Effect of nitrogen

Leaf length is an important parameter for spinach production. Significant variation was recorded for leaf length among the treatments due to different nitrogen doses. In rooftop the highest leaf length (24.47 cm) was found from the treatment N_2 (84 kg ha^{-1} N) which was significantly varied from other treatments. On the contrary, the lowest leaf length (11.61 cm) was recorded from the N_0 (control) treatment.

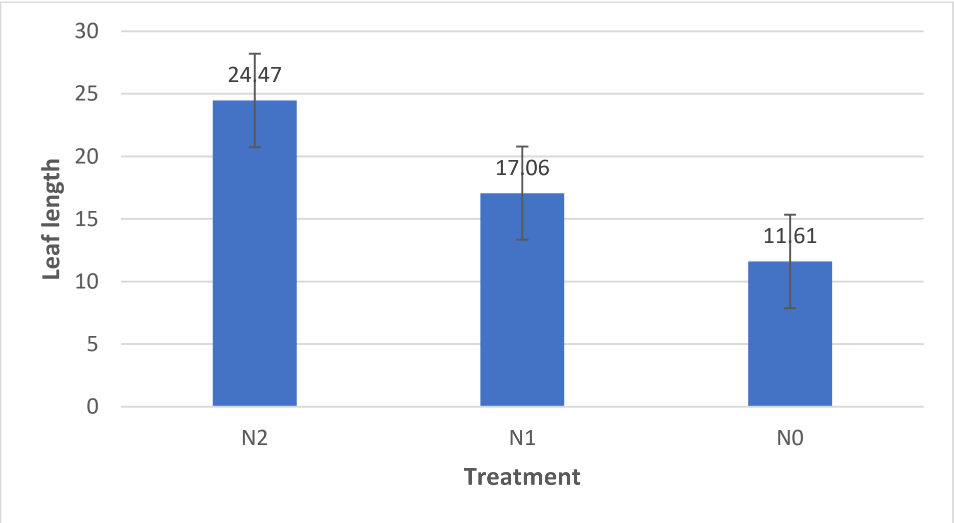


Figure. 4.17 Effect of nitrogen on leaf length (cm) of spinach in rooftop

Here, N_0 = 0 kg ha-1; N_1= 56 kg N_2 ha-1; N_2= 84 kg N_2 ha-1

In the farm, the largest leaf length (14.01 cm) was found due to N_2 (84 kg ha^{-1} N) application which was statistically significant and the smallest leaf length (8.92 cm) was observed in the N_0 (control) treatment (Figure 4.18). So, it revealed that, N_2 (84 kg ha^{-1} N) is the optimum dose for getting highest leaf length that was supported by Hamid (2018).

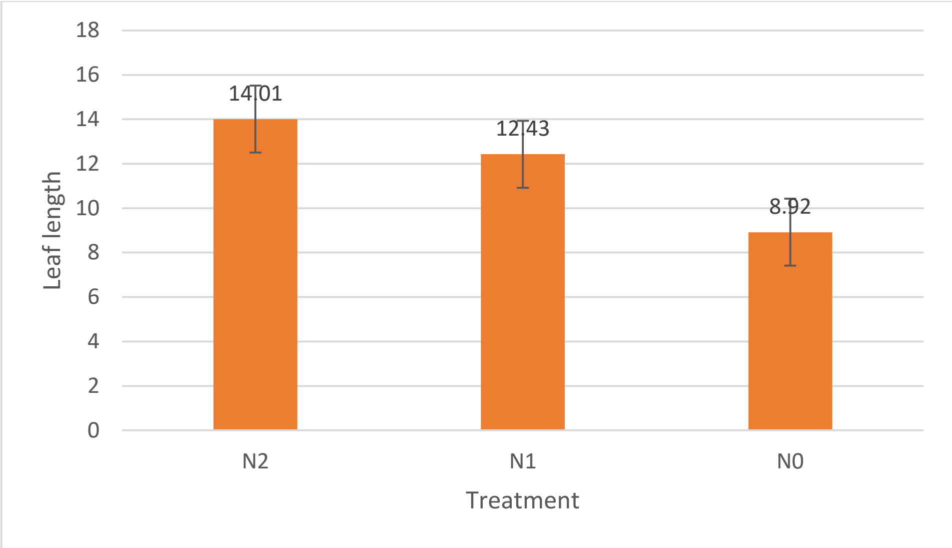


Figure. 4.18 Effect of nitrogen on leaf length (cm) of spinach in farm

Here, N_0 = 0 kg ha-1; N_1= 56 kg N_2 ha-1; N_2= 84 kg N_2 ha-1

4.5.2 Effect of phosphorus

Moreover, significant variation was also found on leaf length due to application of different doses of phosphorus in both rooftop and farm condition (Fig. 4.5). The

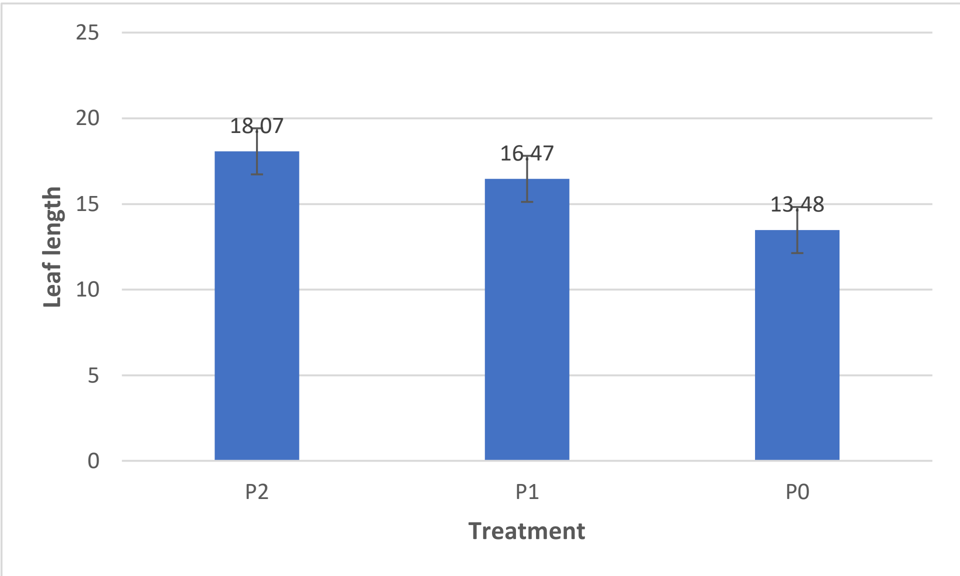


Figure. 4.19 Effect of phosphorus on leaf length (cm) of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

maximum leaf length (18.07 cm) in rooftop was marked due to application of P_2 (57.5 kg ha^{-1} P) and the minimum leaf length (13.48 cm) was observed due to the effect of P_0 (control) treatment.

In the same manner, in the farm condition, the largest leaf length (13.22 cm) was found due to P_2 (57.5 kg ha^{-1} P) application which is significantly different from others. The smallest leaf length (9.88 cm) is the outcome of P_0 (control) treatment. In both condition, leaf length increases with the increased use of phosphorus fertilizer doses up to P_2 (57.5 kg ha^{-1} P) and it provides the highest leaf length as Zaman et al. (2018) reported in his experiment.

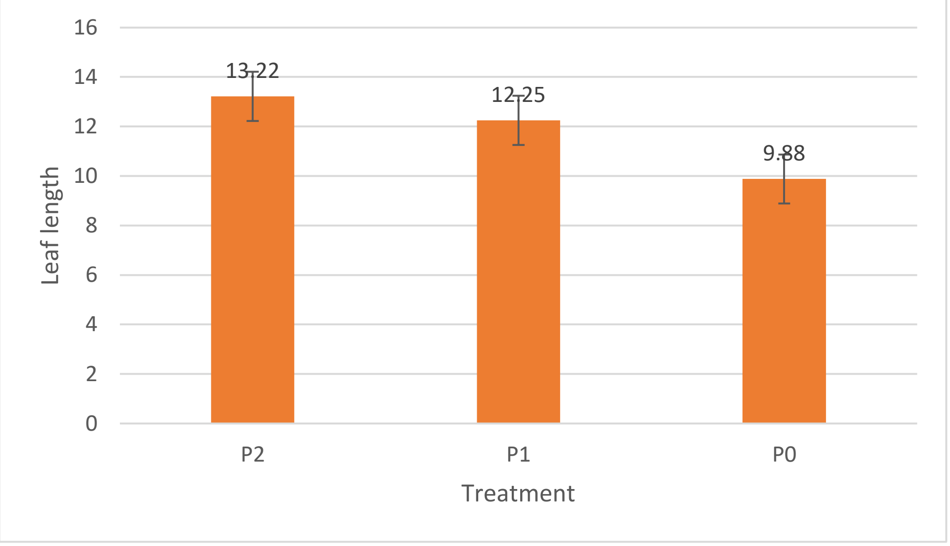


Figure. 4.20 Effect of phosphorus on leaf length (cm) of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

4.5.3 Combined effect of nitrogen and phosphorus

The combination effect of nitrogen and phosphorus was observed, that had significant influence on the leaf length of spinach. In rooftop, the highest leaf length (22.10 cm) was recorded owing to the application of N_2P_2 (84 kg ha^{-1} N + 57.5 kg ha^{-1} P) treatment which is significantly different from one another. The lowest leaf length (9.37 cm) was found from the N_0P_0 (control) treatment. On the other hand, in farm, the maximum leaf length (15.98 cm) was noticed at N_2P_2 (84 kg ha^{-1} N + 57.5 kg ha^{-1} P) treatment combination which is statistically identical to N_2P_1 (84 kg ha^{-1} N + 80 kg ha^{-1} P_2O_5) treatment. The similar trend to increase was observed in N_1P_2 (56 kg ha^{-1} N + 57.5 kg ha^{-1} P). The minimum leaf length was 7.74 cm, due to the application of N_0P_0 (control) treatment which was also statistically identical to N_0P_1 (0 kg ha^{-1} N + 80 kg ha^{-1} P_2O_5).

Table 1. Combined effect of nitrogen and phosphorus on Germination %, Germination index, plant height, no. of leaves, leaf length and leaf breadth of spinach in rooftop

Treatment	Germination %	Germination index	Plant height	No. of leaves	Leaf length	Leaf breadth
N_0P_0	72.33 g	13.17 f	10.74 i	10.04 e	9.37 h	3.31 f
N_0P_1	78.13 f	17.38 e	13.40 h	13.69 d	11.90 g	4.76 e
N_0P_2	83.69 d	19.34 d	14.89 g	17.41 c	13.56 fg	5.31 e
N_1P_0	80.24 e	18.43 de	16.39 f	15.10 cd	15.04 ef	6.05 d
N_1P_1	91.37 a	23.42 a	19.58 d	25.42 a	17.58 cd	6.16 d
N_1P_2	87.11 b	22.12 bc	20.87 c	22.68 ab	18.56 bc	6.72 cd
N_2P_0	85.62 c	21.21 c	18.14 e	16.28 cd	16.01 de	7.23 bc
N_2P_1	90.60 a	22.40 ab	22.36 b	21.75 b	19.93 b	7.74 ab
N_2P_2	86.49 bc	21.76 bc	23.86 a	21.21 b	22.10 a	8.25 a
$LSD_{0.05}$	**1.15**	**1.17**	**1.26**	**5.92**	**1.91**	**0.68**
CV (%)	**0.47**	**2.03**	**2.45**	**8.77**	**4.11**	**3.81**

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Co-efficient of variation in percentage

Here,

- N_0 = 0 kg N ha^{-1} (Control)
- N_1 = 56 kg N ha^{-1}
- N_2 = 84 kg N ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 36 kg P_2O_5 ha^{-1}
- P_2 = 57.5 kg P_2O_5 ha^{-1}

4.6 Leaf breadth

4.6.1 Effect of nitrogen

Leaf breadth of spinach significantly varied due to various levels of nitrogen. Howsoever, the highest leaf breadth in rooftop was 7.39 cm which was recorded from the N_2 (84 kg ha^{-1} N) treatment whereas the lowest leaf breadth (4.46 cm) was observed due to the treatment of N_0 (control) treatment.

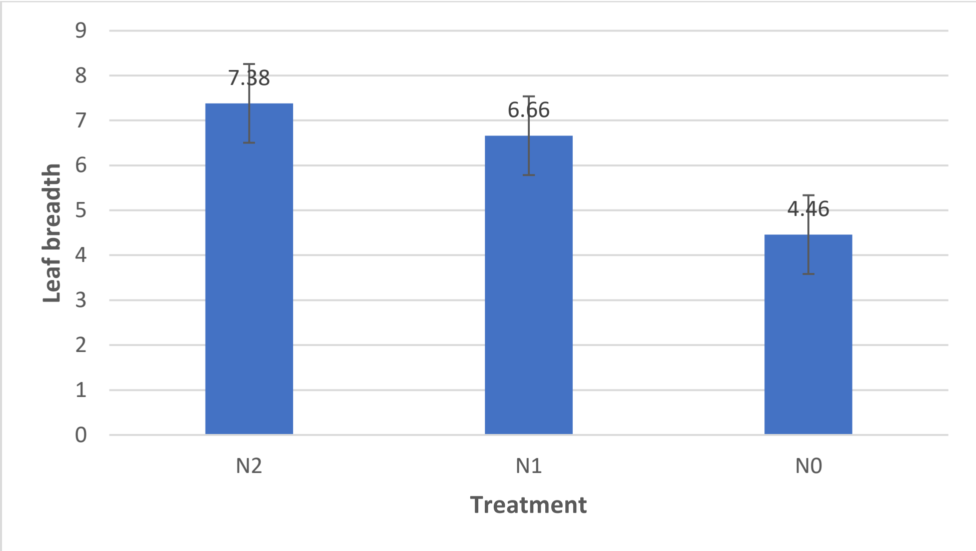


Figure 4.21 Effect of nitrogen on leaf breadth (cm) of spinach in rooftop

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

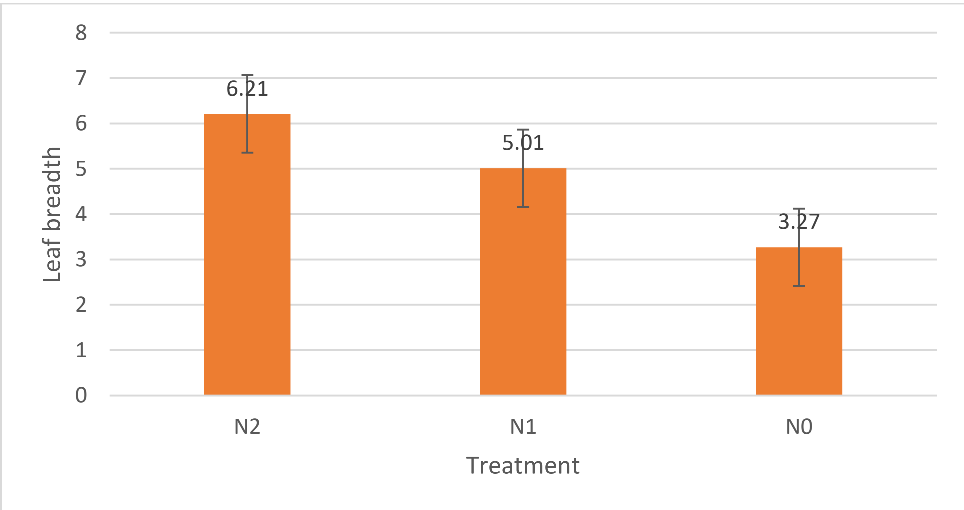


Figure 4.22 Effect of nitrogen on leaf breadth (cm) of spinach in farm

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

On the other hand, in the farm, the largest leaf breadth (6.21 cm) was also found as a result of N_2 (84 kg ha^{-1} N) nitrogen dose application (Figure 22.) and the least breadth

(3.27 cm) was observed from the application of N_0 (control) treatment. Solangi and Velo (2015).

4.6.2 Effect of phosphorus

A significant variation was recorded on leaf breadth due to the single effect of phosphorus doses. In rooftop, the maximum leaf breadth (6.93 cm) was observed owing to the application of P_2 (57.5 kg ha^{-1} P) fertilizer dose (Figure 23.). Alternatively, the minimum leaf breadth (5.17 cm) was found due to the effect of P_0 (control) treatment condition.

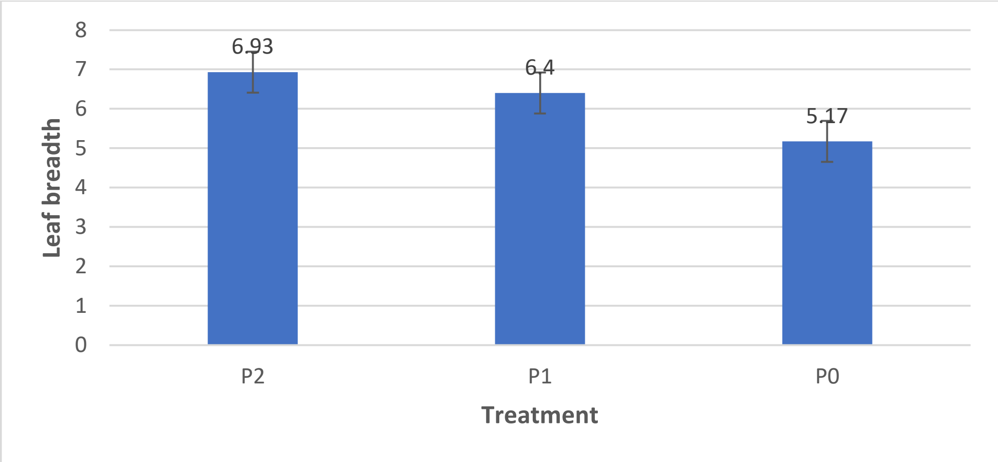


Figure 4.23 Effect of phosphorus on leaf breadth (cm) of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

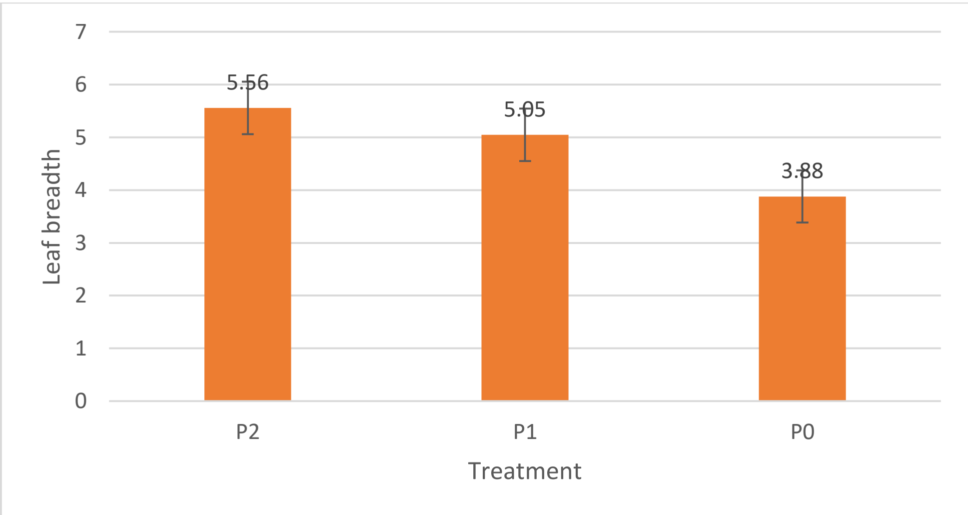


Figure 4.24 Effect of phosphorus on leaf breadth (cm) of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

Similarly, in the farm, the highest value (5.56 cm) of leaf breadth was recorded due to the use of P_2 (57.5 kg ha^{-1} P) treatment and the lowest breadth value (3.88 cm) was due to P_0 (control) treatment condition (Figure 24.).

4.6.3 Combined effect of nitrogen and phosphorus

Combined effect of nitrogen and phosphorus showed significant variation on leaf breadth of spinach. In rooftop, the highest leaf breadth (8.25 cm) was recorded due to the application of N_2P_2 (84 kg ha^{-1} N + 57.5 kg ha^{-1} P) dose that was statistically identical to N_2P_1 (84 kg ha^{-1} N + 36 kg ha^{-1} P). The lowest leaf breadth (3.31 cm) was seen in farm condition due to N_0P_0 (control) treatment. Accordingly, in the farm the maximum leaf breadth (7.22 cm) was found due to the application of N_2P_2 (84 kg ha^{-1} N + 57.5 kg ha^{-1} P) treatment that was statistically identical to N_2P_1 (84 kg ha^{-1} N + 36 kg ha^{-1} P) where the trend observed in N_1P_2 (56 kg ha^{-1} N + 57.5 kg ha^{-1} P) treatment. The lowest leaf breadth (2.27 cm) was seen due to N_0P_0 (control) treatment. In the same way, N_2P_2 (84 kg ha^{-1} N + 57.5 kg ha^{-1} P) produced the largest leaf breadth in field condition. So N_2P_2 (84 kg ha^{-1} N + 57.5 kg ha^{-1} P) treatment was the optimum dose for obtaining the higher breathed leaf in both rooftop and farm condition. Ambia et al. (2016) observe the same result also. But to compare between rooftop and farm, rooftop provided the maximum output in this study.

Table 2. Combined effect of nitrogen and phosphorus on germination %, germination index, plant height, no. of leaves, leaf length and leaf breadth of spinach in farm

Treatment	Germination %	Germination index	Plant height	No. of leaves	Leaf length	Leaf breadth
N_0P_0	68.51 g	12.93 h	6.20 h	5.81 e	7.74 g	2.27 e
N_0P_1	73.23 f	15.29 g	9.46 g	8.67 de	9.15 fg	3.58 de
N_0P_2	75.06 de	16.55 ef	11.40 f	9.88 cd	9.87 ef	3.97 d
N_1P_0	74.97 d-f	16.18 f	13.29 e	8.39 de	10.80 d-f	4.63 cd
N_1P_1	82.58 a	21.50 a	17.48 c	14.95 a	12.67 cd	4.75 cd
N_1P_2	77.32 c	19.30 c	17.83 c	13.57 ab	13.82 bc	4.91 cd
N_2P_0	73.54 ef	17.103e	15.60 d	8.98 c-e	11.11 de	5.51 bc
N_2P_1	79.56 b	20.35 b	19.32 b	12.12 a-c	14.95 ab	6.68 ab
N_2P_2	76.34 cd	18.23 d	20.94 a	10.57 b-d	15.98 a	7.22 a
$LSD_{0.05}$	**1.76**	**0.56**	**1.18**	**3.34**	**3.34**	**1.36**
CV (%)	**0.80**	**1.11**	**2.78**	**11.12**	**5.57**	**9.69**

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Co-efficient of variation in percentage

Here,

- N_0 = 0 kg N ha^{-1} (Control)
- N_1 = 56 kg N ha^{-1}
- N_2 = 84 kg N ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 36 kg P_2O_5 ha^{-1}
- P_2 = 57.5 kg P_2O_5 ha^{-1}

4.7 Shoot length

4.7.1 Effect of nitrogen

Significant variation was recorded for shoot length of spinach due to different nitrogen doses in rooftop. The highest shoot length (16.04) was found from the treatment N_2 (84 kg ha^{-1} N). On the contrary, the lowest shoot length (11.97 cm) was recorded from the control treatment N_0.

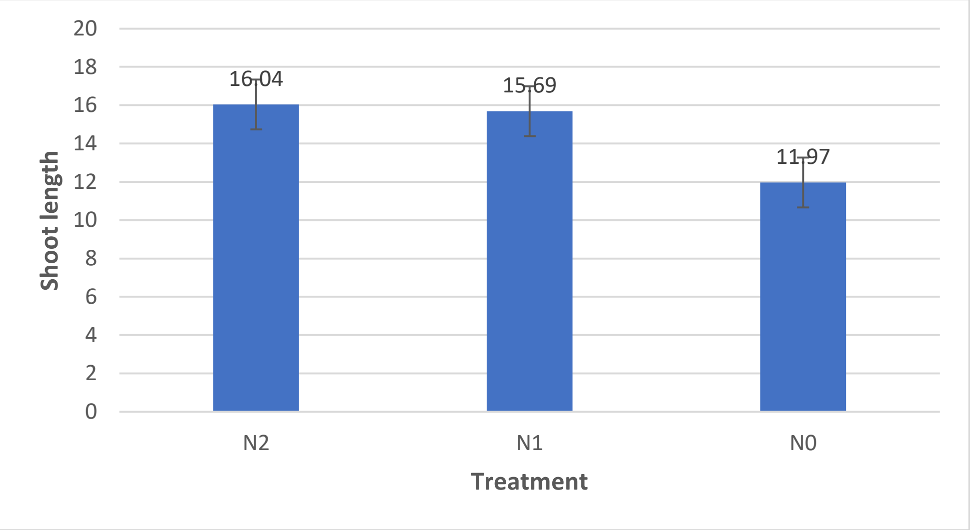


Figure 4.25 Effect of nitrogen on shoot (cm) of spinach in rooftop

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

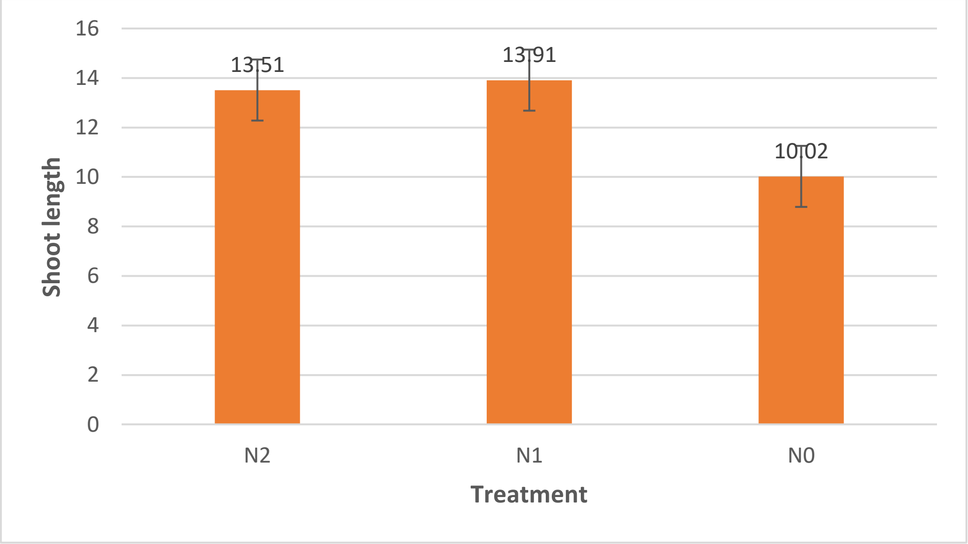


Figure 4.26 Effect of nitrogen on shoot length (cm) of spinach on farm

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

Accordingly, in the farm condition, the highest shoot length (13.91cm) was found due to N_1 (56 kg ha^{-1} N) application. And the lowest shoot length (10.02 cm) was observed from N_0 (control) treatment.

4.7.2 Effect of phosphorus

Significant variation was observed on shoot length of spinach due to the application of phosphorus at different levels. Among the different phosphorus doses P_1 (36 kg/ha P)

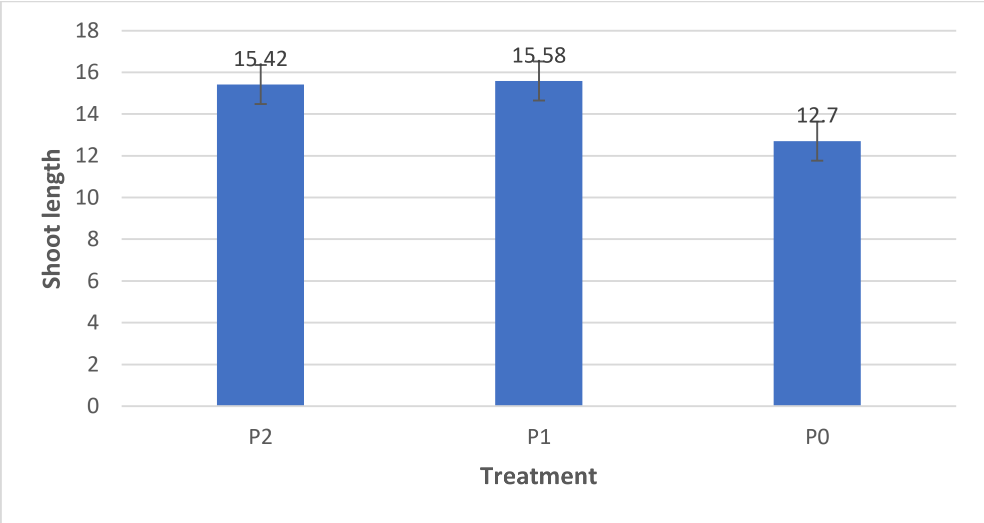


Figure 4.27 Effect of phosphorus on shoot length (cm) of spinach on rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

produced the maximum shoot length (15.58 cm) that was found in rooftop condition. It was statistically identical to P_2 (57.5 kg/ha P). The minimum shoot length (12.70 cm) was recorded from P_0 (control) treatment.

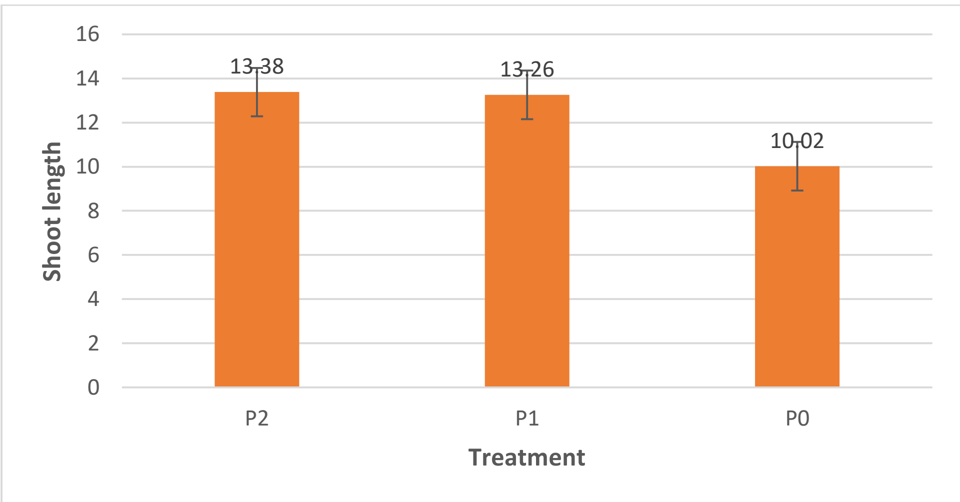


Figure 4.28 Effect of phosphorus on shoot length (cm) of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

While on the other hand, in the farm, the maximum shoot length (13.38 cm) was observed in P_2 (57.5 kg/ha P) treatment. And the least shoot length (10.02 cm) was from P_0 (control) treatment.

4.7.3 Combined effect of nitrogen and phosphorus

Statistically significant variation was observed in the shoot length of spinach because of combined application of nitrogen and phosphorus doses. The highest shoot length (18.16 cm) was gained from the N_1P_1 (56 kg ha^{-1}N + 36.8 kg/ha P) treatment in rooftop which was statistically significant. Again, the lowest shoot length (9.02 cm) was recorded due to N_0P_0 (control) treatment. Accordingly, in the farm, the highest shoot length (15.54 cm) was found owing to the application of N_1P_1 (56 kg/ha N + 36.8 kg/ha P) which is statistically significant. The smallest length (7.14 cm) was found from N_0P_0 (control) treatment.

4.8 Root length

4.8.1 Effect of nitrogen

Root length of spinach varied significantly due to the different doses of nitrogen in rooftop and farm condition. In this experiment the highest root length (13.18 cm) was found in rooftop due to the application of N_2 (84 kg ha^{-1} N) which was significant statistically. Alternatively, the lowest root length (8.95 cm) was observed on N_0 (control) treatment.

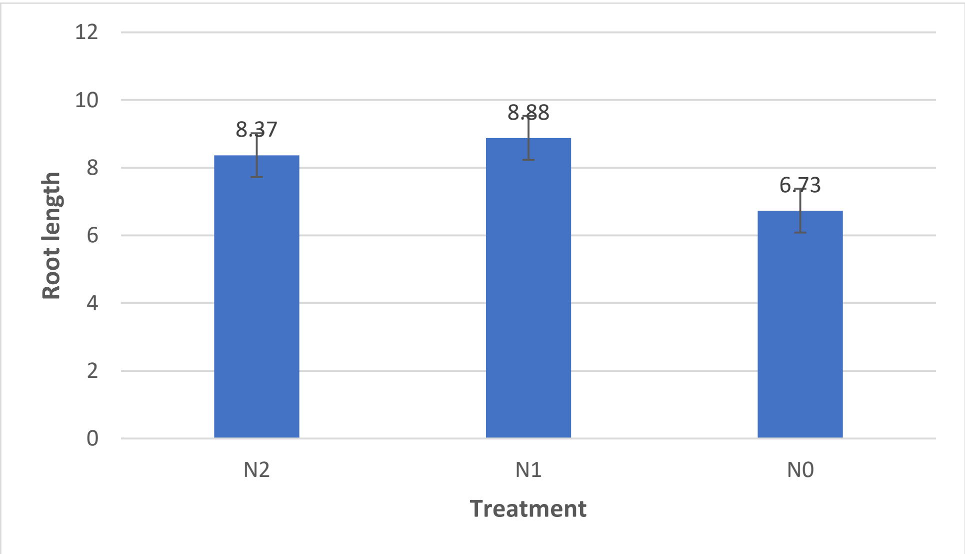


Figure 4.29 Effect of nitrogen on root length (cm) of spinach in rooftop

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

Accordingly, in the farm, the highest root length (8.61 cm) was also revealed in farm due to N_1 (56 kg/ha N) treatment and the lowest root length (6.73 cm) was from N_0 (control) treatment. These results are also supported by Schenk et al (1991).

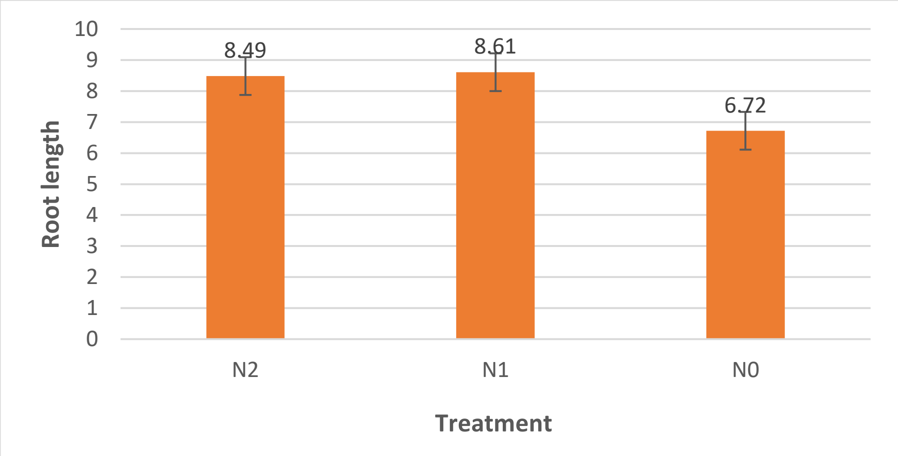


Figure 4.30 Effect of nitrogen on root length (cm) of spinach in farm

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

4.8.2 Effect of phosphorus

Significant variation was observed on root length of spinach due to different doses of phosphorus in rooftop. Among the different phosphorus doses P_2 (57.5 kg ha^{-1} P) produced the highest root length (12.59 cm) the lowest root length (8.95 cm|) was recorded from P_0 (control) treatment. While on the other hand, in farm, the maximum shoot length (8.60 cm) was observed in P_1 (36 kg/ha P) and the minimum shoot length (6.84 cm) was recorded from P_0 (control) treatment and Zaman et al. (2018) showed the same result.

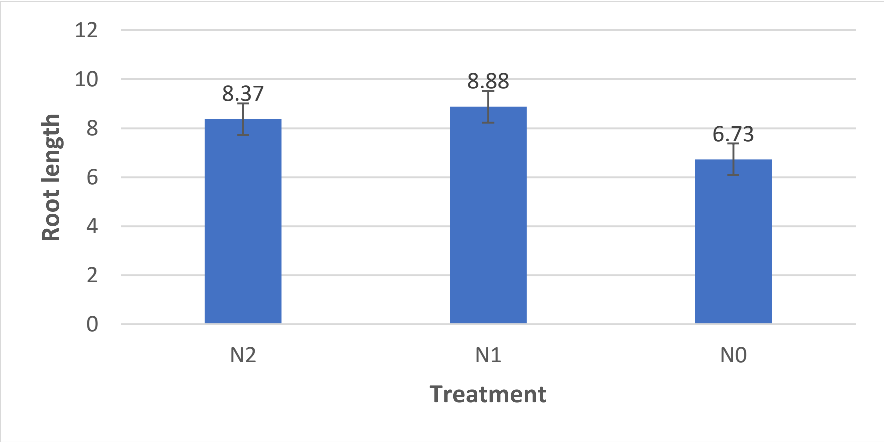


Figure 4.31 Effect of phosphorus on root length (cm) of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

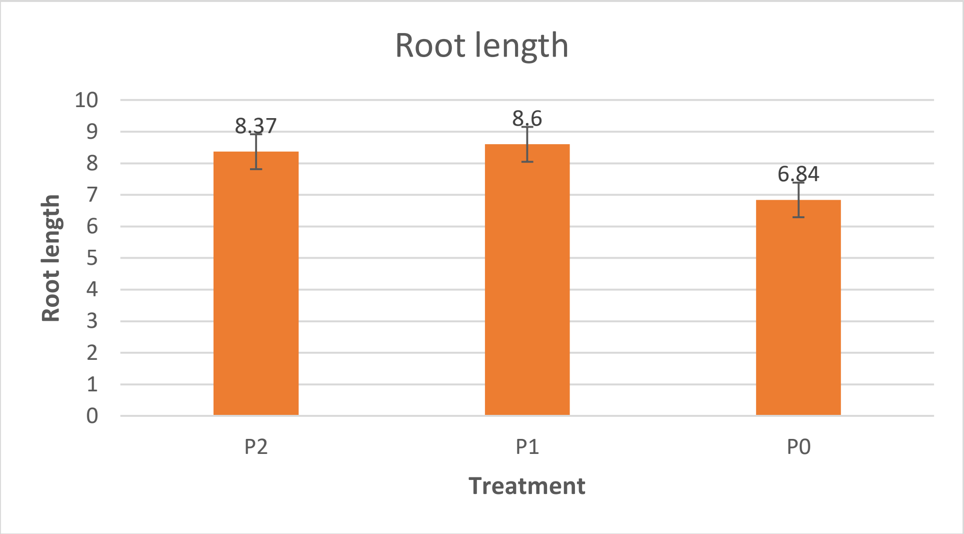


Figure 4.32 Effect of phosphorus on root length (cm) of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

4.8.3 Combined effect of nitrogen and phosphorus

A significant effect of combined nitrogen and phosphorus doses was seen in the root length of spinach. In the rooftop, the highest root length (15.63 cm) of spinach was observed due to the application of N_2P_2 (84 kg ha^{-1} N + 57.5 kg ha^{-1} P) treatment which is statistically significant with other treatments while the lowest root length (7.07 cm) was recorded due to the N_0P_0 (control) treatment. Further, in the farm, the highest root length (9.37 cm) was resulted from N_1P_1 (56 kg ha^{-1} N + 36 kg ha^{-1} P) which was statistically significant. And the least root length (4.64 cm) was found in N_0P_0 (control) treatment.

4.9 Fresh weight plant^{-1}

4.9.1 Effect of nitrogen

Fresh weight plant^{-1} of spinach significantly varied due to various levels of nitrogen. The highest fresh weight plant^{-1} (15.46 gm) of spinach was recorded from the N_1 (56 kg ha^{-1} N) treatment in rooftop whereas the lowest fresh weight plant^{-1} (11.08 gm) was observed due to the treatment of N_0 (control) treatment.

On the other hand, in the farm condition the maximum fresh weight plant^{-1} (12.45 gm) was also found as a result of N_1 (56 kg ha^{-1} N) nitrogen dose application the minimum fresh weight (9.55 gm) was recorded from N_0 (control) treatment.

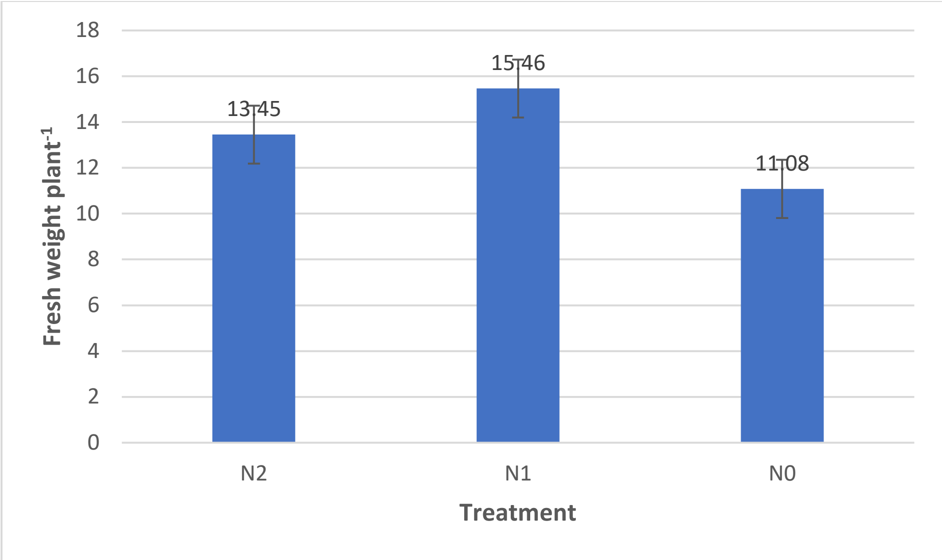


Figure 4.33 Effect of nitrogen on fresh weight plant^{-1} of spinach in rooftop

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

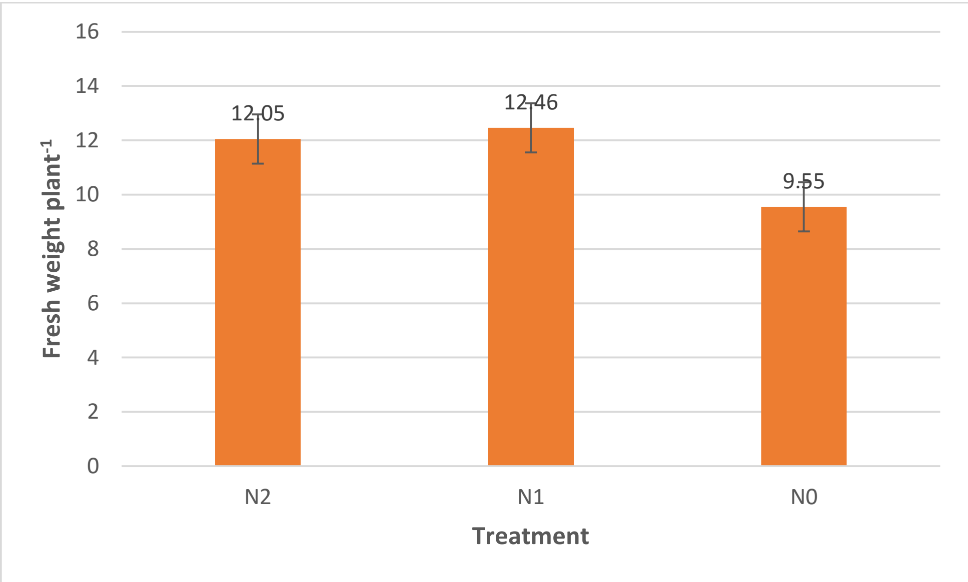


Figure 4.34 Effect of nitrogen on fresh weight plant^{-1} of spinach in farm

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

4.9.2 Effect of phosphorus

In rooftop, the maximum fresh weight plant^{-1} (14.80 gm) was observed owing to the application of P_1 (36 kg ha^{-1} P) fertilizer dose and the least fresh weight (11.81 gm) was observed in P_0 (control) treatment (Figure 4.35).

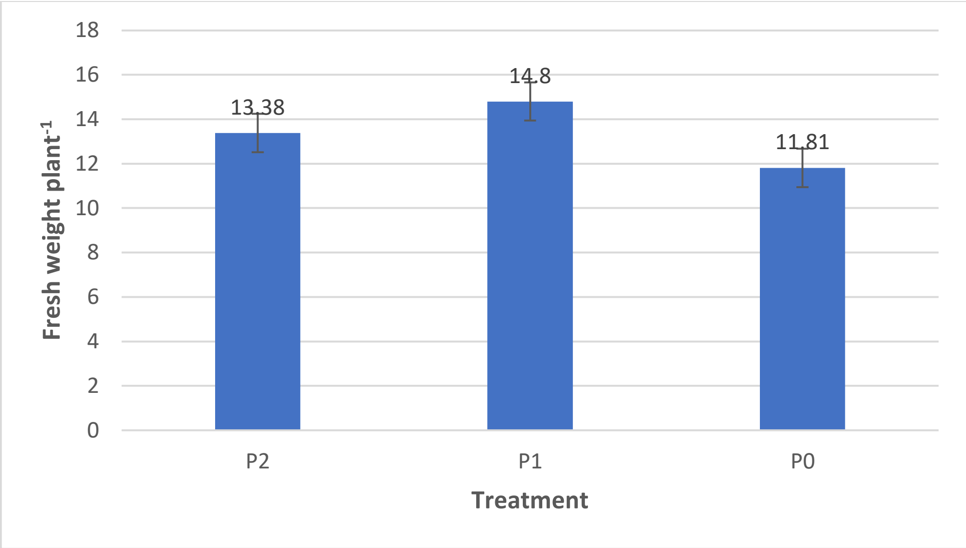


Figure 4.35 Effect of phosphorus on fresh weight plant^{-1} of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

Alternatively, in the farm, the largest fresh weight plant^{-1} (12.35 gm) was found due to the effect of P_2 (57.7 kg/ha P) treatment (Figure 4.36) which is significantly different from one another and the smallest fresh weight (9.78) was found from the P_0 (control) treatment.

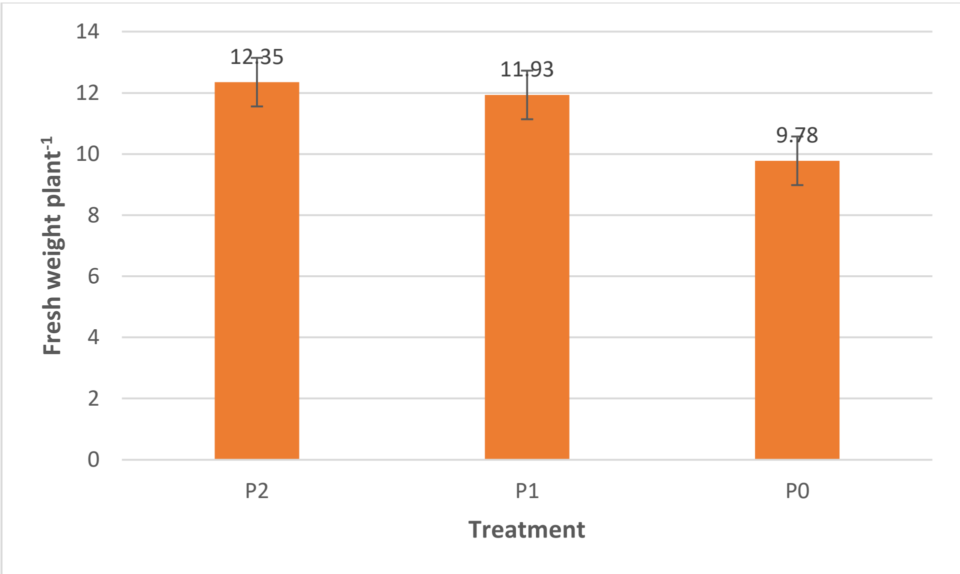


Figure 4.36 Effect of phosphorus on fresh weight plant^{-1} of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

4.9.3 Combined effect of nitrogen and phosphorus

Combined effect of nitrogen and phosphorus get found significant variation on fresh weight plant^{-1} of spinach. The highest fresh weight plant^{-1} (18.15 gm) was found in rooftop due to the application of N_1P_1 (56 kg/ha N + 36.8 kg/ha P) dose and the lowest fresh weight plant^{-1} (9.44 gm) was recoded due to N_0P_0 (control) treatment.

In the same way, in the farm, the maximum fresh weight plant^{-1} (13.57 gm) was produced due to N_1P_1 (56 kg/ha N + 36.8 kg/ha P) which was statistically identical to N_1P_2 (56 kg/ha N +57.5 kg/ha P) given 13.05 gm fresh weight. Similar result found in the study of Wahocho et al. (2016).

4.10 Dry weight plant^{-1}

4.10.1 Effect of nitrogen

The effect of nitrogen on dry weight plant^{-1} showed significant variation among the treatments. The highest dry weight plant^{-1} (1.50 gm) was found from the treatment N_1 (56 kg/ha N) which was significantly varied from other treatments. On the contrary, the lowest dry weight plant^{-1} (0.92 gm) was recorded from the control treatment N_0 (control) in the farm condition.

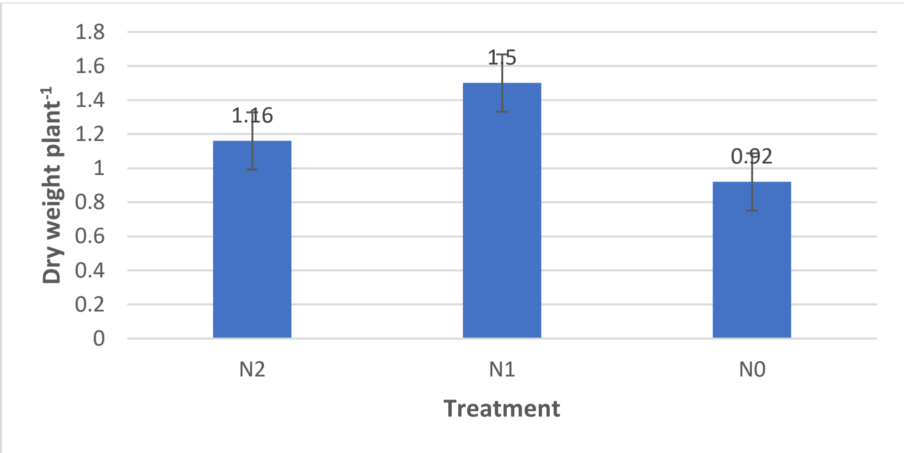


Figure 4.37 Effect of nitrogen on dry weight plant^{-1} of spinach in rooftop

Here, N_0 = 0 kg ha^{-1} N; N_1= 56 kg ha^{-1} N; N_2= 84 kg ha^{-1} N

Accordingly, in the farm condition, the highest dry weight plant^{-1} (1.01 gm) was found due to N_1 (56 kg/ha N) treatment and the lowest weight (0.75 gm) was recorded from N_0 (control) treatment application. 12So, it revealed that, N_1 (56 kg/ha N) gave the maximum dry weight plant^{-1} (Figure 4.19) in both rooftop and field condition. And it is the optimum dose for getting highest dry weight plant^{-1}.

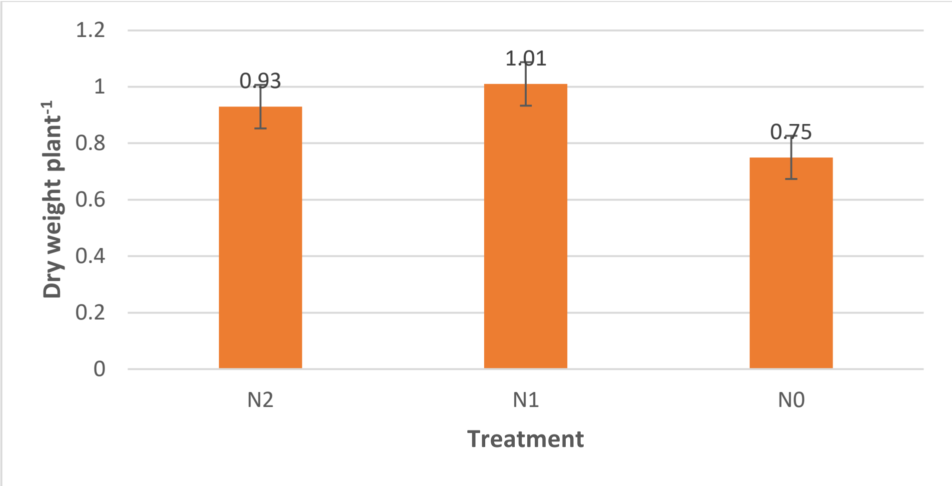


Figure 4.38 Effect of nitrogen on dry weight plant^{-1} of spinach in farm

Here, N_0 = 0 kg ha^{-1} N; N_1= 56 kg ha^{-1} N; N_2= 84 kg ha^{-1} N

4.10.2 Effect of phosphorus

The effect of phosphorus on dry weight per plant showed significant variation in rooftop. The maximum dry weight plant^{-1} (1.38 gm) was marked in rooftop due to application of P_1 (36.8 kg/ha P) and the minimum dry weight value (0.92 cm) was recorded from P_0 (control) treatment.

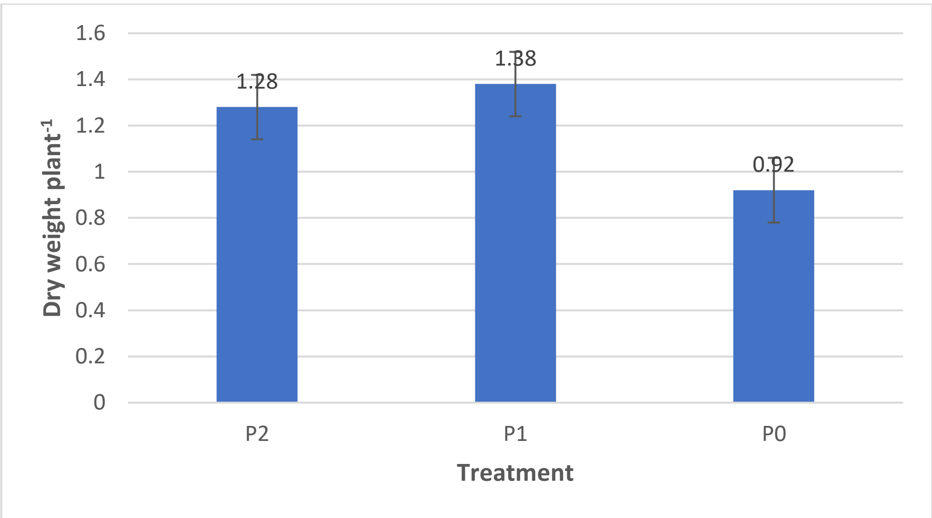


Figure 4.39 Effect of phosphorus on dry weight plant^{-1} of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36.8 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

Accordingly, in the farm, the largest dry weight plant^{-1} (0.971 gm) was found due to P_2 (36.8 kg/ha P) treatment application which is statistically identical to P_1 (36.8 kg/ha P) treatment. The minimum dry weight plant^{-1} (0.76 gm) was observed in farm condition due to effect of P_0 (control) treatment.

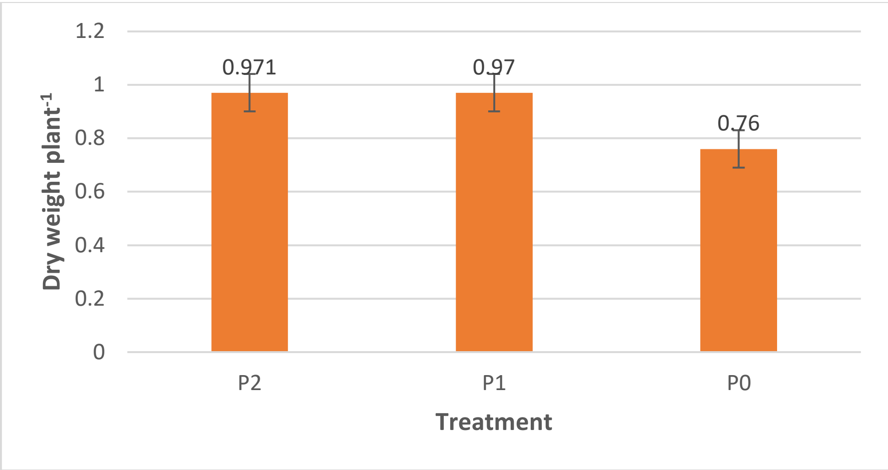


Figure 4.40 Effect of phosphorus on dry weight plant^{-1} of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36.8 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

4.10.3 Combined effect of nitrogen and phosphorus

The combination effect of nitrogen and phosphorus in spinach was observed in both rooftop and farm condition. In rooftop, the highest dry weight plant^{-1} (1.88 gm) was recorded owing to the application of N_1P_1 (56 kg/ha N + 36.8 kg/ha P) which is statistically significant. The lowest dry weight plant^{-1} (0.81 gm) was noticed at N_0P_0 (0 kg /ha N and P) control treatment combination. On the other hand, in farm, the maximum dry weight plant^{-1} (1.18 gm) was also recorded due to the application of N_1P_1 (56 kg/ha N + 36.8 kg/ha P) which is statistically significant. The lowest dry weight plant^{-1} (0.63 gm) was noticed at N_0P_0 (control) treatment.

4.11 Yield plot^{-1}

4.11.1 Effect of nitrogen

Different levels of nitrogen showed significant difference on yield of spinach per plot in rooftop (Figure 4.41). The maximum yield (1.82 kg) per plot of spinach was recorded in rooftop due to the application of N_1 (56 kg/ha) treatment and it is statistically significant; where the lowest yield (0.94 kg) was observed in N_0 (control) treatment. On the converse, in the farm, the highest yield (1.30 kg) per plot was recorded from N_1 (56 kg ha^{-1} N) treatment and minimum yield (0.72 kg) per plot was observed due to N_0 (control) treatment. Therefore, as a single factor N_1 (56 kg/ha) is the optimum nitrogen dose for highest yield of spinach, also reported by Hamid et al. (2018).

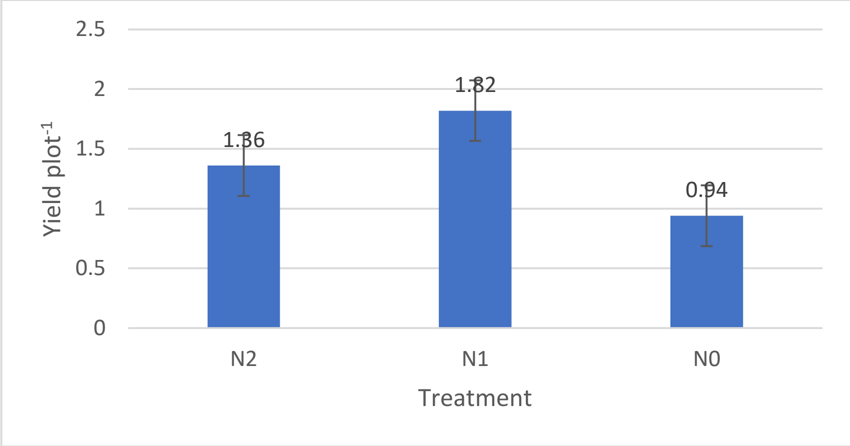
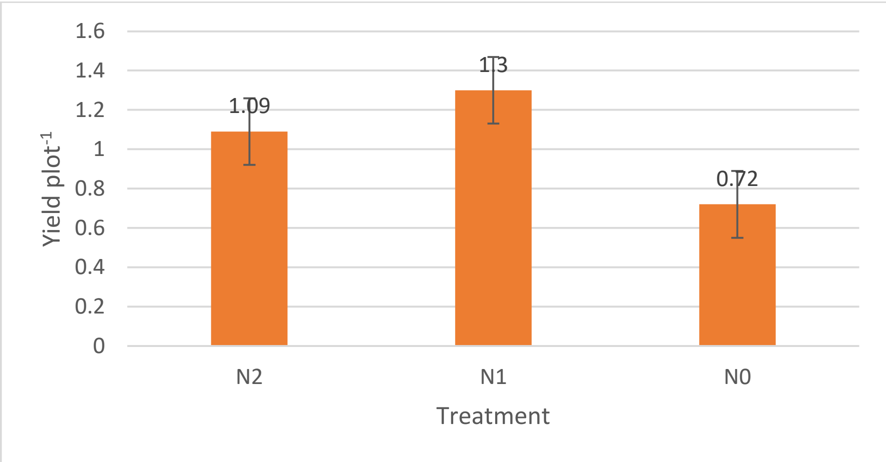


Figure 4.41 Effect of nitrogen on yield plot^{-1} of spinach in rooftop

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}



Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg N_2 ha^{-1}; N_2= 84 kg N_2 ha^{-1}

Figure 4.42 Effect of nitrogen on yield/plot of spinach of spinach in farm

4.11.2 Effect of phosphorus

Statistically significant variation was observed in the yield of spinach because of different doses of phosphorus. In rooftop, the highest yield (1.67 kg) was gained from the P_1 (36.8 kg/ha) treatment in rooftop condition. Again, the lowest yield (0.97 kg) was recorded due to P_0 (control) treatment.

In addition, in the farm, P_1 (36.8 kg/ha) caused the greatest yield (1.24 kg) of spinach. On the other hand the lowest yield per plot was due to P_0 (control) treatment. The result revealed that, with the increased use of phosphorus up to P_1 (36 kg/ha) the yield of spinach increased. Mahdi (2009) worked with spinach and lettuce and got similar output.

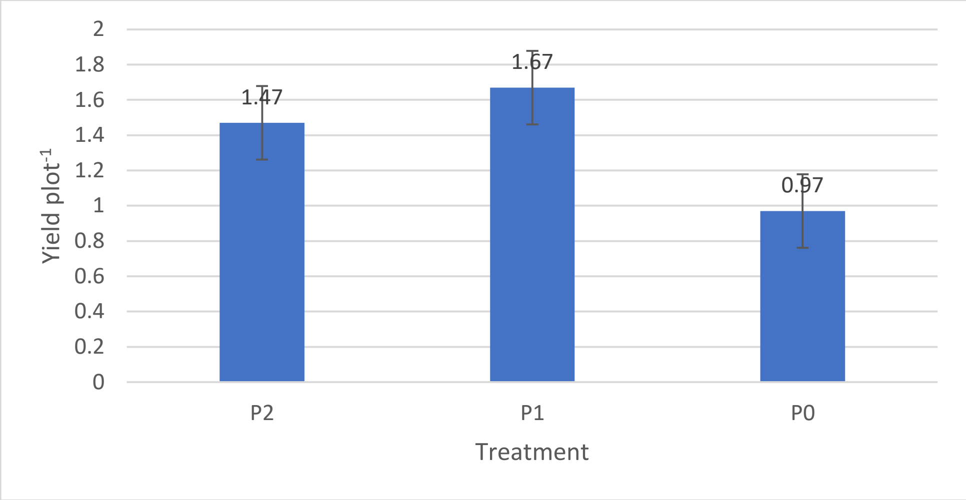


Figure 4.43 Effect of phosphorus on yield plot^{-1} of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36.8 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O

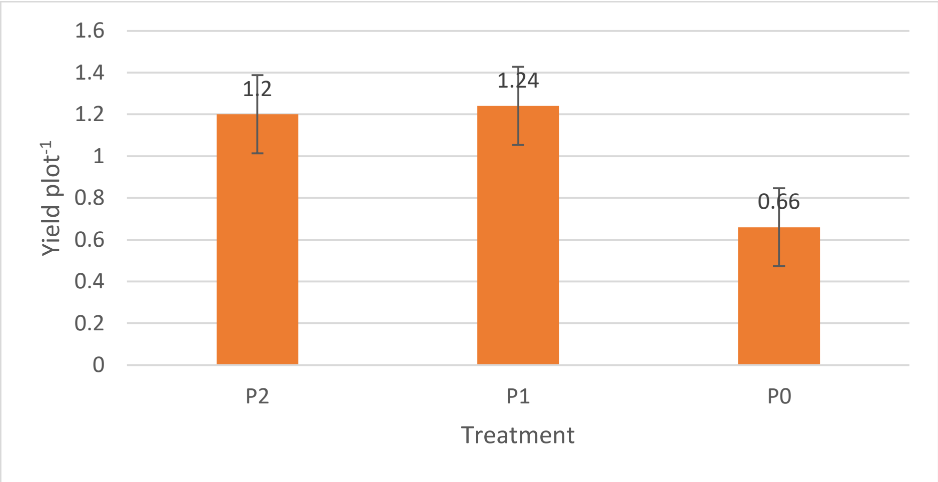


Figure 4.44 Effect of phosphorus on yield plot^{-1} of spinach in farm

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36.8 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

4.11.3 Combined effect of nitrogen and phosphorus

There is a great interactive effect of nitrogen and phosphorus in the yield of spinach. In rooftop, the highest yield (2.49 kg) of spinach was observed in rooftop due to the application of N_1P_1 (56 kg/ha N + 36.8 kg/ha P) treatment that is statistically significant and the lowest yield (0.67 kg) was recorded from the N_0P_0 (control) treatment. Again, in the farm, the highest yield of spinach (1.77 kg) was found due to the application of N_1P_1 (56 kg/ha + 36.8kg/ha) treatment, which is statistically significant. Where, the minimum yield (0.40 kg) was recorded from N_0P_0 (control) treatment. Similar result was found by Nayak and Maji, (2018) in Palak cultivation. Kalidasu et al. (2008) also observed the same in coriander.

Table 3. Combined effect of nitrogen and phosphorus on root length, shoot length, fresh weight plant^{-1}, dry weight plant^{-1}, yield plot^{-1} and yield ha^{-1} of spinach in rooftop

Treatment	Shoot length	Root length	Fresh weight plant^{-1}	Dry weight plant^{-1}	Yield plot^{-1}	Yield ha^{-1}
N_0P_0	9.023 g	7.07 f	6.20 h	0.81 f	0.67 g	7.38 g
N_0P_1	12.62 f	9.63 e	9.46 g	0.91 ef	0.97 f	10.69 f
N_0P_2	14.27 d	10.16 e	11.40 f	1.04 de	1.18 de	13.04 de
N_1P_0	13.30 e	9.85 e	13.29 e	0.96 ef	1.08 ef	11.98 e
N_1P_1	18.16 a	11.54 cd	17.48 c	1.88 a	2.49 a	27.44 a
N_1P_2	15.62 c	11.99 c	17.83 c	1.67 b	1.88 b	20.79 b
N_2P_0	15.78 c	11.16 d	15.60 d	1 de	1.17 de	12.85 de
N_2P_1	15.96 c	12.77 b	19.32 b	1.35 c	1.56 c	17.26 c
N_2P_2	16.38 b	15.63 a	20.94 a	1.14 d	1.35 d	14.88 d
$LSD_{0.05}$	**0.41**	**0.71**	**1.18**	0.16	**0.08**	**2.14**
CV (%)	**0.98**	**2.23**	**2.78**	4.87	**12.69**	**4.88**

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Co-efficient of variation in percentage

Here,

- N_0 = 0 kg N ha^{-1} (Control)
- N_1 = 56 kg N ha^{-1}
- N_2 = 84 kg N ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 36 kg P_2O_5 ha^{-1}
- P_2 = 57.5 kg P_2O_5 ha^{-1}

4.12 Yield ha^{-1}

4.12.1 Effect of nitrogen

In rooftop, yield ha^{-1} of spinach varied significantly due to nitrogen doses. The highest yield ha^{-1} of spinach (20.07 ton) was recorded in rooftop condition due to N_1 (56 kg ha^{-1} N) which is statistically significant and the lowest yield (10.37 ton) was recorded from the N_0P_0 (control) treatment. While on the other hand, in the farm, the maximum yield ha^{-1}(14.33) was observed owing to the application of N_1 (56 kg ha^{-1} N) treatment and

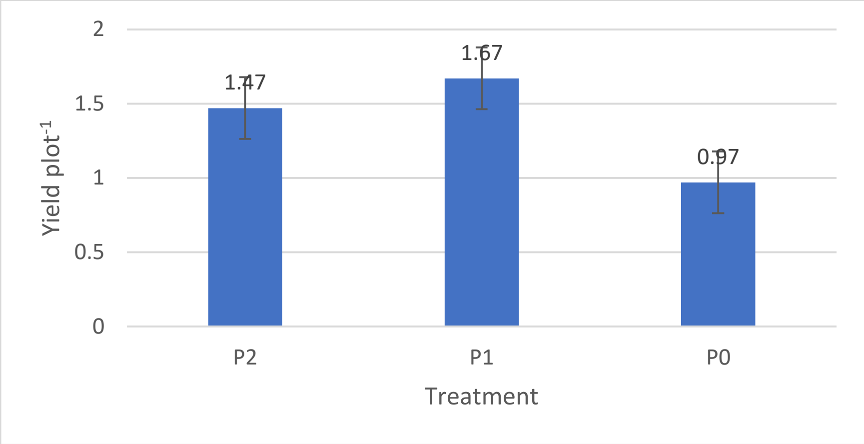


Figure 4.45 Effect of nitrogen on yield ha^{-1} of spinach in rooftop

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg ha^{-1}; N_2= 84 kg ha^{-1} N

the minimum yield (9.40 ton) was resulted from N_0 (control) treatment. Patel et al. (2021) also observed the same result in his study.

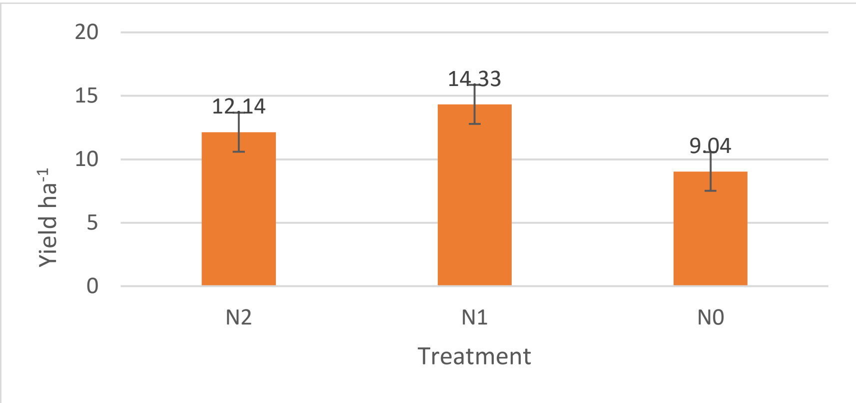


Figure 4.46 Effect of nitrogen on yield ha^{-1} of spinach in farm

Here, N_0 = 0 kg ha^{-1}; N_1= 56 kg ha^{-1}; N_2= 84 kg ha^{-1} N

4.12.2 Effect of phosphorus

Statistically significant variation was observed in the yield ha^{-1} of spinach because of different doses of phosphorus. In rooftop, the highest yield (18.46 ton ha^{-1}) of spinach was gained from the P_1 (36.8 kg ha^{-1} P) treatment which is statistically significant. Again, the lowest yield (10.73 ton was recorded due to P_0 (control) treatment. In addition, in farm condition, also P_1 (36.8 kg ha^{-1} P) caused the greatest yield (14.19 ton ha^{-1}) that is statistically identical to P_1 (36.8 kg ha^{-1} P) treatment. The lowest yield(7.99 ton) was resulted from P_0 (control) treatment. Tomar (2001) also revealed the similar result in his work.

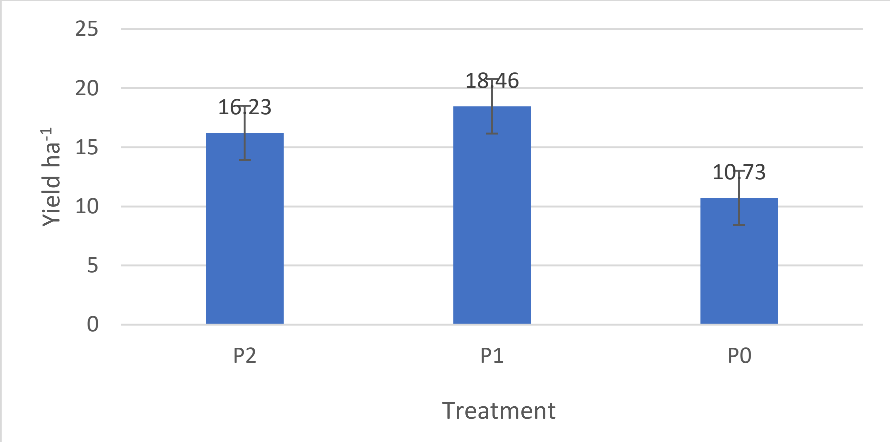


Figure 4.47 Effect of phosphorus on yield ha^{-1} of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36.8 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

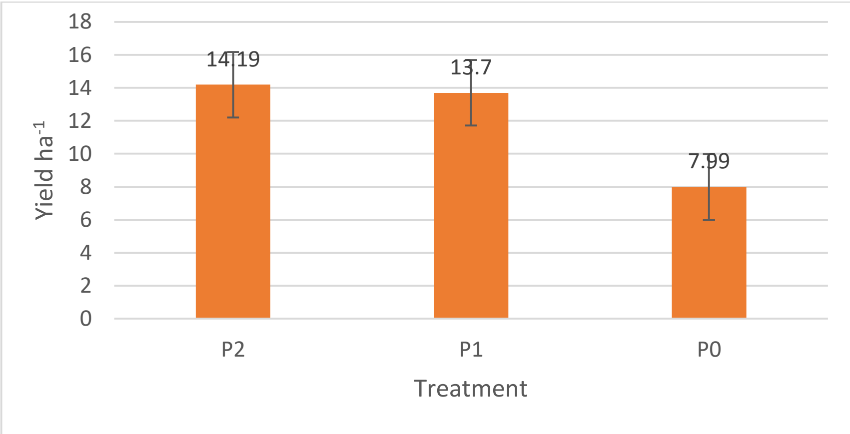


Figure 4.48 Effect of phosphorus on yield ha^{-1} of spinach in rooftop

Here, P_0 = 0 kg ha^{-1} P_2O_5; P_1= 36.8 kg ha^{-1} P_2O_5; P_2= 57.5 kg ha^{-1} P_2O_5

4.12.3 Combined effect of nitrogen and phosphorus

A great interactive effect of nitrogen and phosphorus was seen in the yield of spinach per ha. There in rooftop, the highest yield ha^{-1} (27.44 ton) of spinach was observed in rooftop due to the application of N_1P_1 (120 kg ha^{-1} N + 80 kg ha^{-1} P_2O5) treatment which is statistically significant. And the lowest yield (7.38 ton) was recorded due to the N_0P_0 (control) treatment. Moreover, N_1P_1 (120 kg ha^{-1} N + 80kg ha^{-1} P_2O5) also resulted the highest yield (19.51 ton ha^{-1}) of spinach in the farm which is statistically identical to N_1P_2 (120 kg ha^{-1} N + 57.5 kg ha^{-1} P_2O5). Here, the lowest yield was 6.42 ton ha^{-1} which was resulted from N_0P_0 (control) treatment. Solangi and Velo (2015) had also observed the same findings in their study.

Table 4. Combined effect of nitrogen and phosphorus on root length, shoot length, fresh weight plant^{-1}, dry weight plant^{-1}, yield plot^{-1}, yield ha^{-1} of spinach in farm

Treatment	Shoot length	Root length	Fresh weight plant^{-1}	Dry weight plant^{-1}	Yield plot^{-1}	Yield ha^{-1}
N_0P_0	7.14 f	4.68 f	7.12 g	0.63 g	0.40 h	6.42 f
N_0P_1	10.48 e	7.48 e	9.60 f	0.73 f	0.67 g	7.41 e
N_0P_2	12.46 cd	8.01 d	11.95 cd	0.90 d	1.09 d	8.04 de
N_1P_0	12.09 d	7.71 e	10.76 e	0.80 e	0.73	12.78 c-e
N_1P_1	15.54 a	9.37 a	13.57 a	1.18 a	1.77 a	9.51 b-d
N_1P_2	14.12 b	8.75 b	13.05 ab	1.05 b	1.4 b	14.14 b-c
N_2P_0	13.18 bc	8.15 cd	11.47 de	0.85 de	0.86 e	14.36 bc
N_2P_1	13.78 b	8.95 b	12.63 bc	0.99 c	1.28 c	15.43 ab
N_2P_2	13.57 b	8.37 c	12.05 cd	0.96 c	1.12 d	19.54 a
$LSD_{0.05}$	**1.76**	**0.25**	**0.73**	**0.05**	**0.05**	**5.08**
CV (%)	**0.80**	**1.08**	**2.22**	**2.10**	**9.85**	**14.62**

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Co-efficient of variation in percentage

Here,

- N_0 = 0 kg N ha^{-1} (Control)
- N_1 = 56 kg N ha^{-1}
- N_2 = 84 kg N ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 36 kg P_2O_5 ha^{-1}
- P_2 = 57.5 kg P_2O_5 ha^{-1}

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the rooftop of Soil Science department and the research farm of Sher-e-Bangla Agriculture University, Dhaka, Bangladesh during the rabi season (October 2020 to December 2020) to study the performance of spinach on the rooftop and farm. The experimental area belongs to the Agro-ecological zone (AEZ) of "The Madhupur Tract", AEZ-28. And the soil of the field of experiment belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment on rooftop and farm was done by RCBD design with three replications. A local variety was used in the study as at the test crop. The total number of plot was 27 and the size of the unit plot was 1.10 m^2 (1.10 m × 1 m).

Nitrogen and phosphorus were applied as per treatment and other fertilizers were applied as per recommendation. Statistics software, Statistix10 was used for processing and data analysis. The mean differences were adjusted by Least LSD test (Significance Difference) at 5% level of significance. Data on yield and different yield contributing parameters were recorded for studying the experiment. Germination percentage, germination index, plant height, number of leaf, leaf length, leaf breadth, shoot length, root length, fresh weight per plant, dry weight per plant, yield per plot and yield per hectare were significantly influenced by different levels of nitrogen and phosphorus.

The effect of nitrogen showed significant variation in the yield and yield contributing parameters of spinach. In rooftop, the maximum germination percentage (87.57) was recoded from the N_2 and the minimum germination percentage (78.05) was found from N_0 treatment. The highest and lowest germination index (21.79 and 16.63) were observed due to the N_2 and N_0 treatment respectively. The tallest and shortest plant (24.45 cm and 13.01) cm were recorded from N_2 treatment and the maximum and minimum number of leaves (21.75 and 13.78) were observed due to N_1 and N_0 respectively. The highest and lowest leaf length (24.47 cm and 11.61 cm), leaf breadth (7.38 cm and 4.46 cm), shoot length (16.04 cm and 11.97 cm), root length (13.18 cm and 8.95 cm) were measured from N_2 treatment. And the maximum and minimum fresh weight per plant (15.46 gm and 11.08 gm), dry weight per plant (1.5 gm and 0.92 gm), yield per plot (1.82 kg and 0.94 kg) and yield per hectare (20.07 ton and 10.37 ton) were found from N_1 treatment.

In the farm the highest germination percentage, (78.29) was recorded from N_1 while the lowest germination percentage (72.27) was from N_0 respectively. The highest and germination index and number of leaves (18.99 and 12.30) were marked from N_1 and the lowest values were found in N_0 treatment. Moreover, the maximum and minimum plant height, (18.62 and 9.02), leaf length (14.01 cm and 8.92 cm), and leaf breadth, (6.21 cm and 3.27 cm) were measured from N_2 and N_0 treatment respectively. The highest and lowest shoot length (13.91 cm and 10.02 cm), root length (8.61 cm and 6.72 cm), fresh weight per plant (12.46 gm and 9.55 gm), dry weight per plant (1.01 gm and 0.75 gm), yield per plot (1.3 kg and 0.72 kg) and yield per hectare (14.33 ton and 9.04 ton) were found from N_1 treatment.

The effect of phosphorus had significant influence on the growth and yield of spinach. In the rooftop, the maximum and minimum germination percentage (86.7 and 79.4) and germination index, (21.07 and 17.6) were recorded from P_1 and P_0 respectively. The tallest and shortest plant, (19.87 and 15.09), the maximum and minimum number of leaves (20.43 and 13.81) leaf length (18.07 cm and 8.92 cm), and leaf breadth, (6.93 cm and 5.17 cm), root length (12.59 cm and 8.95 cm) were observed from P_2 and P_0 treatment respectively. The highest and lowest shoot length (15.58 cm and 12.70 cm), fresh weight per plant (14.8 gm and 11.81 gm), dry weight per plant (1.38 gm and 0.92 gm), yield per plot (1.67 kg and 0.72 kg) and yield per hectare (118.46 ton and 9.04 ton) were found from N_1 and N_0 treatment respectively.

Similarly, in the farm, the maximum and minimum germination percentage (78.45 and 72.24), germination index (19.04 and 15.04), number of leaves, (11.91 and 7.73), root length, (8.37 cm and 6.84 cm), yield per plot (1.24 kg and 0.56 kg) were recorded from P_1 and P_0 treatment respectively. On the other hand, the highest and lowest plant height (16.72 cm and 11.7 cm), leaf length (13.22 cm and 9.88 cm), and leaf breadth, (5.56 cm and 3.88 cm), fresh weight per plant (12.35 gm and 9.78 gm), dry weight per plant (0.971 gm and 0.76 gm), and yield per hectare (14.19 ton and 7.99 ton) were found from P_2 and P_0 treatment respectively.

The combined effect of different application doses of nitrogen and phosphorus showed statistically significant influence on the yield and yield contributing parameters of spinach. In rooftop, the maximum and minimum germination percentage (14.8 gm and 11.81 gm), germination index (23.42 gm and 13.17 gm), number of leaves (25.42 and 10.04), shoot length (18.16 gm and 9.02 gm), fresh weight per plant (18.15 gm and 9.44

gm), dry weight per plant (1.88 gm and 0.81 gm), yield per plot (2.49 kg and 0.67 kg) and yield per hectare (27.44 ton and 7.38 ton) were found from N_1P_1 treatment. While, the tallest and shortest plant (23.86 cm and 10.76 cm), the highest and lowest leaf length (22.10 cm and 9.37 cm), leaf breadth (8.25 cm and 3.31 cm), root length (15.63 cm and 7.07 cm) were marked from the N_2P_2 and N_0P_0 treatment combination respectively.

Accordingly in the farm, the maximum germination percentage (14.8 gm and 11.81 gm), germination index (23.42 gm and 13.17 gm), number of leaves (14.95 cm and 5.81), shoot length (15.54 gm and 7.14 gm), root length (9.37 cm and 4.68 cm) fresh weight per plant (13.57 gm and 7.12 gm), dry weight per plant (1.18 gm and 0.63 gm), yield per plot (1.77 kg and 0.40 kg) and yield per hectare (19.54 ton and 6.42 ton) were found from N_1P_1 treatment. While, the highest and lowest plant height (20.94 cm and 6.20 cm), leaf length (15.98 cm and 7.74 cm), leaf breadth (7.22 cm and 2.27 cm) were observed in the N_2P_2 and N_0P_0 treatment combination respectively.

CONCLUSION

Considering the above experimental results, the following conclusions can be drawn:

1. Nitrogen had a positive effect on the growth and yield contributing characters of spinach. The application of N_1 treatment (56 kg ha^{-1} N) provide higher growth and yield of spinach in both rooftop and farm.
2. The optimum use of phosphorus had a positive effect on the morphological and yield contributing characters of spinach. Application of P_1 (36 kg ha^{-1} P) results better growth and yield of spinach in rooftop while in the farm P_2 treatment (57.5 kg ha^{-1} P) shows better output.
3. The combination effect of nitrogen and phosphorus N_1P_1 (56 kg/ha N + 36.8 kg/ha P) positively affect the yield and yield contributing characters of spinach in both rooftop and farm.

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APPENDICES

Appendix I. Characteristics of soil of experimental field

A. Morphological characteristics of the farm of experimental

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
Soil type	Deep red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Soil characteristics of experimental field of Sher-e-Bangla Agricultural University, Dhaka

- **Physical properties**

Constituents	Percent (%)
Sand	45
Silt	27
Clay	28
Textural class	Sandy clay

- **Chemical characteristics**

Properties	Value
pH	5.85
Organic carbon (%)	0.46
Organic matter (%)	0.75
Total nitrogen (%)	0.03
Available P (ppm)	20.88
Exchangeable K (me/100 g soil)	0.12
CEC	11.23

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

Appendix II. Monthly meteorological information during the period from October, 2020 to March, 2021

October, 2020 to March, 2021

Year	**Month**	**Air Temperature (0 c)**		**Relative Humidity (%)**	**Total Rainfall (mm)**
		Maximum	**Minimum**		
2021	October	34.45	24.25	61	28
	November	33.65	23.21	62	36
	December	31.23	22.23	65	54
	January	30.25	18.21	64	69
	February	29.78	17.63	63	66
	March	28.56	14.43	62	52

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix III. Some plates related to the study

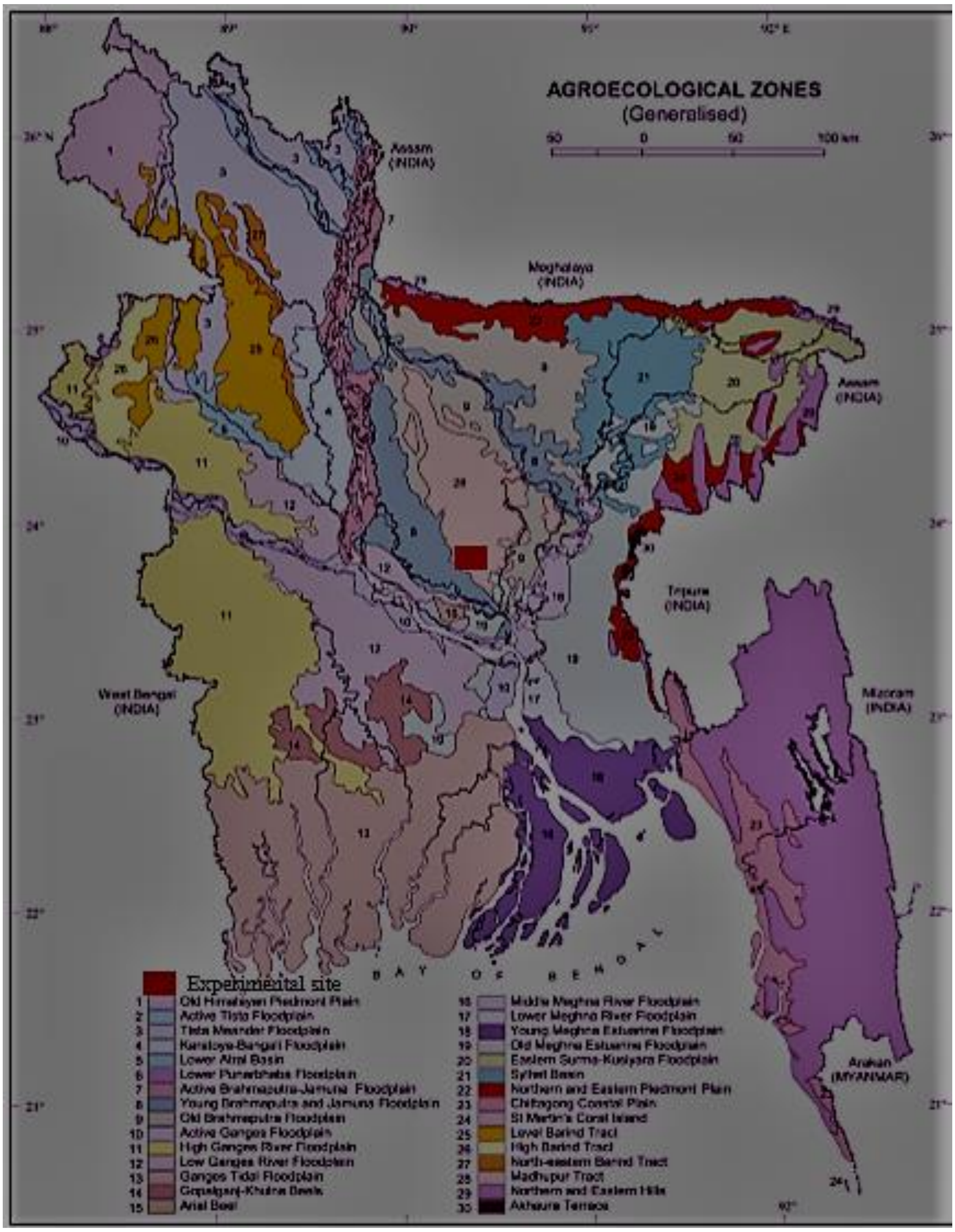

Plate 1: Experimental site

Plate 2. Rooftop land structure

Plate 3. Field land structure

Plate 4. Seed sowing in farm

Plate 5. Spinach cultivation in rooftop

Plate 6. Spinach cultivation in farm condition

Plate 3. Data collection