

EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND SEED YIELD OF SPINACH

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EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND SEED YIELD OF SPINACH

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EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND SEED YIELD OF SPINACH

ABSTRACT

The experiment was conducted at the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November, 2016 to March, 2017 to study the effect of nitrogen and phosphorus on the growth and seed yield of spinach. The experiment consisted of two factors. Factor A: Nitrogen management 4 levels; $N_0 = 0$ kg/ha $N_1 = 27.6$ kg/ha, $N_2 = 55.2$ kg/ha, $N_3 = 82.8$ kg/ha, and factor B: Phosphorus management 4 levels; $P_0 = 0$ kg/ha; $P_1 = 15.84$ kg/ha, $P_2 = 31.68$ kg/ha, $P_3 = 47.52$ kg/ha. There were 16 treatment combinations. RCBD design was followed with three replications in this experiment. The local variety was used in this experiment as the test crop. Nitrogen and phosphorus were applied as per treatment variables and other fertilizer were applied as per BARI recommendation. Data on different yield contributing characters and seed yield were recorded to find out the optimum levels of nitrogen and phosphorus for higher yield of spinach. The result indicated significant variations in all the parameters studied due to the effect of Nitrogen and Phosphorus. It was also evident that, N_3 (82.8 kg/ha) treatment influenced significantly on the morphological characters, whereas N_2 (55.2 kg/ha) treatment influenced yield contributing characters, yield and seed quality of spinach. On the other hand P_3 (P 47.52 kg/ha) treatment influenced significantly on the morphological characters, whereas P_2 (31.68 kg/ha) influenced the seed yield contributing characters and seed quality of spinach. Among the treatment combinations N_2P_2 (N 55.2 kg/ha + P 31.68 kg/ha) seemed to be more suitable for getting higher seed yield of spinach. The highest BCR (1.59) was found in the treatment of N_2P_2 , and the second highest BCR found in N_2P_3 (1.4) whereas the lowest BCR (1.01) was found N_0P_0 .

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LIST OF ACRONYMS

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
<i>et al.</i>	= And others
FAO	= Food and Agriculture Organization
g	= gram
ha ⁻¹	= Per hectare
kg	= Kilogram
LSD	= Least Significant Difference
Max	= Maximum
mg	= milligram
Min	= Minimum
MoP	= Muriate of Potash
N	= Nitrogen
No.	= Number
NPK	= Nitrogen, Phosphorus and Potassium
NS	= Not significant
SAU	= Sher-e-Bangla Agricultural University
SRDI	= Soil Resources and Development Institute
TSP	= Triple Super Phosphate
wt.	= Weight
%	= Percent
°C	= Degree Celsius

CHAPTER I

INTRODUCTION

Spinach (*Spinacia oleracea*) is a leafy green cool season vegetable which is known for its nutritive value and is considered one of the most popular vegetable in Bangladesh. Spinach belongs the member of the family Amaranthaceae, Sub-family *Chenopodioideae*. 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 common edible vegetable consumed either fresh, or after storage using preservation techniques by canning, freezing, or dehydration. It may be eaten cooked or raw, and the taste differs considerably; the high oxalate content may be reduced by steaming. It is an annual cool season flowering plant that produces a rosette of leaves during its vegetative stage (rarely biennial), growing as tall as 30 cm (1ft). Spinach may over winter in temperate regions. The leaves are alternate, simple, ovate to triangular, and variable in size: 2–30 cm (1–12 inch) long and 1–15 cm (0.4–5.9 inch) broad, with larger leaves at the base of the plant and small leaves higher on the flowering stem. The flowers are inconspicuous, yellow-green, 3–4 mm (0.1–0.2 inch) in diameter, and mature into a small, hard, dry, lumpy fruit cluster 5–10 mm (0.2–0.4 inch) across containing several seeds. By weight, spinach consists of 91.4% water, 3.6% carbs and 2.9% protein. There are 23 calories in 100 grams of spinach. Spinach seed is one of numerous vegetable crops grown for fresh market and its seed within country. The seed is produced for commercial consumption and for seed companies which supply seed throughout the country

Fertilizer application to the plants greatly affects their growth, production and plant 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 to thrive. It is an important component of many structural, genetic and metabolic compounds in plant cells. Increasing the levels of nitrogen during the vegetative stage can strengthen and support plant roots, enabling plants to take in more water and nutrients; and allows a plant to grow more rapidly and produce large amounts of succulent, green foliage, which in turn can generate higher yields, tastier vegetables, and a crop that is more resistant to pests, diseases, and other adverse conditions (Eckert *et al.*, 2010). Similarly, Phosphorus (P) is an essential nutrient both as a part of several key plant structure compounds and act as catalyst in the conversion of numerous key biochemical reactions in plants. P stimulated root development, increased stem strength, improved flower formation and seed production, more uniform and earlier crop maturity (Dinesh kumar, 2008).

Improvements in crop quality, and increased resistance to plant diseases phosphorus application is needed (Griffith *et al.*, 2010). Leafy vegetables, particularly, the spinach is highly responsive to fertilization (Cantliffe *et al.*, 1992) and oxalates which are the main indexes of the quality due to a very efficient uptake system and inefficient reductive systems (Jaworska *et al.*, 2005). Spinach requires a high level of fertility, especially nitrogen. Early spring spinach may require larger quantities of fertilizer than fall crops. The fertilizer requirements on sandy and sandy loams are 85 to 120 kg N, 75 to 85 kg P₂O₅, and 85 to 150 kg K₂O. On heavier clay soils, 75 kg ha⁻¹ of each nutrient should be adequate. Application of nitrogen and phosphorus fertilizers has essential role in the development of crop yield and quality of the produce. Farmers apply nitrogen fertilizers to their field in higher amounts without considering the need of crop.

Adequate supply of fertilizers can promote plant growth and increase crop production, but excessive and inappropriate use of chemical fertilizers causes accumulation of compounds in the edible products which have a detrimental impact on human health, cause an environmental pollution and economical losses (Wang *et al.*, 2002). El-Fadaly (Fadaly *et al.*, 2000) found that N increased the spinach yield and enhanced the accumulation of N and P in leaves. Luyen (Luyen *et al.*, 2004) concluded that spinach is a vegetable with a high potential to convert efficiently the nitrogen in urea into edible biomass with high nitrogen content. (Assiouty *et al.*, 2005) reported that application of 40 kg N + 15.0 kg P₂O₅ increased plant fresh yield by 27.2 and 42.3% and 16.3 and 10.4% in seed yield over the control in the first and second seasons, respectively. (Boroujerdnia *et al.*, 2007) achieved the highest yield with 120 kg N ha⁻¹. (Odueso *et al.*, 2011) reported that NPK 20-10-10 were observed to be better for growth and yield of spinach.

In Bangladesh spinach occupies 22000 acres with an annual production of 66000 ton (BBS, 2017). In comparison to other countries this yield is much lower. So, to increase the production it is needed to improve the crop management through improved technologies. Use of quality seeds of high yielding varieties is the foremost important way of maximizing yield per unit area. Quality seed can increase vegetable production upto 25-50% (George, 1985). Farmers saved seeds are annual of about 50 tons and are used every year, which are in most of cases of inferior in quality (Anon, 1995). To save the hard earned foreign currencies of the country and to increase spinach production there is no alternative but to increase quality seed yield per unit area.

Judicious application of both N and P in spinach is crucial for good growth and quality seed production. But a little information is available on the effect of nitrogen and

phosphorus for seed production of spinach. The present study was carried out to investigate the influence of different nitrogen and phosphorus levels on the growth and yield of spinach. Seeds with the following broad objectives.

- i. To determine the optimum level of nitrogen for maximizing the growth and seed yield of spinach,
- ii. To find out the optimum level of phosphorus on growth and seed yield of spinach, and
- iii. To identify the combined effect of nitrogen and phosphorus on growth and quality seed of spinach.

CHAPTER II

REVIEW OF LITERATURE

Spinach is a super vegetable in Bangladesh. It is loaded with tons of nutrients in a low-calorie package. Dark, leafy greens like spinach are important for skin, hair, and bone health. They also provide protein, iron, vitamins, and minerals. The possible health benefits of consuming spinach include improving blood glucose control in people with diabetes, lowering the risk of cancer, and improving bone health, as well as supplying minerals and vitamins. It can be incorporated quite easily into any diet, as it is cheap and easy to prepare. In Bangladesh there are a little study effect of nitrogen and phosphorus on the growth and seed yield of spinach. However, available literature and research findings related to the present study have been presented in this chapter.

Ambia *et al.* (2016) carried out an experiment at the farm of Department of Horticulture, BSMRAU, Salna, Gazipur-1706 on six spinach (*Beta vulgaris* var. *bengalensis* Hort) genotypes to observe their seed production potentiality and to evaluate the quality of produced seeds. Six genotypes of spinach were Shathi, BADC kopi palong, kopi palong from Northern Seed Ltd, Debgiri, BRAC kopi palong and a Local cultivar of Gazipur. Different data were collected from field as plant height, leaf number, days to 50% flowering, and days to maturity of seed. Laboratory seed testing were conducted according to ISTA rules to evaluate the quality of seeds. In case of seed yield (kg/ha), BRAC kopi palong produced the highest (1445kg) amount of seeds. The cultivar Debgiri produced lowest seed yield (915.7kg). Quality tests of seed were done based on germination test (%), Seed vigor test (Electrical conductivity), and thousand seed weight (g) of seeds. The seeds of cultivar BRAC kopi palong perform best in quality tests as highest germination percentage and lowest value in conductivity test. On the other hand, the seeds of cultivar Debgiri had the lowest quality among all the cultivars with lowest germination percentage and highest value in conductivity and tests. The relationship between the seed yield and seed quality were found to be positive, as high seed producing cultivar possessed good seed quality.

Zaman *et al.* (2018) conducted an experiment at PARC National Tea and High Value Crops Research Institute Shinkiari, Mansehra, (Pakistan) during 2016-17. The design of the experiment was Randomized Complete Block design with split plot arrangement including treatments namely T₁(00), T₂(25-50), T₃(50-60), T₄(75-70), T₅(100-80), T₆(125-90) and T₇(150-100) NP kg/ha. Data revealed that maximum day to first cut (45) was recorded in T₁ (control plot) as compared to 41 days in T₇ receiving (150-100) NP kg/ha. Maximum, plant height of (27.98 cm), leaf area (231.75cm²), leaf length (27.25cm) was recorded in T₇ (150-100) NP kg/ha followed by plant height of (26.10 cm), leaf area(181.75cm²), leaf length (25.00cm) was recorded in T₆ plot provided (125-90 NP kg/ha) as compared to 15.98 cm plant height, leaf area (87.5cm²) and leaf length (16cm) in T₁(without NP). Maximum no. of leaves was recorded in Treatment T₆ (21) followed by T₅ and T₇ where 19 number of leaves/plant recorded. However, lowest no. of leaves (8) obtained in case of T₁ (without NP). Maximum fresh yield of 23.15 tons/ha was recorded in T₇, followed by 22.32 tons/ha in T₆ and 16.80 tons/ha in T₅ while T₁ (Without NP fertilizer) produced the lowest spinach fresh leaves yield of 4.844 tons /ha. Nitrogen and phosphorus @ 125-90 and 150-100 NP kg/ha proved to be optimum dose for getting maximum production from spinach.

Ahammed *et al.* (2016) conducted an experiment at the Horticulture Research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) during March 2008 to July 2008 to determine the optimum rate of N, P and K for better stem growth and seed yield of amaranth. The amaranth genotype SA040 was used as test crop for the study. The experiment was laid out in randomized complete block design with three replications having five levels of N (0, 50, 100, 150 and 200 kg ha⁻¹), five levels of P (0, 25, 50, 75 and 100 kg ha⁻¹) and five levels of K (0, 25, 50, 75 and 100 kg ha⁻¹). The highest stem yield (105.51 t ha⁻¹), was yield attributes, were found with the application of 150 kg N, 25 kg P and 50 kg K ha⁻¹. Maximum seed yield (4.66 t ha⁻¹) was found by the application of 100 kg N, 50 kg P and 50 kg K ha⁻¹. The response regression curve suggest that 165.5 kg N, 64.4 kg P and 52.04 kg K ha⁻¹ and 168 kg N, 55 kg P, 58.5 kg K ha⁻¹ are optimum for higher stem and seed yield of amaranth, respectively. A positive linear relationship between stem weight /plant and stem diameter, and a negative linear relationship between dry matter content with the stem yield were observed.

Rop *et al.* (2012) observed that *Basella alba* is highly nutritious compared to most indigenous leafy vegetables coupled with medicinal benefits. Sadly, this vegetable is not included in the top 10 priority indigenous African vegetables for research in Kenya. *Basella alba* has the potential of alleviating malnutrition among certain vulnerable groups in the rural poor communities in Kenya, but there is lack of appropriate agronomic practices particularly correct nitrogen levels for increased high quality leaf yield. The aim of the current study was to evaluate the response of inorganic nitrogen fertilizer on growth, yield and quality of *Basella alba*. This study was conducted in the glasshouse at Larenstein International Agricultural College (LIAC), Deventer, Netherlands. Five (0 kg N ha⁻¹, 30 kg N ha⁻¹, 60 kg N ha⁻¹, 90 kg N ha⁻¹ and 120 kg N ha⁻¹) levels of nitrogen were applied. Treatments were arranged in a completely randomized design (CRD) and replicated five times. Data collected was analysed for variance using SAS programme package. Applying 90 kg N ha⁻¹ or 120 kg N ha⁻¹ at 6 weeks after transplanting (WAT) increased stem length, number of leaves, leaf area, leaf weight and maintained green leaf colour. However, the effects of the nitrogen levels on number of racemes were not apparent. Interestingly only 120 kg N ha⁻¹ increased harvest index in *Basella alba* at 6 WAT. Our results suggest that either 90 kg N ha⁻¹ or 120 kg N ha⁻¹ can be used to enhance quality and leaf yield in *Basella alba*. Therefore, we recommend application of 90 kg N ha⁻¹ by resource poor farmers in the production of *Basella alba* for improved food security and wealth creation.

Zaki *et al.* (2015) conducted an experimental farm of the faculty of agriculture Moshtohor Quliubia governorate during the winter seasons of 2013/2014 and 2014/2015 to investigate 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 5ml/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. Obtained results showed that increasing nitrogen levels up to the highest used levels (50 or 75 kgN/fed) reflected the highest values of number of female plants, sex ratio (M/F), produced seed yield either per plants, or feddan, seed index (weight of 100 seeds), germination percentage and germination rate. In addition, treating the plants two times during the growing season with all tested growth stimulants enhanced positively the number of female plants and sex ratio towards femalenss and improved the produced seed yield

and its quality (seed index, germination percentage and germination rate). Therefore, it could be recommended to add nitrogen fertilizer at 50 or 75 kg N/fed combined with soil addition of biogen at 800g/fed to get the highest seed yield with best quality.

Solangi *et al.* (2015) evaluated the effect of different levels of nitrogen and phosphorus fertilizers on the growth and yield of spinach, experiment was laid out in a three replicated RCB Design testing seven treatments such as: T_1 =Control, T_2 =25-50 kg ha⁻¹, T_3 =50-60 kg ha⁻¹, T_4 =75-70 kg ha⁻¹, T_5 =100-80 kg ha⁻¹, T_6 =125-90 kg ha⁻¹ and T_7 =150-100 kg ha⁻¹. The results revealed that the significant ($P<0.05$) effect of various N-P levels on plant height, leaves plant⁻¹, fresh weight of leaves plant⁻¹, days to 1st cut, leaf length, yield plot⁻¹ and yield ha⁻¹. The highest N-P level of 150-100 kg ha⁻¹ resulted in 29.79 cm plant height, 33.67 leaves plant⁻¹, 220.67 g fresh weight of leaves plant⁻¹, took 19.00 days to 1st cut, 25.92 cm leaf length, 9.27 kg yield plot⁻¹ and 8826.67 kg yield ha⁻¹. Crop fertilized with N-P @ 125-90 kg ha⁻¹ produced 28.12 cm plant height, 34.00 leaves plant⁻¹, 220.10 g fresh weight of leaves plant⁻¹, took 18.00 days to 1st cut, 24.47 cm leaf length, 9.25 kg yield plot⁻¹ and 8804.00 kg yield ha⁻¹; while under 100-80 kg ha⁻¹ there was 24.69 cm plant height, 30.33 leaves plant⁻¹, 179.44 g fresh weight of leaves plant⁻¹, took 20.00 days to 1st cut, 21.48 cm leaf length, 7.54 kg yield plot⁻¹ and 7177.60 kg yield ha⁻¹. Spinach receiving lower N-P rates (75-70, 50-60, 25-50 kg ha⁻¹) and control resulted 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 showed similarity ($P>0.05$) under N-P levels of 150-100 kg and 125-90 kg ha⁻¹ and assumed that N-P application beyond 125-90 kg ha⁻¹ was uneconomical; and 125-90 kg ha⁻¹ was considered as an optimum N-P level.

Assiouty *et al.* (2005) carried out an experiment during two successive winter seasons (2002-2003 & 2003-2004) at Kaha Vegetable Farm, Horticulture Research Institute, ARC. It studies the effect of bio-fertilizers (*Azotobacter chroococcum* & phosphorein) singly or in combination with different rates of N and P chemical fertilizers on growth, yield, sex ratio, seeds (yield & quality) of spinach plants cv. Dokki. Results showed that seed inoculation with 300 g phosphorein inoculum/ fed. in the presence of 40 kg N/ fed (100% of the recommended N dose) + 15.0 or 7.5 kg/ fed (66.7 or 33% of the recommended dose of P₂O₅) as well as seed inoculation with 300 g *Azotobacter* inoculum in the presence of the full dose of P₂O₅ (22.5 kg P₂O₅/ fed.) + 50% of the full

dose of N (20 kg/ fed) gave the highest favorable effect on growth, yield, sex ratio, and higher seed yield with the best quality compared with control treatment (40 kg N + 22.5 kg P₂O₅ fed.). Seeds inoculation with bio-fertilizers (Azotobacter & phosphorein) enriched the plant rhizosphere with such microorganisms compared with un-inoculated control. Application of 40 kg N + 15.0 kg P₂O₅ + 300 g phosphorein increased plant fresh yield by 27.2 and 42.3% and 16.3 and 10.4% in seed yield over the control in the first and second seasons, respectively.

Shormin *et al.* (2018) were carried to study 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⁻¹ from urea, NH₄NO₃, NH₄Cl, (NH₄)₂SO₄, NaNO₃. The treatments were arranged in a randomized complete block design with three replications. The results of the study indicated that addition of nitrogen from various inorganic fertilizers significantly affected the number of leaves plant⁻¹, plant height, fresh and dry weight of leaves, stem and root. The maximum number of leaves plant⁻¹ and the highest plant height at 45 and 60 days after sowing (DAS) were obtained with supplying nitrogen from urea whereas at 30 DAS these values were obtained with nitrogen from NaNO₃. At all the growth stages, the lowest number of leaves plant⁻¹ and the lowest plant height were observed with control treatment. The highest fresh and dry weight of leaves, stem and root were found with nitrogen application from urea and the lowest values of these were found with control treatment. The results suggested generally that applying nitrogen from urea was the most effective compared to other sources of nitrogen on the growth and yield characters of Indian spinach.

Myers (1998) proposed on seed amaranth (*Amaranthus* spp.) is an ancient crop that is now receiving fresh attention. This study evaluated the effect of N fertilizer on amaranth grain yield, yield components, and growth and development. The study was carried out in three Missouri environments with five levels of N fertilizer (NH₄NO₃ broadcast preplant at 0, 45, 90, 135, and 180 kg N ha⁻¹) and three cultivars (Plainsman, D136, and K266). Averaged across cultivars and environments, N fertilizer at the top rate of 180 kg N ha⁻¹ produced a yield increase of 42% relative to plots receiving no N fertilizer. Yields were consistently improved by additions of 45 and 90 kg N ha⁻¹, but additional N fertilizer above the 90 kg N ha⁻¹ rate increased yield in only one out of three environments. At the one site where yield components were evaluated, yield

differences were due to increases in seed number per plant, since seed weight and plant population at maturity were unaffected by N fertilizer rate. Plots with high rates of N fertilizer had later maturity, as indicated by time of flowering and seed moisture. Average moisture of seeds harvested from plots receiving 180 kg N ha⁻¹ was 320 g kg⁻¹, while seeds from plots with no N fertilizer had 240 g kg⁻¹ moisture. Comparing the same high-N treatment to the control with no N showed height increases of 14, 24, and 44% in the three environments. Although amaranth yield is responsive to N fertilization, high rates of N fertilization can negatively affect seed harvest in terms of excessive plant height, increased lodging, and delayed crop maturity.

Wahocho *et al.* (2016) evaluated that Nitrogen is one of the most critical nutrients for plant growth and development. Hence its optimum use in crop cultivation is a prerequisite for sustainability of Agriculture. A field trial was conducted during the growing season of 2014-15 to evaluate the response of nitrogen (N) on the growth and productivity of spinach. The study was designed according to randomized complete block design with three replicates. Five N doses viz; 0, 35, 70, 105 and 140 kg ha⁻¹ were applied to evaluate the growth and yield parameters of spinach. The results revealed that various N levels had significant ($P < 0.05$) effects on all the growth and yield contributing traits of spinach. The crop treated with the highest N level of 140 kg ha⁻¹ showed positive effects on all the investigated parameters. In contrast, there was a significant reduction in all the growth and yield related attributes in control plants, where N was not applied. The crop fertilized with highest N level (140 kg ha⁻¹) showed maximum plant height (26.50 cm), took less days for the first cutting of the crop (21.633), produced increased number of leaves plant⁻¹ (17.167), and leaf length (23.767 cm), highest fresh weight of leaves (25.550 g), and maximum yield plot⁻¹ (11.700 kg) and yield ha⁻¹ (9777.8 kg). However, a non-significant difference ($P > 0.05$) was observed between N levels 140 kg ha⁻¹ and 105 kg ha⁻¹ for all the investigated growth and yield related parameters. Hence, 105 kg ha⁻¹ was considered an optimum level for better growth and production of spinach.

Richard *et al.* (2011) conducted that protein malnutrition is a major cause of morbidity and mortality in developing countries where the cost and availability of animal protein remain prohibitive. Seed amaranth (*Amaranthus caudatus* L) has the potential to substitute expensive animal protein. Its production and consumption is however low in Kenya. Nitrogen is a key limiting element in seed amaranth production. This study

investigated the effects of different rates of inorganic nitrogen and cattle manure on the growth and yield of grain amaranth over a period of two years. Inorganic fertilizer at the rate of 100 kg N/ha significantly delayed flowering. Seed yield showed a linear response to inorganic and organic N application. Regression analysis projected the optimum inorganic fertilizer and manure application rates of 87.5 kg N/ha and 9 t/ha respectively with yield of 1.84 t/ha. The highest profitability was achieved at the optimum manure and fertilizer rates. The projected manure and inorganic fertilize rates may however not be affordable by the small-scale farmers. Thus a follow-up study to test the combined effect of inorganic and organic fertilizers is recommended.

Abgad *et al.* (2015) investigated on effect of P and K levels on yield and quality of spinach was carried out 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 (P_0), 10 kg (P_1), 20 kg (P_2) and potassium viz., 0 kg (K_0), 15 kg (K_1), 30 kg (K_2). The experiment was laid out in RCBD with three replications. The experimental soil was slightly calcareous, alkaline in reaction and clayey in texture. It was sufficient in potassium and low in organic carbon, available nitrogen and phosphorus. Among the quality parameters, the maximum leaf area (112.03 cm² and 111.84 cm²), protein (10.97% and 11.21%), chlorophyll (1.93 and 1.98 mg g⁻¹), and ascorbic acid content (71.48 mg and 71.54 mg) were found in treatment which received phosphorus @ 20 kg ha⁻¹ and potassium @ 30 kg ha⁻¹, respectively at harvesting.

Marvi and Mahdi (2009) observed that Lettuce (*Lactuca sativa*) and Spinach (*Spinacea oleracea*) were used as a case study vegetable crop to compare models for estimating Fertilizer Use Efficiency based on nitrogen and phosphorous fertilizer and nitrate concentration. Field studies were conducted to measure yield, nitrate, fertilizer use efficiency, response to applied Nitrogen and phosphorous fertilizer in two plants. The area was located between 25° 21 E longitude and 51°38 N latitude in the North of Varamin city, (Tehran province, Iran) in the alluvial plain of Varamin. Soils family were fine, mixed, active, thermic, typic haplocambids based on soil taxonomic system (1999). Plants were received five rates of Nitrogen (0, 150, 200, 250 and 300 kg N ha⁻¹) as a urea in split applications and five rates of Phosphorous (0.0, 37.5, 50, 62.5 and 75 kg P₂O₅ ha⁻¹) as a triple super phosphate (TSP). Data for plant fresh mass (ton ha⁻¹) and Nitrate uptake (nitrate) (mg kg⁻¹) were recorded. Models were described the data for cultivar quite well, with correlation coefficients of 0.80 and above. All of models

for Lettuce and Spinach production were compared graphically and analytically. The model coefficients were then used to make improved estimates of fertilizer recommendations for field production of Lettuce and Spinach in Iran. Results showed that most suitable mode for prediction of fertilizer use efficiency was $Y=16.77+0.0522N+0.0576P$ ($R_2=0.81$) in lettuce (N: kg and P: kg P_2O_5 ha⁻¹ in lettuce. Based on we could predicted fertilizer use efficiency that help to agricultural practice management until nitrogen and phosphorous fertilizers used suitable and avoid leaching of nitrogen in lettuce culture.

Kintimo *et al.* (2006) conducted that phosphorus (P) is expensive to the Sub- Saharan African resource- poor farmers; therefore, there is a need for investigation of locally available alternative P sources to enhance farmers' productivity. Optimum P rate was determined during the early and late rains of 1999. Using the optimum P rate, influences of three P sources ogun rock phosphate (ORP), sokoto rock phosphate (SRP), single super phosphate (SSP) and a control were evaluated on amaranth varieties in 2000 at the vegetable research plots of the National Horticultural Research Institute (NIHORT), Ibadan, Nigeria. In 1999, three seed amaranth varieties (NH84/452, NH84/445, and NH84/493) were combined factorially with four P rates: 0, 30, 60, and 90 kgP/ha. Application of P significantly increased plant height, number of branches, leaf dry weight, and seed yield per plant. Significant increase in seed yield was in the order NH/493>NH/445>NH/452. Optimum P rates across varieties for leaf dry- matter yield was established at 51.8 kg P/ha and for seed yield production was 48.4 kg P/ha. The experiment in the following year, 2000, was a RCB design using the optimum P determined in 1999. Three P sources (ORP, SRP, SSP) and a control were factorially combined with the three amaranth varieties. In the 2000 experiment, seed yield was 21.3, 16.9, 16.0, and 7.8 g/plant, respectively, for SSP, SRP, ORP, and the control. Growth was ranked in the order SSP>ORP>SRP>control. It was concluded for fertilizer recommendation purposes that 50 kg P/ha is optimum for grain amaranth production and that amaranth productivity indices could be alternatively improved with indigenous P sources.

Kaminishi *et al.* (2006) observed that reduction of nitrate and oxalate content in spinach (*Spinacia oleracea* L.). The primary objectives of this study were 1) to determine the seasonal change in nitrate and oxalate concentrations 2) to elucidate the relationship between growth rate and concentration of nitrate and oxalate in spinach. In a replicated

field experiment in Hiratsuka, Japan, the authors grew 182 cultivars of spinach over four growing seasons (winter, spring, summer, and fall) under the nitrogen application rate of 100 kg N ha⁻¹. Reduction of nitrate and oxalate content in spinach (*Spinacia oleracea* L.) has become the major concern in terms of their toxicity to human health. The primary objectives of this study were 1) to determine the seasonal change in nitrate and oxalate concentrations and 2) to elucidate the relationship between growth rate and concentration of nitrate and oxalate in spinach. In a replicated field experiment in Hiratsuka, Japan, the authors grew 182 cultivars of spinach over four growing seasons (winter, spring, summer, and fall) under the nitrogen application rate of 100 kg N ha⁻¹. Relative nitrate concentration showed a moderate negative correlation with relative days required for harvest ($r = 0.411$, $P < 0.001$), whereas relative oxalate concentration showed a strong positive correlation with relative days required for harvest ($r = 0.566$, $P < 0.001$). Accordingly, a moderate negative correlation ($r = 0.325$, $P < 0.001$) was detected between nitrate and oxalate concentrations. Moreover, fast-growing cultivars contained higher nitrate and lower oxalate, whereas slow-growing cultivars contained lower nitrate and higher oxalate.

Stagnari *et al.* (2007) were carried out 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 features of processing spinach. Experiment 1, as treatments, included spinach genotypes and N forms CO(NH₂)₂; Agricote; NH₄NO₃; experiment 2 included three N forms (Ca(NO₃)₂; (NH₄)₂SO₄; NH₄NO₃) applied at rates of 0, 75, 150, 200 kg N ha⁻¹. This research work confirmed differences among spinach genotypes in terms of efficiency in N use and oxalate and nitrate accumulation. Spinach accumulated much more nitrate in petioles and much more oxalate in blades indicating that nitrate and oxalate might play a counter role to each other. Fertilizers containing N under forms not readily available to the crop, i.e. Agricote, CO(NH₂)₂ and (NH₄)₂SO₄, increased nitrate and oxalate accumulations less than fast N-release fertilizers, but their effect on yield was limited. Highest yield with contents of nitrate and oxalate lower than the limits imposed to avoid health problems, were achieved with Ca(NO₃)₂, at rates of 130 and 150 kg N ha⁻¹ NH₄NO₃. A good accumulation in some important macronutrients for the human diet such as Ca, K and P were allowed by application of Ca(NO₃)₂, at rates of 130 and 150 kg N ha⁻¹ NH₄NO₃. The glucose, fructose, sucrose

as well as Mg accumulation were not alterable in spinach with nitrogen fertilization or with genotype choice.

Ali *et al.* (2013) were carried out during the two seasons of 2010 and 2011 at the experimental station of National Research Centre, Beheira Governorate (North of Egypt) to investigate the effect of bio and chemical fertilizer (NPK) at different rates for influence plant growth, total yield and chemical properties of spinach plants. The important results are as following: 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 as well as total yield of leaves (ton/ha). Also gave the highest percentage of protein, N, P, K and NO₃ content ppm. 2) Addition of 70 % of recommended rate (RR) of chemical fertilizer resulted 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, i.e. protein, N, P, K and NO₃ content in leaves tissues. 3) The interaction treatments showed 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 NO₃.

Antonio *et al.* (1998) When grown in solution culture spinach plants confirmed the preference toward NO₃⁻ nutrition and showed heavy toxicity to NH₄⁺. In open field condition the highest yield was achieved with the ammonium sulphate in Bari (autumn-winter cycle-110 days) and with calcium nitrate in Policoro (winter-spring cycle-64 days). By increasing N level, yield, nitrates and oxalates leaf content increased. Oxalate content was not affected by nitrogen form. Remarkable differences were observed between leaf petiole and blade in nitrate (4062 vs 925 mg kg⁻¹ of fresh mass) and oxalate (1051 vs 6999 mg kg⁻¹ of fresh mass).

Pospisil *et al.* (2006) proposed that Amaranth, an alternative cereal, is attracting researchers' attention mainly because of the high nutritional value of its seed, which can be influenced by nitrogen fertilization. The goal of the research carried out on eutric cambisol in Zagreb in the period 2002–2004 was to determine the influence of nitrogen fertilization upon seed yield, seed protein concentration, 1000-seed weight, dry matter content in flowering, plant height and inflorescence length of two grain amaranth varieties belonging to different species: G6 (*Amaranthus cruentus* L.) and 1008

(*Amaranthus hypochondriacus* L.) grown in the agroecological conditions of north-western Croatia. As nitrogen fertilization is among the most important factors of high yielding of all field crops, knowledge of the grain amaranth nitrogen requirements has an important role for its efficient production.

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, intercultural operations, data collection and statistical analysis.

3.1. Location

The field experiment was conducted at the Agronomy field laboratory, Sher-e- Bangla Agricultural University, Dhaka during the period from November, 2017 to March, 2018. The location of the experimental site has been shown in Appendix I.

3.2. Soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It is a medium high land with non-calcareous dark grey soil. The pH value of the soil was 5.6. The physical and chemical properties of the experimental soil have been shown in Appendix II.

3.3. Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October, 2017 to March, 2018. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix III.

3.4. Experimental details

3.4.1. Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of Doses of Nitrogen and Phosphorus. The 16 treatment combinations of the experiment were assigned at random into 16 plots of each replication. The size of each unit plot $1.5\text{m} \times 1\text{ m}$. The spacing between blocks and plots were 0.75 m and 0.5 m, respectively.

3.4.2. Treatments

The experiment comprised as two factors.

Factor A: There were 4 levels of nitrogen

- i. N_0 = Control (0 kg/ha)
- ii. N_1 =27.6 kg/ha
- iii. N_2 = 55.2 kg/ha
- iv. N_3 = 82.8 kg/ha

Factor B: There were 4 levels of phosphorus

- i. P_0 = Control (0 kg/ha)
- ii. P_1 = 15.84 kg/ha
- iii. P_2 = 31.68 kg/ha
- iv. P_3 = 47.52 kg/ha

There were 16 (4×4) treatment combinations viz., N_0P_0 , N_0P_1 , N_0P_2 , N_0P_3 , N_1P_0 , N_1P_1 , N_1P_2 , N_1P_3 , N_2P_0 , N_2P_1 , N_2P_2 , N_2P_3 , N_3P_0 , N_3P_1 , N_3P_2 and N_3P_3

3.5. Details of the field operations

3.5.1. Preparation of the main field

The plot selected for the experiment was opened on the 15th November, 2016 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for seed sowing.

3.5.2. Seed collection

The seeds of the test crop i.e., Local variety were collected from local market of Pabna.

3.5. 3. Dose and method of application of fertilizers and manures in the spinach field

Manure/fertilizer	Dose/ha	Application
Cowdung	5 ton	All manures were applied during final land preparation
N(as urea)	N ₀ =0 kg N ₁ =60 kg N ₂ =120 kg N ₃ =180 kg	As per treatment
P ₂ O ₅ (as TSP)	P ₀ =0 kg P ₁ =75kg P ₂ =150kg P ₃ =225 kg	As per treatment
K ₂ O(as MOP)	180 kg	Applied during final land preparation

Source: Fertilizer recommendation guide, 2016

3.5.4. Sowing of seed

The healthy seeds were selected for better germination and growth. Then the seeds were soaked in water for 24 hour and after that seeds were sown in line sowing by hand.

3.6. Intercultural operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the crop.

3.6.1. Irrigation and drainage

The experimental plots required two irrigations during the crop growth season and sometimes drainages were done at the time of heavy rainfall.

3.6.2. Gap filling

First gap filling was done for all of the plots at 10 days after sowing (DAS).

3.6.3. Weeding

Three weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. First weeding was done at 15 days after sowing (DAS), 2nd and 3rd weeding were done at 30 and 45 DAS.

3.6.4. Plant protection

At early stage of growth few Leaf miners and aphid attacked plants during the crop production. Leaf miners and aphid were successfully controlled by the application of Diazinon 50 EC and Ripcord @ 1 L ha⁻¹ on the time of 50% pod formation stage.

3.6.5. Stalking

Stalking was provided in each plot using bamboo and rope, to keep the plant erect and to protect them from the damage caused by storm and heavy wind.

3.7. Harvesting, threshing and cleaning

The crop was harvested at full maturity on 15th March 2018 and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of spinach seed. Fresh weight of seeds were recorded plot wise. The seeds were cleaned and finally the weight was adjusted to a moisture content of 12%.

3.8. Seed quality

Seeds obtained from the field experiment were taken separately. These seeds were used for taking quality determination experiments in the laboratory. For this purpose

standard germination test was conducted and other different quality attributes were studied.

3.9. Data collection

3.9.1. Plant height (cm)

The height of plant was recorded in centimeter (cm) before flowering and at the time of harvest. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaves.

3.9.2. Number of leaves per plant

Number of leaves per plant was counted at 60 DAS. Leaves number per plant were recorded by counting all leaves from each plant of each plot and mean was calculated.

3.9.3. Number of inflorescence per plant

Ten plants from each plot were randomly selected. Inflorescences number per plant were recorded by counting all inflorescences from each plant of each plot and mean was calculated.

3.9.4. Number of seed per inflorescence

Ten inflorescence were randomly selected from all the seeds collected from 10 sample plants. The seeds of selected 10 inflorescence were weighed and was averaged.

3.9.5. Seed yield per plant (g)

Ten plants selected at random from the inner rows of each plot were harvested to take seed yield per plant. The seeds were threshed, cleaned, weighed and then averaged in g per plant.

3.9.6. Seed yield per plot (g)

All plots were harvested individually and the average yield of seeds per plot was recorded in gram.

3.9.7. Seed yield per hectare (ton)

The yield of seed in g per plot was adjusted at 12% moisture content of seed and then it was converted to ton per hectare.

3.9.8. 1000 seeds weight (g)

One thousand cleaned and dried seeds were counted randomly from sample and weighed by using a digital electric balance and expressed in gram.

3.9.9. Total germination (TG %)

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

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

3.9.10. Germination index (GI)

Germination index (GI) was calculated as following formula

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

3.9.11. Shoot (cm) and root (cm) length of seedling

Randomly selected 5 seedlings from each treatment were collected and cotyledons were removed from them. Shoot and root length of seedling were measured with a measuring scale.

3.9.12. Seedling dry weight (mg)

The dried radicles and shoots were weighted to the nearest milligram (mg) and the mean radicle and shoot dry weight and consequently mean seedling dry weight were determined with an electric balance.

3.9.13. Electrical conductivity test

Electrical conductivity (EC) test was done using EC meter and for this 25 g seeds were soaked in water for 24h.

3.10. Statistical analysis

The data collected on different characters were statistically analyzed to observe the significant difference by using the STATIX-10 computer package program. The mean values of all the characters were calculated and analysis of variance was performed. Mean separation was done following the Least Significant Different Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

3.11. Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of nitrogen and phosphorus for quality seed production of spinach. All the non-material and material input costs and interests on running capital were considered for computing the cost of production. The interests were calculated for six months @ 14% per year. The price of one kg spinach seed was considered to be Tk. 150.

The benefit cost ratio (BCR) was calculated by the following formula.

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return (tk /ha)}}{\text{Total cost of production (tk /ha)}}$$

CHAPTER IV

RESULTS AND DISCUSSION

Present study was undertaken to determine the effect of nitrogen and phosphorus on the growth and seed yield of spinach. Data on different morphological characters, yield contributing characters and yield were recorded to find out the optimum level of nitrogen and phosphorus on spinach seed yield. The results of the experiment have been presented and discussed in this chapter.

4.1 Effects on morphological characters

4.1.1 Plant height (cm)

Significant variation was observed on plant height of spinach due to the application of different levels of nitrogen (Table 1.). The highest plants height (13.94 cm and 47.69 cm) were obtained before flowering and at harvest respectively due to N₃ (82.8 kg/ha) followed by N₂ (55.2 kg/ha). The lowest plant heights (11.01 cm and 34.88 cm) were obtained at before flowering and at harvest respectively due to N₀ (control) treatment. It was observed that plant height increased gradually with the increase of nitrogen doses.

Table 1. Effect of nitrogen on plant height (before flowering and at the time of harvest) leaves per plant of spinach

Treatments	Plant height before flowering (cm)	Plant height at harvest (cm)	Leaves per plant
N ₀	11.01c	34.88 d	6.42 d
N ₁	12.34 b	40.35 c	7.24 c
N ₂	13.07 b	43.75 b	8.46 a
N ₃	13.94 a	47.69 a	7.84 b
LSD	0.87	3.12	0.54
CV %	8.34	9.00	8.70

Means in a column followed by the same letter(s) are not significantly different at 5% level of probability.

Here, N₀= 0 kg/ha; N₁=27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha.

Significant variation was observed on plant height of spinach due to the application of different doses of phosphorus (Table 2.). Among the different doses of phosphorus, P₃ (47.52 kg/ha) showed the highest plant heights (13.64 cm) and (46.68 cm) at before flowering and at harvest respectively followed by P₂ (31.68 kg/ha) at before flowering and at harvest also. On the other hand, the lowest plant heights (11.60 cm and 35.18 cm) at before flowering and at harvest respectively were observed in P₀ (control) treatment where phosphorus was not applied.

Table 2. Effect of phosphorus on plant height (before and at the time of harvest), Leaves per plant of spinach

Treatments	Plant height before flowering (cm)	Plant height at harvest (cm)	Leaves per plant
P₀	11.60 c	35.18 c	6.36 c
P₁	12.16 b	40.37 b	7.24 b
P₂	12.96 b	44.44 a	8.30 a
P₃	13.64 a	46.68 a	8.06 a
LSD	0.87	3.11	0.543
CV %	8.34	9.00	8.70

Means in a column followed by the same letter(s) are not significantly different at 5% level probability.

Here, P₀= 0 kg/ha; P₁= 15.84 kg/ha; P₂= 31.68 kg/ha; P₃= 47.52 kg/ha.

Combined effect of different levels of nitrogen and phosphorus application showed significant effect on plant height of spinach (Table.3). The highest plant heights (15.21 cm and 55.25 cm) at before flowering and at harvest respectively were observed in the treatment combination of N₃P₃ (82.8 kg/ha + 47.52 kg/ha). While the lowest plant heights (10.10 cm and 27.7 cm) at before flowering and at harvest respectively were recorded in N₀P₀ (control) treatment where no nitrogen and phosphorus were applied. It was observed from the data that plant height increased gradually with the increase of nitrogen and phosphorus levels.

Table 3. Combined effect of nitrogen and phosphorus on plant height (before and at the time of harvesting) and leaves per plant of spinach

Treatments	Plant height before flowering (cm)	Plant height at harvest (cm)	Leaves per plant
N₀P₀	10.10 h	27.7 g	5.01 g
N₀ P₁	10.63 gh	34.34 f	6.25 f
N₀ P₂	11.25 f-h	37.31 ef	6.66 ef
N₀ P₃	12.07 d-g	40.18 d-f	7.76 b-d
N₁ P₀	11.49 e-h	34.65 f	6.60 ef
N₁ P₁	12.15 d-g	41.03 de	7.33 c-f
N₁ P₂	12.60 c-f	42.44 c-e	7.46 c-e
N₁ P₃	13.12 b-e	43.29 c-e	7.58 c-e
N₂ P₀	12.14 d-g	37.88 ef	6.91 d-f
N₂ P₁	12.54 c-f	21.80 c-e	7.81 b-d
N₂ P₂	13.42 b-d	47.31 bc	10.35 a
N₂ P₃	14.17 a-c	48.01 bc	8.76 b
N₃ P₀	12.65 c-f	40.51 d-f	6.93 d-f
N₃ P₁	13.35 b-d	44.30 cd	7.56 c-e
N₃ P₂	14.56 ab	50.71 ab	8.73 b
N₃ P₃	15.21 a	55.25 a	8.13 bc
LSD	1.75	6.25	1.08
CV %	8.34	9.00	8.70

Means in a column followed by the same letter(s) are not significantly different at 5% level probability.

Here, N₀= 0 kg/ha; N₁=27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha.
P₀= 0 kg/ha; P₁= 15.84 kg/ha; P₂= 31.68 kg/ha; P₃= 47.52 kg/ha.

4.1.2. Number of leaves per plant

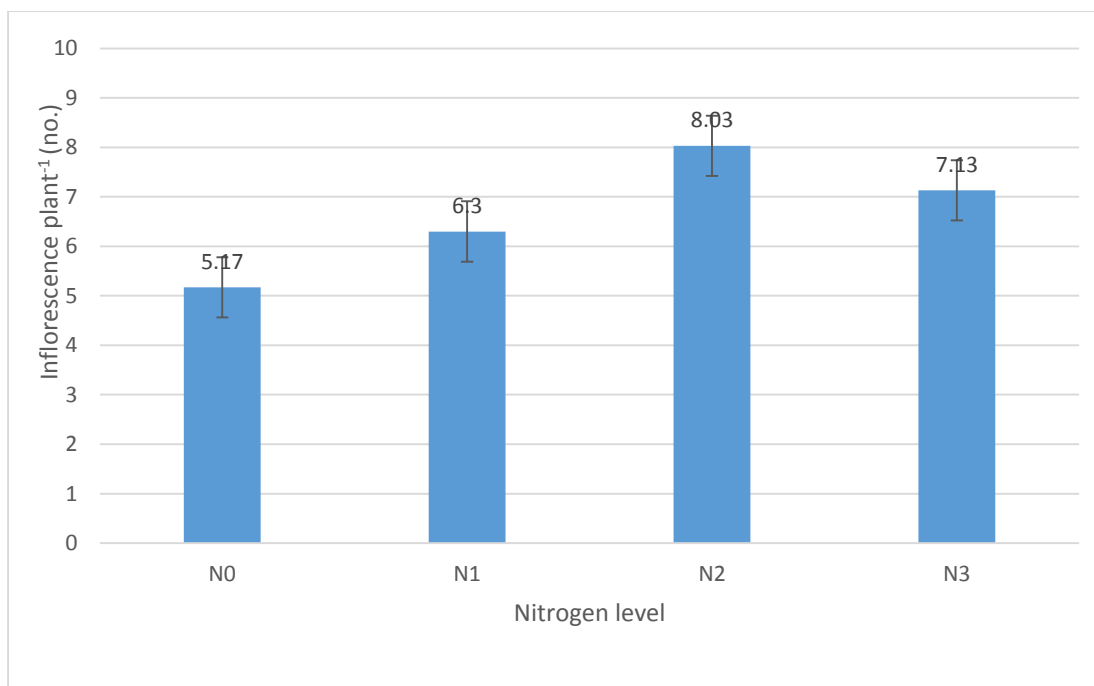
The effect of nitrogen on number of leaves per plant of spinach was significant (Table 1). The highest number of leaves (8.46) was produced from N₂ (55.2 kg/ha N) treatment. On the other hand, the lowest number of leaves (6.42) was observed in N₀ (control). From this study it was observed that the highest number of leaves per plant of spinach was increased due to their increase in vegetative growth of plants. This result indicated that N₂ lead to increase in number of leaves per plant.

Significant variation was observed on number of leaves per plant of spinach due to the application of different levels of phosphorus (Table 2). Among the different phosphorus levels P₂ (31.68 kg/ha P) produced the maximum leaves per plant (8.30). On the other hand, the minimum leaves per plant (6.36) was observed in P₀ (control). The results showed that P₂ lead to increase in number of leaves per plant.

Combined effect of different levels of nitrogen and phosphorus showed significant effect on number of leaves per plant of spinach (Table 3.). The maximum leaves per plant (10.35) was observed in N₂P₂ (N 55.2 kg/ha +P 31.68 kg/ha) followed by N₃P₂, N₂P₃ and N₃P₃. On the other hand, the lowest number of leaves per plant (5.01) was recorded in N₀P₀ (control) treatment. This result indicated that NP application lead to a linear increase in the number of leaves per plant. Number of leaves per plant is a yield contributing factor of spinach. Optimum level of N and P might have increased availability and absorption of plant nutrients. The photosynthesis and other physiological process of plant depends on nitrogen and phosphorus resulting better performance of the crop and ultimately produce more leaves per plant. Ambia *et al.* (2016) also found the similar result.

4.2. Yield attributes 4.2.1. Number of inflorescence per plant

Statistically significant differences were found on number of inflorescence per plant of spinach due to the application of different levels of nitrogen (Fig. 1). The highest number of inflorescence per plant (8.03) was recorded from treatment N₂ (55.2 kg/ha) whereas, the lowest number of inflorescence per plant (5.17) was observed in N₀ treatment.



Here, N₀= 0 kg/ha; N₁= 27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha.

Fig. 1. Effect of nitrogen on number of inflorescence per plant (LSD_(0.05) = 0.47)

Number of inflorescences per plant of spinach differed significantly due to the different level of phosphorus application (Table 4) which indicated that highest number of inflorescence per plant (7.80) in P₂ (31.68 kg/ha) treatment and the lowest (4.94) in P₀ (control).

Table 4. Effect of phosphorus on number of inflorescence per plant, inflorescence length and seeds per inflorescence of spinach

Treatments	Number of inflorescence per plant	Inflorescence length (cm)	Seeds per inflorescence
P₀	4.94 c	20.58 c	39.13 c
P₁	6.26 b	24.12 b	48.19 b
P₂	7.80 a	28.43 a	57.19 a
P₃	7.64 a	28.97 a	56.15 a
LSD	0.48	1.85	3.39
CV %	8.48	8.73	8.12

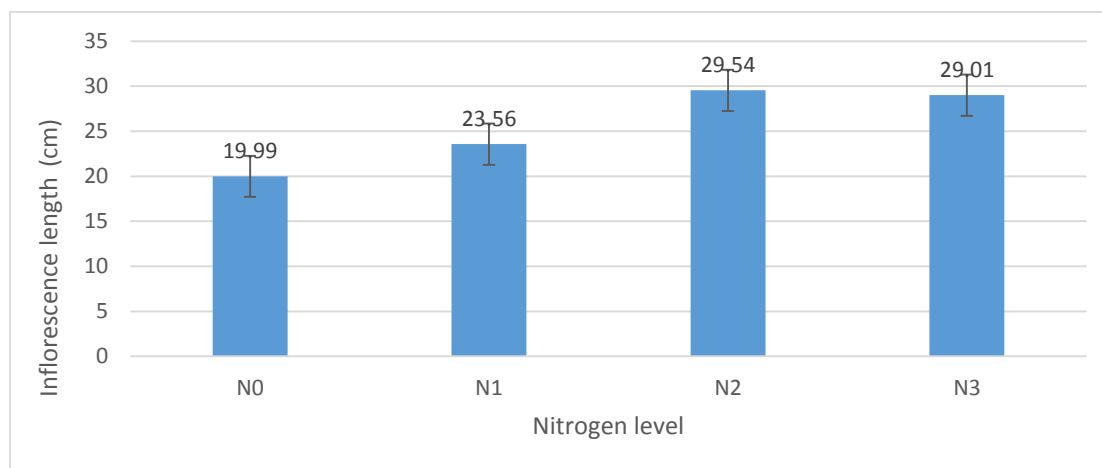
Means in a column followed by the same letter(s) are not significantly different at 5% level

Here, P₀= 0 kg/ha; P₁= 15.84 kg/ha; P₂= 31.68 kg/ha; P₃= 47.52 kg/ha.

Combined effect of nitrogen and phosphorus showed significant variation in number of inflorescences per plant (Table 5). The table showed that the highest number of inflorescence per plant (10.53) in the treatment of combination of N_2P_2 (N 55.2 kg/ha +P 31.68 kg/ha) which was followed by N_2P_3 (N 55.2 kg/ha +P 47.52 kg/ha). On the other hand, the lowest number of inflorescence per plant (3.90) was recorded in N_0P_0 (control) treatment combination.

4.2.2. Length of inflorescence

Significant variation was observed on the length of inflorescence of spinach when different levels of nitrogen were applied (Fig.2). The highest length of inflorescence (29.54cm) was recorded in N_2 (55.2 kg/ha) treatment. On the other hand, the lowest length of inflorescence (19.09 cm) was recorded in N_0 (control) treatment.



Here, $N_0 = 0$ kg/ha; $N_1 = 27.6$ kg/ha; $N_2 = 55.2$ kg/ha; $N_3 = 82.8$ kg/ha.

Fig. 2. Effect of nitrogen on inflorescence length (LSD $_{(0.05)} = 1.85$)

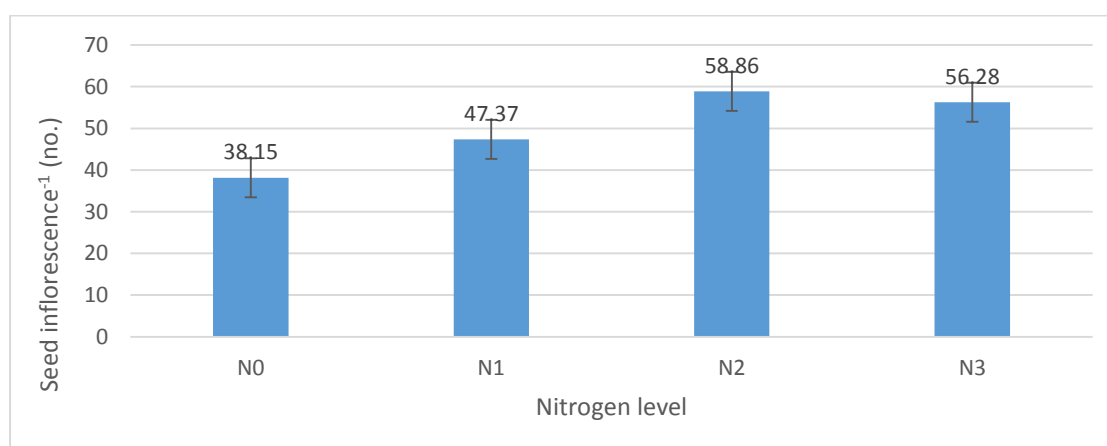
The effect of phosphorus on length of inflorescence of spinach was found significant (Table 4). The highest length of inflorescence (28.97 cm) was recorded in P_3 (47.52 kg/ha) which was identical to P_2 (31.68 kg/ha). On the other hand, the lowest length of inflorescence (20.58 cm) was recorded in P_0 (control) treatment.

Combined effect of different levels of nitrogen and phosphorus showed significant effect on the length of inflorescence (Table 5). The highest length of inflorescence (35.04 cm) was observed in N_2P_2 (N 55.2 kg/ha +P 31.68 kg/ha). On the other hand, the lowest length of inflorescence (15.19 cm) was recorded in N_0P_0 (control) treatment.

combination. It was observed that the inflorescence length of spinach increased due to N_2 and P_2 .

4.2.3. Number of seeds per inflorescence

Statistically significant differences were found on number of seeds per inflorescence of spinach due to the application of different nitrogen levels (Fig.3). The maximum number of seeds per inflorescence (58.68) was recorded in N_2 (55.2 kg/ha) treatment and the minimum (38.15) in N_0 (control).



Here, $N_0 = 0$ kg/ha; $N_1 = 27.6$ kg/ha; $N_2 = 55.2$ kg/ha; $N_3 = 82.8$ kg/ha.

Fig.3. Effect of nitrogen on seed per inflorescence (LSD_(0.05) = 3.39)

Number of seeds per inflorescence of spinach differed significantly due to the application of different levels of phosphorus (Table 3.). Number of seeds per inflorescence increased steadily with increases of phosphorus. However, the highest number of seeds per inflorescence (57.19) was recorded in P_2 treatment. The lowest number of seeds per inflorescence (39.13) was found in P_0 (control) treatment.

The number of seeds per inflorescence was significantly influenced by the combined effects of nitrogen and phosphorus (Table 5). The maximum number of seeds per inflorescence (70.41) was recorded in the treatment combination of N_2P_2 (N 55.2 kg/ha +P 31.68 kg/ha) which was statistically similar to N_2P_3 (65.48). The lowest number of seeds per inflorescence (35.33) was found in N_0P_0 (control) treatment combination. These results indicated that the different levels of N and P when used combinedly supplied adequate amount of plant nutrients and provided better growth of plant in respect to reproductive growth as well as maximum number of seeds per inflorescence.

Table 5. Combined effect of nitrogen and phosphorus on number of inflorescence per plant, inflorescence length and seeds per inflorescence of spinach

Treatments	Number of inflorescence per plant	Inflorescence length(cm)	Seeds per inflorescence
N₀P₀	3.9 j	15.19 j	28.03 j
N₀P₁	5.03 i	18.95 i	35.33 i
N₀P₂	5.70 g-i	21.86 g-i	43.82 h
N₀P₃	6.06 f-h	23.96 e-g	45.43 gh
N₁ P₀	5.08 i	19.91 hi	36.27 i
N₁ P₁	6.23 e-g	22.91 f-h	47.79 e-h
N₁ P₂	6.75 ef	24.72 e-g	51.74 d-g
N₁ P₃	7.15 de	26.69 de	53.70 c-f
N₂ P₀	5.23 hi	22.84 f-h	45.25 gh
N₂ P₁	7.05 e	26.15 d-f	54.29 c-e
N₂ P₂	10.53 a	35.04 a	70.41 a
N₂ P₃	9.31 b	34.15 ab	65.48 ab
N₃ P₀	5.55 g-i	24.38 eg	47.00 f-h
N₃ P₁	6.73 ef	28.48 cd	55.34 cd
N₃ P₂	8.21 c	32.10 a-c	62.80 b
N₃ P₃	8.03 cd	31.10 bc	60.00 bc
LSD	0.94	3.71	6.79
CV (%)	8.48	8.73	8.12

Means in a column followed by the same letter(s) are not significantly different at 5% level probability.

Here, N₀= 0 kg/ha; N₁=27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha.
P₀= 0 kg/ha; P₁= 15.84 kg/ha; P₂= 31.68 kg/ha; P₃= 47.52 kg/ha.

4.3. Seed Yield of spinach

4.3.1. Seed yield per plant (g)

The effect of nitrogen on seed yield per plant was significant (Table. 6). The maximum seed yield per plant (3.36 g) was observed in N₂ (55.2 kg/ha) treatment and the lowest seed yield per plant (2.71 g) was observed in N₀ (control) treatment.

The effect of phosphorus on seed yield per plant was significant (Table. 7). The maximum seed yield per plant (3.49 g) was observed in P₂ (31.68 kg/ha) treatment and the lowest seed yield per (2.81 g) plant was observed in P₀ (control).

Table 6. Effect of nitrogen on seed yield (per plant, per plot and per hectare) and 1000 seed weight

Treatments	Seed yield per plant (g)	Seed yield per plot (g)	Seed yield per hectare (t)	1000 seed weight (g)
N ₀	2.71 d	81.58 d	0.81 d	9.24 b
N ₁	3.03 c	91.25 c	0.91 c	9.58 ab
N ₂	3.66 a	110.00 a	1.10 a	10.19 a
N ₃	3.36 b	101.08 b	1.01 b	10.14 a
LSD	0.22	6.62	0.06	0.75
CV (%)	8.29	8.28	8.28	9.19

Means in a column followed by the same letter(s) are not significantly different at 5% level of probability.

Here, N₀= 0 kg/ha; N₁=27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha.

The combined effect of nitrogen and phosphorus showed (Table.8) significant variation in seed yield per plant of spinach (Table.8). The highest seed yield per plant (4.43 g) was recorded from the treatment combination of N₂P₂ (N 55.2 kg/ha +P 31.68 kg/ha). The lowest (2.30 g) was recorded in N₀P₀ (control).

4.3.2. Seed yield per plot (g)

The effect of nitrogen on seed yield per plot was significant (Table. 6). The maximum seed yield per plot (110.00 g) was observed in N₂ (55.2 kg/ha) and the lowest seed yield per plot (81.58 g) was observed in N₀ (control).

The effect of phosphorus on seed yield per plot was significant (Table. 7). The maximum seed yield per plot (105.00 g) was observed in P₂ (31.68 kg/ha) and minimum (84.58 g) was observed in P₀ (control).

Table 7. Effect of phosphorus on seed yield (per plant, per plot and per hectare) and 1000 seed weight

Treatments	Seed yield per plant (g)	Seed yield per plot (g)	Seed yield per hectare (t)	1000 seed weight (g)
P₀	2.81 c	84.58 c	0.84 c	9.23 b
P₁	3.09 b	93.00 b	0.93 b	9.56 ab
P₂	3.49 a	105.00 a	1.05 a	10.20 a
P₃	3.37 a	101.33 a	1.01 a	10.18 a
LSD	0.23	6.63	0.067	0.75
CV (%)	8.29	8.28	8.28	9.19

Means in a column followed by the same letter(s) are not significantly different at 5% level of probability.

Here, P₀= 0 kg/ha; P₁= 15.84 kg/ha; P₂= 31.68 kg/ha; P₃= 47.52 kg/ha.

The combined effect of nitrogen and phosphorus showed (Table.8) significant variation in seed yield per plot of spinach (Table.8). The highest seed yield per plot (130.00 g) was recorded in N₂P₂ (N 55.2 kg/ha +P 31.68 kg/ha). The lowest (69.00 g) was recorded in N₀P₀ (control).

4.3.3. Seed yield per hectare (ton)

Significant differences were found for seed yield per ha of spinach due to different nitrogen level (Table 6.). The maximum seed yield (1.10 t ha^{-1}) was recorded in N_2 (55.2 kg/ha) treatment. On the other hand, the minimum (0.81 t ha^{-1}) was recorded in N_0 (control).

Significant differences were found for seed yield per ha of spinach due to different phosphorus levels (Table 7.). The maximum seed yield (1.05 t ha^{-1}) was recorded from P_2 (31.68 kg/ha) treatment. On the other hand, minimum (0.84 t ha^{-1}) was recorded in P_0 (control).

The combined effect of nitrogen and phosphorus showed significant variation in seed yield of spinach (Table 8.). The highest seed yield (1.30 t/ha) was recorded from the combination of N_2P_2 ($N \text{ } 55.2 \text{ kg/ha} + P \text{ } 31.68 \text{ kg/ha}$) followed by N_2P_3 . The lowest (0.69 t ha^{-1}) was recorded from the combination of N_0P_0 . Ahammed *et al.* (2016) reported that 165.5kg N and 64.4 kg P with 52.4 kg K per ha exhibited the higher seed yield of amaranth.

4.3.4. 1000 seed weight (g)

Variation was found for 1000 seed weight of spinach due to nitrogen level (Table 6.). The maximum 1000 seed weight (10.19 g) was recorded in N_2 treatment. The lowest (9.24 g) was recorded in N_0 treatment.

Wide variations were found for 1000 seed weight of spinach due to different of phosphorus (Table 7). The maximum 1000 seed weight (10.20 g) was recorded in P_2 treatment which was statistically identical to that of the P_3 (10.18 g) and similar to P_1 (9.56 g) treatment. The lowest (9.23 g) was recorded in P_0 treatment.

Combined effect of nitrogen and phosphorus showed significant variation in 1000 seed weight of spinach (Table 8). The highest 1000 seed weight (11.06 g) was recorded in N_2P_2 . The lowest (8.77 g) was recorded in the treatment combination of N_0P_0 .

Table 8. Combined effect of nitrogen and phosphorus seed yield (per plant, per plot and per hectare) and 1000 seed weight

Treatments	Seed yield per plant (g)	Seed yield per plot (g)	Seed yield per hectare (t)	1000 seed weight (g)
N₀P₀	2.30 h	69.00 h	0.69 h	8.77 d
N₀P₁	2.76 g	83.00 g	0.83 g	9.22 b-d
N₀P₂	2.85 fg	85.67 fg	0.85 fg	9.43 b-d
N₀P₃	2.95 e-g	88.67 e-g	0.88 e-g	9.56 b-d
N₁ P₀	2.76 g	83.00 g	0.83 g	9.15 cd
N₁ P₁	3.03 d-g	91.00 d-g	0.91 d-g	9.47 b-d
N₁ P₂	3.16 d-g	95.00 d-g	0.95 d-g	9.76 a-d
N₁ P₃	3.20 c-g	96.00 d-g	0.96 d-g	9.95 a-d
N₂ P₀	3.12 d-g	93.67 d-g	0.93 d-g	9.26 b-d
N₂ P₁	3.32 c-e	99.67 c-e	0.99 c-e	9.74 a-d
N₂ P₂	4.33 a	130.00 a	1.30 a	11.06 a
N₂ P₃	3.88 b	116.67 b	1.16 b	10.70 ab
N₃ P₀	3.08 d-g	92.67 d-g	0.92 d-g	9.73 a-d
N₃ P₁	3.27 c-f	98.33 c-f	0.98 c-f	9.80 a-d
N₃ P₂	3.64 bc	109.33 bc	1.09 bc	10.53 a-c
N₃ P₃	3.46 b-d	104.00 b-d	1.04 b-d	10.50 a-c
LSD	0.44	13.25	0.13	1.50
CV (%)	8.29	8.28	8.28	9.19

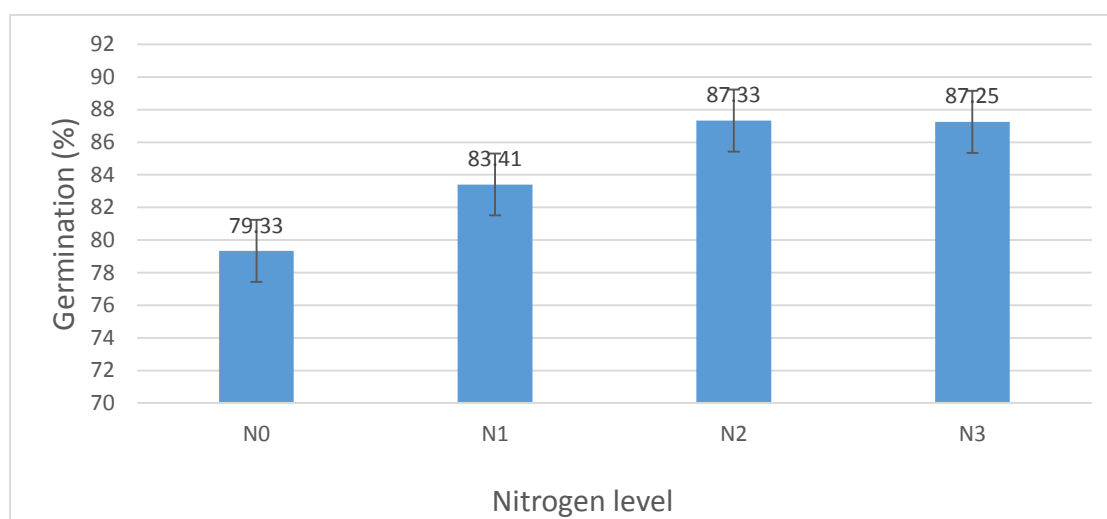
Means in a column followed by the same letter(s) are not significantly different at 5% level

N₀= 0 kg/ha; N₁=27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha; P₀= 0 kg/ha; P₁= 15.84 kg/ha; P₂= 31.68 kg/ha; P₃= 47.52 kg/ha

4.4. Seed quality test

4.4.1. Germination percentage

A significant difference was observed on germination % due to the application of different fertilizer levels (fig 4.). The maximum germination percentage (87.33 %) was recorded in N₂ (55.2 kg/ha) which, was statistically identical to N₃ (87.25 %). The minimum (79.33 %) was found in N₀ (control). Zaki *et al.* (2016) reported that seed yield and its quality of spinach were improved due to the increasing rate of nitrogen levels. Application of 60 kg N produced the higher seed yield with better germination percentage and germination rate.



Here, N₀= 0 kg/ha; N₁= 27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha.

Fig. 4. Effect of nitrogen on germination (%) (LSD_(0.05) = 4.95) of spinach

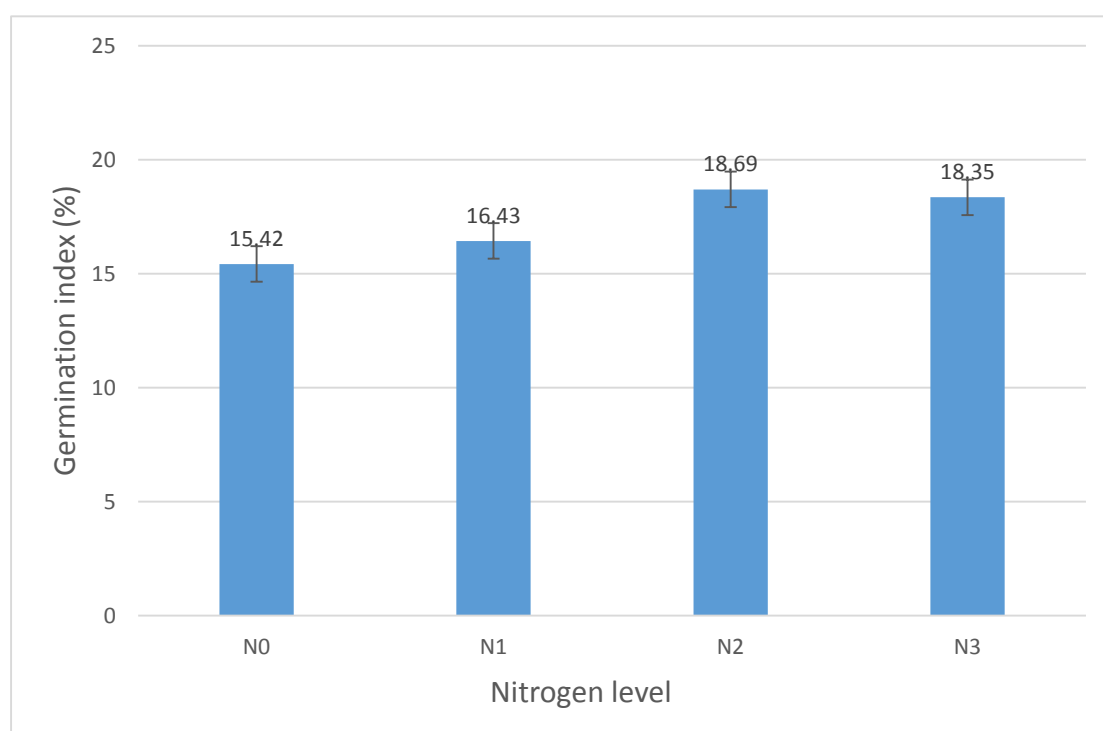
Germination percentage was significantly stirred due to the application of different levels of phosphorus (Table 9). The maximum germination percentage (87.08 %) was recorded in P₃ (47.52 kg/ha) treatment which was statistically identical to P₂ (86.52 %). On the other hand the minimum (79.91 %) was found in P₀ (control).

The combined effect of nitrogen and phosphorus was found significantly influenced on germination percentage of spinach (Table 10). The highest germination percentage (91.33 %) was recorded in N₂P₂ (55.2 N kg/ha + 31.68 P kg/ha). On the other hand, the lowest germination percentage (72.66 %) was recorded in N₀P₀ (control). Ambia *et al.* (2016) carried out an experiment at the farm of department of Horticulture, BSMRAU, Salna, Gazipur on 6 spinach genotypes to observe their seed production potentiality and

to evaluate the quality of produced seed. They reported that quality test of seed was done based on germination test (%), seed vigour test (Electrical conductivity), moisture test (%) and thousand seed weight (g) of seeds. The cultivar BRAC kopi Palong perform best in quality test showing highest germination percentage, lowest value in electrical conductivity test and the lowest moisture content.

4.4.2. Germination index

A significant difference was found in germination index due to the application of different levels of nitrogen (Fig.5). The maximum germination index (18.69 %) was recorded from treatment N₂ (55.2 kg/ha) whereas, the minimum (15.42 %) was found in N₀ (control) treatment.



Here, N₀ = 0 kg/ha; N₁ = 27.6 kg/ha; N₂ = 55.2 kg/ha; N₃ = 82.8 kg/ha.

Fig. 5. Effect of nitrogen on germination index (%) (LSD (0.05) = 1.11) of spinach

Germination index was found to vary due to the application of different levels of phosphorus (Table 9.). The highest germination index (18.22 %) was recorded in P₂ (31.68 P kg/ha) treatment which was statistically similar to P₃ (17.98 %). The minimum (15.74%) was found in P₀ (control).

Table 9. Effect of phosphorus on germination, germination index, electrical conductivity test, dry weight of seedling, Shoot length and root length of spinach

Phosphorus	Germination (%)	Germination index (%)	Electrical conductivity test (ds/cm)	Dry weight of seedling (g)	Shoot length (cm)	Root length (cm)
P₀	79.91 b	15.74 c	13.35 a	11.66 b	12.34 c	6.94 c
P₁	83.75 ab	16.94 b	12.57 ab	12.75 a	14.07 b	7.57 b
P₂	86.58 a	18.22 a	11.79 b	13.61 a	15.60 a	8.21 a
P₃	87.08 a	17.98 ab	11.81 b	13.54 a	15.99 a	7.96 ab
LSD	4.95	1.12	0.85	1.04	1.01	0.50
CV (%)	7.05	7.80	8.25	9.72	8.37	7.95

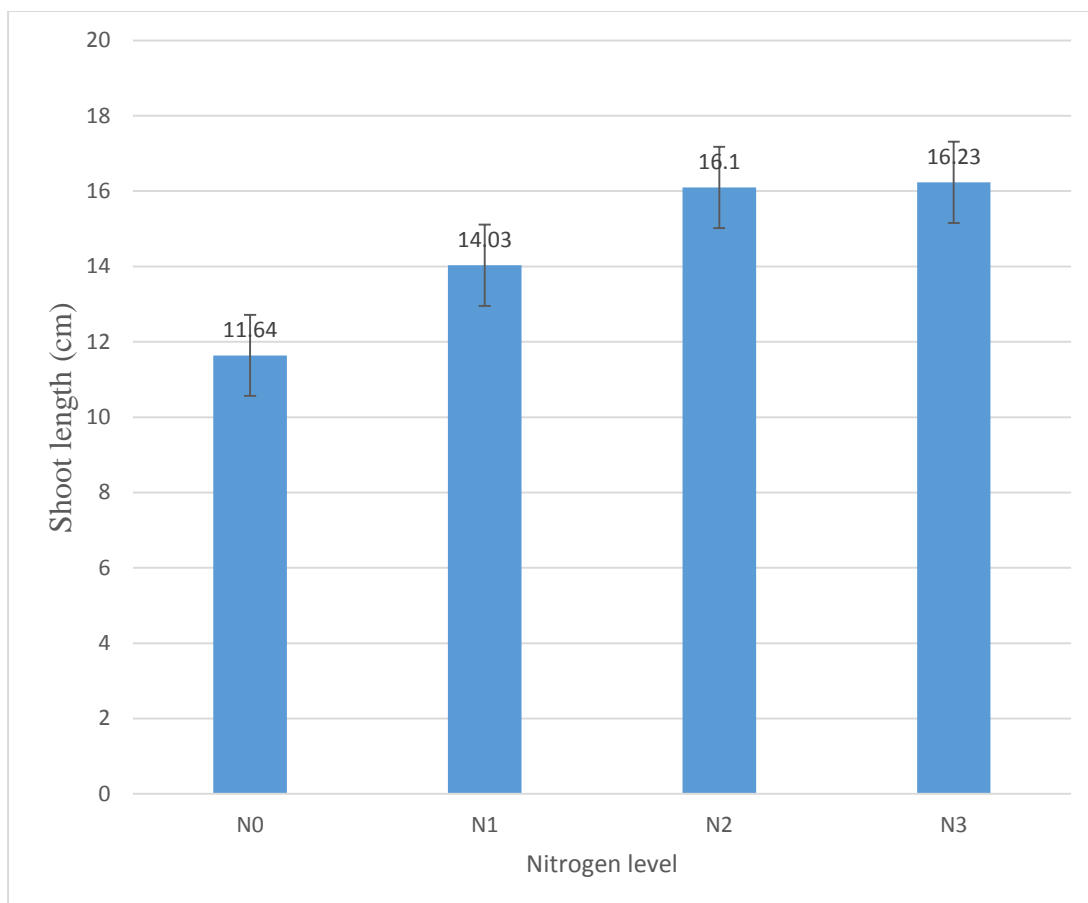
Means in a column followed by the same letter(s) are not significantly different at 5% level of probability.

Here, P₀= 0 kg/ha; P₁= 15.84 kg/ha; P₂= 31.68 kg/ha; P₃= 47.52 kg/ha.

The combined effect of nitrogen and phosphorus was significant on germination index of spinach (Table 10). The highest germination index (21.01) was recorded from the treatment combination of N₂P₂ treatment which was statistically similar to N₃P₂ (19.21) and N₂P₃ (19.66). On the other hand, the lowest germination index (13.81) was recorded in N₀P₀ (control).

4.4.3. Shoot length

A significant difference was found in shoot length due to nitrogen level (Fig.6.). The figure showed an increasing trend with the increases of nitrogen rate. The maximum shoot length (16.23 cm) was recorded in N₃ (82.8 kg/ha) whereas, the minimum (11.64 cm) was found in N₀ (control).



Here, $N_0 = 0$ kg/ha; $N_1 = 27.6$ kg/ha; $N_2 = 55.2$ kg/ha; $N_3 = 82.8$ kg/ha.

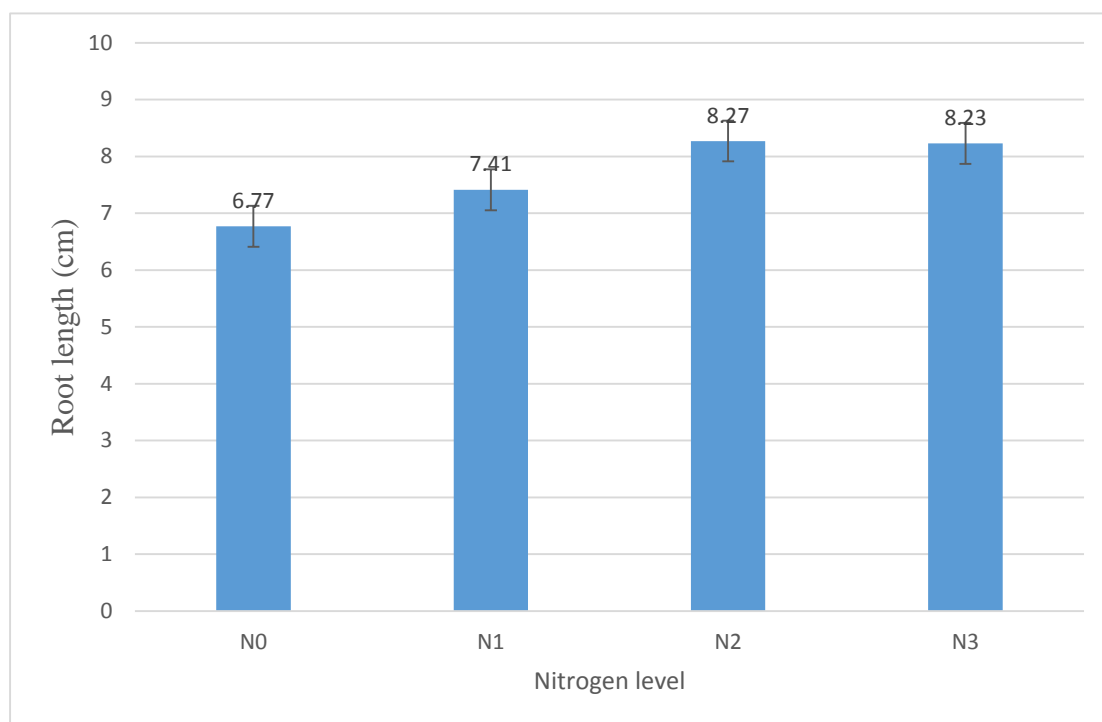
Fig. 6. Effect of nitrogen shoot length of seedlings ($LSD_{(0.05)} = 1.01$)

Noticeable difference was found in shoot length due to phosphorus (Table 9). It was observed that shoot length increased gradually with the increase of phosphorus level. The maximum shoot length (15.99 cm) was recorded in P_3 treatment which is statistically identical to P_2 . The minimum (12.34 cm) was found in P_0 (control).

The combined effect of nitrogen and phosphorus was significant on shoot length of spinach (Table 10). The highest shoot length (18.83 cm) was recorded in N_2P_2 which was statistically similar to N_2P_3 and N_3P_3 . On the other hand, the lowest shoot length (9.16 cm) was recorded in N_0P_0 (control).

4.4.4. Root length

A significant difference was found in root length due to the application of different levels of nitrogen (fig. 7.). It was observed from the figure that root length increased gradually with the increase of nitrogen. The highest root length (8.27 cm) was recorded from the highest nitrogen treatment N₂ whereas, the lowest (6.77 cm) was found in N₀ (control) treatment.



Here, N₀ = 0 kg/ha; N₁ = 27.6 kg/ha; N₂ = 55.2 kg/ha; N₃ = 82.8 kg/ha.

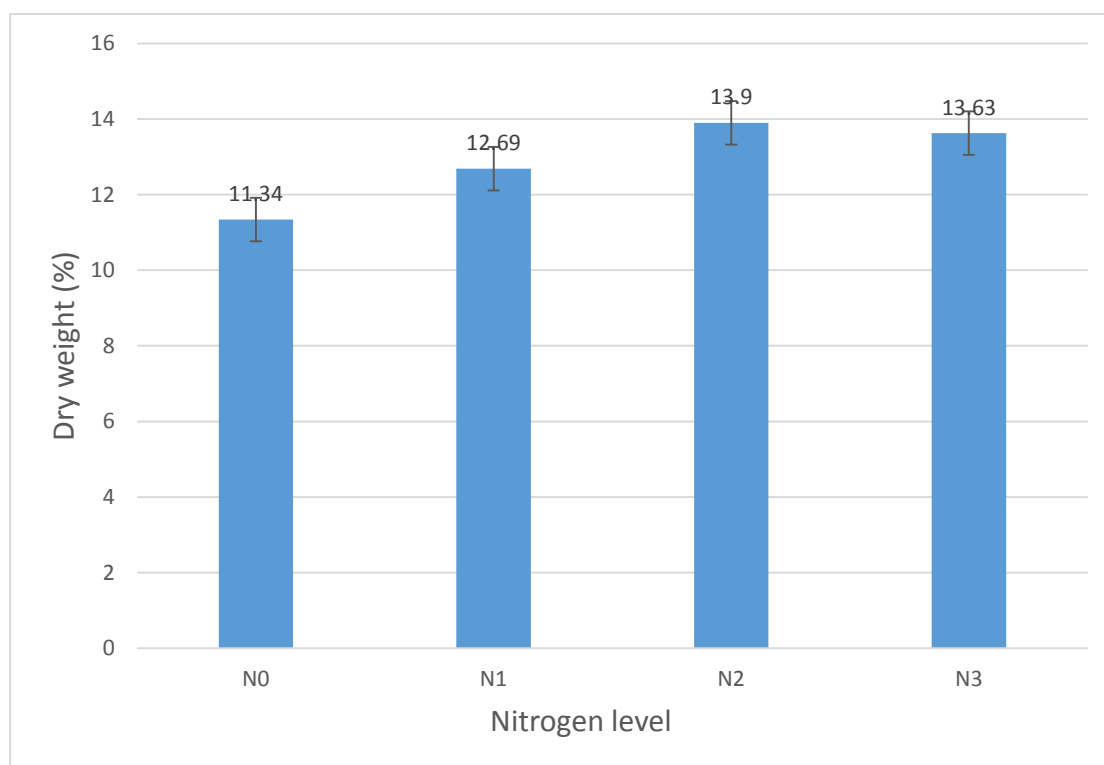
Fig. 7. Effect of nitrogen on root length (LSD_(0.05) = 0.50)

A significant difference was found in root length due to the application of different levels of phosphorus (table 9). The highest root length (8.21 cm) was recorded in P₂ which was statistically similar to P₃ (7.96 cm). The lowest root length (6.94 cm) was found in P₀ (control).

The combined effect of nitrogen and phosphorus was significant on root length of spinach (Table 10). The data presented in the table showed an increasing trend with the increase of nitrogen and phosphorus. The highest root length (9.57 cm) was recorded in (N₂P₂) treatment combination which was statistically similar to N₃P₂ (8.60 cm). On the other hand, the lowest root length (5.95 cm) was recorded in N₀P₀.

4.4.5. Dry weight of seedling

A significant difference was found in dry weight of seedling due to the application of different levels of nitrogen (Fig. 8). The maximum dry weight of seedling (13.90 %) was recorded in N_2 which was statistically similar to N_3 (13.63 %). On the other hand, the lowest dry weight of seedling (11.34 %) was recorded in N_0 .



Here, $N_0 = 0$ kg/ha; $N_1 = 27.6$ kg/ha; $N_2 = 55.2$ kg/ha; $N_3 = 82.8$ kg/ha.

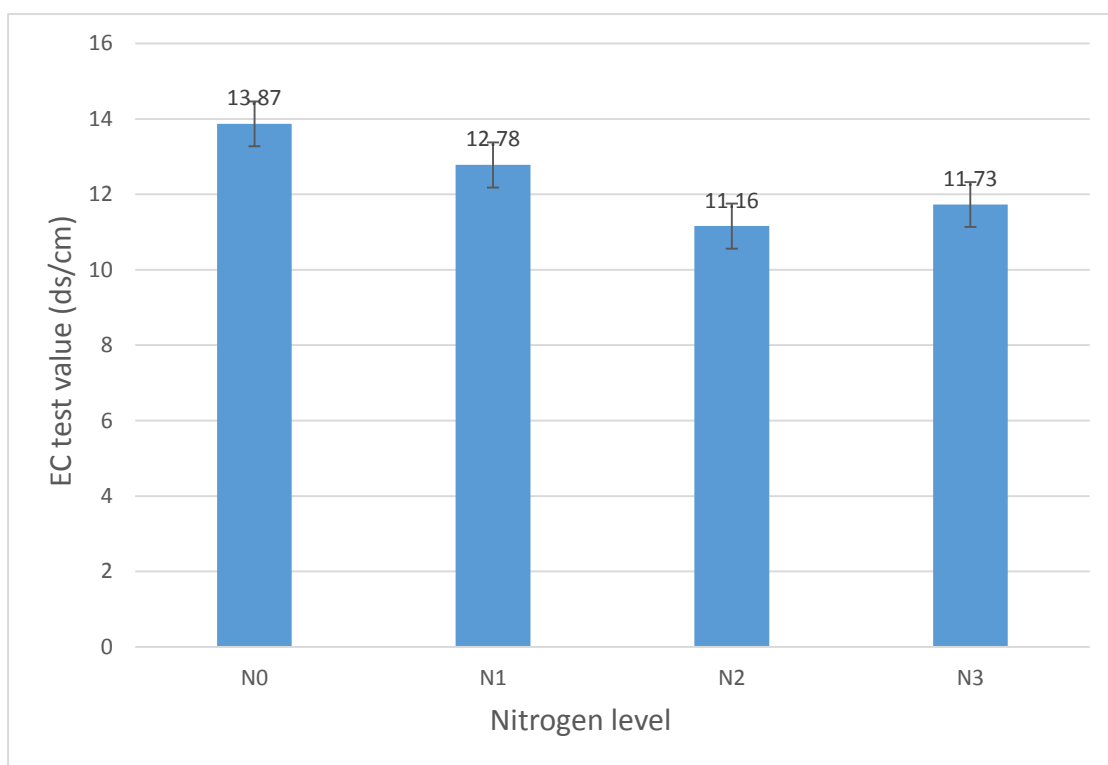
Fig. 8. Effect of nitrogen on dry weight (LSD_(0.05) = 1.04)

Distinct difference was found in dry weight of seedling due to the application of different levels of phosphorus (Table 9). The maximum dry weight of seedling (13.61 %) was recorded in P_2 which was statistically identical to P_3 (13.54 %). On the other hand, the lowest dry weight of seedling (11.66 %) was recorded in P_0 (control).

The combined effect of nitrogen and phosphorus was significant on dry weight of seedling of spinach (Table 10). The maximum dry weight of seedling (15.26 %) was recorded from the treatment combination of N_2P_2 treatment which was statistically similar to N_1P_3 , N_2P_1 , N_2P_2 , N_2P_3 , N_3P_0 , N_3P_1 and N_3P_2 . On the other hand, the lowest dry weight of seedling (10.08 %) was recorded in N_0P_0 .

4.4.6. Electrical conductivity test

Remarkable difference was found in electrical conductivity value due to the application of different levels of nitrogen (Fig.9.). The highest EC value (13.87 dS/cm) was recorded in N₀ whereas, the lowest (11.16 dS/cm) was found in N₂ treatment which was statistically identical to N₃ (11.73 dS/cm).



Here, N₀= 0 kg/ha; N₁= 27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha.

Fig. 9. Effect of nitrogen on EC test value (LSD_(0.05) = 0.84) of spinach

Table 10. Combined Effect of phosphorus and nitrogen on germination, germination index, electrical conductivity test dry weight of seedling, shoot length and root length of seedling of spinach

Treatment	Germination (%)	Germination index	Electrical conductivity test(ds/cm)	Dry weight of seedling (g)	Shoot length (cm)	Root length (cm)
N₀P₀	72.66 e	13.81 g	14.83 a	10.08 g	9.16 j	5.95 g
N₀ P₁	80.00 c-e	15.27 fg	13.97 ab	11.13 fg	11.41i	6.88 fg
N₀ P₂	81.00 b-e	16.03 d-g	13.37 a-c	11.87 e-g	12.43 g-i	7.09 ef
N₀ P₃	83.66 a-d	16.56 d-f	13.30 a-c	12.28 d-f	13.56 e-h	7.18 d-f
N₁ P₀	79.00 d-e	15.85 e-g	13.55 a-c	11.94 d-g	11.66 hi	7.04 ef
N₁ P₁	84.00 a-d	16.51 d-f	12.85 b-d	12.61 b-f	13.73 e-g	7.33 d-f
N₁ P₂	84.66 a-d	16.64 d-f	12.58 b-e	12.95 b-f	14.53 d-f	7.56 c-f
N₁ P₃	86.00 a-d	16.72 d-f	12.14 c-e	13.26 a-e	16.20 b-d	7.71 b-f
N₂ P₀	83.33 a-d	16.31 d-f	12.59 b-e	12.24 d-f	13.24 f-i	7.13 ef
N₂ P₁	84.66 a-d	17.77 b-e	11.46 d-g	13.49 a-e	15.06 c-f	7.91 b-e
N₂ P₂	91.33 a	21.01 a	10.20 g	15.26 a	18.83 a	9.57 a
N₂ P₃	90.00 ab	19.66 ab	10.42 fg	14.63 ab	17.26 ab	8.47 bc
N₃ P₀	84.66 a-d	16.98 c-f	12.45 b-e	12.38 c-f	15.30 b-e	7.64 b-f
N₃ P₁	86.33 a-d	18.22 b-d	12.01 c-f	13.76 a-e	16.10 b-d	8.18 b-d
N₃ P₂	89.33 a-c	19.21 a-c	11.03 e-g	14.38 a-c	16.60 bc	8.60 ab
N₃ P₃	88.66 a-d	18.98 a-c	11.41 d-g	14.00 a-d	16.93 a-c	8.48 bc
LSD	9.91	2.23	1.70	2.08	2.02	1.01
CV (%)	7.05	7.80	8.25	9.72	8.37	7.95

Means in a column followed by the same letter(s) are not significantly different at 5% level

Here, N₀= 0 kg/ha; N₁= 27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha, P₀= 0 kg/ha; P₁= 15.84 kg/ha; P₂= 31.68 kg/ha; P₃= 47.52 kg/ha.

A significant variation was found in EC test value due to the application of different levels of phosphorus (table 9.). The maximum EC value (13.35 dS/cm) was recorded in P_0 which, was statistically similar to P_1 (12.57 dS/cm). On the other hand, the minimum EC value (11.79 dS/cm) was recorded in treatment P_2 which was identical to P_3 .

The combined effect of nitrogen and phosphorus was significant on EC value of spinach (Table 10). The highest EC value (14.83 dS/cm) was recorded in (N_0P_0) which, was statistically similar to N_0P_1 (13.97 dS/cm), N_0P_2 (13.37 dS/cm), N_0P_3 (13.30 dS/cm) and N_1P_0 (13.55 dS/cm). On the other hand, the lowest EC test value (10.20 dS/cm) was recorded in N_2P_2 which was similar to N_2P_3 .

4.4.7. Economic analysis

Input cost for land preparation, spinach seed cost, organic manures, pesticides, irrigation and manpower required for all the operations from sowing to harvesting of spinach seed were recorded for unit plot and converted into cost per hectare. Price of spinach seed was considered as per market rate.

4.4.7.1. Gross return

The combination of nitrogen and phosphorus showed different gross return. The highest gross return (195000 Tk.) was obtained from N_2P_2 and the second highest gross return (174000 Tk.) was found from N_2P_3 . The lowest gross return (117000 Tk.) was obtained from the treatment combination of N_0P_0 (Table.11)

4.4.7.2. Net return

The combination of nitrogen and phosphorus showed different net return. The highest net return (72546 Tk.) was obtained in N_2P_2 and the second highest net return (49860.7 Tk.) was found in N_2P_3 . The lowest net return (13156 Tk.) was found in N_0P_0 (Table.11)

Table 11. Cost and return analysis of spinach seed considering nitrogen and phosphorus

Treatments	Seed yield (t/ha)	Gross return (Tk/ha)	Total cost of production(Tk)	Net return (Tk/ha)	Benefit cost ratio (BCR)
N₀P₀	0.69	117000	116656.8	13156	1.01
N₀ P₁	0.83	124500	118342	6158	1.05
N₀ P₂	0.85	127500	120027.3	7472.7	1.06
N₀ P₃	0.88	132000	121712.5	10287.5	1.08
N₁ P₀	0.83	124500	117870.1	6629.9	1.05
N₁ P₁	0.91	136500	119555.4	16944.6	1.14
N₁ P₂	0.95	142500	121240.6	21259.4	1.17
N₁ P₃	0.96	144000	122925.9	21074.1	1.17
N₂ P₀	0.93	133500	119083.5	14416.5	1.12
N₂ P₁	0.99	148500	120768.8	27731.2	1.22
N₂ P₂	1.30	195000	122454	72546	1.59
N₂ P₃	1.16	174000	124139.3	49860.7	1.40
N₃ P₀	0.92	138000	120296.9	17703.1	1.14
N₃ P₁	0.98	147000	121982.1	25017.9	1.20
N₃ P₂	1.09	163500	123667.4	39832.6	1.32
N₃ P₃	1.04	156000	125352.6	30647.4	1.24

Total cost of production was done in details according to the procedure of Krishitattik Fasaler Utpadon O Unnayon (in Bengali), 1989 Alam et al., pp. 231-239.

- Sale of marketable seed @ Tk.150/kg
- Gross return = Marketable yield x Tk./kg
- Net income = Gross return- Total cost of production
- BCR = Gross return ÷ cost of production

4.4.7.3. Benefit cost ratio

The combination of nitrogen and phosphorus showed different benefit cost ratio. The highest benefit cost ratio (1.59) was obtained in N_2P_2 and the second highest benefit cost ratio (1.40) was found in N_2P_3 . The lowest benefit cost ratio (1.01) was obtained in the treatment combination of N_0P_0 (Table.11). From Economic point of view, it was apparent from the above results that the combination of N_2P_2 treatment combination was more profitable than rest of the combination.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during rabi (November, 2016 to March, 2017) to study the effect of nitrogen and phosphorus on the growth and seed yield of spinach. The experimental field belongs to the Agro-ecological zone (AEZ) of “The Madhupur Tract”, AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors. Factor A: Nitrogen management 4 levels, N_0 = Control (0 kg/ha) N_1 = 27.6 kg/ha, N_2 = 55.2 kg/ha, N_3 = 82.8 kg/ha, and factor B: P_0 = Control (0 kg/ha); P_1 = 15.84 kg/ha, P_2 = 31.68 kg/ha, P_3 = 47.52 kg/ha. There were 16 treatment combinations. RCBD design was followed with three replications for this experiment. The local variety was used in this experiment as the test crop. The total numbers of unit plots were 48. The size of unit plot was 1.5 m² (1.5 m × 1 m). Nitrogen and phosphorus were applied as per treatment variables and other fertilizer were applied as per BARI recommendation. Data on different yield contributing characters and yield were recorded to find out the optimum levels of nitrogen and phosphorus for higher yield of spinach.

Different growth of plant and seed yield parameters along with seed quality were significantly influenced by different levels of nitrogen. The tallest plants (13.94 cm and 47.69 cm before flowering and at harvest respectively) were measured in N_3 , while the shortest plants (11.01 cm and 34.88 cm before flowering and at harvest respectively) were found in N_0 treatment. The maximum and minimum leaves per plant (8.46 and 6.42) were obtained in N_2 and N_0 treatment respectively. The highest and the lowest number of inflorescence per plant (8.03 and 5.17), length of inflorescence (29.54 cm and 19.99 cm), number of seeds per inflorescence (58.86 and 38.15), seed yield per plant (3.64 g and 2.71 g), seed yield per plot (110.00 g and 81.58 g), seed yield per ha (1.10 t and 0.81 t) and 1000 seed weight (10.19 g and 9.24 g) were recorded in N_2 and N_0 treatments respectively. The highest and the lowest germination percent (87.33 % and 79.33 %), germination index (18.69 % and 15.42 %), shoot length (16.23 cm and 11.64 cm), root length (8.27 cm and 6.77 cm), dry weight of seedling (13.90 % and 11.34 %) were found in N_2 and N_0 treatments respectively. The highest and the lowest

EC values (13.87 dS/cm and 11.16 dS/cm) were found in N₀ and N₂ treatments respectively.

Different growth of plant and seed yield parameters, seed quality were significantly influenced by different levels of phosphorus. The tallest plants (13.64 cm and 46.68 cm before flowering and at harvest respectively) were found in P₃, while the shortest plants (11.60 cm and 35.18 cm before flowering and at harvest respectively) were observed in P₀ treatment. The maximum and the minimum leaves per plant (8.30 and 6.36) were obtained in P₃ and P₀ treatments respectively. The highest and the lowest number of inflorescence per plant (7.80 and 4.94), length of inflorescence (28.97 cm and 20.58 cm), number of seeds per inflorescence (57.19 and 39.13), seed yield per plant (3.49 g and 2.81 g), seed yield per plot (105.00 g and 84.58 g), seed yield per ha (1.05 t and 0.84 t) and 1000 seed weight (10.20 g and 9.23 g) were recorded in P₂ and P₀ treatments respectively. The highest and the lowest germination percent (87.08 % and 79.91 %), germination index (18.22 % and 15.74 %), shoot length (15.99 cm and 12.34 cm), root length (8.21 cm and 6.94 cm), dry weight of seedlings (13.61 % and 11.66 %) were found in P₂ and P₀ treatments respectively. The highest and the lowest EC values (13.35 dS/cm and 11.79 dS/cm) were found in P₀ and P₂ treatment respectively.

Different growth of plant and seed yield parameters studied were significantly varied by the combined effects of different levels of nitrogen and phosphorus. The tallest plants (15.21 cm and 55.25 cm before flowering and at harvest respectively) in N₃P₃, while the shortest plants (10.10 cm and 27.70 cm before flowering and at harvest respectively) in N₀P₀. The maximum and the minimum leaves per plant (10.35 and 5.01) and were obtained in N₂P₂ and N₀P₀ treatment combinations respectively. The highest and the lowest number of inflorescence per plant (10.53 and 3.90), length of inflorescence (35.04 cm and 15.19 cm), number of seeds per inflorescence (70.41 and 28.03), seed yield per plant (4.33 g and 2.30 g), seed yield per plot (130.00 g and 69.00 g), seed yield per ha (1.30 t and 0.69 t) 1000 seed weight (11.06 g and 8.77 g) were recorded in N₂P₂ and N₀P₀ treatment combinations respectively. The highest and the lowest germination percent (91.33 % and 72.66 %), germination index (21.01 % and 13.81 %), shoot length (18.83 cm and 9.16 cm), root length (9.57 cm and 6.5.95 cm), dry weight of seedling (15.26 % and 10.08 %) were found in N₂P₂ and N₀P₀ treatment combinations respectively. The highest and the lowest EC values (14.83 dS/cm and 10.74 dS/cm) were found in N₂P₂ and N₀P₀ treatment combinations respectively.

Based on the experimental results, it may be concluded that-

- i) Nitrogen had a positive effect on morphological characters, yield contributing characters, seed yield and seed quality of spinach. Application of N 55.2 kg /ha seemed to be suitable for seed production.
- ii) Phosphorus also had a positive effect on morphological characters, yield contributing characters, seed yield and seed quality of spinach. Application of P 31.68 kg /ha seemed to be suitable for seed production.
- iii) The combined effect of nitrogen and phosphorus had positive effect on morphological characters, seed yield contributing characters, yield and seed quality of spinach. Application of N 55.2 kg/ ha with P 31.68 kg/ ha combination seemed to be more suitable for getting higher seed yield of spinach.

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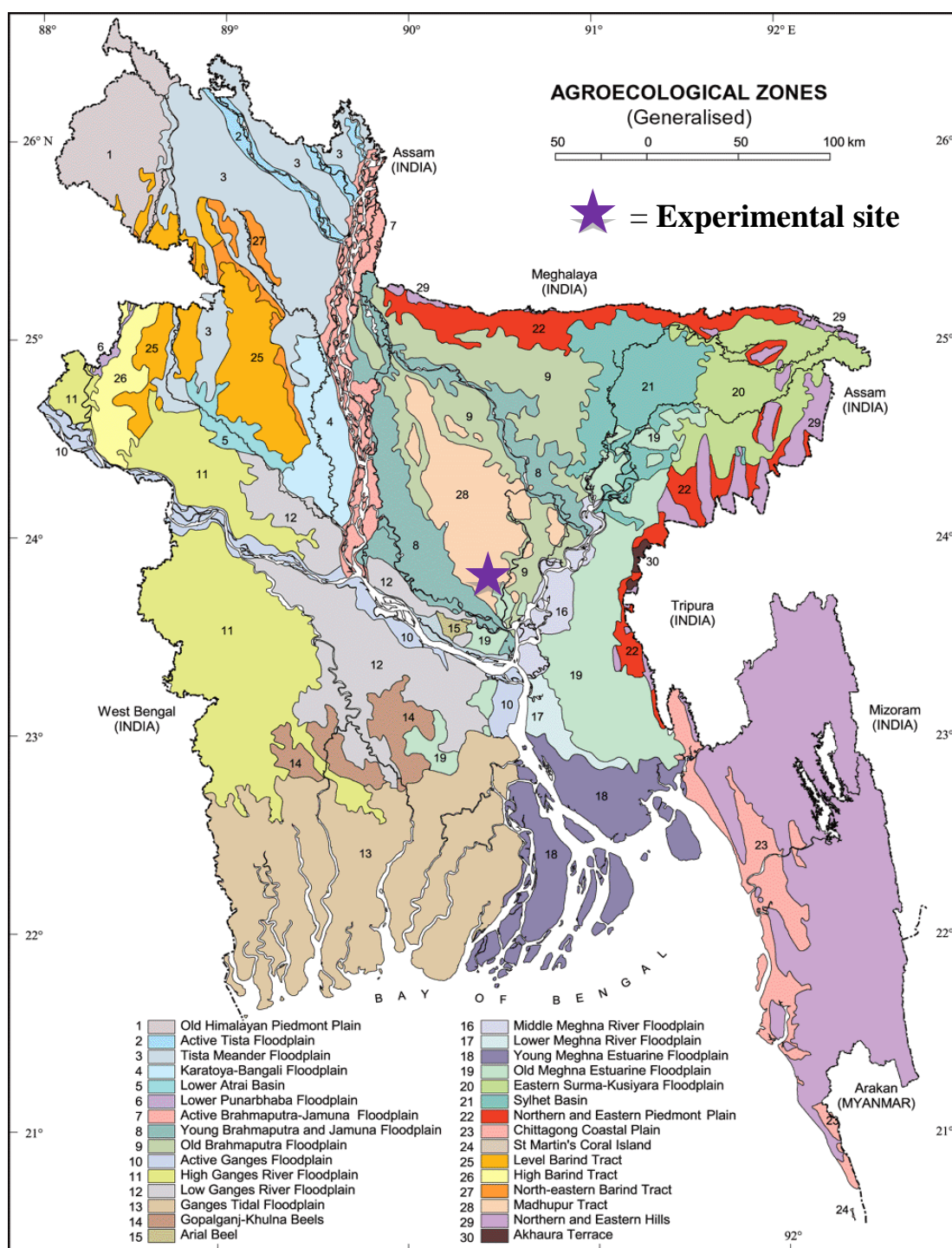
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APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

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

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

Physical characteristics	
Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	Value
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.48
Total nitrogen (%)	0.05
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

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

Appendix III. Monthly meteorological information during the period from November, 2017 to March, 2018

Year	Month	Air temperature (°C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2016	November	28.9	11.2	58	46
	December	25.00	9.5	65.34	0
	January	30.4	15.6	68.4	50
	February	32.30	21.80	74.3	75
	March	33.9	23.6	55.29	102

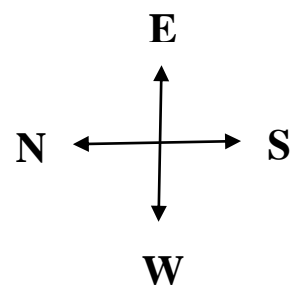
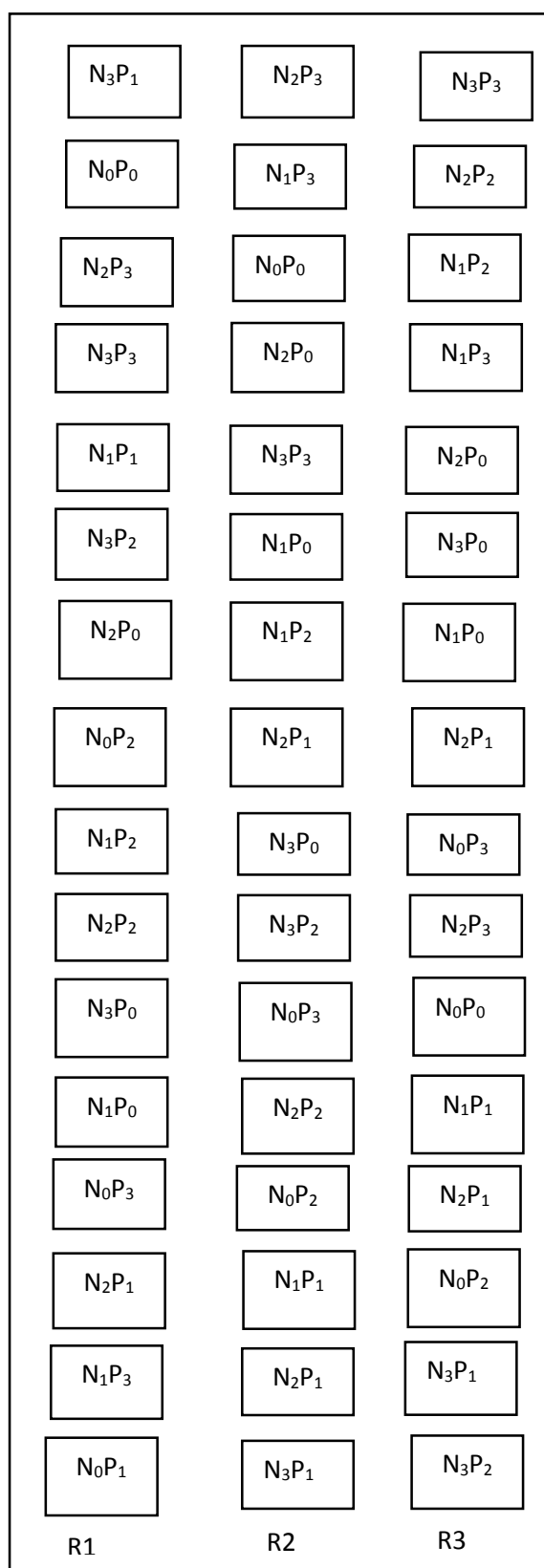
Source: Meteorological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Layout for experimental field.

Total number of unit plots: $16 \times 3 = 48$

Unit plot size: $1.5 \text{ m} \times 1 \text{ m} = 1.5 \text{ m}^2$

The main plot and unit plots were separated by 0.75m and 0.5m, respectively.



Appendix V. Analysis of variance of the data on plant height (cm) before flowering, Plant height at the time of harvest, no. of leaves per plant of spinach as influenced by combined effect of nitrogen and phosphorus

Source of variation	df	Mean square value		
		plant height (cm) before flowering	Plant height (cm) at the time of harvest	no. of leaves per plant
Replication	2	5.42	10.02	0.63
Nitrogen (A)	3	18.43	353.68	9.05
Phosphorus (B)	3	9.63	306.29	9.25
Nitrogen (A) X Phosphorus (B)	9	0.14	7.98	1.14
Error	30	1.10	14.05	0.42

Appendix VI. Analysis of variance of the data on no. of inflorescence per plant, Length of inflorescence, no. of seed per inflorescence of spinach influenced by combined effect of different level of nitrogen and phosphorus

Source of variation	df	Mean square value		
		No. of inflorescence per plant	Length of inflorescence	No. of seed per inflorescence
Replication	2	0.76	1.00	228.08
Nitrogen (A)	3	17.76	251.28	1060.43
Phosphorus (B)	2	21.49	186.97	843.14
Nitrogen (A) X Phosphorus (B)	9	1.66	85.25	20.61
Error	30	0.31	4.96	16.6

Appendix VII. Analysis of variance of the data on seed yield (per plant, per plot and per ha) and 1000 seed weight of spinach influenced by combined effect of different level of nitrogen and phosphorus

Source of variation	df	Mean square value			
		Seed yield per plant	Seed yield per plot	Seed yield per ha	1000 seed weight
Replication	2	0.01	14.65	0.01	0.15
Nitrogen (A)	3	2.00	1808.97	0.18	2.48
Phosphorus (B)	2	1.1	995.13	0.09	2.73
Nitrogen (A) X Phosphorus (B)	9	0.11	103.26	0.01	0.21
Error	30	0.07	63.2	0.01	0.81

Appendix VIII. Analysis of variance of the data on germination %, germination index, root length, shoot length, dry matter of seedling and EC test value as influenced by combined effect of different level of nitrogen and phosphorus

Source of variation	df	Mean square value					
		Germination %	Germination index	Root length cm	Shoot length cm	Dry matter of seedling %	EC test value dS/cm
Replication	2	1.01	0.28	5.56	5.01	7.01	5.14
Nitrogen (A)	3	173.38	29.16	6.16	55.73	16.05	17.07
Phosphorus (B)	3	129.88	15.41	3.66	33.05	9.94	6.60
Nitrogen (A) X Phosphorus (B)	9	8.24	1.73	0.42	2.56	0.47	0.25
Error	30	35.35	1.8	0.37	1.47	1.57	1.04

Appendix IX. Per hectare production cost of spinach seed production as influence by nitrogen and phosphorus

A. Input cost

Treatment	Cost of production (Tk)								
	Labor	Seed	Pesticide	Ploughing	Irrigation	Organic Manure(Tons)			Sub-total (A)
						CD	urea	TSP	
N ₀ P ₀	20000	7500	2000	10000	1000	10000	0	0	50500
N ₀ P ₁	20000	7500	2000	10000	1000	10000	0	1500	52000
N ₀ P ₂	20000	7500	2000	10000	1000	10000	0	3000	53500
N ₀ P ₃	20000	7500	2000	10000	1000	10000	0	4500	55000
N ₁ P ₀	20000	7500	2000	10000	1000	10000	1080	0	51580
N ₁ P ₁	20000	7500	2000	10000	1000	10000	1080	1500	53080
N ₁ P ₂	20000	7500	2000	10000	1000	10000	1080	3000	54580
N ₁ P ₃	20000	7500	2000	10000	1000	10000	1080	4500	56080
N ₂ P ₀	20000	7500	2000	10000	1000	10000	2160	0	52660
N ₂ P ₁	20000	7500	2000	10000	1000	10000	2160	1500	54160
N ₂ P ₂	20000	7500	2000	10000	1000	10000	2160	3000	55660
N ₂ P ₃	20000	7500	2000	10000	1000	10000	2160	4500	57160
N ₃ P ₀	20000	7500	2000	10000	1000	10000	3240	0	53740
N ₃ P ₁	20000	7500	2000	10000	1000	10000	3240	1500	55240
N ₃ P ₂	20000	7500	2000	10000	1000	10000	3240	3000	56740
N ₃ P ₃	20000	7500	2000	10000	1000	10000	3240	4500	58240

N₀= 0 kg/ha; N₁=27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha.
 P₀= 0 kg/ha; P₁= 15.84 kg/ha; P₂= 31.68 kg/ha; P₃= 47.52 kg/ha.
 CD= cowdung

Appendix IX. (Continued)

B. Overhead cost (Tk/ha)

Treatment combination	Cost of lease of land for 6 month (14% of value of Tk. 800000/year)	Miscellaneous cost (Tk. 5 % of the input cost)	Interest on running capital for 6 months(14% of cost/year)	Sub-total (Tk.) (B)	Total cost of production Tk./ha input cost (A) + overhead cost (B)
N₀P₀	56000	2525	7631.75	66156.75	116656.8
N₀ P₁	56000	2600	7742	66342	118342
N₀ P₂	56000	2675	7852.25	66527.25	120027.3
N₀ P₃	56000	2750	7962.5	66712.5	121712.5
N₁ P₀	56000	2579	7711.13	66290.13	117870.1
N₁ P₁	56000	2654	7821.38	66475.38	119555.4
N₁ P₂	56000	2729	7931.63	66660.63	121240.6
N₁ P₃	56000	2804	8041.88	66845.88	122925.9
N₂ P₀	56000	2633	7790.51	66423.51	119083.5
N₂ P₁	56000	2708	7900.76	66608.76	120768.8
N₂ P₂	56000	2783	8011.01	66794.01	122454
N₂ P₃	56000	2858	8121.26	66979.26	124139.3
N₃ P₀	56000	2687	7869.89	66556.89	120296.9
N₃ P₁	56000	2762	7980.14	66742.14	121982.1
N₃ P₂	56000	2837	8090.39	66927.39	123667.4
N₃ P₃	56000	2912	8200.64	67112.64	125352.6

N₀= 0 kg/ha; N₁=27.6 kg/ha; N₂= 55.2 kg/ha; N₃= 82.8 kg/ha.
P₀= 0 kg/ha; P₁= 15.84 kg/ha; P₂= 31.68 kg/ha; P₃= 47.52 kg/ha. CD= cowdung