RESPONSE OF NITROGEN AND PHOSPHORUS FERTILIZERS ON MORPHO-PHYSIOLOGICAL TRAITS AND YIELD ATTRIBUTES OF SOYBEAN (*Glycine max* L. Merill.)

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DECEMBER, 2020

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Registration No.: **18-09083**

A Thesis

Submitted to the Department of Soil Science, Faculty of Agriculture,

Sher-e-Bangla Agricultural University, Dhaka in partial

Fulfillment of the requirement for the degree of

MASTER OF SCIENCE (MS)
IN
SOIL SCIENCE

Semester: July-December/2020

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CERTIFICATE

This is to certify that the thesis entitled, **"Response of nitrogen and phosphorus fertilizers on morpho-physiological traits and yield attributes of soybean (*Glycine max* L. Merill.)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirement for the degree of **Master of Science in Soil Science,** embodies the result of a piece of *bona fide* research work carried out by **Md. Al-Amin Hossain,** Registration No.:**18-09083**, under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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To my parents and sisters
For always loving and supporting me

ACKNOWLEDGEMENT

The author expresses the endless gratitude to the supreme ruler Almighty Allah Who enabled him to complete the thesis successfully.

The author expresses his deepest sense of gratitude, immense indebtedness and profound appreciation to his reverend research supervisor **Professor Dr. Mohammad Mosharraf Hossain**, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for planning the research work, vigilant supervision, constructive suggestions, sympathetic encouragement to conduct the research work as well as preparation and for going through the manuscript of the thesis.

He also expresses his grateful appreciation and deep sense of respect to his research co-supervisor **Professor Dr. Alok Kumar Paul**, Department of Soil Science, and honorable Dean, Post-Graduate Studies, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for proper guidance, continuous advice, constructive criticism, painstaking suggestions, kind help and encouragement during the course of research work and preparation of this manuscript.He is immensely indebted to **Professor A T M Shamsuddoha**, Chairman of the Department of Soil Science, Sher-e-Bangla Agricultural University,Dhaka, Bangladesh for providing his the facilities to conduct the experiment.He expresses his gratitude and profound respect to all of his respective teachers of the Department of Soil Science, Sher-e-Bangla Agricultural University ,Dhaka for their valuable teaching and co-operations in completing the research study.

He also expresses his sincere gratitude and thanks to all other staff of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for their kind and untiring help and sincere cooperation during the research period.

It is beyond words to express her appreciation, gratitude and esteemed respect for his parents for their unconditional love, ever willing help, patience, constant encouragement and their faith in his which always kept his focused on his objectives and helped to achieve his goals.

At last but not the least, the author wishes to express his profound gratitude and deepest appreciation to his all other relatives for their ever-ending prayer, encouragement, sacrifice and dedicated efforts to educate his to this level.

Dhaka, Bangladesh

December, 2020 **The author**

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By

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ABSTRACT

Soybean (*Glycine max* L.) is one of the most important sources of oil and protein and is commonly used in both human and animal diets. For better production of soybean, it is compulsory to focus on the application of different essential nutrients in the form of fertilizers. For this purpose, a research work was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka during the period from March, 2019 to July, 2019 to study growth and yield of Soybean (BARI Soybean 4) as influenced by different levels of nitrogen and phosphorus. The experiment included three levels of nitrogen viz., 0, 25, and 40 kg N ha^{-1} and four levels of phosphorus viz., 0, 18, 36 and 54 kg P ha^{-1}. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Nitrogen fertilizer had significant effect on growth and yield of Soybean. Application of nitrogen @ 25 kg ha^{-1} gave the highest plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$, number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, 1000-seed weight, seed yield and Stover yield. In all cases the lower values were found with the untreated control treatment. Phosphorus fertilizers also had significant effect on growth and yield of soybean. Application of phosphorus @ 54 kg ha^{-1} produced the highest plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$, number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, 1000-seed weight, seed yield and Stover yield. In all the cases lower values were found with the control treatment. Nitrogen @ 25 kg ha^{-1} was found statistically superior to all other treatments. Nitrogen in combination with phosphorus showed significant effect on yield and yield attributes of Soybean. Combined application of nitrogen @ 25 kg ha^{-1} and phosphorus @ 54 kg ha^{-1} resulted the highest plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$, number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, 1000-seed weight, seed yield and Stover yield.

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LISTS OF ACRONYMS

Abbreviations	Elaboration
%	Percent
@	At the rate
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
BINA	Bangladesh Institute of Nuclear Agriculture
CEC	Cation Exchange Capacity
cm	Centi-meter
CV%	Percentage of coefficient of variation
df	Degrees of Freedom
LSD	Least Significant Difference
EC	Emulsifiable concentration
et al	and others
etc	Etcetera
FAO	Food and Agricultural Organization
g	Gram
H	Hours
J.	Journal
kg ha^{-1}	Kilograms per hectre
t ha^{-1}	Ton per hectare
Kg	kilogram
m	Metre
m^2	square metre
MoA	Ministry of Agriculture
MSE	Mean square of the error
No.	Number
ppm	parts per million
RCBD	Randomized Complete Block Design
Rep.	Replication
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
SE	Standard Error
Univ.	University
var.	variety

RESPONSE OF NITROGEN AND PHOSPHORUS FERTILIZERS ON PHYSIOLOGICAL TRAITS AND YIELD ATTRIBUTES OF SOYBEAN (*Glycine max* L. Merill.)

INTRODUCTION

Soybean *(Glycine max L.* Merill) ranks first as an oilseed crop of the world. It has a tremendous value in agriculture as a good source of high-quality plant protein and vegetable oils in one hand and nitrogen fixing ability on the other. It belongs to the family Leguminosae, sub family Papilionaceae. Soybean is originated in East Asia, but now it is widely cultivated in tropical, subtropical, and temperate climatic regions with an optimum mean temperature of 20-30°C. Soybean is quite wide spread in different regions of the world and grows well from the tropics to the temperate zones with greater production in the United States, Brazil, China, Mexico, Indonesia and Argentina. The world average seed yield of soybean is 2.48 t ha^{-1} in 2013, and high in the USA (2.91 t ha^{-1}), Brazil (2.93 t ha^{-1}), Argentina (2.54 t ha^{-1}), Paraguay (2.95 t ha^{-1}), and Canada (2.86 t ha^{-1}) compared with China (1.89 t ha^{-1}), Japan (1.55 t ha^{-1}), India (0.98 t ha^{-1}) and Bangladesh (1.50 to 2.30 t ha^{-1}) (FAOSTAT, 2016). Global production of soybeans is forecast to be 324 million tons in 2016, a 5% increase from the 2014 world total.

Soybean is also called as “Golden Bean” or “Miracle crop” of the 21st century on account of its multiple uses. It has highest protein 40 %, oil 20 %, rich in lysine and vitamins A, B and D and also rich in mineral salts. Soybean is one of the most important oilseed pulse crop in the world for human being. Soybean seeds contain about 40% protein and 20% oil which provide approximately 60% of the world supply of vegetable protein and 30% of the oil (Fehr. 1989). It has become the miracle crop of 20th century on account of having high protein and oil content and known as

"Golden Bean". Soybean is now figure out as "protein hope of future" for its nutritional value in Bangladesh. Soybean seed contains 40-45% protein, 20-22% oil, 20-26% carbohydrate and a high amount of Ca, P and vitamins (Rahman *et al*., 2011).

Prospects of soybean farming in Bangladesh is bright as it can successfully be grown under a wide range of climatic and soil conditions and cultivated throughout the year in Bangladesh (Rahman, 1982). Soybean helps to improve the soil by fixing the atmospheric nitrogen through *Rhizobium* bacteria. Steward (1966) observed that the soybean plants could fix 94 kg nitrogen ha^{-1} in soil in a season. In Bangladesh the area under soybean cultivation is about 5000 ha with a production of 4000 ton & the yield ranges from 1.50 to 2.30 t ha^{-1} (BARI, 2005). The lower yield of soybean at farmer's level is mainly attributed to the lack of improved agronomic management practices of which judicious fertilizer application is an important determinant for better yield of soybean.

Fertilization could adversely affect the growth, yield and yield components of soybean. Nutrient deficiency during the plant growth stage decreases seed yield, and seed number and size (Desclaux *et al*., 2000; Larry *et al*., 1986; Rebafka *et al*., 1993; Westgate and Peterson, 1993), but the magnitude of effects vary with the variety and quantity of the fertilizer (Pandey *et al*., 1984a). Among the nutrients, nitrogen is a major essential plant nutrient element. It has the quickest and most pronounced effect on plant growth and yield of crops. It tends primarily to encourage above ground vegetative growth and to impart deep green colour to the leaves. In all plants, nitrogen governs a considerable degree of utilization of potassium, phosphorus and other nutrients. Plants receiving insufficient nitrogen are stunted in growth with restricted root systems. The leaves turn yellow or yellowish green and tend to drop off. A high yield of soybean requires a large amount of N, and soybean plants should continue to assimilate nitrogen during both vegetative and reproductive stages. Many field data showed that the total amount of N assimilated in a plant shoot is highly correlated with the soybean seed yield. Most of the soil in Bangladesh is deficient in nitrogen. Nitrogen is responsible to increase the dry matter and protein percentage of grain as well as methionine and triptophen content in seed (Vidhate *et al.*, 1986). Utilization of the majority of this N occurs during seed development. Nitrogen sources for the soybean include mineralization, soil organic matter, symbiotically fixed N, and N incorporated into plant tissue. Under certain soil, climatic, and yield conditions, N supply may limit soybean seed production.

Phosphorus (P) is vital to plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next. Phosphorus plays a vital role in virtually every plant process that involves energy transfer. High-energy phosphate, held as a part of the chemical structures of adenosine diphosphate (ADP) and ATP, is the source of energy that drives the multitude of chemical reactions within the plant. When ADP and ATP transfer the high-energy phosphate to other molecules, the stage is set for many essential processes to occur. It is also critical in biological energy transfer processes that are vital for life and growth. Adequate phosphorus results in higher grain production, improved crop quality, greater stalk strength, increased root growth, and earlier crop maturity. Phosphorus is critical for root development and seed development and growth. Soybean is generally planted when soil temperatures are warmer and plants have a more vigorous rooting system than corn. Adequate P supplied to crops results in higher yield potential, improved crop quality, greater stalk strength, increased root growth, and earlier crop maturity. Phosphorus stimulates rhizobial activity, nodule formation and thus helps in N_2-fixation. It increases the water use efficiency, improves storage quality and hardness of the bean seed coat. As phosphorus plays a role in photosynthesis, respiration, energy storage and transfer, cell division and enlargement, it has been shown to be important for growth, development and yield of soybean (Kakar *et al*., 2002). It helps uptake of more nutrients and balances the nitrogen deficiency in soil and assists in seed maturation.

Despite voluminous works done at home and abroad, more research is needed to specify the amount of nitrogen and phosphorus for exploiting the maximum productivity of soybean, which is rather a new but promising crop in Bangladesh. The purpose of the present study was to determine the optimum level of nitrogen and phosphorus fertilizer as well as their combination for the maximum growth and yield performance of soybean. A very little is known about the soybean response in term of growth attributes toward applied nitrogen and phosphorus fertilizers. In view of the facts stated above, a field experiment was conducted under the following objectives:

i) To evaluate the response of soybean to nitrogen and phosphorus

ii) To determine the effect of different levels of nitrogen and phosphorus and their interaction on the growth and yield of soybean

Chapter III

REVIEW OF LITERATURE

A. The Biology of Soybean

Cultivated soybean, *Glycine max* (L.) Merr., is a diploidized tetraploid (2n=40), in the family *Leguminosae*, the subfamily *Papilionoideae*, the tribe *Phaseoleae*, the genus *Glycine* Willd and the subgenus *Soja* (Moench). It is an erect, bushy herbaceous annual that can reach a height of 1.5 metres. Three types of growth habit can be found amongst soybean cultivars viz. determinate, semi-determinate and indeterminate (Bernard and Weiss, 1973). Determinate growth is characterized by the cessation of vegetative activity of the terminal bud when it becomes an inflorescence at both axillary and terminal racemes. Determinate genotypes are primarily grown in the southern USA. Indeterminate genotypes continue vegetative activity throughout the flowering period and are grown primarily in central and northern regions of North America. Semi-determinate types have indeterminate stems that terminate vegetative growth abruptly after the flowering period. None of the soybean varieties are frost tolerant, and they do not survive Canadian winter conditions.

The primary leaves are unifoliate, opposite and ovate, the secondary leaves are trifoliolate and alternate, and compound leaves with four or more leaflets are occasionally present. The nodulated root system consists of a taproot from which emerges a lateral root system. The plants of most cultivars are covered with fine trichomes, but glabrous types also exist. The papilionaceous flower consists of a tubular calyx of five sepals, a corolla of five petals (one banner, two wings and two keels), one pistil and nine fused stamens with a single separate posterior stamen. The stamens form a ring at the base of the stigma and elongate one day before pollination, at which time the elevated anthers form a ring around the stigma. The pod is straight or slightly curved, varies in length from two to seven centimetres, and consists of two halves of a single carpel which are joined by a dorsal and ventral suture. The shape of the seed, usually oval, can vary amongst cultivars from almost spherical to elongate and flattened.

Soybean is grown primarily for the production of seed, has a multitude of uses in the food and industrial sectors, and represents one of the major sources of edible vegetable oil and of proteins for livestock feed use. The main food use is as purified oil, utilized in margarines, shortenings and cooking and salad oils. It is also used in various food products, including tofu, soya sauce, simulated milk and meat products. Soybean meal is used as a supplement in feed rations for livestock. Industrial use of soybeans ranges from the production of yeasts and antibodies to the manufacture of soaps and disinfectants.

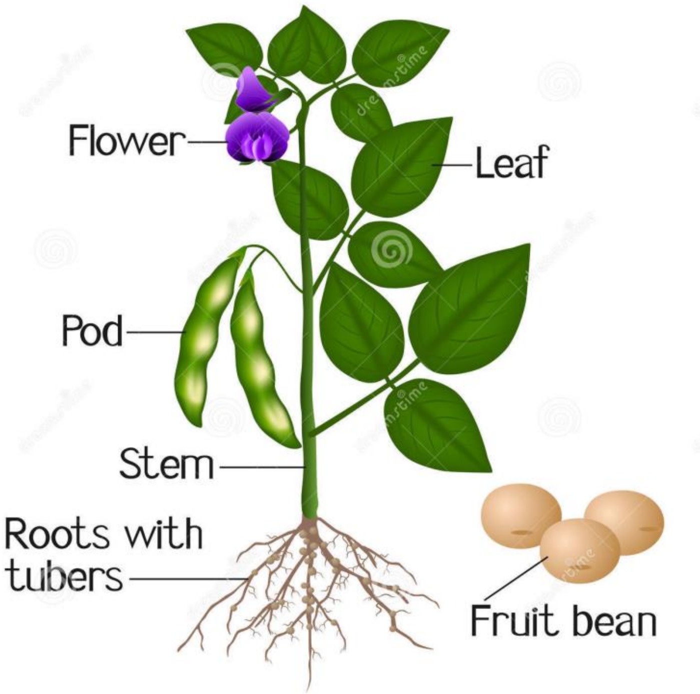

Fig. 1A: A mature soybean plant

Fig. 1B: A mature soybean plant **Fig. 1C: A mature soybean plant**

B. Nutrient Requirement of Soybean

High yielding soybeans require large amounts of nitrogen (N), phosphorus (P), and potassium (K) as well as a smaller amount of sulfur (S) and some micronutrients. Although soybean requires considerably less P and S than N or K, all are important for plant growth and development. Soybean grown in Iowa does not require an application of N fertilizer. Leguminous crops, like soybean, meet their demand for N through a process called biological N fixation. Soybean forms a symbiotic relationship with soil borne rhizobia bacteria (*Bradyrhizobium japonicum*) to convert, or 'fix' atmospheric N gas to ammonia (NH_3) N, a form usable by the plant. The rhizobia bacterium attaches to new soybean roots just behind the root tip then colonizes the plant. In response to bacterial chemical signals, plant root cells form nodules, which help protect the bacteria from oxygen. Nodules grow very rapidly and will continue to supply N to the plant for approximately six weeks. Nodules begin supplying N during the early vegetative growth phase and will continue through seed fill.

Soybeans are a legume and are able to obtain N from the atmosphere because they form a symbiotic relationship with N fixing bacteria called *Bradyrhizobium japonicum*. These N fixing bacteria colonize the roots of the soybean plant forming nodules. Within these nodules, the bacteria are able to convert N_2 gas from the atmosphere to ammonium (NH_4^+), which is a plant available form. The relationship is considered to be symbiotic because the soybean plant provides a food source (carbon) for the bacteria and the bacteria provide N to the soybean plant. Maximum N_2 fixation potential by soybean is estimated to be 300 lb/ac under ideal environmental conditions (e.g., adequate soil, soil moisture, fertility, and sunlight; no compaction in root zone; etc.). Soybean can also obtain inorganic N from the soil in the plant available forms of

NH_4^+ or NO_3^-. Some plant available N may be residual in the soil, meaning it was left over from fertilization of previous crops or breakdown of crop residues and residual manure applications. Soil organic matter is also a source of plant available N. When organic matter or are broken down by soil microbes, the organic N is converted to NH_4^+ via a process called mineralization.

P is considered an “immobile nutrient” compared to nitrogen (N) as it has a relatively short range of movement within soil. Plants take up soluble P that is in soil solution; however, the amount of soluble P in solution at any one time is quite low. As the supply of soil solution P decreases from plant uptake, the “supply” is replenished from other sources of soil phosphate. Essentially, unavailable P is slowly released to available forms to replenish P in soil solution. This is a continuous process, as the “pool” of soluble P may be replenished up to 500 times during the growing season to meet crop needs. The rate of replenishment is influenced by soil pH, current phosphorus levels, soil P fixation, and the placement of added phosphate fertilizers. Optimum phosphorus availability is at a soil pH range of 6.0 to 7.0. When soil is very acidic, aluminum and iron can bind to P to form insoluble phosphate compounds. With alkaline soils, phosphorus reacts with excess calcium to form unavailable compounds.

There are large amounts of K in the soil (frequently over 40,000 lbs/acre) but only a small fraction is available for plant uptake. Three forms of K exist in soils, unavailable, slowly available or fixed, and readily available or exchangeable. K that is dissolved in soil water and held on clay particles (exchangeable K) is considered readily available to plants. As soluble K concentration declines due to plant uptake, exchangeable K is released from clay particles to replenish the soluble K “pool”. Over time "slowly available K" is released replacing exchangeable K; however, plants cannot use much of this form of K in a single growing season.

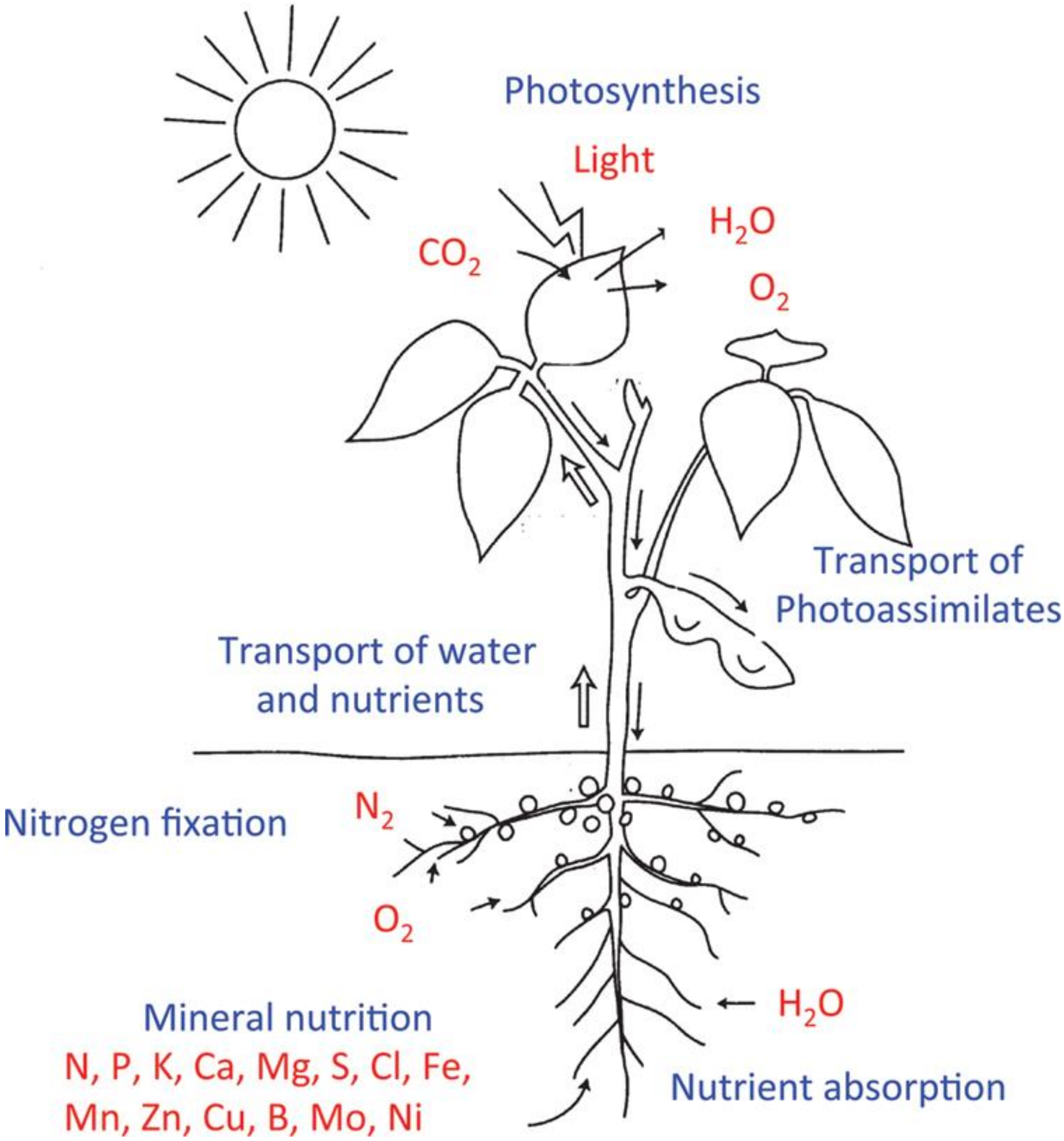

Fig.: Physiological processes of nutrient acquisition by soybean (Adapted from: Takuji *et al*., 2017)

2.1 Effect of nitrogen on growth, yield and yield contributing characters of soybean

Azadi *et al.* (2013) observed that different nitrogen levels influenced different growth and yield attributes of soybean such as plant height, seed yield, stem diameter, number of node and 75 kg N ha^{-1} showed higher performance than the other N doses (50, 100 and 150 kg N ha^{-1}).

Achakzai *et al.* (2012) found that different nitrogen levels influenced most of the growth attributes of the soybean. Maximum days to flowering, number of branches $plant^{-1}$, number of leaves $plant^{-1}$, plant height, number of branches $plant^{-1}$, leaf area and grain yield recorded for plants subjected to highest dose of applied N fertilizer @ 100 kg ha^{-1}.

Sultana *et al.* (2009) reported that application of 20 kg N ha^{-1} as basal dose and 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher values of all growth parameters of soybean like leaf area, shoot dry weight, number of branches, pods $plant^{-1}$ and seed yield.

Sultana (2006) noticed that plant height of soybean showed superiority at 30 kg N ha^{-1} followed by 40 kg N ha^{-1}. Nitrogen fertilizer significantly influenced plant height at all growth stages of soybean. At 20, 35, 50, 65 DAS and harvest, the maximum height were observed in the plants treated with 30 kg N ha^{-1}.

Ghosh (2004) used different levels of nitrogen and indicated that number of branches $plant^{-1}$ of soybean was gradually increased with increasing N level @ 25 kg N $ha^{-1.}$

Masud (2003) observed that highest plant height of soybean with the application of 30 kg N ha^{-1} while Ghosh (2004) at 25 kg N ha^{-1}.

Rudreshhappa and Halikatti (2002) explained the effect of N levels (0, 12.5 and 25 kg ha^{-1}) on growth, yield and nutrient uptake of green gram in paddy fallows. Application of 12.5 kg N ha^{-1} was recorded to produce significantly higher seed yield. Further increase in N doses (25 kg ha $^{-1}$) did not significantly increase the yield.

Srinivas *et al.* (2002) examined the effects of N (0, 20, 40 and 60 Kg ha^{-1}) and P_2O_5, 50 and 75 Kg ha^{-1}) along with seed inoculation with *Rhizobium* culture on the growth, yield and yield components of soybean. They observed that number of pods plant^{-1}, pod length and seeds pod^{-1} were increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} and also observed that 1000-seed weight in greengram.

Tank *et al.* (1992) found that soybean fertilized with 20 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} produced significantly higher number of pods plant^{-1} over the unfertilized control treated plot.

Pathak *et al*. (2001) evaluated the effect of N levels (0, 10, 20 and 30 kg ha^{-1}) on growth and yield of soybean under rainfed condition during the summer of 1999 and found that application of 20 kg N ha^{-1} yielded poorer than 30 kg N ha^{-1}.

Hamid (1999) revealed the effects of foliar application of nitrogen on soybean cv. Mubarik. In both pot and field trials, result showed 10 kg N ha^{-1} increased the number of pods plant^{-1}.

Yadravi and Angadi (2015) visualized that application of nitrogen 60 kg ha^{-1} recorded significantly higher soybean plant height (50.6 cm), number of branches plant^{-1} (6.8), total dry matter production plant^{-1} (34.4 g), leaf area plant^{-1} (10.9 dm2) and leaf area index plant^{-1} (3.6) compared to other treatments.

Mandic et al. (2015) conducted an experiment on two soybean genotypes and concluded that application of 46 kg urea ha^{-1} along with ferticare-I (5 kg ha^{-1}) recorded significantly higher plant height (140 and 107 cm, respectively) and higher nodes $plant^{-1}$ (16 and 13, respectively) in the two genotypes (JS-95-60 and JS-97-52).

Shafii *et al.* (2011) opined that application of 60 kg N ha^{-1} recorded significantly higher dry matter (2014 g m^{-2}) compared to other treatments. However, varying nitrogen levels didn't affect the soybean plant height significantly.

Koushal *et al.* (2011) conducted an experiment at Amritsar, observed that application of 50 % recommended N applied through urea + 50 % N applied through FYM + PSB recorded maximum plant height of 16.89 cm, 65.78 cm and 73.37 cm at 30, 60 and 90 DAS, respectively and number of trifoliate leaves 6.93, 26.70 and 21.20 at 30, 60 and 90 DAS, respectively, over the other treatments in soybean.

Mandal and Sikdar (1999) laid out a greenhouse pot experiment where soybean (BS-4) grown on saline soil and given 0, 50 or 100 kg N ha^{-1} and 0, 75 or 150 kg P ha^{-1}. Growth and yield increased significantly with N application while P significantly increased the setting of pods and seeds. Root growth was significantly improved by both individual and combined application of these two fertilizers.

Mozumder (1998) studied the effect of five N levels (0, 20, 40, 60 and 80 kg N ha^{-1}) and two varieties of summer soybean, shohag and BS-4, found that N exerted negative effect on the harvest index.

In an experiment with the foliar application of nutrients on the growth and yield of soybean cv. Kowmy-1, Abd-El-Latif *et al.* (1998) revealed that application of urea increase the number of branches $plant^{-1}$ on soybean plant.

Provorov *et al*. (1998) observed the effect of seed inoculation of soybean with strain CIAMI 901 of *Bradyrhizobium* and found that the seed yield was increased by 39.2% and 1000 seed weight 16%. These results were equivalent to applying 120 kg N ha^{-1}. Best results obtained with inoculations + 60 kg N ha^{-1}

Satyanarayanamma *et al.* (1996) in a field experiment found that spraying of 2% urea at flowering and pod development stage produced the highest seed yield (1.59 t ha^{-1}) over the untreated control.

Kaneria and Patel (1995) reported that the application of 10 kg N ha^{-1} to soybean significantly increased seed yield attributes.

Quah and Jafar (1994) noted that plant height of soybean was significantly increased by the application of nitrogen fertilizer with 50 kg ha^{-1} and also noted that 1000-seed weight of soybean increased significantly by the application of N at 50 kg ha^{-1}.

Gopala *et al.* (1993) found that the response of soybean cultivars (Pusa Baishakhi, LGG 407, LGG 410 and MS 267) to a uniform dose of 20 kg N ha^{-1} and found that plant height, net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR) were increased at 20 kg N ha^{-1}.

Tank *et al.* (1992) observed that soybean fertilized with 40 kg N ha^{-1} produced the highest seed yield $plant^{-1}$ while the lowest was observed in control treatment (0 kg N ha^{-1}).

Sarkar and Banik (1991) revealed that application of 10 kg N ha^{-1} to soybean resulted in appreciable improvement in yield attributes. They found that the stover yield of soybean increased significantly due to use of N up to 10 kg N ha^{-1}. On an average, the stover yield increased by 24% due to the application 10 kg N ha^{-1} over no N. They also observed that application of 10 kg N ha^{-1} to soybean resulted in appreciable improvement in number of pods plant^{-1} over no N application.

Suhartatik (1991) also reported that NPK fertilizers significantly increased the plant height of soybean.

Agbenin *et al.* (1991) revealed that application of N significantly increased plant height, seed yield, dry weight, crop growth rate and nutrient uptake of soybean over unfertilized control.

Leelavathi *et al.* (1991) reported that different levels of N showed significant differences in seed yield of soybean up to a certain level.

Samiullah *et al.* (1987) recorded that number of seeds pod^{-1} were the highest with 10 kg N + 75 kg P_2O_5 + 60 kg K_2O in summer soybean.

Mahmud and Gad (1988) observed that application of N increased the stover yield up to a certain level under different row spacing of soybean.

Patel and Parmer (1986) observed that increasing N application to rainfed soybean (*glycine max* L. cv. Gujrat-1) from 0-45 kg ha^{-1} increase average seed yield from 0.83 to 0.94 t ha^{-1} and also increased protein content, plant height, number of branches plant^{-1}, pods plant^{-1}, seeds plant^{-1} and 1000-seed weight.

Patel *et al.* (1993) studied that, in summer season on clayey soil application of 0, 10, 20 and 30 kg N ha^{-1} significantly increased the number of pods plant^{-1}.

Mandic *et al*. (2015) indicated that application of Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}) recorded higher number of pods plant^{-1} (58.1), number of grain plant^{-1} (124.8), 1000 grain weight (185.84 g) and grain yield (3961 kg ha^{-1}) compared to other treatments in soybean.

Ahmed (2013) concluded that Rhizobium + 80 kg N ha^{-1}, increased the seed yield (2.54 t ha^{-1}), number of pods $plant^{-1}$ (90.3) and number of seeds pod^{-1} (3.8) compared to other treatments, but the 100-seed weight was non-significant among the treatments in soybean.

Janagard et al. (2013) revealed that application of urea 16.5 kg ha^{-1} + 49.5 kg ha^{-1} + B. japonicum + PSB recorded significantly higher pod weight $plant^{-1}$ (12.2 g) and grain yield per unit area (321.8 g) compared to other treatments in soybean.

Singh and Singh (2013) reported that 20 kg N ha^{-1} as basal and 10 kg N at pod filling stage recorded higher grain yield (25.1 q ha^{-1}), straw yield (43.5 q ha^{-1}), biological yield (68.6 q ha^{-1}) and harvest index (36 %) as compared to control in soybean.

2.2 Effect of phosphorus on growth, yield and yield contributing characters of soybean

Malik *et al.* (2006) conducted a field experiment in Faisalabad, Pakistan in 2000 and 2001 to evaluate the interactive effects of irrigation and phosphorus on green gram *(Vigna radiata,* cv. NM-54). Five phosphorus doses (0, 20, 40, 60 and 80 kg P ha^{-1}) were arranged in a split plot design with four replications. Phosphorus application at 40 kg P_2O_5 ha^{-1} affected the crop positively, while below and above this rate resulted in no significant effects. Interactive effects of two irrigations and 40 kg P_2O_5 ha^{-1} were the most effective. The rest of the combinations remained statistically non-significant to each other. It may be concluded that greengram can be successfully grown with phosphorus at 40 kg P_2O_5 ha^{-1}.

Geeta and Radder (2015) observed that application of 80 kg P_2O_5 along with cured FYM + PSB + VAM recorded significantly higher plant height (66.27 cm), number of branches palnt^{-1} (6.67) and total dry matter production (27.49 g) compared to other treatments in soybean.

Mahmoodi *et al*. (2013) reported that application of 90 kg P_2O_5 ha^{-1} recorded significantly higher plant height (78.66 cm) over the control, 30 and 60 P_2O_5 kg ha^{-1} in soybean.

Bhattacharjee *et al*. (2013) opined that application of 90 kg P_2O_5 ha^{-1} recorded significantly higher plant height (75.3 cm) and number of leaves (27.4) compared to 30 and 60 kg P_2O_5 ha^{-1} in soybean.

Rana *et al*. (2012) revealed that growth attributes of soybean like plant height (81 cm) and dry matter production (803 g m^{-2}) increased with the application of 60 kg P_2O_5 ha$_{-1}$ in soybean.

Tickoo *et al.* (2006) carried out an experiment on soybean and cultivars Pusa 105 and Pusa Vishal which were sown at 22.5 and 30.0 m spacing and was supplied with 36-46 and 58-46 kg of N/P/ha in a field experiment conducted in New Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 and 1.63 t ha^{-1}) respectively compared to cv. Pusa 105. Nitrogen and phosphorus rates had no significant effects on both the biological and grain yield of the crop. Row spacing at 22.5 cm resulted in higher grain yields in both the cultivars.

A field experiment was conducted by Raman and Venkataramana (2006) during February to May 2002 in Annamalainagar, Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram *(V. radiata).* There were 10 foliar spray treatments, consisting of water spray. 2% diammonium phosphate (DAP) at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA, DAP + NAA, DAP + Penshibao, DAP + Zn chelate, DAP +

Penshibao + NAA, and DAP + NAA + Zn chelate. Crop nutrient uptake, yield and its attributes (number of pods/plant and number of seeds/pod) of greengram augmented significantly due to foliar nutrition. The foliar application of DAP + NAA + Penshibao was significantly superior to other treatments in increasing the values of N. P and K uptakes, yield attributes and yield. The highest grain yield of 1529 kg/ha was recorded with this treatment.

Bhat *et al.* (2005) conducted a study during the summer of 2004 in Uttar Pradesh, India to examine the effects of phosphorus levels on greengram. Four phosphorus rates (0. 30, 60 and 90 kg/ha) were used. All the phosphorus rates increased the seed yield significantly over the control. The highest seed yield was observed with 90 kg P/ha, which was at a with 60 kg P/ha and both were significantly superior to 30 kg P/ha. Likewise, 60 kg P/ha significantly improved the yield attributes except test weight compared to control. For the phosphorus rates, the stover yield followed the trend observed in seed yield.

A field experiment was conducted by Vikrant (2005) on a sandy loam soil in Hisar, Haryana India during khatif 2000-01 and 2001-02 to study the effects of P (0. 20. 40 and 60 kg $P_2O_5 ha^{-1}$) application to green gram cv. Asha. Application of 60 kg P, being at par with 40 kg P, was significantly superior to 0 and 20 kg P/ha in respect of grain, stover and protein yields of green gram.

Manpreet *et al.* (2005) conducted a field experiment to assess the response of different soybean genotypes in terms of nutrient uptake and quality to incremental levels of phosphorus application. Genotypes showed significant differences for straw and grain N content and grain P content while straw P content, N and P uptake differed non-significantly. Phosphorus application resulted in significant increase in N and P content and their uptake.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg/ha) on the growth and yield of soybean cv. AEM 96 in Tandojam, Pakistan, during the spring season of 2004. The different NPK levels significantly affected the crop parameters. The 10-30-30 kg NPK/ha was the best treatment, recording plant height of 56.3 germination of 90.5% satisfactory plant population of 162.0 prolonged days taken to maturity of 55.5. long pods of 5.02 cm, seed weight of 10.5 g, seed index of 3.5 g and the highest seed yield of 1205.2 kg/ha. There was no significant change in the crop parameters beyond this level.

A field experiment was conducted by Edwin *et al.* (2005) during 1995 and 1996 pre-kharif seasons in Imphal. Manipur, India to study the effect of sources (Single superphosphate (SSP), diammonium phosphate (DAP). Mussoorie rock phosphate (MRP). phosphate solubilizing organism (PSO) and farmyard manure) and levels (10, 15, 30 and 60 kg P2O5 ha^{-1}) of P on the growth and yield of greengram cv. AAU-34. The highest number of branches $plant^{-1}$ (3.23) was obtained with 30 kg MRP + 30 kg SSP ha^{-1}. Single super phosphate at 60 kg/ha gave the highest number of clusters $plant^{-1}$ (4.36). Pod length (7.34 cm), seeds pod^{-1} (10.5) 1000 seed weight (34.9 g) and seed yield (15.1 q ha^{-1}). Maximum plant height (31.2 cm), dry matter $plant^{-1}$ (36.1 g) and number of pods $plant^{-1}$ (l 7.4) was obtained with 60 kg DAP ha^{-1}.

Khan *et al.* (2004) conducted a study to determine the effect of different levels of phosphorus on the yield components of soybean cv. NM-98 in D.I. Khan Pakistan in 2000. Treatments comprised: 0, 20, 40, 60, 80, and 100 kg P/ha. The increase in phosphorus levels decreased the days to flowering and increased the branches/plant, number of pods/plant, 1000-grain weight and grain yield. The highest yield of 1022 kg/ha was obtained at the phosphorus level of 100 kg/ha compared to a 774-kg/ha yield in the control. However, the most economical phosphorus level was 40 kg/ha, because it produced a grain yield statistically comparable to 100 kg P/ha.

A field experiment was conducted by Manpreet *et al.* (2004) in Ludhiana, Punjab, India during summer 2000 to investigate the response of soybean genotypes (SML 1 34. SML 357 and SML 668) to P application (0. 20. 40 and 60 kg P_2O_5/ha) under irrigated conditions. Yield attributes such as number of branches/plant and pods/plant were significantly higher in SML 357 and SML whereas pod length and 100-seed weight were higher in SML 668, which accounted for higher grain yield in this cultivar compared to SML 134 but was at par with SML 357. The straw yield showed the reverse trend with significantly higher value for SML 1 34, thus lowering the harvest index significantly compared to SML 668 and SML 357. Phosphorus application showed a non-significant effect on number of branches/plant, number of seeds/pod, pod length and 100 seed weight. However, the increase in P level showed significant increase in the number of pods per plant, which accounted for significantly higher grain and straw yields at higher levels (40 and 60 kg/ha) compared to lower levels (0 and 20 kg/ha). Harvest index remained unaffected with P application. The economic optimum P level for all the 3 summer soybean genotypes was found to be 46. 1 kg P_2O_5/ha.

Nadeem *et al.* (2004) studied the response of soybean cv. NM-98 to seed inoculation and different levels of fertilizer (0-0, 15-30, 30-60 and 45-90 kg N- P_2O_5 ha^{-1}) under field conditions. Application of fertilizer significantly increased the yield and the maximum seed yield was obtained when 30 kg N ha^{-1} was applied along with 60 kg P_2O_5 ha^{-1}.

Asif *et al.* (2003) conducted a field trial to find out the influence of phosphorus fertilizer on growth and yield of soybean in India. They found that various levels of phosphorus significantly affected the number of leaves plant^{-1}, number of pods plant^{-1}, plant height, number of grain pod^{-1} and 1000-grain weight. Phosphorus level of 35 kg ha^{-1} produced the maximum grain yield.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying levels of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of soybean cv. NM-98 in 2001. They observed that number of flowers/plant was found to be significantly higher by 25 kg N ha^{-1}. Number of seeds/pod was significantly affected by varying levels of nitrogen and phosphorus. Growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg P ha^{-1}resulted with maximum seed yield (1.1ton ha^{-1}).

Satish *et al.* (2003) conducted an experiment in Haryana, India in 1999 and 2000 to investigate the response of soybean cultivars Asha, MH 97-2, MH 85-111 and K 851 to different P levels (0, 20, 40 and 60 kg P_2O_5/ha). Results revealed that the highest dry matter content in the leaves, stems and pods was obtained in Asha and MH 97-2. The total above-ground dry matter as well as the dry matter accumulation in leaves, stems and pods increased with increasing P level up to 60 kg P/ha. MH 97-2 and Asha produced significantly more number of pods and branches/plant compared to MH 85-111 and K 851. Phosphorus at 40 and 60 kg/ha increased the number of pods/plant grain yield and grains per pod over the control and P at 20 kg/ha. The number of branches plant^{-1} increased with increasing P rates.

Rajender *et al.* (2002) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on soybean genotypes MH 85- 111 and T44. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield. The number of branches, number of pods plant^{-1}, numbers of seeds pod^{-1}. 1000 seed weight and straw yield increased with increasing rates P. whereas grain yield increased with increasing rates up to 40 kg P ha^{-1} only

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels on soybean at the Agronomic Research Station, Farooqabad in Pakistan. They revealed that various yield components like 1000-grain weight was affected significantly with 50-50-0 N kg ha^{-1}, P kg ha^{-1}, K kg ha^{-1} application. Again they revealed that seed inoculation with 50-50-0 N kg ha^{-1}, kg ha^{-1}, K kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

Nita *et al.* (2002) carried out a field experiment on soybean and showed that seed yield, protein content and net production value increased with increasing rates of K and S.

Srinivas *et al.* (2002) conducted an experiment on the performance of soybean at different levels of nitrogen and phosphorus. Different rates of N (0, 25 and 60 kg ha^{-1}) and P (0, 25, 50 and 60 kg ha^{-1}) were tested. They observed that the number of pods/plant was increased with the increasing rates of N up to 40 kg ha^{-1} followed by a decrease with further increase in N. They also observed that 1000-seed weight was increased with increasing rates of N up to 40 kg ha^{-1} along with increasing rates of P which was then followed by a decrease with further increase in N.

Yadav and Rathore (2002) carried out a field trial to find out the effect of phosphorus and iron fertilizer on yield, protein content and nutrient uptake in soybean on loamy sandy soil in India. The results indicated that the seed and stover yield increased with the increasing phosphorus levels but significantly increased up to 60 kg P_2O_5 ha^{-1}. These results were confirmative to earlier reports of Singh *et al.* (1993).

Umar *et al.* (2001) observed that plant height and numbers of branches per plant were significantly increased by phosphorus application. Number of pods per plant, number of seeds per pod, 1000-seed weight and grain yields were also increased significantly by application of phosphorus along with nitrogen.

Teotia *et al.* (2001) conducted a greenhouse experiment to study the effect of P and S interaction on yield and nutrient composition of soybean cv. *Pant Moong-2* and revealed that P and S applied individually or in combination increased the N and K content of the grain and straw and the yield of the plant.

Two field experiments were conducted in Kalubia Governorate. Egypt, in 1999 and 2000 summer seasons by El-Metwally and Ahmed (2001) to investigate the effects of P levels (0, 15. 30 and 45 kg ha^{-1}) on the growth, yield and yield components as well as chemical composition of soybean cv. Kawmy-1. Growth, yield and yield components of soybean were markedly improved with the addition of 45 kg P ha^{-1}. Addition of 45 kg P ha^{-1} markedly increased total carbohydrates and protein percentages compared with other treatments. Application of 45 kg P ha^{-1} markedly increased the number of pods $plant^{-1}$. Addition of 30 kg P ha^{-1} was the recommended treatments to obtain the best results for growth, yield and yield components as well as chemical composition of soybean.

Prasad *et al.* (2000) conducted a pot experiment to study the effect of potassium on yield K-uptake by summer soybean (cv. T-44) and showed that the grain yield increased potassium application but result was statistically non- significant. Increasing potassium levels significantly increased potassium uptake. Available K in soil after K harvest of crop increased with increasing levels of K.

A field experiment was carried out by Sharma and Sharma (1999) during summer seasons at Golaghat. Assam. India. Soybean was grown using farmers practices (no fertilizer) or using a combinations of fertilizer application (30 kg N + 35 kg P_2O_5 ha^-

^{1}). Seed yield was 0.40 ton $ha^{-1}$with farmer's practices, while the highest yield was obtained by the fertilizer application (0.77 ton ha^{-1}).

Mastan *et al.* (1999) stated that the number of pods $plants^{-1}$ of summer soybean cv. LOG 127 increased with increasing P rates.

Mitra *et al.* (1999) reported that soybean grown in acid soils of Tripura. The maximum number of pods/plants were recorded with application of 50 kg P_2O_5 ha^{-1}.

Raundal *et al.* (1999) also reported that application of phosphorus 60 kg ha^{-1} to soybean grown in *Kharif* season significantly increase the dry matter yield.

Karle and Pawar (1998) examined the effect of varying levels of N and P fertilizers on summer soybean. They reported that soybean produced higher seed yield with the application of 15 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

Singh and Ahlawat (1998) reported that application of phosphorus to soybean cv. PS 16 increased the number of branches $plant^{-1}$ up to 12.9 kg ha^{-1} when grown in a sandy loam soil, low in organic carbon and N, and medium in P and K and with a pH of 7.8.

Ramamoorthy and Raj (1997) obtained 517 kg ha^{-1} seed yield of rainfed green gram without applied phosphorus and the highest (1044kg) with 25kg P_2O_5 ha^{-1}

Sharma and Singh (1997) carried out a field experiment during 1989 and 1990 to study the effect of various levels of phosphorus (0, 25, 50 and 75 kg ha^{-1}) on the growth and yield of soybean. Results of their study revealed that application of phosphorus at 30 kg ha^{-1} enhanced the plant height significantly.

Thakur *et al.* (1996) conducted an experiment with greengram *(Vigna radiata)* grown in kharif [monsoon] 1995 at Akola, Maharashtra, India which was given 0. 25. 50 or 75 kg P2O5 ha^{-1} as single superphosphate or diammonium phosphate. Seed and straw yields were not significantly affected by P source, and seed yield averaged 0.91, 1.00, 1.24 and 1.13 ha^{-1} at the 4 P rates, respectively. Phosphorus uptake was also highest with 50.

Shukla and Dixit (1996) conducted a field trial to study the response of soybean to different levels of phosphorus. They also reported that application of phosphorus up to 50 kg P_2O_5 ha^{-1} significantly increased the vigour of the plants resulted in more dry matter production.

Bayan and Saharia (1996) carried out an experiment to study the effect of phosphorus on soybean during the kharif seasons of 1994-95 in Bishanath Chariali Assam, India. The results indicated that plant height was unaffected by phosphorus application.

Rajkhowa *et al.* (1992) reported that application of phosphorus at 0- 60 kg $P2O_5$ ha^{-1} increased seed yield of soybean. However, the increase was significant up to 20 kg P_2O_5 ha^{-1} application.

Satter and Ahmed (1992) reported that phosphorus application up to 60 kg P_2O_5 ha^{-1} on soybean progressively and significantly increased nodulation, shoot length and weight, grain yield and total protein content.

Singh and Choudhury (1992) conducted a field experiment with green gram and observed that phosphorus had beneficial effect on branches per plant, yield attributes and yield. Application of 30 kg P_2O_5 ha^{-1} recorded significantly higher values of these attributes than the control.

Sarkar and Banik (1991) conducted a field experiment and stated that increase in P_2O_5 up to 60 kg ha^{-1} progressively increased the number of nodules/plants of soybean.

Solaiman *et al.* (1991) found that higher dose of phosphorus decrease the grain and other parameters. Phosphorus application at the rate of 60kg P_2O_5 ha^{-1} significantly increased nodule number, dry weight of plant tops and soybean yield

Patel and Patel (1991) observed that plant height of soybean showed superiority at 60 kg P_2O_5 ha^{-1} followed by 40 kg P_2O_5 ha^{-1} application rate, growth on the soil which was sandy in texture, low in total N (0.04%), higher in available Phosphorus (77.33 kg ha^{-1}) and rich in available potassium (388.15 kg ha^{-1}) with the pH 7.5. Thus plant height was found to be increased with increasing levels of phosphorus from 0 to 60 kg ha^{-1}.

Reddy *et al.* (1990) set up an experiment with three cultivars of soybean in 1987, applying 0 or 50 kg P_2O_5 ha^{-1} as a basal dressing or 50 kg P_2O_5 ha^{-1} in two equal split dressing at the sowing and flowering stages. They found that application of phosphorus increased the dry matter accumulation in soybean.

Thakuria and Saharia (1990) observed that phosphorus levels significantly influenced the grain yield of green gram. The highest plant height, pods $plant^{-1}$ and the grain yield were recorded with 20kg P_2O_5 ha^{-1}, which was of equal value with 40 and 60 kg $P_2O_5ha^{-1}$.

Kamble and Kathmale (2014) reported that application of 100 % RDP (75 kg P_2O_5 ha^{-1}) + inoculation of Pencilium bilaji 104 recorded significantly higher seed yield (2919 kg ha^{-1}), straw yield (3874 kg ha^{-1}) and 100 seed weight (12.20 g) compared to 50 % RDP in soybean.

Dhage et al. (2014) opined that application of 90 kg P_2O_5 ha^{-1} recorded significantly higher grain yield (2339.2 kg ha^{-1}), straw yield (4909.8 kg ha^{-1}) and biological yield (7251.7 kg ha^{-1}) over the control, 30 and 60 kg P_2O_5 ha^{-1} in soybean.

Mahmoodi et al. (2013) revealed that application of 90 kg P_2O_5 ha^{-1} recorded higher number of pods $plant^{-1}$ (66.30), number of seeds $plant^{-1}$ (129.97), 1000 seed weight

(167.20 g) and seed yield (5158.27 kg ha^{-1}) over control, 30 and 60 kg P_2O_5 ha^{-1} in soybean.

Shivran et al. (2012) opined that application of 60 kg P_2O_5 ha^{-1} + PSB recorded higher pods plant-1 (67.47), seeds pod^{-1} (2.7), seed index (10.08 g), seed yield (24.67 q ha^{-1}), straw yield (38.10 q ha^{-1}) and harvest index (39.29 %) compared to other treatments in soybean.

Kalita (1989) conducted an experiment with applying 30 kg P_2O_5 ha^{-1} to soybean and observed that application of phosphorus increased the number of pods $plants^{-1}$. In another trial, Reddy *et al.* (1990) found similar result.

Arya and Kalra (1988) found that application of phosphorus had no effect on the growth of summer mung, while number of grains per pod, weight of 1000-seeds and grain yield were found to be increased with increasing level of phosphorus from zero to 50 kg P_2O_5 ha^{-1}. Phosphorus content was also found to be affected by application of phosphorus.

Ahmed *et al.* (1986) carried out an experiment with various levels of phosphorus on the growth and yield of soybean. They noted that phosphorus application up to 60 kg ha^{-1} progressively and significantly enhanced the plant height. They also stated that phosphorus application significantly increased plant height, number of pods per plant, grain and straw yields and protein content of soybean.

Samiullah *et al.* (1986) conducted a field experiment on summer was running to study the effect of four levels of phosphorus (0, 30, 45, 60 P_2O_5 ha^{-1}). They noted that 60 kg P_2O_5 ha^{-1} proved optimum for yield parameters such as length, 1000-seed weight, pod number, seed number and seed yield.

Patel *et al.* (1984) studied the effect of 0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1} on growth and seed yield of summer soybean. They reported that 40 kg $P_2O_5ha^{-1}$ significantly increased the seed yield, number of pods per plant and 1000-seed weight.

Rajput and Verma (1982) found the beneficial effect of phosphorus on grain yield, number of pods per plant and seeds per pod of soybean. The highest response was recorded with 50 kg P_2O_5 ha^{-1} in most of the characters.

Anwar *et al.* (1981) reported beneficial effect of P application on greengram in respect to number of pods $plant^{-1}$, number of seed $plant^{-1}$, weight of 1000 seeds at low doses of P but higher doses of P showed depressing effect. The maximum grain yield of 1446.6 kg ha^{-1} was recorded at 60kg P_2O_5 ha^{-1} compared to only 886.6 kg ha^{-1} in control.

Sharma and Yadav (1976) conducted field experiment using 4 doses of phosphorus (0, 40, 80 and 120 kg P_2O_5 ha^{-1}). They reported that phosphorus application had a significant effect on grain yield of gram. They observed that yield increased up to a dose of 50 kg P_2O_5 ha^{-1}, but declined slightly when the doses were further increased. Straw yield was not significantly affected by phosphorus levels.

C. Interaction effect of nitrogen and phosphorus on growth, yield and yield contributing characters of Soybean

Aziz et al. (2016) observed that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded higher number of pods $plant_{-1}$ (75), 100 seed weight (12.36 g) and grain yield (1864 kg ha^{-1}) over the control in soybean.

Shinde et al. (2015) indicated that application of 100 % RDF recorded higher number of pods $plant^{-1}$ (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean.

Gharpinde et al. (2014) revealed that application of 30:75:25 NPK kg ha^{-1} + biofertilizers recorded higher grain yield (14.26 q ha^{-1}) and straw yield (30.68 q ha^{-1}) over rest of the treatments in soybean.

Sikka et al. (2013) reported that application of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1} along with 5 t FYM ha^{-1} to soybean recorded significantly higher number of pods $plant^{-1}$ (150.3), test weight (10.4 g) and seed yield (32.6 q ha^{-1}) compared to control.

Begum *et al.* (2015) conducted an experiment at Bangladesh, reported that application of 25 kg N + 54 kg P_2O_5 ha^{-1} recorded significantly higher plant height (36.88 cm), number of branches (3.71), dry matter production (20.81 g) compared to other treatments in soybean.

Shinde *et al.* (2015) indicated that application of 100 % RDF (30:60:30 N: P_2O_5:K_2O kg ha^{-1}) recorded higher plant height (57.09 cm), number of branches $plant^{-1}$ (5.83), leaf area plant-1 (12.11 dm^2) and dry matter $plant^{-1}$ (33.32 g) in soybean.

Yan *et al*. (2015) conducted an experiment at China, on two soybean genotypes and concluded that for Liaodou 14, application of NPK and NPK + manure increased plant height by 14.5 % and 16.6 %, respectively over control. For Liaodou 21, application of NPK decreased plant height by 2.2 % but NPK + manure increased it by 7.1 % compared to control.

Basavaraja *et al.* (2014) opined that application 100 % NPK + *Bradyrhizobium* + *Aspergillusniger* + VAM recorded highest growth parameter like branches at 30, 60

DAS and at harvest (4.84, 7.79 and 9.76 cm respectively), leaf area at 30, 60 DAS and at harvest (537.41, 999.57 and 1211.94 cm2 respectively) and total dry matter at 30, 60 DAS and at harvest (3.36, 27.23 and 32.73 g plant^{-1} respectively) compare to other treatments in soybean.

Tickoo *et al.* (2006) carried out an experiment on soybean and cultivars Pusa 105 and Pusa Vishal which were sown at 22.5 and 30.0 m spacing and was supplied with 36-46 and 58-46 kg of N/P/ha in a field experiment conducted in New Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 and 1.63 t/ha) respectively compared to cv. Pusa 105. Nitrogen and phosphorus rates had no significant effects on both the biological and grain yield of the crop. Row spacing at 22.5 cm resulted in higher grain yields in both the cultivars.

Nadeem *et al.* (2004) studied the response of soybean cv. NM-98 to seed inoculation and different levels of fertilizer (0-0, 15-30, 30-60 and 45-90 kg N- P_2O_5 ha^{-1}) under field conditions. Application of fertilizer significantly increased the yield and the maximum seed yield was obtained when 30 kg N ha^{-1} was applied along with 60 kg P_2O_5 ha^{-1}.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying levels of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of soybean cv. NM-98 in 2001. They observed that number of flowers/plant was found to be significantly higher by 25 kg N ha^{-1}. Number of seeds/pod was significantly affected by varying levels of nitrogen and phosphorus. Growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg P ha^{-1} resulted with maximum seed yield (1.1 ton ha^{-1}).

Srinivas *et al.* (2002) examined the effects of N (0, 20, 40 and 60 Kg ha^{-1}) and P205, 50 and 75 Kg ha^{-1}) along with seed inoculation with *Rhizobium* culture on the growth, yield and yield components of soybean. They observed that number of pods $plant^{-1}$, pod length and seeds pod^{-1} were increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} and also observed that 1000-seed weight in greengram.

Srinivas *et al.* (2002) conducted an experiment on the performance of soybean at different levels of nitrogen and phosphorus. Different rates of N (0, 25 and 60 kg ha^{-1}) and P (0, 25, 50 and 60 kg ha^{-1}) were tested. They observed that the number of pods/plant was increased with the increasing rates of N up to 40 kg ha^{-1} followed by a decrease with further increase in N. They also observed that 1000-seed weight was increased with increasing rates of N up to 40 kg ha^{-1} along with increasing rates of P which was then followed by a decrease with further increase in N.

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels on soybean at the Agronomic Research Station, Farooqabad in Pakistan. They revealed that various yield components like 1000-grain weight was affected significantly with 50-50-0 N kg ha^{-1}, P kg ha^{-1}, K kg ha^{-1} application. Again they revealed that seed inoculation with 50-50-0 N kg ha^{-1}, kg ha^{-1}, K kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

Rajender *et al*. (2002) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on soybean genotypes MH 85- 111 and T44. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield. The number of branches, number of pods plant^{-1}, numbers of seeds pod^{-1}. 1000-seed weight and straw yield increased with increasing rates P. whereas grain yield increased with increasing rates up to 40 kg P ha^{-1} only.

Karle and Pawar (1998) examined the effect of varying levels of N and P fertilizers on summer soybean. They reported that soybean produced higher seed yield with the application of 15 kg N ha^{-1} and 40 kg P_2O_5ha^{-1}.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg/ha) on the growth and yield of soybean cv. AEM 96 in Tandojam, Pakistan, during the spring season of 2004. The different NPK levels significantly affected the crop parameters. The 10-30-30 kg NPK/ha was the best treatment, recording plant height of 56.3. germination of 90.5%. satisfactory plant population of 162.0. Prolonged days taken to maturity of 55.5. long pods of 5.02 cm, seed weight of 10.5 g, seed index of 3.5 g and the highest seed yield of 1205.2 kg/ha. There was no significant change in the crop parameters beyond this level.

A field experiment was carried out by Sharma and Sharma (1999) during summer seasons at Golaghat, Assam. India. Soybean was grown using farmers practices (no fertilizer) or using a combinations of fertilizer application (30 kg N + 35 kg P_2O_5 ha^{-1}). Seed yield was 0.40 ton ha^{-1} with farmers practices, while the highest yield was obtained by the fertilizer application (0.77 ton ha^{-1}).

Sardana and Verma (1987) made a field trial in Delhi, India with combined application of aldicarb (for the control of various insect pests) with nitrogen, phosphorus and potassium fertilizers and reported that plant height, leaf surface area, number and length of pods, 100 grain weight and yield of green gram were significantly increased.

Mandal and Sikdar (1999) laid out a greenhouse pot experiment where soybean (BARI Mung-5) grown on saline soil and given 0, 50 or 100 kg N ha^{-1} and 0, 75 or 150 kg P ha^{-1}. Growth and yield increased significantly with N application while P significantly increased the setting of pods and seeds. Root growth was significantly improved by both individual and combined application of these two fertilizers.

Tank *et al.* (1992) found that soybean fertilized with 20 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} produced significantly higher number of pods $plant^{-1}$ over the unfertilized control.

Chapter III

MATERIALS AND METHODS

The experiment was conducted at the Sher-e-Bangla Agricultural University Soil Science Farm, Dhaka, Bangladesh during the period from March 2019 to July 2019 to study the effect of different doses of nitrogen and phosphorus application on the growth and yield of soybean. The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1 Location

The present piece of research work was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 23^0 74′ N latitude and 90^0 35′ E longitude with an elevation of 8.2 meter from sea level.

3.1.2 Soil

The soil of the experimental area that used in the pot for rice grown belongs to "The Modhupur Tract", AEZ 28. Soil was silty clay in texture. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system. The physico-chemical properties of initial soil sample have been presented in table 3.2.

3.1.3 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to 2 February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al.,* 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station, Sher-e Bangla Nagar, Dhaka and has been presented in Appendix II.

Table 3.1. Salient features of the experimental field

Morphological Features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Topography	Fairly leveled
Depth of inundation	Above flood level
Drainage condition	Well drained
Land type	High land

Table 3.2. Physic-chemical properties of initial soil of the experimental site

Characteristics	Value
Particle size analysis	
% Sand	33
%Silt	41
% Clay	26
Textural class	Silty-clay
pH	5.7
Organic matter (%)	1.09
Total N (%)	0.05
Available P (ppm)	21.54
Exchangeable K (meq/100 g soil)	0.15

3.1.4 Climate

The experimental area has sub-tropical climate characterized by high temperature, heavy rainfall during May to September and scanty rainfall during rest of the year. The annual precipitation of the site is 2052 mm and potential evapo-transpiration is 1286mm, the average maximum temperature is 30-35^{0}C, average minimum temperature is 14-21^{0}C and the average mean temperature is 12-25^{0}C. The experiment was carried out during rabi season (March-July), 2018.

3.1.5 Seeds and variety

BARI Soybean 4, a high yielding variety of soybean was released by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 2003. It is photo insensitive, short lifespan, 55 to 58 days require to mature and bold seeded crop. The special characteristic of this variety is it is almost synchronized maturity. It was developed from the NM-92 line introduced by AVRDC in 1992. Its yield potentiality is about 1.5 to 1.7 t ha^{-1}. This variety is resistant to yellow mosaic virus diseases, insects and pest attack (BARI, 2008).

3.1.6 Design and layout of experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four levels of nitrogen and three levels of phosphorus fertilizer treatment combinations. Fertilizer treatment consisted of 3 levels of N (0, 25, and 40 kg N ha^{-1} designated as N_0, N_1,and N_2 , respectively) and 4 levels of P (0, 18, 36 and 54kg P ha^{-1} designated as P_0, P_1, P_2,and P_3 respectively). There were twelve (12) treatment combinations. The treatment combinations were as follows:

Treatments and treatment combinations of experiment

A. Rates of nitrogen (4 levels):

1. N_0 = No nitrogen (control)
2. N_1 = 25 kg N ha^{-1}
3. N_2 = 40 kg N ha^{-1}

B. Rates of phosphorus (3 levels)

1. P_0= No phosphorus (control)
2. P_1 = 18 kg P ha^{-1}
3. P_2 = 36 kg P ha^{-1}

4. P_3 = 54 kg P ha^{-1}

Treatment Combinations

1. $N_0 P_0$ = Control (without N and P)

2. $N_0 P_1$ = 0 kg N ha^{-1}+18 kg P ha^{-1}

3. N_0P_2= 0 kg N ha^{-1}+36 kg P ha^{-1}

4. N_0P_3 = 0 kg N ha^{-1}+54 kg P ha^{-1}

5. N_1P_0 = 25 kg N ha^{-1}+0 kg P ha^{-1}

6. N_1P_1= 25 kg N ha^{-1}+18 kg P ha^{-1}

7. N_1P_2 = 25 kg N ha^{-1}+36 kg P ha^{-1}

8. N_1P_3 = 25 kg N ha^{-1}+54 kg P ha^{-1}

9. N_2P_0= 40 kg N ha^{-1}+0 kg P ha^{-1}

10. $N_2 P_1$=40 kg N ha^{-1}+18 kg P ha^{-1}

11. $N_2 P_2$=40 kg N ha^{-1}+36 kg P ha^{-1}

12. $N_2 P_3$=40 kg N ha^{-1}+54 kg P ha^{-1}

3.1.6 Land preparation

The plot selected for the experiment was opened by power tiller driven rotovator on the 15th February 2014; afterwards the land was ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the following section

3.1.7 Fertilizers application

The sources of N, P, K were urea, triple superphosphate (TSP), muriate of potash (M_OP) and all the fertilizers were applied during the final land preparation except urea. Well rotten cow dung (10 t ha^{-1}) was also applied during final land preparation. The fertilizers were then mixed well with the soil by spading and individual unit plots were leveled.

3.1.8 Seed collection and sowing

Seeds of BARI Soybean 4 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Seeds were sown in the main field on the 17^{th} March, 2019 having line to line distance of 30 cm and plant to plant distance of 10 cm.

3.1.9 Cultural and management practices

Various intercultural operations such as thinning of plants, weeding and spraying of insecticides were accomplished whenever required to keep the plants healthy and the field weed free. At the very early growth stage (after l5 days of emergence of seedlings) the plants were attacked by Cutworm, which was removed by applying Malathion-57 EC. Special care was taken to protect the crop from birds especially after sowing and germination stages. The field was irrigated twice- one at 15 days and the other one at 30 days after sowing.

3.1.10 Harvesting

The crop was harvested in three times. The crop was finally harvested at maturity on 9^{th} June, 2019. The harvested crop of each plot was bundled separately. Grain and straw yields were recorded plot wise and the yields were expressed in t ha^{-l}.

3.1.11 Collection of experimental data

Ten (10) plants from each plot were selected as random and were tagged for the data collection. Data were collected at harvesting stage. The sample plants were cut down to ground level prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}
4. Number of pods plant^{-1}
5. Pod length (cm)
6. Number of seeds pod^{-1}
7. Weight of 1000-seeds (g)
8. Seed yield (t ha^{-1})
9. Stover yield (t ha^{-1})

3.1.12 Plant height

The plant height was measured from the ground level to the top. Height of 10 plants randomly from each plot were measured. It was done at the ripening stage of the crop.

3.1.13 Number of leaves plant^{-1}

Leaves were counted at 45 DAS stage. Leaves of 10 plants randomly counted from each plot and then averaged.

3.1.14 Number of branches plant^{-1}

Branches were counted at the ripening stage. Branches of 10 plants randomly from each plot were counted and averaged.

3.1.15 Number of pods plant^{-1}

Pods were counted at the ripening stage. Pods of 10 plants randomly from each plot were counted and averaged.

3.1.16 Pod length

Length of 10 pods from each plot were measured randomly and averaged after harvesting.

3.1.17 Number of seeds pod^{-1}

It was done after harvesting. At first, number of seeds pod^{-1} was counted. Seeds of 10 pods randomly from each plot were counted and averaged.

3.1.18 1000-seeds weight

Thousand seeds of soybean were counted randomly and then weighed plot wise.

3.1.19 Seed yield

Seeds obtained from 1m^2 area from the center of each unit plot was dried, weighted carefully and then converted into t ha^{-1}.

3.1.20 Stover yield

Stover obtained from each individual plot was dried, weighed carefully and the yield expressed in t ha^{-1}.

3.1.21 Statistical Analysis

The collected data were statistically analyzed by using the ANOVA technique. The test of significance of all parameters was done. The Least Significant Difference value was determined with appropriate levels of significance and the means were tabulated. The mean comparison was carried out by LSD technique at 5% level of probability (Gomez and Gomez, 1984). The statistical package Statistix 10 (2013) was used for this purpose.

Chapter IV

RESULTS AND DISCUSSION

The experiment was conducted at Sher-e-Bangla Agricultural University farm to determine the effect of nitrogen and phosphorus on growth and yield of soybean. Data on different growth and yield contributing characters were investigated and recorded to find out the optimum levels of nitrogen and phosphorus on soybean. The results have been presented and discussed and possible interpretations have been given under the following headings:

4.1 Plant height

4.1.1 Effect of nitrogen on the plant height of soybean

The variations in plant height are attributed to the differences in the genetic makeup of the variety and their differences in the utilization ability of the different rates of fertilizers applied. According to the table 4.1 and figure 4.1, plant height was increased in all the treated plots as compared to unfertilized control ($p \leq 0.05$). The effects of nitrogen on the plant height of soybean are presented in table 4.1 and figure 4.1. Significant variation was observed on the plant height of soybean when the field was fertilized with different doses of nitrogen. Among the different doses of nitrogen, N_2 (40 kg N ha^{-1}) showed the highest plant height (34.18 cm) which was statistically different with others nitrogen treated plots. On the other hand, the lowest plant height (30.01 cm) was observed in the control (N_0) treated plot where nitrogen was not applied. It was observed that plant height increased gradually with the increment of nitrogen doses. This might be due to higher availability of nitrogen and uptake that progressively enhanced the vegetative growth of the plant. It is well known that nitrogen nutrition influences the content of photosynthetic pigments, the synthesis of the enzymes taking part in the carbon reduction, the formation of the membrane system of chloroplast, etc. Thus, the increase in growth and yield owing to the application of N-fertilizers may be attributed to the fact that these nutrients being important constituents of nucleotides, proteins, chlorophyll and enzymes, involve in various metabolic processes which have direct impact on vegetative and reproductive phases of plant. This result is agreement with the findings of some other researchers, e.g. Agbenin *et al.* (1991) revealed that application of N significantly increased plant height, seed yield, dry weight, crop growth rate and nutrient uptake of soybean over control. The result was similar to the results of Suhartatik (1991) also reported that NPK fertilizers significantly increased the plant height of soybean. Other researchers also agreed with the findings of Yadravi and Angadi (2015) visualized that application of nitrogen 60 kg ha^{-1} recorded significantly higher soybean plant height (50.6 cm), number of branches plant^{-1} (6.8), total dry matter production plant^{-1} (34.4 g), leaf area plant^{-1} (10.9 dm^{2}) and leaf area index plant^{-1} (3.6) compared to other treatments.

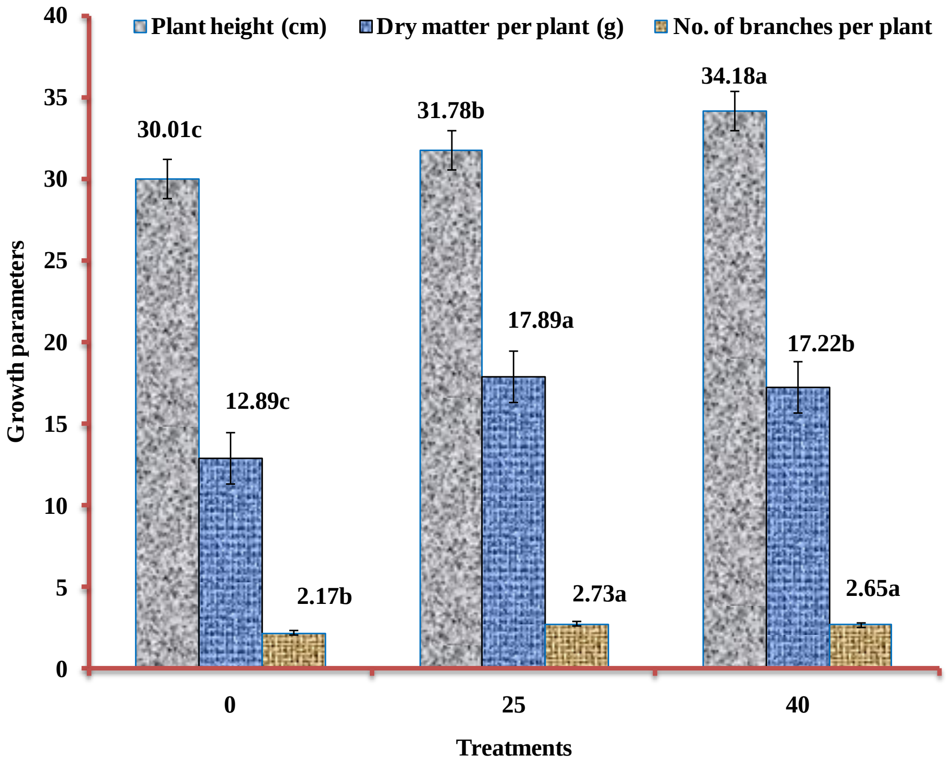

Fig. 4.1 Effect of nitrogen on the growth parameters of soybean

4.1.2 Effect of phosphorus on the plant height of soybean

The present results revealed that significant variation in respect of plant height can be ascribed to differences in the application of different levels of phosphorus fertilizer in the ability of the cultivars to utilize the fertilizer as well partition their photosynthesis and accumulation of dry matter ($p \leq 0.05$). Soybean showed significant variation in plant height in regard to P-fertilization in different doses were shown in table 4.4 and figure 4.2. Among the different P-fertilizer doses, P3 (54 kg P ha^{-1}) showed the highest plant height (34.26 cm), which was significantly similar with P2 (36 kg ha^{-1}) treated plot. On the contrary, the lowest plant height (30.95 cm) was observed in the treatment where no phosphorus fertilizer was applied (P0), which was similar with P1 (18 kg P ha^{-1}) treated plot. This could be due to the fact that P being essential constituent of plant tissue significantly influences the plant height of crop (Kumar and Chandra, 2008 and Shahid *et al*., 2009) were also observed significant improvement in plant height of soybean by P-fertilization. The highest rate of phosphorus application at the study site had no effect on plant height. This might be due to high dose of phosphorus fertilizer tends to form nutrient interaction and may affects the availability of other nutrients which are essential for growth of the soybean varieties. It is worth discussing these interesting facts revealed by the results of Saleh (1976) reported phosphorus application also significantly increased plant height over the control. Accordingly, maximum plant height might be due to stimulated biological activities in the presence of balanced nutrient supply. In agreement to the current study, (Zafar *et al*., 2003) reported that number of branches $plant^{-1}$ was significantly affected by different rates of phosphorus application and this might probably be due to the cumulative effect of phosphorus on the process of cell division and balanced nutrition. This result were in agreement with the findings from other scientists that Geeta and Radder (2015) observed that application of 80 kg P_2O_5 along with cured FYM + PSB + VAM recorded significantly higher plant height (66.27 cm), number of branches palnt^{-1} (6.67) and total dry matter production (27.49 g) compared to other treatments in soybean. The result was similar to Mahmoodi *et al*. (2013) reported that application of 90 kg P_2O_5 ha^{-1} recorded significantly higher plant height (78.66 cm) over the control, 30 and 60 P_2O_5 kg ha^{-1} in soybean.

Table 4.1. Effect of nitrogen on the growth related crop characters of soybean

Level of nitrogen (kg N ha^{-1})	Plant height (cm)	Dry matter plant^{-1} (g)	No. of branches plant^{-1}	No. of nodes plant^{-1}	No. of filled pods plant^{-1}
0	30.01c	12.89c	2.17b	9.88	38.00c
25	31.78b	17.89a	2.73a	10.29	47.59a
40	34.18a	17.22b	2.65a	9.88	40.40b
Sx	0.35	0.11	0.05	0.34	0.65
Level of significance	**	**	**	NS	**

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), Sx = Sample standard deviation; * = Indicates significant at 5% level of probability; ** = Indicates significant at 1% level of probability; NS = Indicates not significant

Table 4.2. Effect of nitrogen on the yield and related crop characters of soybean

Level of nitrogen (kg N ha^{-1})	No. of empty pods plant^{-1}	No. of seeds pod^{-1}	No. of seeds plant^{-1}	Seed wt. Plant^{-1} (g)
0	3.31a	1.64c	64.98c	3.07b
25	2.42c	1.94a	94.93a	3.41a
40	2.75b	1.76b	73.20b	2.91b
Sx	0.06	0.03	1.75	0.11
Level of significance	**	**	**	**

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), Sx = Sample standard deviation; * = Indicates significant at 5% level of probability; ** = Indicates significant at 1% level of probability; NS = Indicates not significant

Table 4.3. Effect of nitrogen on the yield and related crop characters of soybean

Level of nitrogen (kg N ha^{-1})	Stover weight plant^{-1} (g)	1000-seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
0	6.14c	111.26c	1.41c	1.69c
25	8.48a	120.24a	1.95a	2.35a
40	8.20b	117.99b	1.89b	2.25b
Sx	0.07	.55	0.02	0.02
Level of significance	**	**	**	**

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), Sx = Sample standard deviation; * = Indicates significant at 5% level of probability; ** = Indicates significant at 1% level of probability; NS = Indicates not significant

Table 4.4. Effect of phosphorus on the yield and related crop characters of soybean

Level of phosphorus (kg P ha-1)	Plant height (cm)	Dry matter plant^{-1} (g)	No. of branches plant^{-1}	No. of nodes plant^{-1}	No. of filled pods plant^{-1}
0	30.95b	12.12d	1.85d	9.58	29.77d
18	31.30b	16.17c	2.09c	10.00	38.98c
36	31.46a	16.83b	2.75b	10.19	44.74b
54	34.26a	18.89a	3.37a	10.31	54.49a
Sx	0.40	0.13	0.06	0.75	0.75
Level of significance	**	**	**	NS	**

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), Sx = Sample standard deviation; * = Indicates significant at 5% level of probability; ** = Indicates significant at 1% level of probability; NS = Indicates not significant

Table 4.5. Effect of phosphorus on the yield and related crop characters of soybean

Level of phosphorus (kg P ha^{-1})	No. of empty pods $plant^{-1}$	No. of seeds pod^{-1}	No. of seeds $plant^{-1}$	Seed wt. $plant^{-1}$ (g)
0	3.98a	1.27c	38.07d	3.03b
18	2.67b	1.87b	73.31c	3.13ab
36	2.50b	1.91b	85.95b	2.86b
54	2.16c	2.07a	113.48a	3.49a
Sx	0.07	0.03	2.02	0.12
Level of significance	**	**	**	**

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), Sx = Sample standard deviation; * = Indicates significant at 5% level of probability; ** = Indicates significant at 1% level of probability; NS = Indicates not significant

Table 4.6. Effect of phosphorus on the yield and related crop characters of soybean

Level of phosphorus (kg P ha^{-1})	Stover wt. $plant^{-1}$ (g)	1000-seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
0 (P0)	5.67d	109.15d	1.30d	1.61d
18 (P1)	7.71c	115.06c	1.77c	2.11c
36 (P2)	7.99b	119.58b	1.84b	2.21b
54 (P3)	9.07a	122.20a	2.09a	2.46a
Sx	0.09	0.63	0.02	0.02
Level of significance	**	**	**	**

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), Sx = Sample standard deviation; * = Indicates significant at 5% level of probability; ** = Indicates significant at 1% level of probability; NS = Indicates not significant

Table 4.7. Interaction effect of nitrogen and phosphorus on the yield and related crop characters of soybean

Level of nitrogen and phophorus N × P (kg ha^{-1})	Plant height (cm)	Dry matter $plant^{-1}$ (g)	No. of branches $plant^{-1}$	No. of pods $plant^{-1}$
N0P0	31.73de	9.82j	1.63fg	9.27
N0P1	29.02fg	11.79h	1.43g	10.00
N0P2	27.77g	13.28g	2.73bc	9.87
N0P3	31.53de	16.69e	2.87b	10.40
N1P0	31.22d-f	15.48f	2.03e	9.20
N1P1	33.15cd	16.69e	2.48cd	10.07
N1P2	35.48ab	17.55d	2.70bc	10.83
N1P3	36.88a	20.81a	3.71a	11.07
N2P0	30.95d-f	11.07i	1.88ef	10.27
N2P1	30.68ef	20.02b	2.34d	9.93
N2P2	31.13d-f	19.66bc	2.83b	9.87
N2P3	34.36bc	19.18c	3.55a	9.47
Sx	0.22	0.22	0.10	0.68
Level of significance	**	**	**	NS

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), Sx = Sample standard deviation; * = Indicates significant at 5% level of probability; ** = Indicates significant at 1% level of probability; NS = Indicates not significant

Table 4.8. Interaction effect of nitrogen and phosphorus on the yield and related crop characters of soybean

Level of nitrogen and phophorus N × P (kg ha^{-1})	No. of filled pods plant^{-1}	No. of empty pods plant^{-1}	No. of seeds pod^{-1}	No. of seeds plant^{-1}
N0P0	23.5h	4.08a	1.25	29.36i
N0P1	36.48ef	3.24b	1.63	59.62g
N0P2	39.86de	3.12bc	1.78	70.94ef
N0P3	52.14b	2.78cd	1.92	100.01c
N1P0	35.41f	3.85a	1.41	50.11h
N1P1	44.33c	2.20ef	1.98	87.98bd
N1P2	52.34b	2.00f	2.05	107.15b
N1P3	58.28a	1.63g	2.31	134.48a
N2P0	30.41g	4.01a	1.14	34.75hi
N2P1	36.14ef	2.56de	2.00	72.34e
N2P2	42.01cd	2.37ef	1.96	79.76de
N2P3	53.05b	2.07f	2.00	105.94bc
Sx	1.30	0.12	0.06	3.49
Level of significance	**	**	NS	*

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), Sx = Sample standard deviation; * = Indicates significant at 5% level of probability; ** = Indicates significant at 1% level of probability; NS = Indicates not significant

4.1.3 Interaction effect of nitrogen and phosphorus on the plant height of soybean

The application of different fertilizers treatments had a considerable effect on plant height of soybean. Combined application of different doses of nitrogen and phosphorus fertilizers had significant effect on the plant height of soybean ($p \leq 0.05$) (Table 4.7 and Figure 4.3). The plant height during the experimental period showed significant differences among the treatments with regards to the different levels of NP fertilizers application. The lowest plant height (27.77 cm) was observed in the treatment combination of N0P2 (0 kg N ha^{-1} + 36 kg P ha^{-1}) treated plot. On the other hand, the highest plant height (36.88 cm) was recorded with N1P3 (25 kg N ha^{-1} + 54 kg P ha^{-1})

treatment which was statistically identical with N1P2 (25 kg N ha^{-1} + 36 kg P ha^{-1}) (58.31 cm) treatments.

Table 4.9. Interaction effect of nitrogen and phosphorus on the yield and related crop characters of soybean

Level of nitrogen and phophorus N × P (kg ha^{-1})	Seed wt. $plant^{-1}$ (g)	Stover wt. $plant^{-1}$ (g)	1000-Seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
N0P0	3.56a-c	4.69h	105.0e	1.08i	1.28h
N0P1	2.49ef	5.77f	111.23d	1.33g	1.50g
N0P2	2.64d-f	6.18f	114.47d	1.42f	1.77f
N0P3	3.60a-c	7.94d	114.20d	1.83d	2.19d
N1P0	2.30f	5.12g	107.60e	1.66e	2.07e
N1P1	3.15b-e	9.49b	114.27d	1.81d	2.21d
N1P2	3.20a-e	9.30b	122.10bc	1.95c	2.26d
N1P3	3.89a	10.01a	127.98a	2.30a	2.63a
N2P0	3.23a-d	7.20e	114.73d	1.18h	1.49g
N2P1	3.77ab	7.86d	119.67c	2.13b	2.48c
N2P2	2.75d-f	8.49c	122.16bc	2.14b	2.59b
N2P3	2.98c-f	9.26b	124.41b	2.18b	2.70a
Sx	0.22	0.15	1.09	0.03	0.03
Level of significance	**	*	**	**	**

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), Sx = Sample standard deviation; * = Indicates significant at 5% level of probability; ** = Indicates significant at 1% level of probability; NS = Indicates not significant

The increase in plant height with NP fertilizers can be attributed to the fact that macro elements, particularly nitrogen promotes plant growth which ultimately increase the number of nodes and internodes of the plant which results in progressive increase in plant height. The obtained results are consistent with the previous literature of Shinde *et al.* (2015) indicated that application of 100 % RDF (30:60:30 N:P_2O_5:K_2O kg ha^{-1}) recorded higher Plant height (57.09 cm), number of branches $plant_{-1}$ (5.83), leaf area $plant^{-1}$ (12.11 dm^2) and dry matter $plant^{-1}$ (33.32 g) in soybean. The result of the present study was in agreement with the findings of Yan *et al*. (2015) conducted an experiment at China, on two soybean genotypes and concluded that for Liaodou 14, application of

NPK and NPK + manure increased plant height by 14.5 % and 16.6 %, respectively over control.

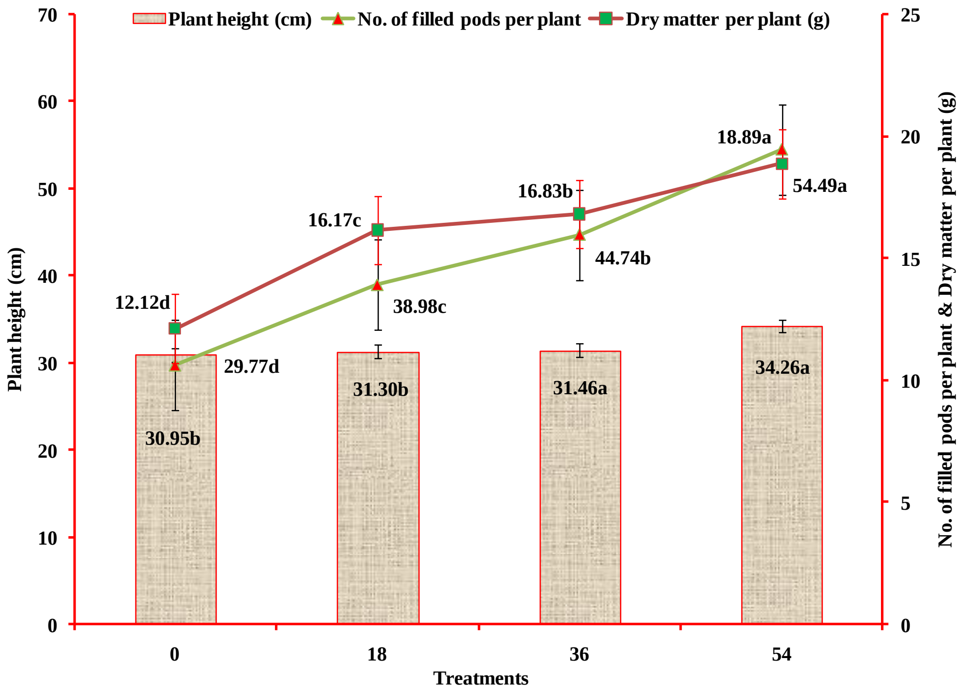

Fig. 4.2 Effect of phosphorus on the growth and yield parameters of soybean

It is worth discussing these interesting facts revealed by the results of Begum *et al.* (2015) conducted an experiment at Bangladesh, reported that application of 25 kg N + 54 kg P_2O_5 ha^{-1} recorded significantly higher plant height (36.88 cm), number of branches (3.71), dry matter production (20.81g) compared to other treatments in soybean.

4.1 Dry matter production

4.1.1 Effect of nitrogen on the dry matter $plant^{-1}$ of soybean

The perusal of data presented in table 4.1 and figure 4.1 reveals that the dry matter production of soybean increased with increasing levels of N-fertilization. Significant variation was observed on the dry matter of soybean when the field was fertilized with different doses of nitrogen ($p \leq 0.05$). Among the different doses of nitrogen, N1 (25 kg

N ha^{-1}) showed the highest dry matter (17.89 g) which was statistically different with others nitrogen treated plots. On the other hand, the lowest dry matter (12.89 g) was observed in the untreated control (N0) plot where nitrogen was not applied.

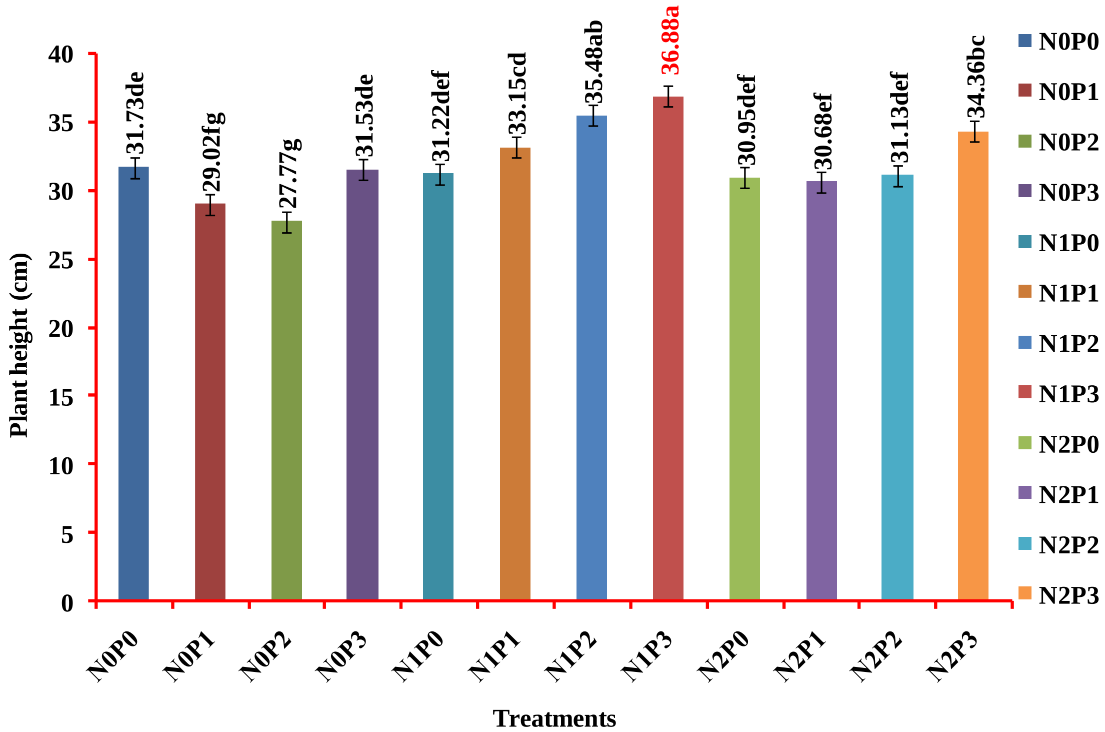

Fig. 4.3 Effect of nitrogen and phosphorus on the growth parameters of soybean

Nitrogen is known to play an important role in accelerating the plant growth, which, ultimately helps in increasing the photosynthetic activity, which leads to the accumulation of higher amount of biomass and also by soil fertility management treatments. It was observed that dry matter increased gradually with the increment of nitrogen doses. This might be due to higher availability of nitrogen and uptake that progressively enhanced the vegetative growth of the plant. This result is agreement with the findings of some other researchers, e.g. Agbenin *et al.* (1991) revealed that application of N significantly increased plant height, seed yield, dry weight, crop growth rate and nutrient uptake of soybean over control. The results of the experiment found clear support for the Suhartatik (1991) also reported that NPK fertilizers significantly increased the plant height of soybean. N is an important nutrient essential for plant growth and development. The application of nitrogen to the crop helps in enhancing above-ground vegetative growth. The parameters like plant height, dry matter production, and crop yield are enhanced with the application of nitrogen. The result was similar to Saxena and Chandal, 1992 studied the effect of nitrogen on crop growth and recorded the maximum plant height with the application of 40 kg N ha^{-1} in soybean. Whereas in a field study conducted by Praharaj (1994), it was reported that with additional application of 30 kg N ha^{-1} at flowering and pod filling stages, there was a significant increase in plant height, leaf area index and dry matter accumulation of soybean.

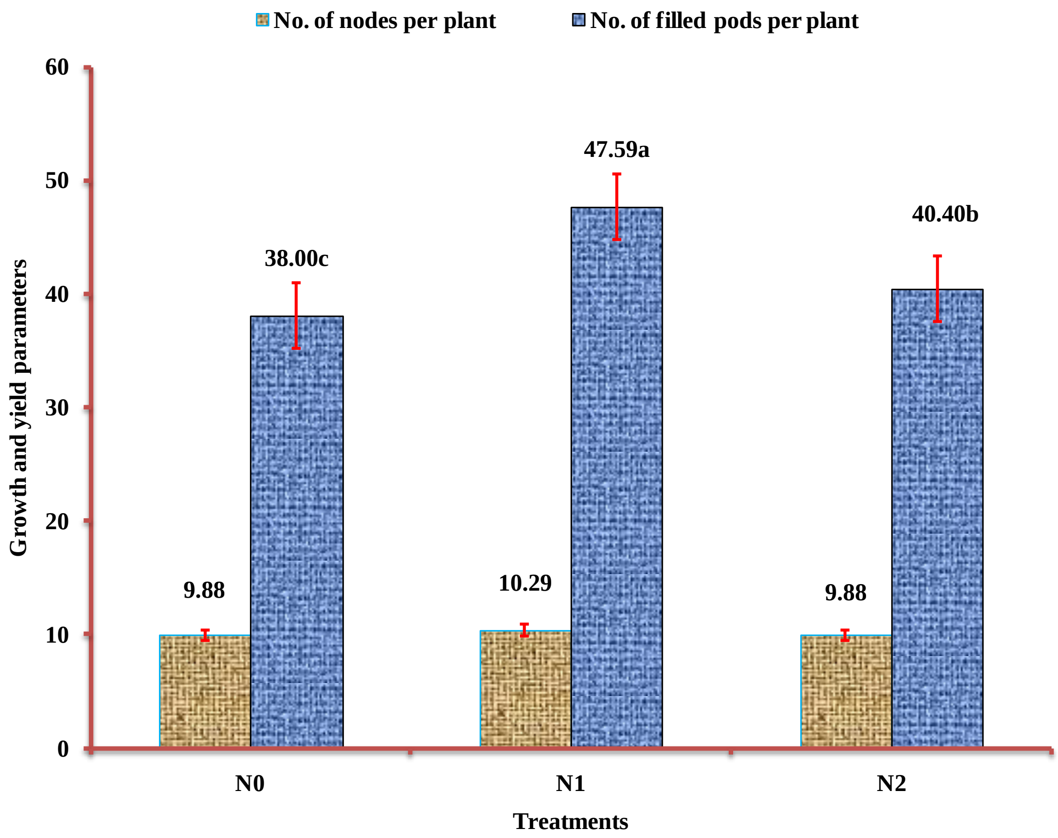

Fig. 4.4 Effect of nitrogen on the growth and yield parameters of soybean

4.1.2 Effect of phosphorus on the dry matter plant^{-1} of soybean

Soybean showed significant variation in respect of dry matter production when phosphorus fertilizers in different doses were applied ($p \leq 0.05$) (Table 4.4 and Figure 4.2). Among the different fertilizer doses, P3 (54 kg P ha^{-1}) showed the highest dry matter (18.89 g), which was significantly different with other treatments. On the contrary, the lowest dry matter (12.12 g) was observed in the treatment where no phosphorus fertilizer was applied (P0). It is worth discussing these interesting facts revealed by the results of Rana *et al*. (2012) revealed that growth attributes of soybean like plant height (81 cm) and dry matter production (803 g m^{-2}) increased with the application of 60 kg P_2O_5 ha^{-1} in soybean. The findings are directly in line with previous findings of Geeta and Radder (2015) observed that application of 80 kg P_2O_5 along with cured FYM + PSB + VAM recorded significantly higher plant height (66.27 cm), number of branches palnt^{-1} (6.67) and total dry matter production (27.49 g) compared to other treatments in soybean.

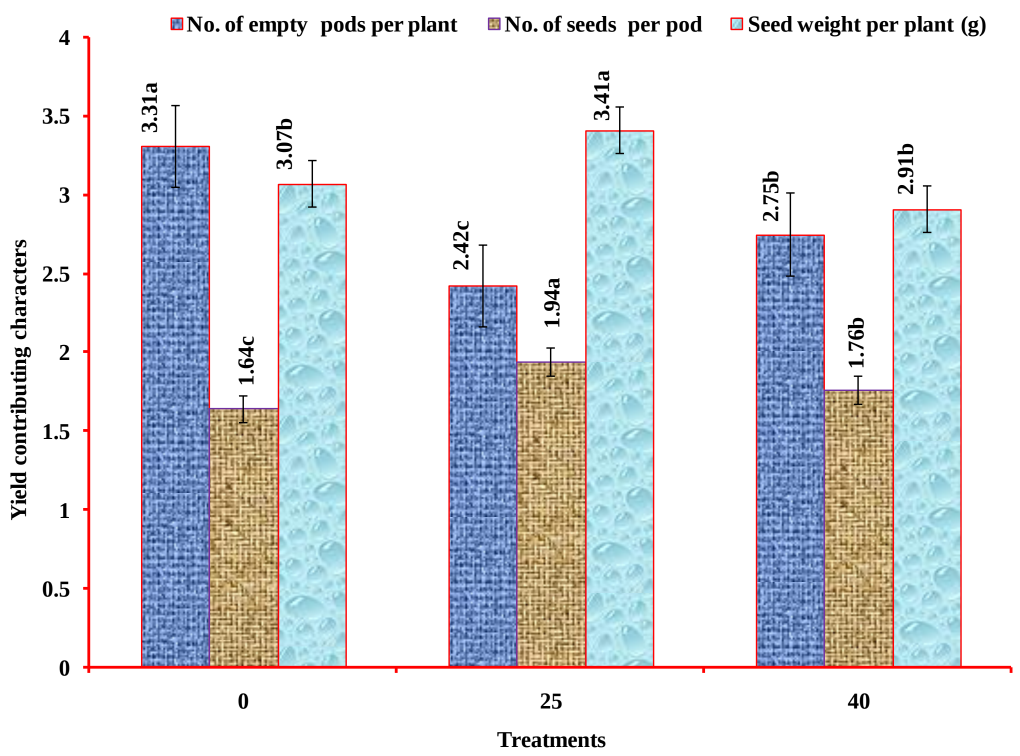

Fig. 4.5 Effect of nitrogen on the yield parameters of soybean

4.1.3 Interaction effect of nitrogen and phosphorus on the dry matter of soybean

Combined application of different doses of nitrogen and phosphorus fertilizers had significant effect on the dry matter production of soybean ($p \leq 0.05$) (Table 4.7 and Figure 4.6). The lowest dry matter (9.82 g) was observed in the treatment combination of N_0P_0 (0 kg N ha^{-1} + 0 kg P ha^{-1}) treated plot. On the other hand, the highest dry matter (20.81 g) was recorded with N_1P_3 (25 kg N ha^{-1} + 54 kg P ha^{-1}) treatment which was statistically different with others treatments. The increase in biomass yield per plant was possibly because of supply of N with other soil mineral N form that was responsible for the highest vegetative growth of soybean. Other results were broadly in line with Mrkovacki *et al*. (2008) reported that maximum results for biomass yield were seen by applying 30 kg ha^{-1} N to inoculated soybean instead of higher rates of N. The findings are directly in line with previous findings of Begum et al. (2015) conducted an experiment at Bangladesh, reported that application of 25 kg N + 54 kg P_2O_5 ha^{-1} recorded significantly higher plant height (36.88 cm), number of branches (3.71), dry matter production (20.81 g) compared to other treatments in soybean. A similar conclusion was reached by Shinde *et al*. (2015) indicated that application of 100 % RDF (30:60:30 $N:P_2O_5:K_2O$ kg ha^{-1}) recorded higher Plant height (57.09 cm), number of branches $plant^{-1}$ (5.83), leaf area $plant^{-1}$ (12.11 dm^2) and dry matter $plant^{-1}$ (33.32 g) in soybean.

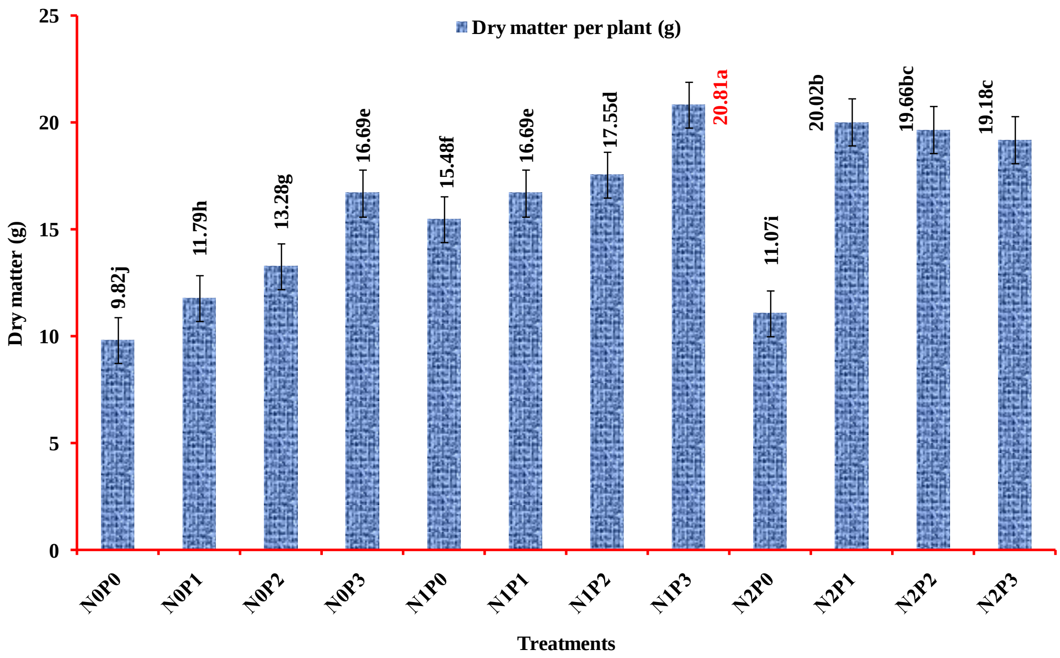

Fig. 4.6 Effect of nitrogen and phosphorus on the dry matter of soybean

4.3 Number of branches plant^{-1}

4.3.1 Effect of nitrogen on the number of branches plant^{-1} of soybean

The responses of soybean plant to different doses of nitrogen fertilizer application in terms of number of branches are as presented in table 4.1 and figure 4.1 ($p \leq 0.05$). Different doses of nitrogen fertilizer showed significant variations in respect of number of branches plant^{-1} (Table 4.1 & Figure 4.1). Among the different doses of nitrogen, N1 (25 kg N ha^{-1}) showed the highest number of branches plant^{-1} (2.73) which was statistically similar with T_2 (2.65) (40 kg N ha^{-1}) treatment. On the contrary, the lowest number of branches plant^{-1} (2.17) was observed with N_0 treatment, where no nitrogen fertilizer was applied. This findings are directly in light with previous findings of Abd-El-Latif *et al.* (1998) revealed that application of urea increases the number of branches plant^{-1} on soybean plant. It is worth discussing these interesting facts revealed by the results of Yadravi and Angadi (2015) visualized that application of nitrogen 60 kg ha^{-1} recorded significantly higher soybean plant height (50.6 cm), number of branches plant[1] (6.8), total dry matter production plant^{-1} (34.4 g), leaf area plant^{-1} (10.9 dm^2) and leaf area index plant^{-1} (3.6) compared to other treatments.

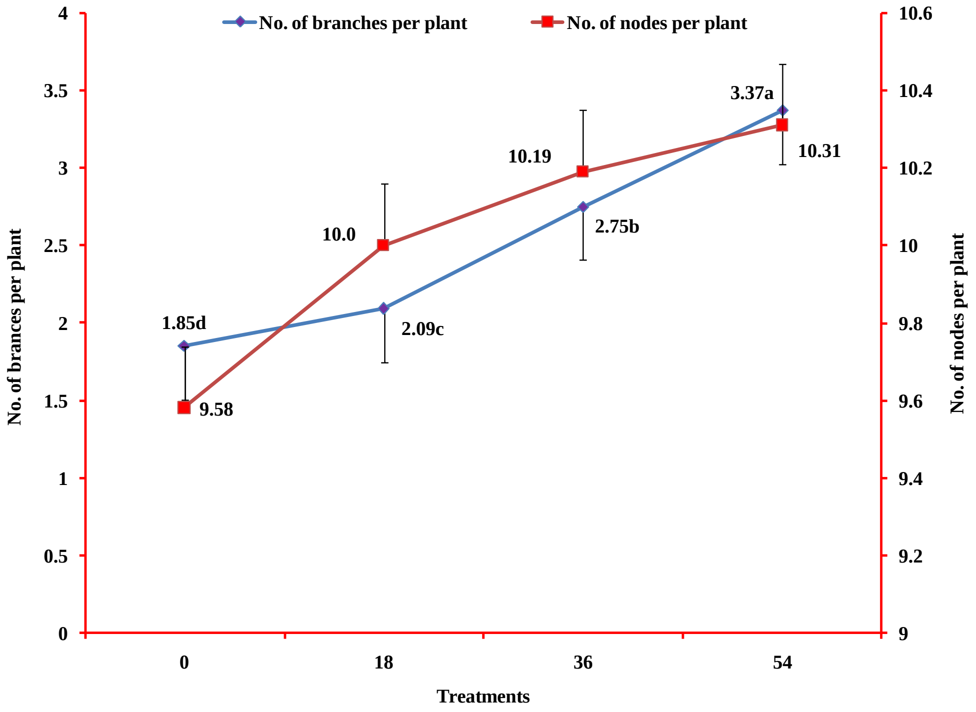

Fig. 4.7 Effect of phosphorus on the growth parameters of soybean

4.3.2 Effect of phosphorus on number of branches plant^{-1} of soybean

The significant differences observed in number of branches plant^{-1} of soybean plant can be ascribed to differences in the application of different levels of P-fertilizer shown in table 4.4 and figure 4.7 ($p \leq 0.05$). The highest number of branches plant^{-1} (3.37) was recorded in P_3 (54 kg P ha^{-1}) which was statistically different from all other treatments. Apart from this, the lowest number of branches plant^{-1} (1.85) was recorded in the P_0 treatment where no phosphorus was applied. The result of the present study was in agreement with the findings of Singh *et al.* (1999) also found similar results with increasing rate of P and they noted that the number of branches plant^{-1} generally increased with the application of P. In confirmation to the current investigation, Geeta and Radder (2015) observed that application of 80 kg P_2O_5 along with cured FYM +

PSB + VAM recorded significantly higher plant height (66.27 cm), number of branches palnt^{-1} (6.67) and total dry matter production (27.49 g) compared to other treatments in soybean.

4.3.3 Interaction effect of nitrogen and phosphorus on the number of branches plant^{-1} of soybean

The data pertaining to the number of branches per plant of soybean as given in table 4.7 and figure 4.8 showed statistically significant variation ($p \leq 0.05$). The combined effect of different doses of NP-fertilization on the number of branches plant^{-1} of soybean was significant (Table 4.7 & Figure 4.8). The highest number of branches plant^{-1} (3.71) was recorded with the treatment combination of N_1P_3 (25 kg Nha^{-1} + 54 kg P ha^{-1}) which was statistically similar with N_2P_3 (40 kg Nha^{-1} + 54 kg P ha^{-1}). On the other hand, the lowest number of branches plant^{-1} (1.43) was found in N_0P_1 treatment (0 kg Nha^{-1} + 18 kg P ha^{-1}). In agreement with the current observations, Begum *et al*. (2015) conducted an experiment at Bangladesh, reported that application of 25 kg N + 54 kg P_2O_5 ha^{-1} recorded significantly higher plant height (36.88 cm), number of branches (3.71), dry matter production (20.81 g) compared to other treatments in soybean. The result of the present study was in agreement with the findings of Shinde *et al.* (2015) indicated that application of 100 % RDF (30:60:30 N:P_2O_5:K_2O kg ha^{-1}) recorded higher plant height (57.09 cm), number of branches plant^{-1} (5.83), leaf area plant^{-1} (12.11 dm^2) and dry matter plant^{-1} (33.32 g) in soybean. The findings are directly in line with previous findings of Basavaraja *et al.* (2014) opined that application 100 % NPK + *Bradyrhizobium* + *Aspergillusniger* + VAM recorded highest growth parameter like branches at 30, 60 DAS and at harvest (4.84, 7.79 and 9.76 cm respectively), leaf area at 30, 60 DAS and at harvest (537.41, 999.57 and 1211.94 cm^2 respectively) and total dry matter at 30, 60 DAS and at harvest (3.36, 27.23 and 32.73 g plant^{-1} respectively) compare to other treatments in soybean.

4.4 Number of nodes plant^{-1}

4.4.1 Effect of nitrogen on the number of nodes plant^{-1} of soybean

Different doses of nitrogen fertilizers showed significant variations in respect of number of nodes plant^{-1} (Table 4.1 & Figure 4.4) ($p \leq 0.05$). Among the different doses of fertilizers, N_1 (25 kg N ha^{-1}) showed the highest number of nodes plant^{-1} (10.29) which was found statistically non-significant with other treatments. On the contrary, the lowest number of nodes plant^{-1} (9.88) was observed with N_2 (40 kg N ha^{-1}) and N0 (control). Another promising finding was that Tank *et al.* (1992) found that soybean fertilized with 50 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} produced significantly higher number of nodes plant^{-1} over the unfertilized control. The result of the present study was in agreement with the findings of Mandic *et al*. (2015) conducted an experiment on two soybean genotypes and concluded that application of 46 kg urea ha^{-1} along with ferticare I (5 kg ha^{-1}) recorded significantly higher plant height (140 and 107 cm, respectively) and higher nodes plant^{-1} (16 and 13, respectively) in the two genotypes.

4.4.2 Effect of phosphorus on the number of nodes plant^{-1}of soybean

The data given in table 4.4 and figure 4.7 suggested that the number of nodes per plant of soybean was affected significantly by the application of different levels of P-fertilization. Significant variation was observed in number of nodes plant^{-1} of soybean when different doses of phosphorus were applied ($p \leq 0.05$) (Table 4.4 & Figure 4.7). The highest number of nodes plant^{-1} (10.31) was recorded in P_3 (54 kg P ha^{-1}) which was found statistically non-significantly different from other treatment.

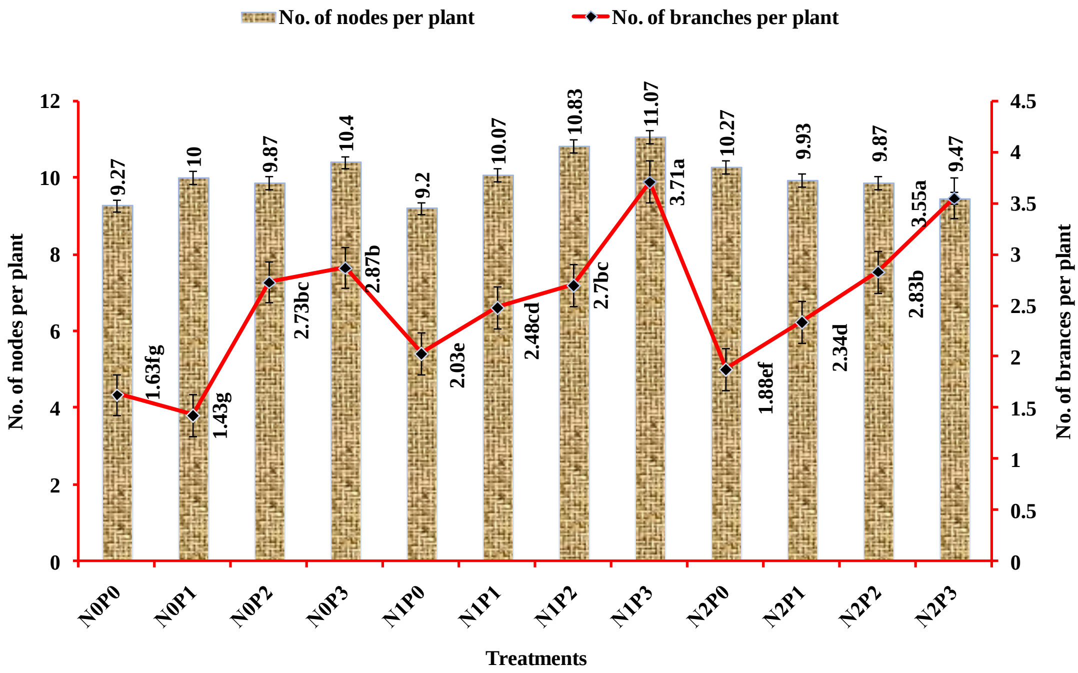

Fig. 4.8 Effect of nitrogen and phosphorus on the growth parameters of soybean

The lowest number of nodes plant^{-1} (9.58) was recorded in the P_0 treatment where no phosphorus was applied. Similar results were found from other scientists like, Srinivas *et al.* (2002), observed that number of nodes plant^{-1}, nodes plant^{-1}, pod length and seeds pod^{-1} were increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} and also observed that 1000-seed weight in green gram. The result of the present study was in agreement with the findings of Mastan *et al.* (1999), Kalita (1989) and Reddy *et al.* (1990).

4.4.3 Interaction effect of nitrogen and phosphorus on the number of nodes plant^{-1} of soybean

The combined effect of different doses of N and P fertilizers on number of nodes plant^{-1} of soybean was significant ($p \leq 0.05$) (Table 4.7 & Figure 4.8). The highest number of nodes plant^{-1} (11.07) was recorded with the treatment combination of N_1P_3 (25 kg N ha^1+ 54 kg P ha^{-1}) which was found statistically non-significantly different from the rest of the treatments. On the other hand, the lowest number of nodes plant^{-1} (9.20) was found in N_1P_0 (25 kg N ha^{-1} + 0 kg P ha^{-1}) treatment. Similar results were found from other scientists like, Srinivas *et al.* (2002), observed that number of nodes plant^{-1}, nodes plant^{-1}, pod length and seeds pod^{-1} were increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} and also observed that 1000-seed weight in green gram.

4.4 Number of filled pods plant^{-1}

4.4.1 Effect of nitrogen on the number of filled pods plant^{-1} of soybean

Different doses of nitrogen fertilizers showed significant variations in respect of number of pods plant^{-1} of soybean ($p \leq 0.05$) presented in table 4.1 and figure 4.4. Among the different doses of N-fertilizers, N_1 (25 kg N ha^{-1}) showed the highest number of pods plant^{-1} (47.59) which was statistically different with others treatments. On the contrary, the lowest number of pods plant^{-1} (38.00) was observed with N_0 unfertilized control treatment. The result of this present research work in agreement with the findings of Tank *et al.* (1992) found that soybean fertilized with 50 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} produced significantly higher number of filled pods plant^{-1} over the unfertilized control. The result of the present study was in agreement with the findings of Mandic *et al*. (2015) indicated that application of Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}) recorded higher number of pods plant^{-1} (58.1), number of grain plant^{-1} (124.8), 1000 grain weight (185.84 g) and grain yield (3961 kg ha^{-1}) compared to other treatments in soybean. In confirmation to the current investigation with the findings of Ahmed (2013) concluded that *Rhizobium* + 80 kg N ha^{-1}, increased the seed yield (2.54 t ha^{-1}), number of pods plant^{-1} (90.3) and number of seeds pod^{-1} (3.8) compared to other treatments, but the 1000-seed weight was non-significant among the treatments in soybean.

4.4.2 Effect of phosphorus on the number of filled pods plant^{-1}of soybean

Significant variation was observed in number of filled pods plant^{-1} of soybean when different doses of phosphorus were applied ($p \leq 0.05$) presented in table 4.4 and figure 4.2). On the one hand, the highest number of filled pods plant^{-1} (54.49) was recorded in P_3 (54 kg P ha^{-1}) which was statistically different from other treatment. On the other hand, the lowest number of filled pods plant^{-1} (29.77) was recorded in the P_0 (0 kg P ha^{-1}) treatment where no phosphorus was applied. The result of the present study was in agreement with the findings of Mastan *et al.* (1999), Kalita (1989) and Reddy *et al.* (1990). In confirmation to the current investigation with the findings of Mahmoodi *et al*. (2013) revealed that application of 90 kg P_2O_5 ha^{-1} recorded higher number of pods plant^{-1} (66.30), number of seeds plant^{-1} (129.97), 1000 seed weight (167.20 g) and seed yield (5158.27 kg ha^{-1}) over control, 30 and 60 kg P_2O_5 ha^{-1} in soybean. It is worth discussing these interesting facts revealed by the results of Shivran *et al*. (2012) opined that application of 60 kg P_2O_5 ha^{-1} + PSB recorded higher pods plant^{-1} (67.47), seeds pod^{-1} (2.7), seed index (10.08 g), seed yield (24.67 q ha^{-1}), straw yield (38.10 q ha^{-1}) and harvest index (39.29 %) compared to other treatments in soybean.

4.4.3 Interaction effect of nitrogen and phosphorus on the number of filled pods Plant^{-1} of soybean

The combined effect of different doses of N and P fertilizers on number of filled pods plant-1 of soybean was found statistically significant ($p \leq 0.05$) in table 4.8 and figure 4.12. The highest number of filled pods plant^{-1} (58.28) was recorded with the treatment combination of N_1P_3 (18 kg N ha^{-1}+ 54 kg P ha^{-1}) which was statistically different from the rest of the treatments. On the other hand, the lowest number of filled pods plant^{-1} (23.5) was found in N_0P_0 (0 kg N ha^{-1} + 0 kg P ha^{-1}) unfertilized control treatment. It is worth discussing these interesting facts revealed by the results of Srinivas *et al.* (2002), observed that number of pods plant^{-1}, pod length and seeds pod^{-1} were increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} and also observed that 1000-seed weight in green gram. In agreement with the current observations of Aziz *et al*. (2016) observed that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded higher number of pods plant^{-1} (75), 100 seed weight (12.36 g) and grain yield (1864 kg ha^{-1}) over the control in soybean. The result of the present study was in agreement with the findings of Shinde *et al*. (2015) indicated that application of 100 % RDF recorded higher number of pods plant^{-1} (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean. It is worth discussing these interesting facts revealed by the results of Gharpinde *et al*. (2014) revealed that application of 30:75:25 NPK kg ha^{-1} + biofertilizers recorded higher grain yield (14.26 q ha^{-1}) and straw yield (30.68 q ha^{-1}) over rest of the treatments in soybean. The results of the experiment found clear support for the results of Sikka *et al*. (2013) reported that application of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1} along with 5 t FYM ha^{-1} to soybean recorded significantly higher number of pods plant^{-1} (150.3), test weight (10.4 g) and seed yield (32.6 q ha^{-1}) compared to control treatment.

4.4 Number of empty pods plant^{-1}

4.4.1 Effect of nitrogen on the number of empty pods plant^{-1} of soybean

Result showed significant variations in respect of number of empty pods plant^{-1} ($p \leq 0.05$) (Table 4.2 & Figure 4.5) in different doses of nitrogen fertilizers application in soybean. Among the different doses of N-fertilizer, N_0 (0 kg N ha^{-1}) showed the highest number of empty pods plant^{-1} (3.31) which was statistically different with others treatments. On the contrary, the lowest number of pods plant^{-1} (2.42) was observed with

N_1 (25 kg N ha^{-1}). The results of the experiment found clear support for the results of Tank *et al.* (1992) found that soybean fertilized with 50 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} produced significantly higher number of empty pods plant^{-1} over the unfertilized control. It is worth discussing these interesting facts revealed by the results of Mandic *et al*. (2015) indicated that application of Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}) recorded higher number of pods plant^{-1} (58.1), number of grain plant-1 (124.8), 1000-grain weight (185.84 g) and grain yield (3961 kg ha^{-1}) compared to other treatments in soybean. The result of the present study was in agreement with the findings of Ahmed (2013) concluded that *Rhizobium* + 80 kg N ha^{-1}, increased the seed yield (2.54 t ha^{-1}), number of pods plant^{-1} (90.3) and number of seeds pod^{-1} (3.8) compared to other treatments, but the 1000-seed weight was non-significant among the treatments in soybean.

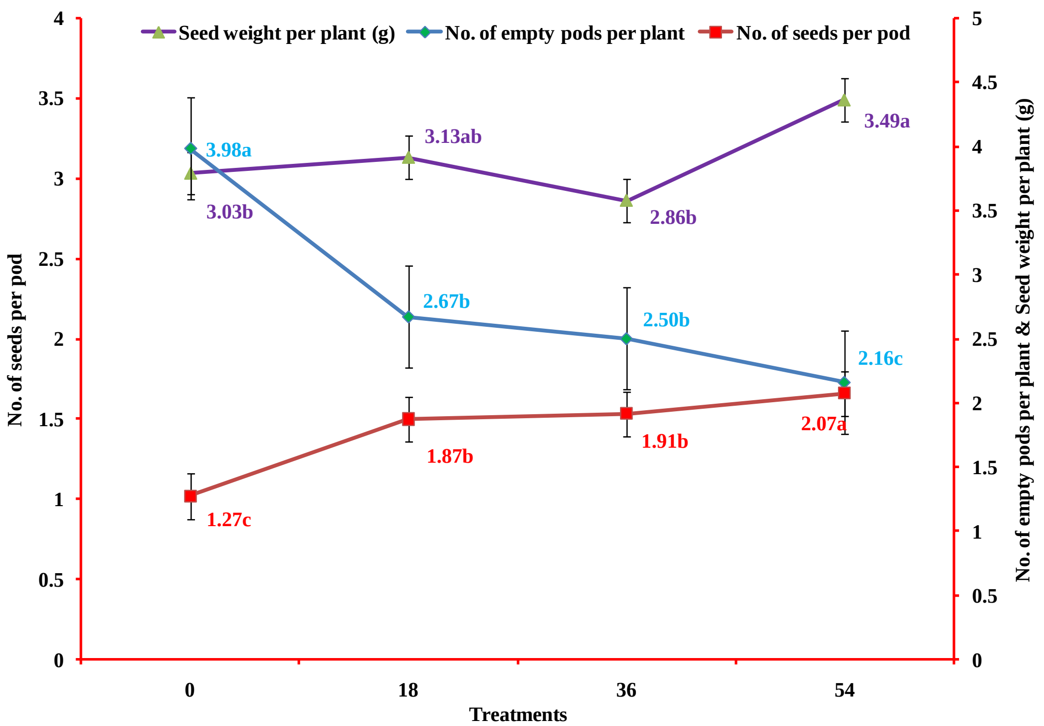

Fig. 4.9 Effect of phosphorus on the yield parameters of soybean

4.4.2 Effect of phosphorus on the number of empty pods plant^{-1}of soybean

Significant variation was observed in number of empty pods plant^{-1} of soybean when different doses of phosphorus were applied ($p \leq 0.05$) (Table 4.5 & Figure 4.9). The highest number of empty pods plant^{-1} (3.98) was recorded in P_0 (0 kg P ha^{-1}) which was statistically different from other treatment. The lowest number of empty pods plant^{-1} (2.16) was recorded in the P_3 (54 kg P ha^{-1}) treatment where 54 kg ha^{-1} phosphorus was applied. The result of the present study was in agreement with the findings of Mastan *et al.* (1999), Kalita (1989) and Reddy *et al.* (1990). A similar conclusion was reached by Mahmoodi *et al*. (2013) revealed that application of 90 kg P_2O_5 ha^{-1} recorded higher number of pods plant^{-1} (66.30), number of seeds plant^{-1} (129.97), 1000-seed weight (167.20 g) and seed yield (5158.27 kg ha^{-1}) over control, 30 and 60 kg P_2O_5 ha^{-1} in soybean. The result of the present study was in agreement with the findings of Shivran *et al*. (2012) opined that application of 60 kg P_2O_5 ha^{-1} + PSB recorded higher pods plant^{-1} (67.47), seeds pod^{-1} (2.7), seed index (10.08 g), seed yield (24.67 q ha^{-1}), straw yield (38.10 q ha^{-1}) and harvest index (39.29 %) compared to other treatments in soybean.

4.4.3 Interaction effect of nitrogen and phosphorus on the number of empty pods Plant^{-1} of soybean

The combined effect of different doses of N and P fertilizers on number of empty pods plant^{-1} of soybean was significant ($p \leq 0.05$) presented in table 4.8 and figure 4.11. The highest number of empty pods plant^{-1} (4.01) was recorded with the treatment combination of N_2P_0 (40 kg N ha^{-1}+ 0 kg P ha^{-1}) which was statistically similar with N_1P_0 (25 kg N ha^{-1}+ 0 kg P ha^{-1}) and N_0P_0 (0 kg N ha^{-1}+ 0 kg P ha^{-1}) treatments. On the other hand, the lowest number of empty pods plant^{-1} (10.39) was found in N_0P_0 (0 kg N ha^{-1} + 0 kg P ha^{-1}) treatment. The results of the experiment found clear support for the results of Srinivas *et al.* (2002), observed that number of pods plant^{-1}, pod length and seeds pod^{-1} were increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} and also observed that 1000-seed weight in green gram. The result of the present study was in agreement with the findings of Aziz *et al*. (2016) observed that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded higher number of pods plant^{-1} (75), 100 seed weight (12.36 g) and grain yield (1864 kg ha^{-1}) over the control in soybean. In confirmation to the current investigation with Shinde *et al*. (2015) indicated that application of 100 % RDF recorded higher number of pods plant^{-1} (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean. The result was similar to Gharpinde *et al*. (2014) revealed that application of 30:75:25 NPK kg ha^{-1} + biofertilizers recorded higher grain yield (14.26 q ha^{-1}) and straw yield (30.68 q ha^{-1}) over rest of the treatments in soybean. In agreement with the current observations, Sikka *et al*. (2013) reported that application of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1} along with 5 t FYM ha^{-1} to soybean recorded significantly higher number of pods plant^{-1} (150.3), test weight (10.4 g) and seed yield (32.6 q ha^{-1}) compared to control.

4.7 Number of seeds pod^{-1}

4.7.1 Effect of nitrogen on the number of seeds pod^{-1} of soybean

It is evident from the data presented in table 4.2 and figure 4.5 that application of N fertilizer brought significant change on number of seeds per pod of soybean ($p \leq 0.05$). Different doses of nitrogen fertilizers showed significant variations in respect of number of seeds pod^{-1} (Table 4.2 & Figure 4.5) in soybean plant. Among the different doses of N-fertilizer, N_1 (25 kg N ha^{-1}) showed the highest number of seeds pod^{-1} (1.94) which was statistically different from all other treatments. On the contrary, the lowest number of seeds pod^{-1} (1.64) was observed with N0 (0 kg N ha^{-1}), where no nitrogen fertilizer was applied. The result was similar to Mandic *et al*. (2015) indicated that application of Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}) recorded higher number of pods plant^{-1} (58.1), number of grain plant^{-1} (124.8), 1000 grain weight (185.84 g) and grain yield (3961 kg ha^{-1}) compared to other treatments in soybean. The results of the experiment found clear support for the results of Ahmed (2013) concluded that *Rhizobium* + 80 kg N ha^{-1}, increased the seed yield (2.54 t ha^{-1}), number of pods plant^{-1} (90.3) and number of seeds pod^{-1} (3.8) compared to other treatments, but the 1000-seed weight was non-significant among the treatments in soybean.

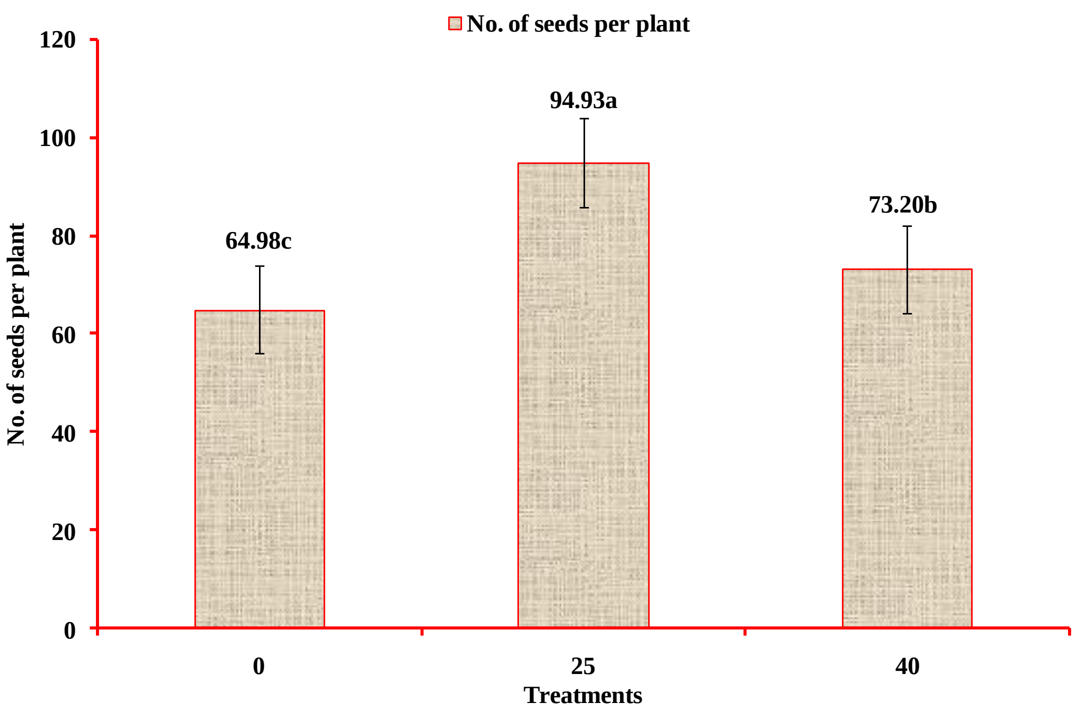

Fig. 4.10 Effect of nitrogen on the yield parameters of soybean

4.7.2 Effect of phosphorus on the number of seeds pod^{-1} of soybean

The analysis of the result demonstrated that the various levels of P-fertilizer application showed statistically significant variation on number of seeds per pod of soybean presented in table 4.5 and figure 4.9 ($p \leq 0.05$). The highest number of seeds pod^{-1} (2.07) was recorded in P_3 (54 kg P ha^{-1}). The lowest number of seeds pod^{-1} (1.27) was recorded in the P_0 (0 kg P ha^{-1}) treatment where no phosphorus was applied. The results of the experiment found clear support for the results of Chiezey *et al*. (2009) suggested that the application of P stimulated leaf expansion, hence more light interception for photosynthetic activity, high assimilated accumulation and seed yield, pod yield and 1000-seeds weight which are important determinants of seed yield increased with P application. These resulted in increased seed yield. The result of the present study was in agreement with the findings of Mahmoodi *et al*. (2013) revealed that application of 90 kg P_2O_5 ha^{-1} recorded higher number of pods $plant^{-1}$ (66.30), number of seeds $plant^{-1}$ (129.97), 1000-seed weight (167.20 g) and seed yield (5158.27 kg ha^{-1}) over control, 30 and 60 kg P_2O_5 ha^{-1} in soybean. The findings are directly in line with previous findings of Shivran *et al*. (2012) opined that application of 60 kg P_2O_5 ha^{-1} + PSB recorded higher pods $plant^{-1}$ (67.47), seeds pod^{-1} (2.7), seed index (10.08 g), seed yield (24.67 q ha^{-1}), straw yield (38.10 q ha^{-1}) and harvest index (39.29 %) compared to other treatments in soybean.

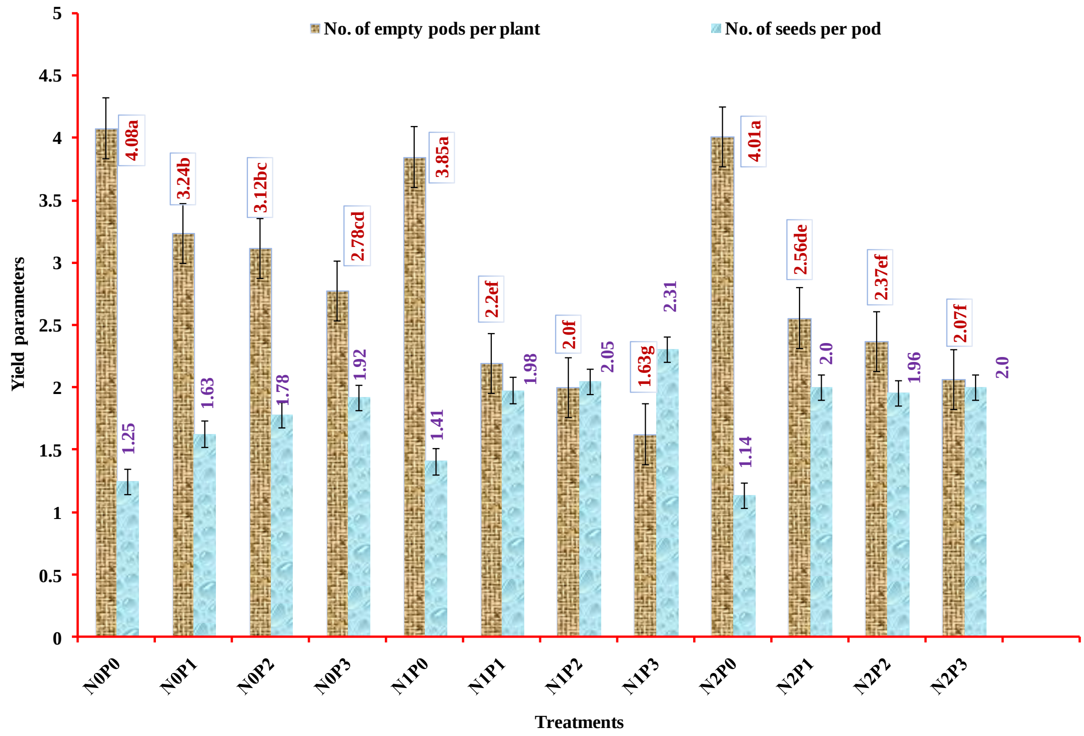

Fig. 4.11 Effect of nitrogen and phosphorus on the yield parameters of soybean

4.7.3 Interaction effect of nitrogen and phosphorus on the number of seeds pod^{-1} of soybean

Results regarding number of seeds pod^{-1} of soybean exhibited that there was a non-significant differences among various treatments of NP fertilizers application when compared it with untreated control treatment presented in table 4.8 and figure 4.11 ($p \leq 0.05$). The combined effect of different doses of N and P fertilizer on number of seeds pod^{-1} of soybean was non-significant (Table 4.8 & Figure 4.11). The highest number of seeds pod^{-1} (2.31) was recorded with the treatment combination of N_1P_3 (25 kg N ha^{-1} + 54 kg P ha^{-1}). On the other hand, the lowest number of seeds pod^{-1} (1.25) was found in N_0P_0 (0 kg N ha^{-1} + 0 kg P ha^{-1}) unfertilized control treatment. The results of the experiment found clear support for the results of Chiezey *et al*. (2009) suggested that the application of P stimulated leaf expansion, hence more light interception for photosynthetic activity, high assimilated accumulation and seed yield, pod yield and

100 seeds weight which are important determinants of seed yield increased with P application and these resulted in increased seed yield. The result of the present study was in agreement with the findings of Aziz *et al*. (2016) observed that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded higher number of pods $plant^{-1}$ (75), 100 seed weight (12.36 g) and grain yield (1864 kg ha^{-1}) over the control in soybean. The result of the present study was in agreement with the findings of Shinde *et al.* (2015) indicated that application of 100 % RDF recorded higher number of pods $plant^{-1}$ (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean.

4.7 Number of seeds $plant^{-1}$

4.7.1 Effect of nitrogen on the number of seeds $plant^{-1}$ of soybean

Different doses of nitrogen fertilizers showed significant variations in respect of number of seeds $plant^{-1}$ ($p \leq 0.05$) presented in table 4.5 and figure 4.10. Among the different doses of N-fertilizer, N_1 showed the highest number of seeds $plant^{-1}$ (94.93) which was statistically different from all other treatments. On the contrary, the lowest number of seeds $plant^{-1}$ (64.98) was observed with N_0, where no nitrogen fertilizer was applied. The result of the present study was in agreement with the findings of Mandic *et al.* (2015) indicated that application of Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}) recorded higher number of pods $plant^{-1}$ (58.1), number of grain $plant^{-1}$ (124.8), 1000 grain weight (185.84 g) and grain yield (3961 kg ha^{-1}) compared to other treatments in soybean. The results of the experiment found clear support for the results of Ahmed (2013) concluded that *Rhizobium* + 80 kg N ha^{-1}, increased the seed yield (2.54 t ha^{-1}), number of pods $plant^{-1}$ (90.3) and number of seeds pod^{-1} (3.8) compared to other treatments, but the 1000-seed weight was non-significant among the treatments in soybean.

4.7.2 Effect of phosphorus on the number of seeds plant^{-1} of soybean

Significant variation was observed in number of seeds plant^{-1} of soybean when different doses of phosphorus were applied ($p \leq 0.05$) in table 4.5 and figure 4.16. The highest number of seeds plant^{-1} (113.48) was recorded in P_3 (54 kg P ha^{-1}). The lowest number of seeds plant^{-1} (38.07) was recorded in the P_0 treatment where no phosphorus was applied. The results of the experiment found clear support for the results of Mahmoodi *et al*. (2013) revealed that application of 90 kg P_2O_5 ha^{-1} recorded higher number of pods plant^{-1} (66.30), number of seeds plant^{-1} (129.97), 1000 seed weight (167.20 g) and seed yield (5158.27 kg ha^{-1}) over control, 30 and 60 kg P_2O_5 ha^{-1} in soybean. In confirmation to the current investigation with Shivran *et al*. (2012) opined that application of 60 kg P_2O_5 ha^{-1} + PSB recorded higher pods plant^{-1} (67.47), seeds pod^{-1} (2.7), seed index (10.08 g), seed yield (24.67 q ha^{-1}), straw yield (38.10 q ha$_{-1}$) and harvest index (39.29 %) compared to other treatments in soybean.

4.7.3 Interaction effect of nitrogen and phosphorus on the number of seeds plant^{-1} of soybean

The combined effect of different doses of N and P fertilizer on number of seeds plant^{-1} of soybean was significant ($p \leq 0.05$) (Table 4.8 & Figure 4.12). The highest number of seeds plant^{-1} (134.48) was recorded with the treatment combination of N_1P_3 (25 kg N ha^{-1} + 54 kg P ha^{-1}). On the other hand, the lowest number of seeds plant^{-1} (29.36) was found in N_0P_0 (0 kg N ha^{-1} + 0 kg P ha^{-1}) treatment (control). In confirmation to the current investigation with Chiezey *et al*. (2009) suggested that the application of P stimulated leaf expansion, hence more light interception for photosynthetic activity, high assimilated accumulation and seed yield, pod yield and 100 seeds weight which are important determinants of seed yield increased with P application and these resulted in increased seed yield. It is worth discussing these interesting facts revealed by the results of Aziz *et al*. (2016) observed that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded higher number of pods plant^{-1} (75), 100 seed weight (12.36 g) and grain yield (1864 kg ha^{-1}) over the control in soybean. The result of the present study was in agreement with the findings of Shinde *et al*. (2015) indicated that application of 100 % RDF recorded higher number of pods plant^{-1} (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean.

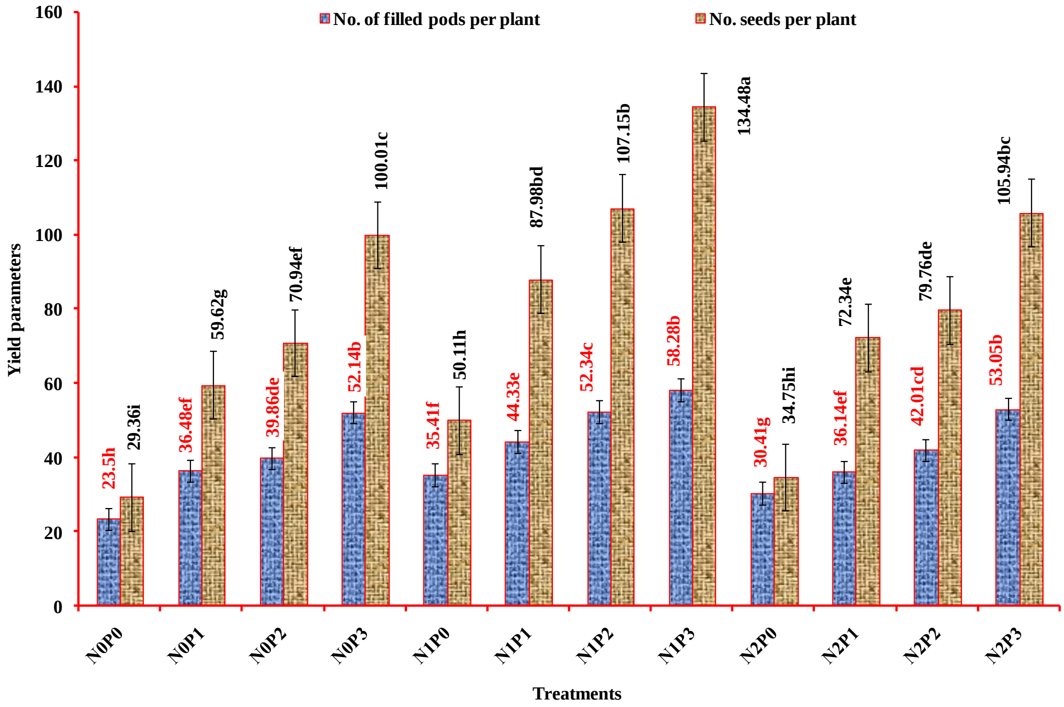

Fig. 4.12 Effect of nitrogen and phosphors on the yield parameters of soybean

4.7 Number of seed weight plant^{-1}

4.7.1 Effect of nitrogen on the number of seed weight plant^{-1} of soybean

Different doses of nitrogen fertilizers showed significant variations in respect of number of seed weight plant^{-1} ($p \leq 0.05$) (Table 4.2 & Figure 4.5). Among the different doses of N-fertilizer, N_1 (25 kg N ha^{-1}) showed the highest number of seed weight plant^{-1} (3.41 g) which was statistically different from all other treatments. On the contrary, the lowest number of seed weight plant^{-1} (3.07 g) was observed with N_0 (0 kg

N ha^{-1}), where no nitrogen fertilizer was applied. The result of the present study was in agreement with the findings of Mandic *et al*. (2015) indicated that application of Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}) recorded higher number of pods plant^{-1} (58.1), number of grain plant^{-1} (124.8), 1000 grain weight (185.84 g) and grain yield (3961 kg ha^{-1}) compared to other treatments in soybean. The results of the experiment found clear support for the results of Janagard *et al*. (2013) revealed that application of urea 16.5 kg ha^{-1} + 49.5 kg ha^{-1} + *B. japonicum* + PSB recorded significantly higher pod weight plant^{-1} (12.2 g) and grain yield per unit area (321.8 g) compared to other treatments in soybean. In agreement with the current observations of Singh and Singh (2013) reported that 20 kg N ha^{-1} as basal and 10 kg N at pod filling stage recorded higher grain yield (25.1 q ha^{-1}), straw yield (43.5 q ha^{-1}), biological yield (68.6 q ha^{-1}) and harvest index (36 %) as compared to control in soybean.

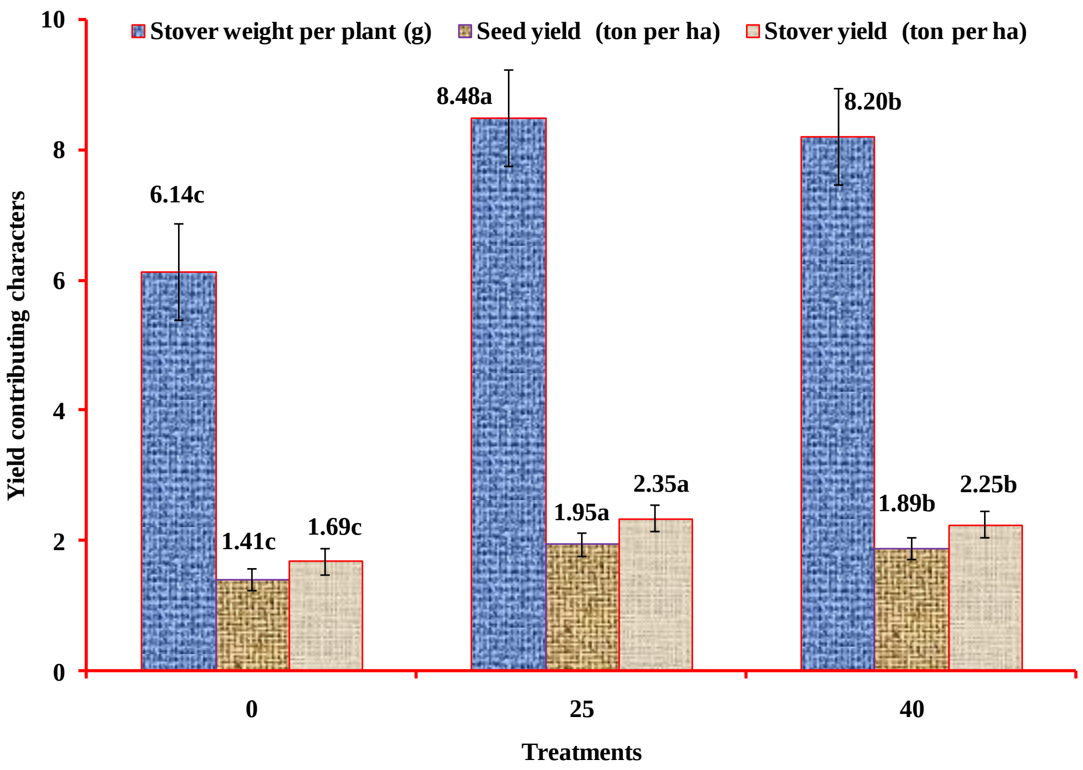

Fig. 4.13 Effect of nitrogen on the yield parameters of soybean

4.7.2 Effect of phosphorus on the number of seed weight plant^{-1} of soybean

Significant variation was observed in number of seed weight plant^{-1} of soybean when different doses of phosphorus were applied ($p \leq 0.05$) (Table 4.5 & Figure 4.9). The highest number of seed weight plant^{-1} (3.49 g) was recorded in P_3 (54 kg P ha^{-1}) which was identical with P_1 (18 kg P ha^{-1}) treatment (3.13 g). The lowest number of seed weight plant^{-1} (3.03 g) was recorded in the P_0 (0 kg P ha^{-1}) treatment where no phosphorus was applied. In agreement with the current observations of Kamble and Kathmale (2014) reported that application of 100 % RDP (75 kg P_2O_5 ha^{-1}) + inoculation of *Pencilium bilaji* 104 recorded significantly higher seed yield (2919 kg ha1), straw yield (3874 kg ha^{-1}) and 100 seed weight (12.20 g) compared to 50 % RDP in soybean. The result of the present study was in agreement with the findings of Mahmoodi *et al*. (2013) revealed that application of 90 kg P_2O_5 ha^{-1} recorded higher number of pods plant^{-1} (66.30), number of seeds plant^{-1} (129.97), 1000-seed weight (167.20 g) and seed yield (5158.27 kg ha^{-1}) over control, 30 and 60 kg P_2O_5 ha^{-1} in soybean.

4.7.3 Interaction effect of nitrogen and phosphorus on the number of seed weight plant^{-1} of soybean

The combined effect of different doses of N and P fertilizer on number of seed weight plant^{-1} of soybean was significant ($p \leq 0.05$) (Table 4.9 & Figure 4.14). The highest number of seed weight plant^{-1} (3.89 g) was recorded with the treatment combination of N_1P_3 (25 kg N ha^{-1} + 54 kg P ha^{-1}). On the other hand, the lowest number of seed weight plant^{-1} (2.30 g) was found in N_1P_0 (25 kg N ha^{-1} + 0 kg P ha^{-1}) treatment (control). The result of the present study was in agreement with the findings of Aziz *et al*. (2016) observed that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded higher number of pods plant^{-1} (75), 100 seed weight (12.36 g) and grain yield (1864 kg ha^{-1}) over the control in soybean. The results of the experiment found clear support for the results of Shinde *et al*. (2015) indicated that application of 100 % RDF recorded higher number of pods plant^{-1} (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean.

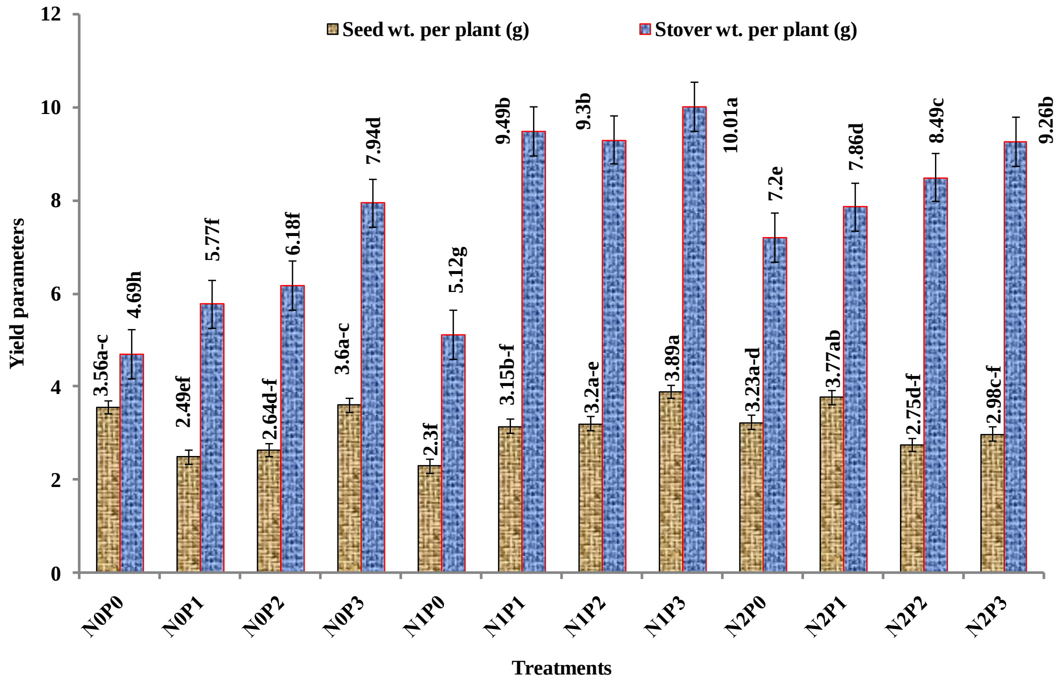

Fig. 4.14 Effect of nitrogen and phosphorus on the yield parameters of soybean

4.7 Stover weight plant^{-1}

4.7.1 Effect of nitrogen on the stover weight plant^{-1} of soybean

Different doses of nitrogen fertilizers showed significant variations in respect of number of stover weight plant^{-1} ($p \leq 0.05$) (Table 4.3 & Figure 4.13). Among the different doses of fertilizer, N_1 (25 kg N ha^{-1}) showed the highest number of stover weight plant^{-1} (8.48 g) which was statistically different from all other treatments. On the contrary, the lowest number of stover weight plant^{-1} **(**6.14 g) was observed with N0 (0 kg N ha^{-1}), where no nitrogen fertilizer was applied. The results of the experiment found clear support for the results of Singh and Singh (2013) reported that 20 kg N ha^{-1} as basal and 10 kg N at pod filling stage recorded higher grain yield (25.1 q ha^{-1}), straw yield (43.5 q ha^{-1}), biological yield (68.6 q ha^{-1}) and harvest index (36 %) as compared to control in soybean.

4.7.2 Effect of phosphorus on the number of stover weight $plant^{-1}$ of soybean

Significant variation was observed in number of stover weight $plant^{-1}$ of soybean when different doses of phosphorus were applied ($p \leq 0.05$) (Table 4.6 & Figure 4.18). The highest number of stover weight $plant^{-1}$ (9.07 g) was recorded in P_3 (54 kg P ha^{-1}). The lowest number of stover weight $plant^{-1}$ (5.67 g) was recorded in the P_0 (0 kg P ha^{-1}) treatment where no phosphorus was applied. The results of the experiment found clear support for the results of Kamble and Kathmale (2014) reported that application of 100 % RDP (75 kg P_2O_5 ha^{-1}) + inoculation of *Pencilium bilaji* 104 recorded significantly higher seed yield (2919 kg ha^{-1}), straw yield (3874 kg ha^{-1}) and 100 seed weight (12.20 g) compared to 50 % RDP in soybean. In confirmation to the current investigation with Dhage *et al*. (2014) opined that application of 90 kg P_2O_5 ha^{-1} recorded significantly higher grain yield (2339.2 kg ha^{-1}), straw yield (4909.8 kg ha^{-1}) and biological yield (7251.7 kg ha^{-1}) over the control, 30 and 60 kg P_2O_5 ha^{-1} in soybean. It is worth discussing these interesting facts revealed by the results of Shivran *et al*. (2012) opined that application of 60 kg P_2O_5 ha^{-1} + PSB recorded higher pods $plant^{-1}$ (67.47), seeds pod^{-1} (2.7), seed index (10.08 g), seed yield (24.67 q ha^{-1}), straw yield (38.10 q ha^{-1}) and harvest index (39.29 %) compared to other treatments in soybean.

4.7.3 Interaction effect of nitrogen and phosphorus on the number of stover weight plant^{-1} of soybean

The combined effect of different doses of N and P fertilizer on number of stover weight plant^{-1} of soybean was significant ($p \leq 0.05$) (Table 4.9 & Figure 4.14). The highest number of stover weight plant^{-1} (10.01 g) was recorded with the treatment combination of N_1P_3 (25kg N ha^{-1} + 54 kg P ha^{-1}). On the other hand, the lowest number of stover weight plant^{-1} (4.69 g) was found in N_0P_0 (0 kg N ha^{-1} + 0 kg P ha^{-1}) treatment (control). The result of the present study was in agreement with the findings of Shinde *et al*. (2015) indicated that application of 100 % RDF recorded higher number of pods plant^{-1} (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean. In confirmation to the current investigation with Gharpinde *et al*. (2014) revealed that application of 30:75:25 NPK kg ha^{-1} + biofertilizers recorded higher grain yield (14.26 q ha^{-1}) and straw yield (30.68 q ha^{-1}) over rest of the treatments in soybean.

4.8 Weight of 1000-seed (g)

4.8.1 Effect of nitrogen on weight of 1000-seed of soybean

The data given in table 4.3 and figure 4.14 suggested that 1000-gain weight (g) of soybean seed was affected significantly by the application of different levels of N-fertilizer ($p \leq 0.05$). Different doses of N fertilizer showed significant variations in respect of the weight of 1000-seed (Table 4.3 & Figure 4.14). Among the different doses of N fertilizer, N_1 (25 kg N ha^{-1}) showed the highest weight of 1000-seed (120.24 g) and it was different from others treatments. On the contrary, the lowest weight of 1000-seed (111.26 g) was observed with N_0 (control) where no N fertilizer was applied. In confirmation to the current investigation with Mandic *et al*. (2015) indicated that application of Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}) recorded higher number of pods plant^{-1} (58.1), number of grain plant^{-1} (124.8), 1000 grain weight (185.84 g) and grain yield (3961 kg ha^{-1}) compared to other treatments in soybean. It is worth discussing these interesting facts revealed by the results of Ahmed (2013) concluded that *Rhizobium* + 80 kg N ha^{-1}, increased the seed yield (2.54 t ha^{-1}), number of pods $plant^{-1}$ (90.3) and number of seeds pod^{-1} (3.8) compared to other treatments, but the 1000-seed weight was non-significant among the treatments in soybean.

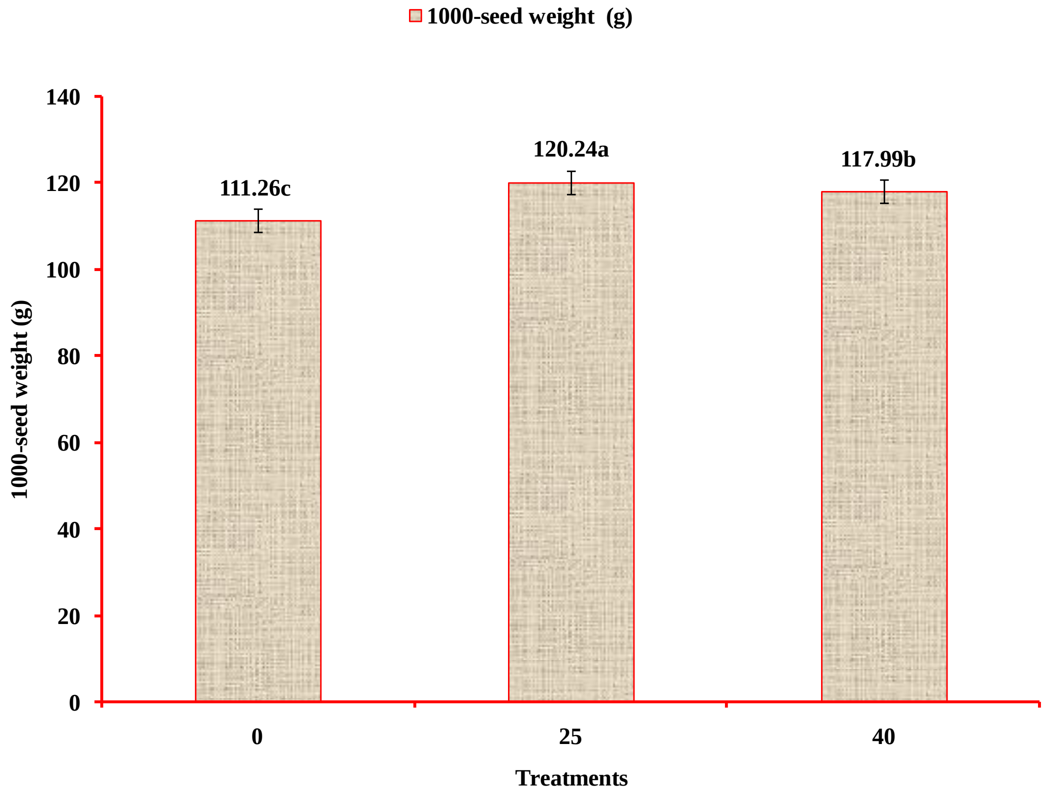

Fig. 4.15 Effect of nitrogen on 1000-seed weight of soybean

4.8.2 Effect of phosphorus on weight of 1000-seed of soygbean

A significant variation was observed on the weight of 1000 seed of soybean when different doses of P were applied ($p \leq 0.05$) (Table 4.6 & Figure 4.16). The highest weight of 1000-seed (122.20 g) was recorded in P_3 (54 kg P ha^{-1}), which was statistically dissimilar with other treatments. On the other hand, the lowest weight of 1000-seed (109.15 g) was recorded in the P_0 (0 kg P ha^{-1}) treatment where no P was applied. It is worth discussing these interesting facts revealed by the results of Kamble and Kathmale (2014) reported that application of 100 % RDP (75 kg P_2O_5 ha^{-1}) + inoculation of *Pencilium bilaji* 104 recorded significantly higher seed yield (2919 kg ha1), straw yield (3874 kg ha^{-1}) and 1000-seed weight (12.20 g) compared to 50 % RDP in soybean. The results of the experiment found clear support for the results of Dhage *et al*. (2014) opined that application of 90 kg P_2O_5 ha^{-1} recorded significantly higher grain yield (2339.2 kg ha^{-1}), straw yield (4909.8 kg ha^{-1}) and biological yield (7251.7 kg ha^{-1}) over the control, 30 and 60 kg P_2O_5 ha^{-1} in soybean. In confirmation to the current investigation with Mahmoodi *et al*. (2013) revealed that application of 90 kg P_2O_5 ha^{-1} recorded higher number of pods plant^{-1} (66.30), number of seeds plant^{-1} (129.97), 1000-seed weight (167.20 g) and seed yield (5158.27 kg ha^{-1}) over control, 30 and 60 kg P_2O_5 ha^{-1} in soybean.

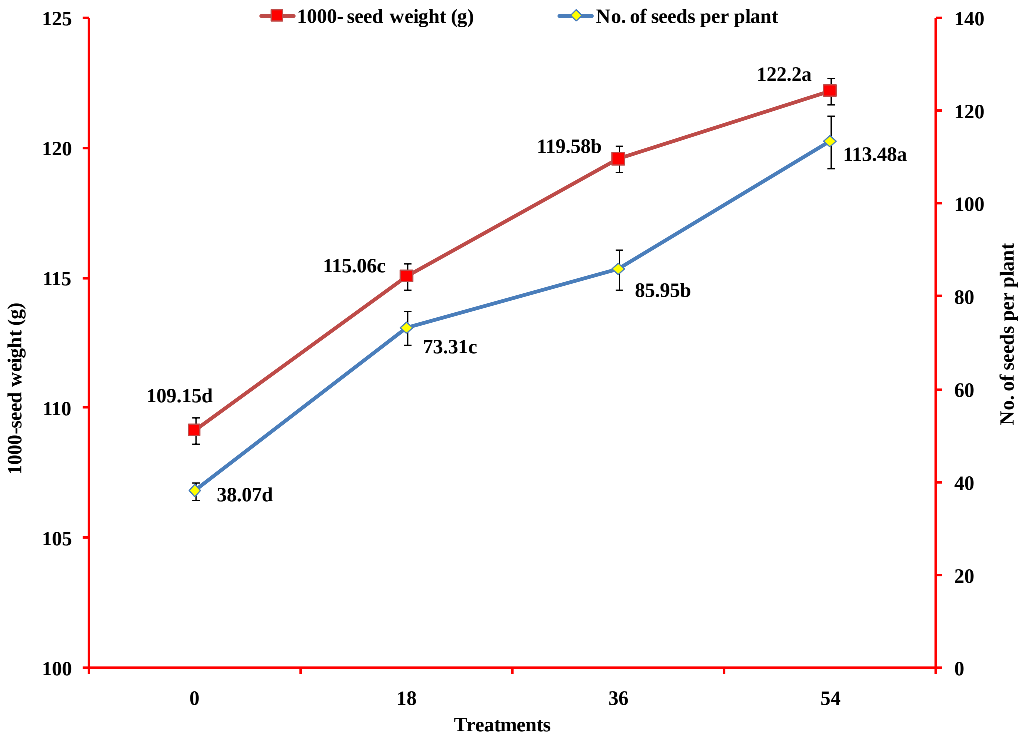

Fig. 4.16 Effect of phosphorus on the yield parameters of soybean

4.8.3 Interaction effect of nitrogen and phosphorus on weight of 1000-seed of soybean

Data presented in table 4.9 and figure 4.17 suggested that the combined effect of different doses of N and P fertilizers on the weight of 1000-seed of soybean was significant ($p \leq 0.05$) (Table 4.9 & Figure 4.17). The highest weight of 1000 seed (127.98 g) was recorded with the treatment combination of N_1P_3 (25 kg N ha^{-1} + 54 kg P ha^{-1}) which was statistically different from all other combinations of treatment. On the other hand, the lowest weight of 1000-seed (105.0 g) was found in N_0P_0 (0 kg Nha^{-1} + 0 kg P ha^{-1}) treatment (control). It might be due to the fact that the application of N fertilizer increased the protein percentage, which in turn increased the grain weight and grain weight is genetically controlled trait, which is greatly influenced by the environment during the process of grain filling stage of plant. In confirmation to the current investigation with Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels on soybean at the Agronomic Research Station, Farooqabad in Pakistan. They revealed that various yield components like 1000 grain weight was affected significantly with 50-50-0 kg N-P-K ha^{-1} application. Again they revealed that seed inoculation with 50-50-0 kg N-P-K ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}). It is worth discussing these interesting facts revealed by the results of Aziz *et al*. (2016) observed that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded higher number of pods $plant^{-1}$ (75), 100 seed weight (12.36 g) and grain yield (1864 kg ha^{-1}) over the control in soybean. The results of the experiment found clear support for the results of Shinde *et al*. (2015) indicated that application of 100 % RDF recorded higher number of pods $plant^{-1}$ (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean. The result of the present study was in agreement with the findings of Gharpinde *et al*. (2014) revealed that application of 30:75:25 NPK kg ha^{-1} + biofertilizers recorded higher grain yield (14.26 q ha^{-1}) and straw yield (30.68 q ha^{-1}) over rest of the treatments in soybean. In confirmation to the current investigation with Sikka *et al*. (2013) reported that application of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha-1 along with 5 t FYM ha^{-1} to soybean recorded significantly higher number of pods $plant^{-1}$ (150.3), test weight (10.4 g) and seed yield (32.6 q ha^{-1}) compared to control.

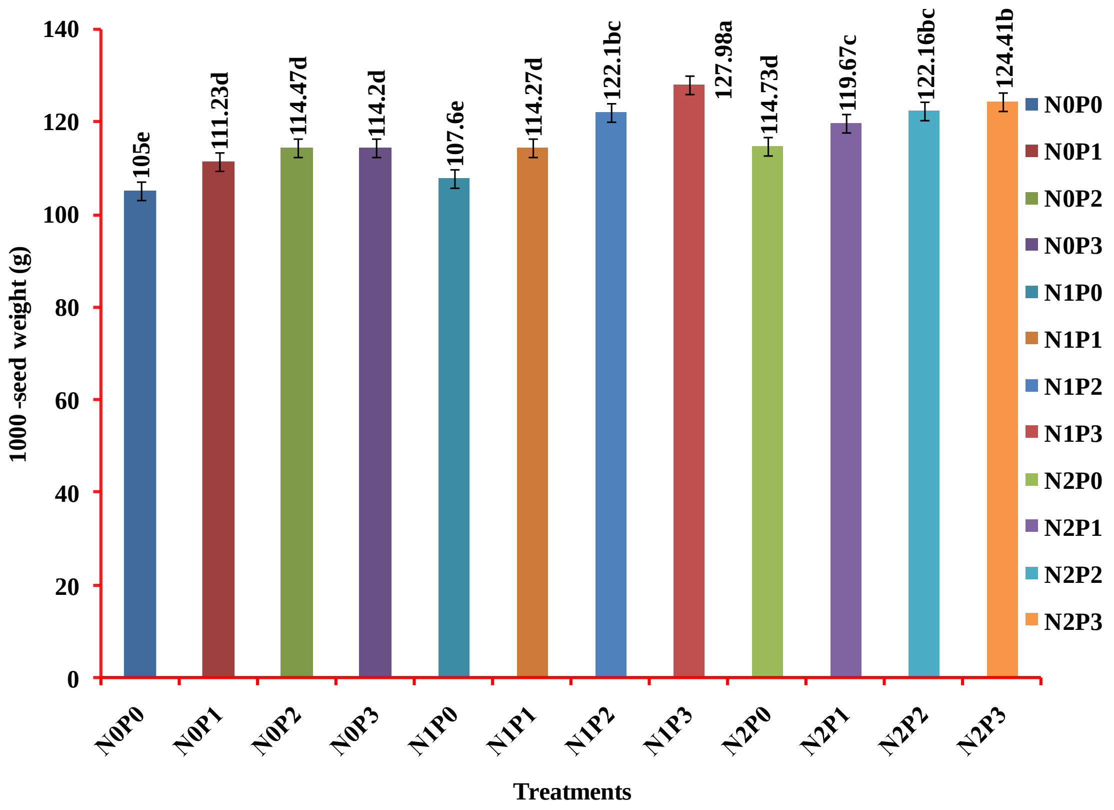

Fig. 4.17 Effect of nitrogen and phosphorus on 1000-seed weight of soybean

4.9 Seed yield of soybean (t ha^{-1})

4.9.1 Effect of nitrogen on the seed yield of soybean

Different doses of nitrogen fertilizers showed insignificant effect of seed yield of soybean ($p \leq 0.05$) (Table 4.3 & Figure 4.13). Among the different doses of N fertilizer, N_1 (25 kg N ha^{-1}) showed the highest seed yield of soybean (1.95 t ha^{-1}) and N fertilizer dose of N_2 (40 kg ha^{-1}) showed 1.89 t ha^{-1}. On the contrary, the lowest seed yield of soybean (1.41 t ha^{-1}) was observed with N_0 where no N fertilizer was applied. In confirmation to the current investigation with Mandic *et al*. (2015) indicated that application of Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}) recorded higher number of pods $plant^{-1}$ (58.1), number of grain $plant^{-1}$ (124.8), 1000 grain weight (185.84 g) and grain yield (3961 kg ha^{-1}) compared to other treatments in soybean. The result of the present study was in agreement with the findings of Ahmed (2013) concluded that *Rhizobium* + 80 kg N ha^{-1}, increased the seed yield (2.54 t ha^{-1}), number of pods $plant^{-1}$ (90.3) and number of seeds pod^{-1} (3.8) compared to other treatments, but the 100 seed weight was non-significant among the treatments in soybean. It is worth discussing these interesting facts revealed by the results of Janagard *et al*. (2013) revealed that application of urea 16.5 kg ha^{-1} + 49.5 kg ha^{-1} + *B. japonicum* + PSB recorded significantly higher pod weight $plant^{-1}$ (12.2 g) and grain yield per unit area (321.8 g) compared to other treatments in soybean. The findings are directly in line with previous findings of Singh and Singh (2013) reported that 20 kg N ha^{-1} as basal and 10 kg N at pod filling stage recorded higher grain yield (25.1 q ha^{-1}), straw yield (43.5 q ha^{-1}), biological yield (68.6 q ha^{-1}) and harvest index (36%) as compared to control in soybean.

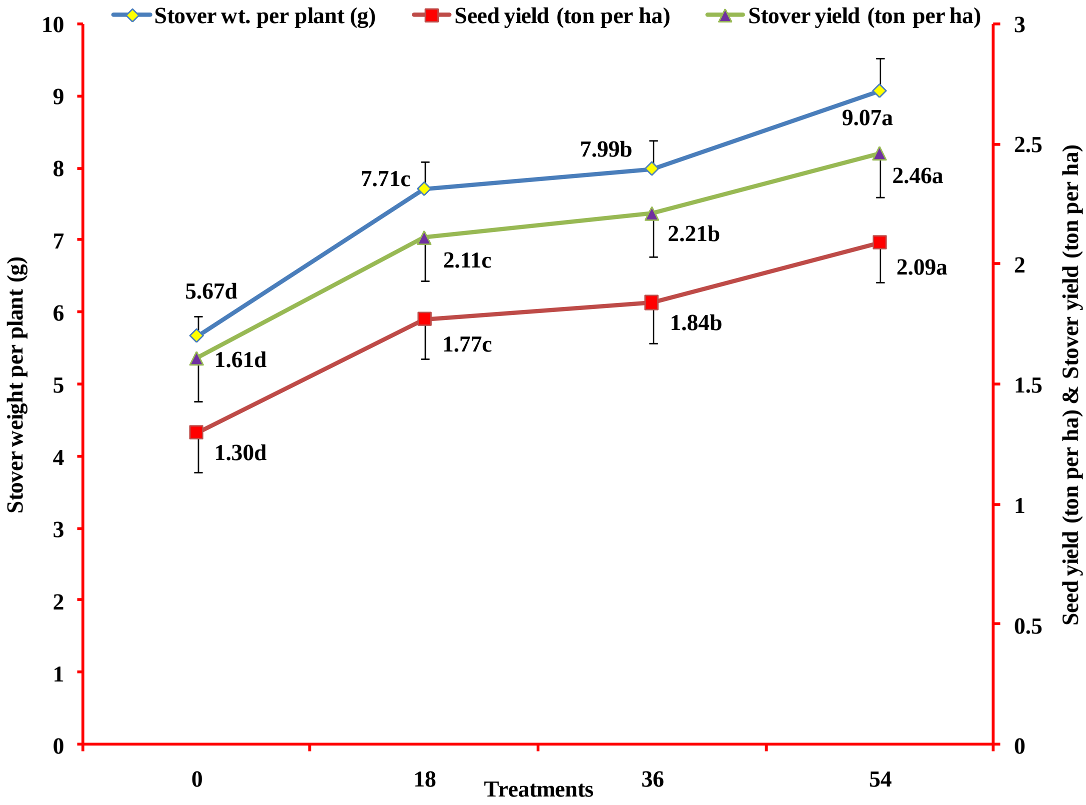

Fig. 4.18 Effect of phosphorus on the yield parameters of soybean

4.9.2 Effect of phosphorus on the seed yield of soybean

Significant variation was observed on the seed yield of soybean when different doses of P were applied ($p \leq 0.05$) (Table 4.6 & Figure 4.18). The highest seed yield of soybean (2.09 t ha^{-1}) was recorded in P_3 (54 kg P ha^{-1}) which was statistically different from other treatments. The lowest seed yield of soybean (1.30 t ha^{-1}) was recorded in the P_0 treatment where no P was applied. These findings are similar with the findings of Satter and Ahmed (1992) and Kamble and Kathmale (2014) reported that application of 100 % RDP (75 kg P_2O_5 ha^{-1}) + inoculation of *Pencilium bilaji* 104 recorded significantly higher seed yield (2919 kg ha^{-1}), straw yield (3874 kg ha^{-1}) and 100 seed weight (12.20 g) compared to 50 % RDP in soybean. It is worth discussing these interesting facts revealed by the results of Dhage *et al*. (2014) opined that application of 90 kg $P_2O_5ha^{-1}$

recorded significantly higher grain yield (2339.2 kg ha^{-1}), straw yield (4909.8 kg ha^{-1}) and biological yield (7251.7 kg ha^{-1}) over the control, 30 and 60 kg P_2O_5 ha^{-1} in soybean. The result of the present study was in agreement with the findings of Mahmoodi *et al*. (2013) revealed that application of 90 kg P_2O_5 ha^{-1} recorded higher number of pods $plant^{-1}$ (66.30), number of seeds $plant^{-1}$ (129.97), 1000 seed weight (167.20 g) and seed yield (5158.27 kg ha^{-1}) over control, 30 and 60 kg P_2O_5 ha^{-1} in soybean. It is important to highlight the fact that Shivran *et al*. (2012) opined that application of 60 kg P_2O_5 ha^{-1} + PSB recorded higher pods $plant^{-1}$ (67.47), seeds pod^{-1} (2.7), seed index (10.08 g), seed yield (24.67 q ha^{-1}), straw yield (38.10 q ha^{-1}) and harvest index (39.29 %) compared to other treatments in soybean.

4.9.3 Interaction effect of nitrogen and phosphorus fertilizers on seed yield of soybean

The pooled data of seed yield revealed that significant yield improvement was recorded due to the combined application of different levels of NP fertilizers treatments presented in table 4.9 and figure 4.19 in soybean ($p \leq 0.05$). The highest seed yield of soybean (2.30 t ha^{-1}) was recorded with the treatment combination of N_1P_3 (25 kg N ha^{-1} + 54 kg P ha^{-1}) which was statistically different from other treatments. On the other hand, the lowest seed yield of soybean (1.08 t ha^{-1}) was found in N_0P_0 (0 kg N ha^{-1} + 0 kg P ha^{-1}) treatment. Result showed that the treated plots resulted markedly in more soybean seed production than that of untreated control plot. Increased seed yield associated with added fertilizers levels might be due to the cumulative effect of increased translocation of photosynthates to sink resulting in enhanced level of yield components. The increased productivity of soybean might also be due to better physical, chemical and biological characteristics of soils due to increased N utilization efficiency that caused a parallel increase in the respective yield components. This is explained by the fact that seed or grain yield is a function of interplay of various yield components. In addition, the availability of P fertilizer influenced the uptake of other essential plants nutrients due to the role of P in the soybean plant roots. The lowest responses of P to seed yields in the untreated control plots was due to initial P content of soil. Another reason is that higher seed yield of soybean due to different levels of NP fertilizers was may be due to better fertilizers responsiveness of the soybean plant. And, also, might be due to the base of flowering and fruiting formed by cumulative stimulating effect of N on the vegetative growth characters. Furthermore, possible reason might be due to the more carbohydrate production and assimilation in seed by the effect of NP. It is important to highlight the fact that Aziz *et al*. (2016) observed that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded higher number of pods $plant^{-1}$ (75), 1000-seed weight (12.36 g) and grain yield (1864 kg ha^{-1}) over the control in soybean. The result of the present study was in agreement with the findings of Shinde *et al*. (2015) indicated that application of 100 % RDF recorded higher number of pods $plant^{-1}$ (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean. The results of the experiment found clear support for the results of Gharpinde *et al*. (2014) revealed that application of 30:75:25 NPK kg ha^{-1} + biofertilizers recorded higher grain yield (14.26 q ha^{-1}) and straw yield (30.68 q ha^{-1}) over rest of the treatments in soybean. It is worth discussing these interesting facts revealed by the results of Sikka *et al.* (2013) reported that application of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1} along with 5 t FYM ha^{-1} to soybean recorded significantly higher number of pods $plant^{-1}$ (150.3), test weight (10.4 g) and seed yield (32.6 q ha^{-1}) compared to control.

4.11 Stover yield of soybean (t ha^{-1})

4.11.1 Effect of nitrogen on the stover yield of soybean

Different doses of N fertilizers showed significant variations in respect of stover yield of soybean ($p \leq 0.05$) (Table 4.3 & Figure 4.13). Among the different doses of N fertilizer, N_1 (25 kg N ha^{-1}) showed the highest stover yield (2.35 t ha^{-1}), which was statistically different from other treatments. On the contrary, the lowest stover yield (1.69 t ha^{-1}) was observed with N_0 (control) unfertilized treatment. It is worth discussing these interesting facts revealed by the results of Mandic *et al*. (2015) indicated that application of Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}) recorded higher number of pods $plant^{-1}$ (58.1), number of grain $plant^{-1}$ (124.8), 1000 grain weight (185.84 g) and grain yield (3961 kg ha^{-1}) compared to other treatments in soybean. The results of the experiment found clear support for the results of Ahmed (2013) concluded that *Rhizobium* + 80 kg N ha^{-1}, increased the seed yield (2.54 t ha^{-1}), number of pods $plant^{-1}$ (90.3) and number of seeds pod^{-1} (3.8) compared to other treatments, but the 1000-seed weight was non-significant among the treatments in soybean. The result of the present study was in agreement with the findings of Janagard *et al*. (2013) revealed that application of urea 16.5 kg ha^{-1} + 49.5 kg ha^{-1} + *B. japonicum* + PSB recorded significantly higher pod weight $plant^{-1}$ (12.2 g) and grain yield per unit area (321.8 g) compared to other treatments in soybean. It is worth discussing these interesting facts revealed by the results of Singh and Singh (2013) reported that 20 kg N ha^{-1} as basal and 10 kg N at pod filling stage recorded higher grain yield (25.1 q ha^{-1}), straw yield (43.5 q ha^{-1}), biological yield (68.6 q ha^{-1}) and harvest index (36 %) as compared to control in soybean.

4.11.2 Effect of phosphorus on the stover yield of soybean

Significant variation was observed on the stover yield of soybean when different doses of P were applied ($p \leq 0.05$) (Table 4.6 & Figure 4.18). The highest stover yield of soybean (2.46 t ha^{-1}) was recorded in P_3 (54 kg P ha^{-1}), which was statistically different from other treatments. The lowest stover yield (1.61 t ha^{-1}) was recorded in the P_0 treatment where no P was applied. It is worth discussing these interesting facts revealed by the results of Kamble and Kathmale (2014) reported that application of 100 % RDP (75 kg P_2O_5 ha^{-1}) + inoculation of *Pencilium bilaji* 104 recorded significantly higher seed yield (2919 kg ha^{-1}), straw yield (3874 kg ha^{-1}) and 100 seed weight (12.20 g) compared to 50 % RDP in soybean. In agreement with the current observations of Dhage *et al*. (2014) opined that application of 90 kg P_2O_5 ha^{-1} recorded significantly higher grain yield (2339.2 kg ha^{-1}), straw yield (4909.8 kg ha^{-1}) and biological yield (7251.7 kg ha^{-1}) over the control, 30 and 60 kg P_2O_5 ha^{-1} in soybean. It is worth discussing these interesting facts revealed by the results of Mahmoodi *et al*. (2013) revealed that application of 90 kg P_2O_5 ha^{-1} recorded higher number of pods plant-1 (66.30), number of seeds $plant^{-1}$ (129.97), 1000 seed weight (167.20 g) and seed yield (5158.27 kg ha^{-1}) over control, 30 and 60 kg P_2O_5 ha^{-1} in soybean. The results of the experiment found clear support for the results of Shivran *et al*. (2012) opined that application of 60 kg P_2O_5 ha^{-1} + PSB recorded higher pods $plant^{-1}$ (67.47), seeds pod^{-1} (2.7), seed index (10.08 g), seed yield (24.67 q ha^{-1}), straw yield (38.10 q ha^{-1}) and harvest index (39.29 %) compared to other treatments in soybean.

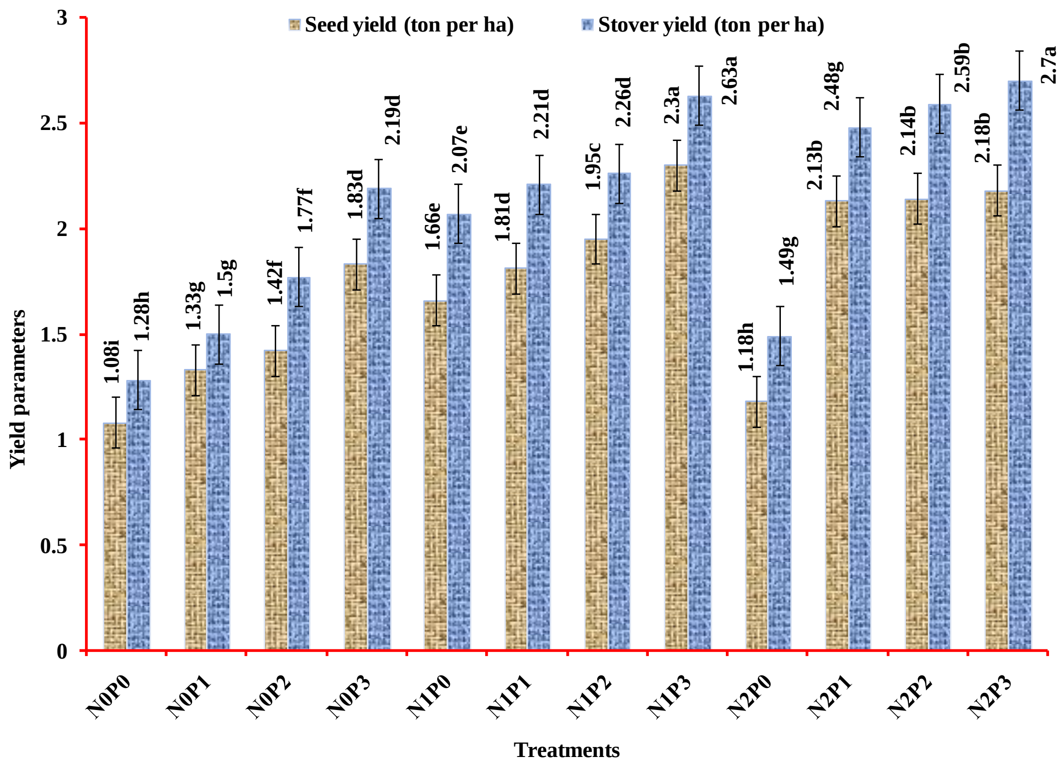

Fig. 4.19 Effect of nitrogen and phosphorus on the yield parameters of soybean

4.11.3 Interaction effect of nitrogen and phosphorus on stover yield of soybean

The combined effect of different doses of N and P fertilizers on the stover yield was significant ($p \leq 0.05$) (Table 4.9 & Figure 4.19). The highest stover yield (2.70 t ha^{-1}) was recorded with the treatment combination of N_2P_3 (40 kg N ha^{-1} + 54 kg P ha^{-1}) which was statistically similar with N_1P_3 (25 kg N ha^{-1} + 54 kg P ha^{-1}). On the other hand, the lowest stover yield (1.28 t ha^{-1}) was found in N_0P_0 (0 kg N ha^{-1} + 0 kg P ha^{-1}) treatment. The results of the experiment found clear support for the results of Aziz *et al*. (2016) observed that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded higher number of pods $plant^{-1}$ (75), 100 seed weight (12.36 g) and grain yield (1864 kg ha^{-1}) over the control in soybean. The result of the present study was in agreement with the findings of Shinde *et al*. (2015) indicated that application of 100 % RDF recorded higher number of pods $plant^{-1}$ (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean. It is worth discussing these interesting facts revealed by the results of Gharpinde *et al*. (2014) revealed that application of 30:75:25 NPK kg ha^{-1} + biofertilizers recorded higher grain yield (14.26 q ha^{-1}) and straw yield (30.68 q ha^{-1}) over rest of the treatments in soybean. The results of the experiment found clear support for the results of Sikka *et al.* (2013) reported that application of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1} along with 5 t FYM ha^{-1} to soybean recorded significantly higher number of pods $plant^{-1}$ (150.3), test weight (10.4 g) and seed yield (32.6 q ha^{-1}) compared to untreated control plot.

Chapter V

SUMMARY AND CONCLUSION

The research work was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka (Tejgaon soil series under AEZ No. 28) during the kharif-I season of March, 2019 to July, 2019 to study the growth and yield of soybean (BARI Soybean 4) as influenced by different levels of nitrogen and phosphorus. Two factor experiments with Randomized Complete Block Design (RCBD) was followed with 12 treatments having unit plot size of 2.5m × 2m ($5m_2$) and replicated thrice. Two factors were nitrogen and phosphorus. The data were collected plot wise for plant height (cm), number of leaves plant^{-1}, number of branches plant^{-1}, number of pods plant^{-1}, pod length (cm), number of seeds pod^{-1}, weight of l000-seed (g), seed yield (t ha^{-1}) and stover yield (t ha^{-1}). All the data were statistically analyzed following LSD and the mean comparison was made by LSD. Plant height was significantly affected by different levels of N and P. Plant height increased with increasing levels of N and P individually. The individual application of N @ 40 kg ha^{-1} (N_2) produced the tallest plant (34.18 cm), whereas application of P @ 54 kg ha^{-1} (P_2) produced the tallest plant of 34.26 cm height. The tallest plant (36.88 cm) was found in N_1P_3 treatment combination, which was higher over other treatments.

The individual application of N and P showed positive effect on the number of leaves plant^{-1}, number of branches plant^{-1}, number of pods plant^{-1}, pod length (cm), number of seeds pod^{-1}, weight of l000-seed (g), seed yield (t ha^{-1}) and Stover yield (t ha^{-1}). All the plant characters increased with increasing levels of N and P up to higher level except 1000-seed weight. Like all other plant characters, seed yield was influenced significantly due to application of N. Grain yield increased with increasing levels of N up to certain level. The highest grain yield (1.95 t ha^{-1}) was found in plants receiving N @ 25 kg ha^{-1} and the lowest was recorded in untreated control treatment. Individual application of phosphorus also showed significant effect in seed yield. Application P @ 54 kg ha^{-1} (P_3) produced the highest seed yield (2.09 t ha^{-1}). The combined application of N and P had positive effect on seed yield of soybean. The highest seed yield of soybean was recorded in N_1P_3 (2.30 t ha^{-1}) treatment combination which was statistically different with each other treatment combinations. The lowest yield was recorded in N_0P_0 treatment combination that is untreated control plot. Combined application of N @ 25 kg ha^{-1} and P @ 54 kg ha^{-1} produced higher seed yield compared to untreated control treatment significantly.

The results of this research work indicated that the plants performed better in respect of seed yield in N_1P_3 treatment over the control treatment (N_0P_0) showed the least performance. It can be therefore, concluded from the above study that the treatment (application of nitrogen, N @ 25 kg ha^{-1} and phosphorus P @ 54 kg ha^{-1}) was found to the most suitable treatment combination for the highest yield of soybean in Deep Red Brown Terrace Soils of Bangladesh.

Based on the results of the present study, the following recommendation may be drawn: -

The combined application of nitrogen and phosphorus fertilizers @ 25 kg N ha^{-1} and 54 kg P ha^{-1} may be recommended in Tejgaon series under AEZ No. 28 to get better growth and yield of soybean and also to maintain soil fertility and productivity compared to their individual applications.

However, to reach a specific conclusion and recommendation, more research work on soybean should be done in different Agro-ecological zones of Bangladesh.

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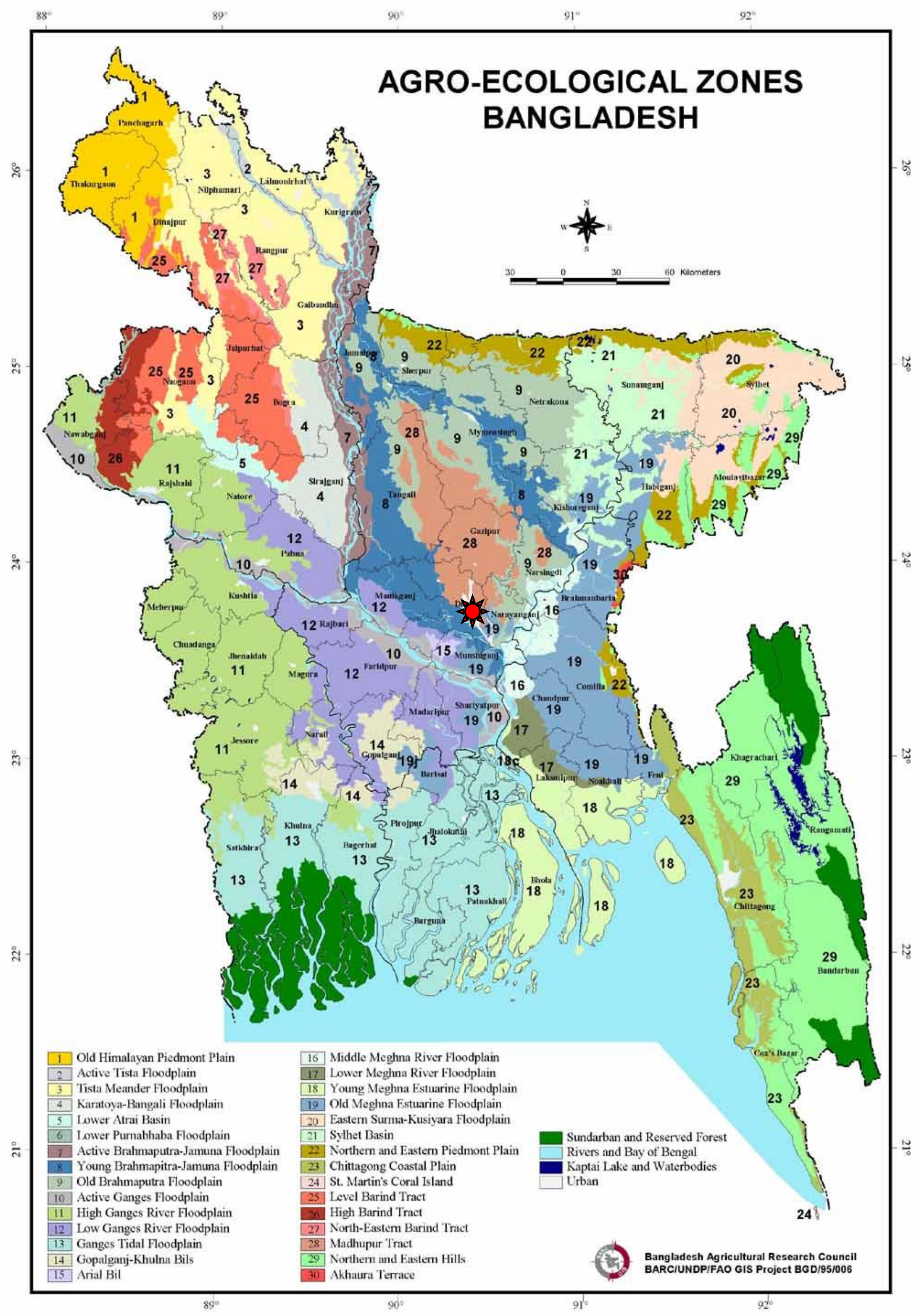
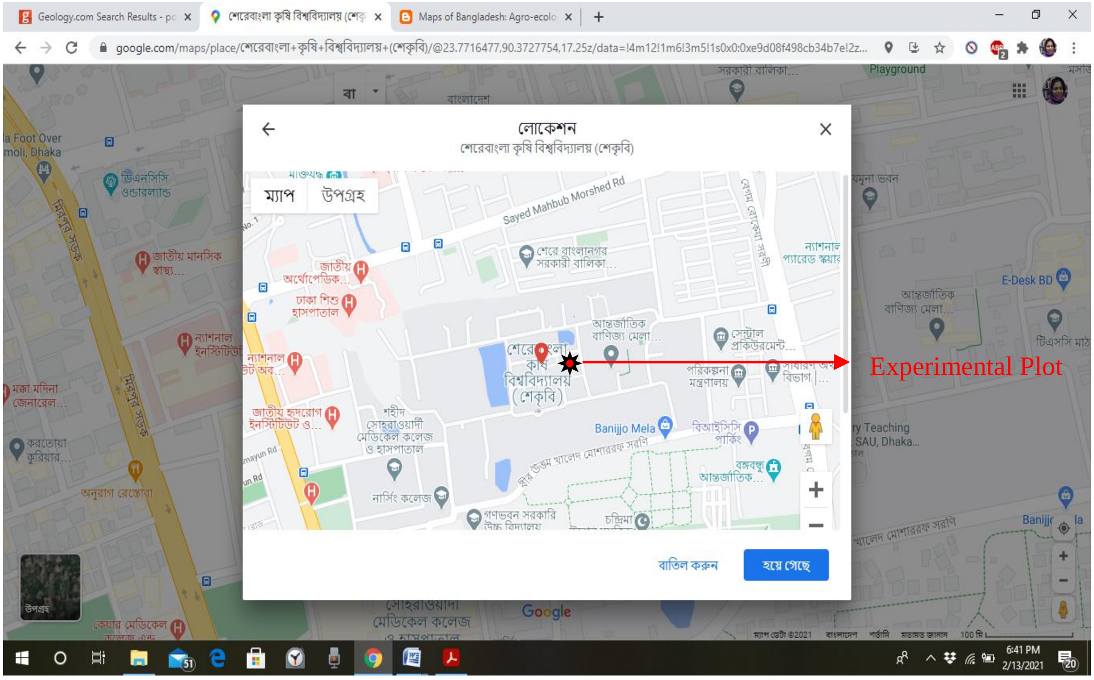
Chapter VI

Appendix

Appendix I. Map showing the experimental site under study



Appendix II: Google map showing experimental site



Appendix III. Monthly meteorological information during the period from March, 2019 to July, 2019

Month	Air temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
March, 2019	31	21	44	62
April, 2019	33	24	56	135
May, 2019	33	24	71	247
June, 2019	32	25	78	316
July, 2019	31	22	78	328

Appendix IV: Layout of the experimental plot

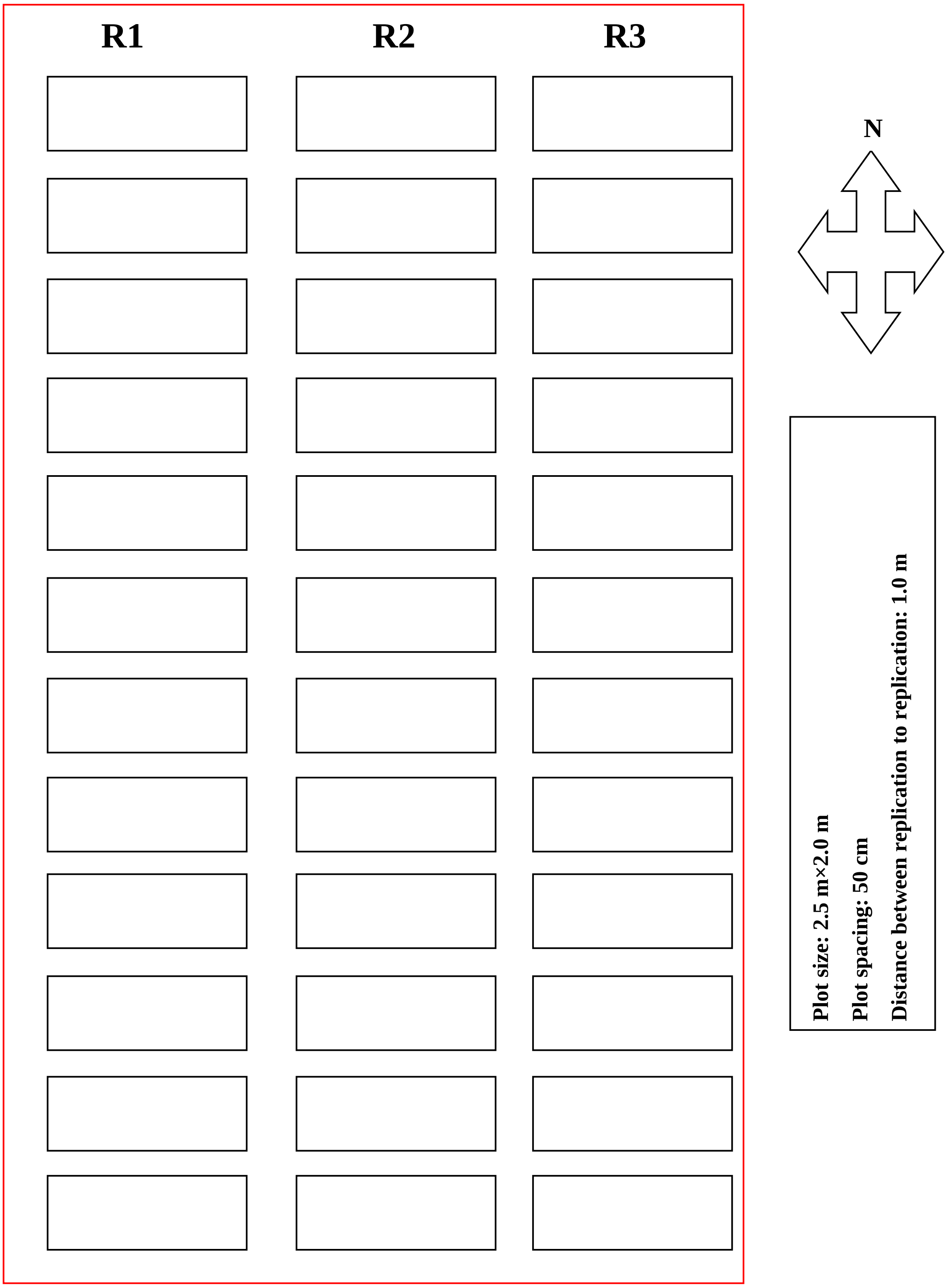


Fig: Layout of the experimental plot

Some pictorial view of experimental sire: