INFLUENCE OF SPACING AND MACRONUTRIENTS ON GROWTH AND YIELD OF GARDEN PEA

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INFLUENCE OF SPACING AND MACRONUTRIENTS ON GROWTH AND YIELD OF GARDEN PEA.

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CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF SPACING AND DIFFERENT LEVEL OF MACRONUTRIENTS ON GROWTH AND YIELD OF GARDEN PEA (*Pisum sativum* L.)"** submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **Horticulture**, embodies the result of a piece of bonafide research work carried out by **KANIJ FATIMA** Registration No. **17-08243-** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

December, 2019
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Dedicated to
My Beloved Parents and to the Farmers who Feed the Nation

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The Author

INFLUENCE OF SPACING AND MACRONUTRIENTS ON GROWTH AND YIELD OF GARDEN PEA

ABSTRACT

Plant spacing and different level of macronutrients are investigated to find out their effect on growth and yield of garden pea.The experiment was conducted in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period of November, 2018 to January, 2019. The experiment consisted of two factors; 3 levels of plant spacing. S_1 (30 cm × 10 cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm) and 4 levels of macro nutrient management viz.,T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters and yield at different days after sowing (DAS) were recorded. Results indicated that the highest seed yield (8.3 t ha^{-1}) and pod yield (10.5 t ha^{-1}) were found from S_1 (30 cm × 10 cm) compared to other plant spacing. Considering macro nutrient application, the highest seed yield (7.5 t ha^{-1}) and pod yield (9.1 t ha^{-1}) were recorded from T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}) showed lowest. In terms of combined the highest number of pods plant^{-1} (26.8), number of seeds pod^{-1} (8.1), length of pod (8.1 cm), breadth of pod (1.5 cm), weight of 10 green pods (46.2 g), weight of green seeds plant^{-1} (20.9 g) and 100 seed weight (5.2 g) were obtained from S_2T_2 but the highest seed yield (9.2 t ha^{-1}) and pod yield (11.8 t ha^{-1}) were obtained from the treatment combination of S_1T_2. Similarly, the lowest number of pods plant^{-1} (13.3), number of seeds pod^{-1} (5.0), length of pod (5.0 cm), breadth of pod (1.2 cm), weight of 10 green pods (39.1 g), weight of green seeds plant^{-1} (15.3 g), 100 seed weight (3.3 g) and percent (%) dry matter (14.4%) were obtained from S_1T_0 but the lowest seed yield (4.6 t ha^{-1}) and pod yield (5.9 t ha^{-1}) were obtained from S_3T_0. In the combination of spacing and macronutrient dose , the highest benefit Cost ratio (3.0) was recorded from the combination of S_1T_2 treatment (Table 10) and the lowest benefit cost ratio (1.0) was obtained from S_3T_0 treatment. Among the different treatment combination of spacing and macronutrients management, S_1T_2 (30 cm × 10 cm) plant spacing with $N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1} macro nutrients) can be considered as best treatment combinations compared to other treatment combinations in respect of yield.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	Mililitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
Mg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization
TDM	=	Total Dry Matter

CHAPTER I

INTRODUCTION

Garden pea (*Pisum sativum* L.) is a valuable vegetable as well as pulse crop all over the world, is also known as 'Matar'. It belongs to the family Leguminosae, self-pollinated crop (Anonymous, 2004). It is a cool season annual vegetable crop grown during the winter months in Bangladesh. It is a widely spread legume belonging to the sub-family Papilionaceae under the family Leguminosae. The garden pea is grown mainly for green seeds and it can be eaten without any cooking process due to its sweet taste. Globally, pea is grown in an area of 1.1 million ha with total production of 9.2 million ton and the productivity is 8.3 t ha^{-1} (Anonymous, 2004).

It is the second most important legume crop of the world (Pawar *et al*., 2017). The green and dry foliage are used as cattle feed and green pods being highly nutritious are preferred for culinary purpose. This legume contain high percentage of digestible protein (7.2 g), carbohydrates (15.8 g), vitamin A (139 I.U.), vitamin C (9 mg), magnesium (34 mg) and phosphorus (139 mg) per 100 g of edible portion (Gopalan, 2007).

Optimum plant population has a promising impact in improving the productivity of legumes. According to Pawar *et al*. (2007), dry weight of green bean was increased with increased row spacing (30 cm) as compared to narrow row spacing (22.5 cm). Wider row spacing (60 and 45 cm) gave significantly higher number of pods $plant^{-1}$ as compared to 30 cm row spacing (Mohammed *et al*., 1984). This is supported by Kakiuchi and Kobata (2004) who concluded that lower plant density increased the pod number $plant^{-1}$ and the higher plant density, decreased the pod number $plant^{-1}$. Samih (2008) reported that high yield was observed in the case of high plant populations (20 x 30 cm) over that of low plant population (60 x 30 cm) of bush beans. Similarly, Gan *et al.* (2007) have shown increase of grain yield at higher plant density in chickpea. The use of high plant density usually increases seed yield of chickpea in areas with a short growing season (Gan *et al.*, 2003), but the magnitude of the yield increase depends on environmental conditions. However, Parihar (1996) indicated that row spacing had no significant effect on seed yield. Other studies by Nawaz *et al.*, (1995) and Felton et al. (1996) concluded that dry matter production and plant height of chick pea were higher in higher plant populations (60 plants m^{-2}), but a population of 40 plants m^{-2} gave the maximum grain yield. Sibhatu *et al.*, (2016) showed that greatest plant height (50.63 cm) was obtained at a spacing of 60x20 cm while the maximum mean grain (544.58 kg ha^{-1}) and biomass yields (1562.65 kg ha^{-1}) were obtained at spacing of 40 x 15 cm.

Garden pea has long been recognized as a restorer of soil fertility due to their unique ability of symbiotic nitrogen fixation (Rana *et al*., 1998). This ability has made the crop as one of the most important and useful component of existing cropping system in the present context of soil fertility degradation. Improving the yield of garden pea depends on proper nutrient management and genetic makeup of the variety.

Fertilizer management is another important factor that contributes the production and yield of any crop. It also plays an important role on growth and productivity of garden pea. Adequate supply of nutrients increases the yield. Since, the land is limited in Bangladesh it is important to increase the per hectare yield of any crop through all possible means. Plants required food for growth and development in the form of proper doses of NPKS and other nutrients.

Nitrogen is essential for synthesis of chlorophyll, enzymes and protein. Nitrogen is essential for root growth, nodulation, energy storage and transfer necessary for metabolic processes.

Phosphorous (P) plays a vital role several key physiological process viz. photo systhesis, respiration, energy storage transfer, cell division and cell enlargement. It stimulates root growth, blooming, fruit setting and root formation (Menom,1996) .Phosphorous is called the key of life, because it is directly involved in the life process.

Potassium (K) is essential in photosynthesis, sugar translocation, nitrogen metabolism, enzyme activation, stomata opening and growth of meristemetic tissue (Chandra,1989).

Sulpher (S) now a days considered as a macro nutrient and carries out many important function for plant growth. It is involved in the synthesis of amino acids like cystine, methionine etc (Zaghlou *et al*., 2015).

Balance application of fertilizer is the prerequisite for obtaining higher yield and better quality pods. But the imbalance and improper use of chemical fertilizers has adverse effect on soil health thereby affecting the yield and sustainability of production, besides causing environmental pollution. Therefore, there is a need for judicious use of fertilizers for sustainable production and better soil health. This will help to sustain crop yield, improve the physical, chemical and biological properties of soil, and increase the efficiency of applied fertilizers (Singh and Biswas, 2000).

In Bangladesh the research work of garden pea on the plant spacing and macronutrients management for maximization of crop yield is very limited. In consideration with the above situation, it is necessary to undertaken research program to develop the appropriate technology for approaching the highest yield and profitability of garden pea.

Under the above circumstances, the present study was undertaken with the following objectives-

1. To investigate the growth and yield of garden pea as influence by different plant spacing.
2. To determine the effective combination of macronutrients for obtaining the maximum yield potential of garden pea.
3. To find out the suitable combined effect of plant spacing and macronutrients on the growth and yield of garden pea.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available in the country and abroad regarding the influence of spacing and different level of macronutrients on growth and yield of garden pea (*Pisum sativum* L.) and other crops to gather knowledge helpful in conducting the present research work and subsequently writing up the results and discussion.

2.1 Effect of plant spacing

Sibhatu *et al*. (2016) conducted a study to determine the appropriate planting spacing of Dekoko (garden pea) that maximizes its productivity under rain fed conditions. Treatments comprised combinations of three plant spacing (10, 15 and 20 cm) and three levels of row spacing (40, 50 and 60 cm) and broad casting were done in a randomized complete block design with three replications. Plant spacing influenced plant height, grain yield and biomass yield. The tallest plant height (50.6 cm) was obtained at a spacing of 60 cm × 20 cm while the maximum mean grain (544.5 kg ha^{-1}) and biomass yields (1562.6 kg ha^{-1}) were recorded at spacing of 40 cm × 15 cm in both cropping seasons.

Agarwal *et al.,* (2015) said that 1000 seeds weight was affected significantly by different planting patterns. Crops sown in 40 cm apart rows produced significantly higher 1000 seeds weight than 60 cm apart double row strips. Significant effect of row spacing on 1000 seeds weight has also been reported by Ali *et al.* (2001).

Tanya *et al.* (2015) carried out an investigation to study the effect of spacing on the growth and yield of different varieties of blackgram. Maximum plant height (36.73 cm) was recorded of 30 cm × 15 cm row to row and plant to plant spacing.

Murade *et al.,* (2014) conducted a field experiment on Blackgram genotype AKU-07-04 and concluded that the numbers of branches and leaves per plant were significantly higher with the spacing of 45 cm × 10 cm (S_2) as compared to the spacing of 30cmx10cm (S_1) at harvest which showed highest plant height. Wider plant spacing which intercepted more photosynthetically active radiation owing to better geometric situation that might have resulted in vigorous plant growth and more number of branches and leaves as compared to narrow spacing.

Prasad *et al.* (2014) observed that different spacing significantly influenced the grain yield and biological yield of Blackgram. The spacing of 30 cm × 10 cm (S_1) recorded significantly higher grain yield (1035.3 kg ha^{-1}) than the yield produced (971.3kg ha^{-1}) by the spacing of 45 cm × 10 cm (S_2). Significantly higher biological yield 2951.25 kg ha^{-1} was also recorded with spacing 30 cm × 10 cm (S_1) than spacing 45 cm × 10 cm (S_2).

Murade *et al.,* (2014) carried out an experiment to study the effect of P fertilizer (0, 30, 60 and 90 kg ha^{-1}) and row spacing (30 cm and 45 cm) on the yield and yield components (pods $plant^{-1}$, seeds pod^{-1} and 1000-seeds weight) of blackgram. Seed yield was the highest with 30 cm row spacing while pods per plant, seeds per pod and 1000-seeds weight were highest with 45 cm row spacing.

Kumar *et al.* (2013) conducted several field studies in Chhattisgarh, India, to identify the effect of plant density on the growth, nodulation and yield of black gram cultivars. The treatments comprised 2 row spacing (30 cm × 10 cm and 45 cm × 10 cm), 3 cultivars (Indira Urd-1, RU-03-16 and RU-03-52) and 3 seed treatments (control, seed treatment with molybdenum and seed treatment with molybdenum followed by 2% foliar spray of urea twice). Results showed that the increase in row spacing decreased the plant height, with Indira Urd-1 being the tallest. Similar results were also recorded by Ihsanullah *et al.,* (2012).

Tomar *et al.,* (2013) conducted a field experiment and reported that the vigorous development of their growth attributes (branches and leaves/plant) ultimately increased the dry matter accumulation plant^{-1}. Higher plant density (500 × 10 plants ha^{-1}) produced taller and lesser branched plants and their lower leaves had not received sufficient solar radiation to accelerate photosynthetic activities, thus become lower leaves parasitic due to high rate of respiration in which larger quantities of stored photosynthates were consumed than produced in photosynthesis. Number of pods plant^{-1} is the key yield component in leguminous crops. Number of pods/plant was maximum (28.2) for 20 cm row spacing. Minimum pods plant^{-1} (22) were for 43 cm row spacing. As in the case of 20 cm row spacing plants were spaced 15 cm within rows while in 43 cm row spacing plants were spaced 7 cm within rows. The result shows that plants needs uniform distribution for maximum pods plant^{-1} and inter or intra row spacing less than optimum results in competition for nutrients light and space. The results are in similarity with that of Rajput *et al.*, (1984), who reported that increasing row or plant spacing increased the number of pods plant^{-1}.

Shaukat *et al*. (2012) conducted an experiment to check the effect of different sowing dates and row spacing on the growth, seed yield and quality of pea (*Pisum sativum* L. cv. Climax). Significant differences were noticed among sowing dates for days to germination while nonsignificant results were noticed for row spacing and interaction (A × B). Maximum days to germination were found in D1 (20th April) and minimum were recorded in D4 (4th June). Germination percentage indicated highly significant differences for sowing dates whereas; non-significant results were found for row spacing and interaction (A × B). Maximum germination percentage was found on sowing date D2 (5th May). Plant height indicated highly significant differences for sowing dates, row spacing and interaction (A × B). Highest plant height was recorded on D2 (5th May), S1 (30 cm) and D1 × S3. Number of branches plant-1 indicated highly significant differences for sowing dates, row spacing and interaction. Maximum number of branches plant-1 were recorded in D1 (20th April), S3 (50 cm) and D1 x S3. Chlorophyll contents showed highly non-significant differences among sowing dates, row spacing and interaction (A × B). Highly significant differences were counted among sowing dates for days to flowering whereas, non-significant results were found for row spacing and interaction (A × B). Lowest days to flowering were taken by plants sown D4 (4th June). Days to pod formation showed highly significant differences for sowing dates whereas, non-significant results were found for row spacing and interaction (A × B). Minimum days to pod formation were recorded in D4 (4th June). A highly significant difference was recorded among sowing dates, row spacing and interaction (A × B) for number of pods plant^{-1}. Maximum numbers of pods plant-1 were recorded in D1 (20th April), S3 (50 cm) and D1 × S3. Pod length indicated highly significant differences among sowing dates, row spacing and interaction (A × B). Maximum pod length was recorded in D1 (20th April), S3 (50 cm) and D1 × S3. Number of seeds pod^{-1} showed highly significant differences among sowing dates, row spacing and interaction. Maximum number of seeds pod-1 were recorded in (20th April), S3 (50 cm) and D1 × S3. Highly significant differences were observed among sowing dates, row spacing and interaction for seed yield ha-1. Maximum seed yield ha-1 was recorded in D1 (20th April), S3 (50 cm) and D1 × S3. Protein contents showed highly significant differences among sowing dates while nonsignificant results were found for row spacing and interaction (A × B). Maximum protein contents (21.10%) were Observed in the plants of D1 (20th April). The effect of different sowing dates, row spacing and interaction (A × B) on Total sugar, Vitamin C and pH was non-significant.

Rasul *et al.,* (2012) conducted an experiment with the interaction of varieties and inter-row spacing. They noticed that the number of pods per plant^{-1} was significantly affected while the highest number of pods plant^{-1} was found at 30 cm × 10 cm spacing and the lowest one was found at 40 cm × 30 cm. However, 20 cm

× 20 cm spacing produced similar pods plant^{-1} as that of 40 cm × 30 cm spacing. It was stated by Kabir and Sarkar (2008).

Tomar *et al.,* (2011) reported that effect of row spacing was non-significant for the pod length. It has values of 7.57, 7.50 and 7.75 cm pod length in 20, 30 and 43 cm spaced rows respectively. It could be concluded that pod length is a genetically controlled parameter and is less affected by the changes in the micro environment. Yield attributes (no. of pods, pod length, no. of grains/pod and 1000 grains weight) were increased with the decrease plant density from 500 × 10 to 333 × 10 plants ha^{-1} due to better growth attributes and ultimately the grain and straw yield per ha due to translocation of larger synthesized food material from leaves (source) to the site of yield attributes (sink). The larger translocation of photosynthates towards yield attributes resulted the higher grain yield per ha.

Kabir and Sarkar (2008) conducted an experiment on mungbean in Bangladesh and reported that the highest pod length was obtained at 30 cm × 10 cm spacing. The lowest pod length was observed at 20 cm × 20 cm spacing, which was statistically identical to 40 cm × 30 cm spacing.

Kabir *et al.,* (2002) carried out a field experiment to investigate the effects of six different seed rates *viz*., 15, 17.5, 20, 22.5, 25 and 27.5 kg ha^{-1} on the growth, yield and yield attributes of mash bean *(Vigna mungo* (L.) Hepper). This study was conducted for two consecutive years at the Agriculture Research Institute (ARI) under the existing semi-arid climatic, edaphic and water conditions of Quetta, Baluchistan. Results revealed that grain yield plant^{-1} and grain yield ha^{-1} were significantly ($p<0.05$) influenced by varying seed rates. However, other mentioned growth and yield attributes did not respond significantly. Statistically and numerically a maximum yield plant^{-1} (20.98 g) and yield ha^{-1} (3120 kg) were obtained in applied seed @ 20 kg ha^{-1}.

Achakzai and Panizai (2007) conducted a field experiment to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mash bean grown under semi-arid climate. Results revealed that yield plant^{-1} and yield ha^{-1} responded insignificantly in response to various levels of row spacing. However, numerically a maximum grain yield plant^{-1} (12.73 g) and yield ha^{-1} (2516 kg) were obtained from 35 cm row spacing. Though data are statistically not significant, but there is a trend that as row spacing increases, grain yield also increases.

Bhatti *et al.,* (2005) conducted a field experiment for two consecutive years (2001 and 2002) to evaluate the effect of intercrops and planting patterns on the agronomic traits of sesame. The planting patterns comprised 40 cm spaced single rows, 60 cm spaced 2- row strips and 100 cm spaced 4-row strips, while the cropping systems were sesame + mungbean, sesame + mashbean *(Vigna aconitifolia),* sesame + soyabean, sesame + cowpea and sesame alone. Among the intercropping patterns, sesame intercropped with mungbean, mashbean, soyabean and cowpea in the pattern of 100 cm spaced 4-row strips (mash bean 25 cm apart) proved to be feasible, easily workable and more productive than sesame mono cropping.

2.2 Effect of macro nutrient management

Devi *et al*. (2018) conducted a study with the main objective of studying the influence of nutrient management practices on yield and yield attributes of garden pea varieties viz., Vivek Matar-11 and Vivek Matar-12 during rabi season, 2017. The experiment consisted of seven nutrient management practices replicated thrice in factorial RBD. The results revealed that the tallest plant (99.74 cm), significantly early flowering (89.83 days), maximum number of pods per plant (16.67), number of seeds per pod (7.33) and pod yield (9.63 t ha^{-1}) was recorded in Vivek Matar-12 with 50% recommended dose of N through urea + 50%

recommended dose of N through FYM + recommended dose of PK through single super phosphate (SSP) and muriate of potash (MOP) + 0.2% B. The same treatment combination also recorded second highest B: C ratio in both the evaluated varieties.

Chethan *et al*., (2018) conducted a study on the "Effect of N P K and Zn on Physico-chemical properties of soil, growth parameters and yield by pea (*Pisum sativum* L.) Cv. Rachna", at the Soil Science Research Farm, Sam Higginbottom University of Agriculture & Technology Sciences. Allahabad during Rabi season 2017-2018. The number of pods plant-1 (19.53), number of seeds pod-1 (6.20) and pod yield (77.67 qha^{-1}) were significantly increased with the application of 50% recommended dose of N P K fertilizers and 100% Zinc fertilizer. The maximum yield was obtained in T5 – [N @ 20 kg + P @ 40 kg + K @ 2 kg and Zn @ 20 kg ha^{-1}]. Growth parameters, soil properties, increased significantly with the application of 100% recommended dose of fertilizers i.e. T8 – [N@ 40kg + P@ 80kg + K@ 40kg and Zn@ 20kg ha-1], pH, EC (dSm-1) and bulk density (gcm-3) were they decreased with increase in fertilizer levels. The lowest values related to all parameters were obtained in control treatment. Cost benefit ratio (C:B) 1: 2.29 was highest in T5 - (i.e. N@ 20kg + P@ 40kg + K@ 20kg and Zn@ 20kg ha-1) 50% recommended dose of NPK and 100% Zinc was more profitable Rs. 59234.00 than any other treatments and recommendations.

Manore and Alteye (2018) evaluate the effect different level of Phosphorous (0, 23, 46 and 69 kg/ha) with four type field pea varieties: Local Tegegnech, Bunkitu and Wolimera combined in RCBD . Data grain yield and yield components were recorded during specific physiological stages. The effect of phosphorous was significant in hastening physiological maturity of crop, and its effect was significant on flowering and growth parameters. The grain yield ranged between 2.43 t/ha at 0 kg phosphorous and 2.67 to t/ha at applications of 69 kg phosphorous per ha. Besides, total biomass was also significantly influenced by phosphorous and ranged between 4.4 t/ha at control to 4.87 t/ha at rate of 69 kg p ha^{-1}. The highest phosphorous use efficiency (48.3%) was obtained at 69 kg p/ha and increased with increasing rates of phosphorous application, whereas apparent phosphorous recovery was found to be highest at 46 and 69 kg p/ha respectively Both and physiological phosphorous use efficiencies of the crop were highest at the rate of 69 kg p/ha. Therefore, Wolimera and Birukit with application of 69 kg p/ha are recommended for field pea production at Duna area.

Kharbamon *et al.,* (2016) tried to find out the availability of vegetables during off-season with higher yield an experiment was conducted to study the response of semi-dwarf photo-insensitive line of dolichos bean (RCDL-10) to time of planting (May, June, July, August, September and October) and graded dosage of phosphorus (30, 40, 50 and 60 kg/ha P_2O_5) for growth, flowering behavior, yield and quality traits. Longest vine (331.16 cm) and highest number of primary branches (15.31) were recorded in the July sowing whereas, shortest vine length (158.66 cm) and lowest number of branches per plant was recorded in October sowing (10.08). May sowing took the least number of days to complete the physiological and developmental stages. May planting gave the highest yield (168.70 g/plant) and yield attributes as well as highest crude protein (25.3%) content of the pods. Similarly, phosphorus dose of 60 kg/ha recorded the highest plant growth, number of flowers per panicle (9.41), yield (123.04 g/plant) and maximum protein content (25.22 %) of the pods as compared to the lower dosage. Hence, photo-insensitive line RCDL-10 can be cultivated as an off season crop during may having higher yield with the application of 60 kg P_2O_5 ha^{-1}.

Dubey *et al.,* (2012) conducted an experiment to find out the effect of integrated nutrient management in garden pea (*Pisum sativum* var. Hortense). The results indicated that application of vermicompost @ 1 t ha^{-1} + rest PK (50:25 kg ha^{-1}) through chemical fertilizers with variety Azad Pea-3 resulted maximum height of plant (59.40 cm), number of pods plant^{-1} (8.46), weight of pods plant^{-1} (41.22 g), shelling per cent age (50.66%) and yield of green pod (126.54 q ha^{-1}). On the basis of cost of cultivation, maximum net return of Rs. 44392/ha and C.B. ratio (1:2.93) was recorded under Azad Pea-3 with the application of vermicompost @ 1 t ha^{-1} + rest PK (50:25 kg ha^{-1}) and next best treatment was FYM @ 3 t ha^{-1} + rest PK (48:10 kg ha^{-1}) in the same variety which gave Rs. 41796 ha^{-1} with C:B ratio 1:2.57.

Lal *et al.,* (2004) reported that the effects of N (at 0, 20, 40 and 60 kg/ha) and P (at 0, 30, 60 and 90 kg/ha) on the seed yield of pea cv. Arkel and French bean [*phaseolus vulgaris*] cv. Contender were investigated in uttar Pradesh India during 2002-03 N at 40 kg/ha was optimum for obtained the maximum pea and bean seed yields. Seed yield of both crops increased with increasing P rates up to 60 kg/ha.

Clayton *et al*. (2004) reported that the close proximity of a highly concentrated band of N fertilizer had a greater impact on nodulation and subsequent N_2 fixation than the residual soil N level under field conditions, soil applied inoculants improved N nutrition of field pea compared to seed applied inoculation with or without applied urea-N.

Kushwaha *et al*. (2001) conducted a field study involving four rates of N (0, 30, 60 and 90 kg/ha) and reported the nitrogen use efficiency of 20.23 kg/ha grain kg N with application of 90 kg N.

Uddin *et al*., (2001) conducted an experiment at BSMRAU farm in Bangladesh, from November 1997 to January 1998, and reported that the highest amount of crude protein of green seed was recorded under 40 kg N/ha. A row spacing of 30 cm among with the application of 60 kg N/ha was found to be the best combination for achieving the highest yield and quality of garden pea in saline soil services under Madhupur soil tract in Bangladesh.

Gangwar *et al*., (1998) conducted a field study at Pantnagar in rabi [winter] 1994/95, the requirement of N, P and K for the production of 0.1 t of vegetables pea seed was 8.2, 1.0 and 5.6 kg, respectively. The percentage utilization of soil available N (organic carbon), P205 (Olsen-P) and K_2O (ammonium acetate-K) was 36.5, 13.8 and 11.8, respectively.The contribution from fertilizer as a percentage of its nutrient content was 188.8, 20.7 and 46.5 for N, P and K, respectively.

Michalojc *et al*., (1997) found In trials at Lublin, Poland, in 1980-81, peas cv. Rarytas were given 0, 20 or 40 kg N/ha, 60 kg P205/ha and 0, 150 or 300 kg K_2O/ha. The highest seed yield and best seed quality (as determined by vitamin C, saccharose and macro-and microelements contents) were obtained by applying 40 kg N.

Brkic *et al*., (2004) conducted an experiment by using different rates of N (0, 40, 80, 120 kg N/ha) during 1999-2000 on two soils (Mollic Gleysols and Eutric cambiosls) in Croatia, they reported that the effect of nitrogen fertilization depend on the soil type, i.e. its chemical properties. The highest seed yield nodule dry matter and seed protein content obtained from plants fertilized with 40 kg N/ha on Mollic Gleysols (3.96% humus) were 4.02 t/ha, 0.48 g/plant, and 26.91% respectively. The highest seed yield nodule dry matter and seed protein content observed from plants grown on Eutric Cambisols (1.07% humus) with 80 kg N/ha were 3.65 t/ha, 0.456 g/plant and 26.48%, respectively. Mishra, *et al*., (2002) carried out a field experiment and reported that the higher mean seed yield (3354 kg/ha) was obtained with 20 kg/ha. The application of 40 kg/ha under moisture stress at branching and flowering and no moisture stress treatments increased the yield by 29, 18 and 30% respectively. Kushwaha *et al*., (2001) conducted a field study involving four rates of N (0, 30, 60 and 90 kg/ha) and reported the nitrogen use efficiency of 20.23 kg/ha grain kg N with application of 90 kg N.

Pkalita *et al*., (1994) reported that foliar spray of 2% N at first flowering and post flowering stages of pea produced significantly higher yield in the treated plot compared with the control. They also concluded that N stress both at flowering and pod filling stages was likely responsible for decline in yield performance of pea.

Saini *et al*., (1996) found in a field experiment during the summer seasons of 1990-91, at Leo, peas cv. Lincoin were given 0-60 kg N and 0-66 kg P/ha. Mean green pod yield increased with up to 30 kg N (17.4 t/ha) and was highest with up to 52.8 kg P (20.9 t).

Akhtar *et al*., (2003) evaluate the growth and yield response of pea (Pisum sativum) crop to phosphorus and potassium application Phosphorus (0, 23, 46 or 69 kg P_2O_5/ha) and potassium (0, 50, 100 or 150 kg K_2O/ha) were applied in different combinations to pea cv. Samrina Zard at the time of seed bed preparation. Nitrogen level (46 kg N/ha) was kept constant and applied in two split doses, i.e. half at the time of sowing while the other half was applied before flowering. Vine length, number of pods per plant, pod length, number of grains per pod and green pod yield were significantly affected by the levels of P_2O_5. Number of grains pod and green pod yield were maximum at the highest dose of P_2O_5 (69 kg/ha). However, vine length, number of pods per plant and pod length increased up to the level of 46 kg P_2O_5 per ha. Application of K_2O to the crop up to the dose of 100 kg/ha had significant positive effect on all the parameters studied, beyond this dose further application of K_2O was ineffective. As combined effect of P_2O_5 and K_2O is concerned, it significantly influenced the pod length and green pod yield. Maximum pod length was attained when 69 or 46 kg P_2O_5/ha was applied in combination with 100 or 150 kg K_2O /ha. Green pod yield was maximum at 69 kg P_2O_5/ha × 100 or 150 kg K_2O/ha.

Solaiman (1999) conducted an experiment to study the effect of Bradirhizobium sp . (Vigna) inoculants, P and K fertilization. Plant receiving inoculants along with 25.8 kg P/ha and 33 kg k/ha performed best in all parameters including seed yield.

Singh and Nair (1995) conducted an experiment on the performance of 29 cowpea (*Vigna unguiculata*) genotypes, grown under zero and 120 kg N/ha applied in two equal splits, was evaluated with respect to their nodulation and nitrogen assimilating characteristics. Nitrogenous fertilization treatments, in general, inhibited not only nodulation capacity but also nodule growth. There was an increase in the nodule and root nitrate reductase activity in fertilizer-treated plants. However, in general, no nitrite accumulation was observed. Varieties EC240890 and EC170606, which exhibited good nodulation and desirable metabolic characters under the fertilizer treatment, are recommended for use in cereal-based intercropping systems. Pkalita *et al*., (1994) reported that foliar spray of 2% N at first flowering and post flowering stages of pea produced significantly higher yield in the treated plot compared with the control. They also concluded that N stress both at flowering and pod filling stages was likely responsible for decline in yield performance of pea. Agarwal and Kumar (1993) reported that lentil plants inoculated with *Rhizobium* fixed more atmospheric N and produced significantly higher yield attributes and grain yield than in uninoculated plant. They also obtained significantly higher grain yield at the rate of 20 kg N/ha compared with that in the control.

Negi (1992) carried out an experiment with vegetable pea at 4 levels of N (10, 20, 40, 60 kg/ha) and 3 of P (0, 60, 120 kg P_2O_5 ha^{-1}). He reported that the highest green pod yield could be obtained at the N rate of 20 kg/ha. A combination of 20 kg N and 60 kg P2O5/ha produced yield up to 1.72 t/ha.

Naik *et al,*. (1989) carried out an experiment in 1983-84 at Ranchi, Bihar with garden pea with the cultivar Bonneville, spaced at 30×5, 30×10 or 30×15 cm and given 25-75 kg N, 11-43 kg P and 21-42 kg K/ha. Pod yield was not significantly affected by N or K rate, and was highest with 43 kg P (1.30 t/ha).

Naik *et al.*, (1991) conducted an experiment with P utilization in pea (*Pisum sativum* L.) influenced by time of sampling. In field trials in the Rabi (winter) seasons of 1987-89 on sandy loam soil the effects of 0, 40, 80, 120 kg P_2O_5 ha^{-1} on TDM yield and P uptake of peas were studied at flowering and maturity. P application increased total TDM yield, although the increase was significant only at maturity in 1987-88. P uptake at maturity increased with P application in both the years. Percentage of P derived from fertilizer increased with P application and was higher at maturity than flowering. Percentage utilization of applied P decreased with increasing P application rate.

Prasad and Maurya (1989) carried out an experiment in 1983-84 during the rabi season to observe the effect of application of P at 0, 17.2, 34.4 or 51.6 kg/ha with or without *Rhizobium* inoculation of seeds. P application and *Rhizobium* inoculants alone or in combination resulted significant increase in yield compared with control. The highest yield was obtained with combination of 51.6 kg P and *Rhizobium* inoculants.

Addition of N fertilizer to soil has favoured the yield of cowpea (Tizon 1968; Worley *et al*. 1971). Rahman and Quasem (1982a) reported that under Bangladesh condition N addition up to 60 kg/ha give the positive response in cowpea.

Voisin *et al.,* (2002) investigated the effect of mineral N availability on nitrogen nutrition and biomass partitioning between shoot and roots of pea (*Pisum sativum*, cv. Baccara) under adequately irrigated conditions in the field, using five levels of fertilizer N application at sowing (0, 50, 100, 200 and 400 kg N/ha). Although the presence of mineral N in the soil stimulated vegetative growth, resulting in a higher biomass accumulation in shoots in the fertilized treatments, neither seed yield nor was seed nitrogen concentration affected by soil mineral N availability. However, biomass partitioning within the nodulated roots was changed. Root biomass was greater when soil mineral N availability was increased: root growth was greater and began earlier for plants that received mineral N at sowing.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2018 to January 2019 to study the Influence of spacing and different level of macronutrients on growth and yield of garden pea (*Pisum sativum* L.). The details of the materials and methods have been presented below:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

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

3.3 Climate

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

3.4 Plant materials

The variety 'BARI Motorshuti-1' was used for the present study.

3.5 Experimental details

3.5.1 Treatments

Factor A: Spacing

1. S_1 =30 cm × 10cm
2. S_2 =30 cm × 20 cm
3. S_3 =30 cm × 30 cm

Factor B: Macro nutrient management

1. $T_0 = N_0P_0K_0S_0$ (control)
2. $T_1 = N_{15}P_{25}K_{25}S_5$ (kg ha^{-1})
3. $T_2 = N_{30}P_{50}K_{50}S_{10}$ (kg ha^{-1})
4. $T_3 = N_{45}P_{75}K_{75}S_{15}$ (kg ha^{-1})

Treatment combinations

12 treatment combinations

S_1T_0, S_1T_1, S_1T_2, S_1T_3, S_2T_0, S_2T_1, S_2T_2, S_2T_3, S_3T_0, S_3T_1, S_3T_2 and S_3T_3.

3.5.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the different combination of macronutrients and spacing. The 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot 1.2 m × 0.9 m.The distance between blocks and plots were .75 m and 0.5 m respectively.

3.6 Preparation of the main field

The plot selected for the experiment was opened in the first week of October, 2018 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for transplanting. The land operation was completed on 25 October 2018. The individual plots were made by making ridges around each plot to restrict lateral runoff of irrigation water.

3.7 Fertilizers and manure application

N, P and K were applied as a form of urea, TSP and MoP, respectively. Cowdung also used as organic manure. P was applied as a form of TSP as per treatment. Nutrient doses used under the present study are presented as follows:

Nutrients	Manures/fertilizers	Doses ha^{-1}
Organic fertilizer	Cowdung	10 ton
N	Urea	As per treatment
P	TSP	As per treatment
K	MoP	As per treatment
S	Gypsum	As per treatment

One third (1/3) of whole amount of Urea and full amount of TSP, MoP and cowdung were applied at the time of final land preparation. The remaining Urea was top dressed in two equal installments- at 30 and 55 days after transplanting (DAP).

3.8 Intercultural operations

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

3.8.1 Gap filling

During seed sowing, few seeds were sown in the border of the plots. Seedlings were transferred to fill up the gap where seeds failed to germinate. Seedlings of about 5 cm height were transplanted from border rows with roots plunged 3 cm below the soil in the hills in the evening and watering was done to protect the seedling from wilting. All gaps were filled up within two weeks after germination of seeds.

3.8.2 Weeding

The plots were kept free from weeds by three weeding. First weeding was done at 30 days after planting (DAP), second at 55 DAP and third weeding at 70 DAP. The weeds were eradicated with roots carefully so that the plant did not affect during weeding.

3.8.3 Staking

After 30 days of seed sowing, staking was done with the help of bamboo split.

3.8.4 Irrigation

Irrigation was done whenever necessary. The young plants were irrigated by watering can. Beside this, irrigation was given three times at an interval of 7 to 10 days depending on soil moisture content, where the first irrigation at 25 DAP, second at 45 DAP and the last irrigation at 65 DAP.

3.8.5 Plant protection

At the early stage of growth, some plants were attacked by insect pests. Malathion 57 EC and Nuvacrone were sprayed at the rate of 2 ml/liter at an interval of 15 days. Protection measures were taken to protect the matured seeds against the attack of pigeon and rat. Mole cricket, field cricket and cutw orm are the major insects in particularly during seedling stage for garden pea cultivation. As a preventive measure against the insect pest, Dursban 20 EC was applied at the rate of 0.2% at 15 days interval for three times starting from 20 days after emergence of seed.

3.8.6 Disease management

The crop was healthy and disease free and therefore no fungicide were used in this experiment.

3.9 Harvesting

Harvesting was done at two times. Immature green pods were harvested at tender stage on 25 December, 2018 from three rows of each plot. Second harvest was done at 15 January, 2019 when the pods become yellow and fully dry from rest four rows of each plot. After harvest pods were separated from plants. Then plants and pods were weighted.

3.10 Methods of data collection

Five plants were selected at randomly in such a way that the border effect could be avoided. For this reason, the outer two lines and the outer plants of the middle lines in each unit plot were avoided. Data were recorded under the following parameters at harvesting stage.

3.10.1 Plant height

The plant height was measured at harvest stage with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm. Five plants from each plot was measured for plant height.

3.10.2 Days to first flowering

It was time duration between germination to first flowering. Date of germination of seeds to date of first flowering was recorded.

3.10.3 Grain growth duration

It was time duration between first flowering to harvesting. Total number of days from first flowering to harvesting of green pod was recorded.

3.10.4 Number of pods per plant

Numbers of total pods of selected plants from each plot was counted and the mean numbers was expressed as per plant basis. Data was recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.10.5 Pod length (cm)

Pod length was taken of randomly selected ten pods and the mean length was expressed in cm.

3.10.6 Pod breadth (cm)

Pod breadth was taken of randomly selected ten pods and the mean length was expressed in cm.

3.10.7 Green pod yield per plant (g)

The weight of green pods per plant was recorded from randomly selected 10 plants at the time of harvest. Data was recorded as the average of 10 plants from each plot.

3.10.8 Weight of 10 green pods (g)

Ten cleaned, green pods from each treatment was counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

3.10.9 Number of seeds per pod

The number of seeds per pod was recorded from randomly selected 10 pods at the time of harvest. Data was recorded as the average of 10 pods from each plot.

3.10.10 Weight of 100 green seeds (g)

One hundred cleaned, green seeds from each treatment was counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

3.10.11 Dry matter percentage of plant (%)

A sample of 100 g of plants was collected and dried under direct sunshine for 72 hours and then dried in an oven at 70 ^{0}C for 3 days. After oven drying, plants were weighed. The dry weight was recorded in gram (g) with an electric balance. The percentage of dry matter was calculated by the following formula:

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

3.11 Statistical analysis

The data collected from the experimental plots were analyzed statistically with the help of computer software programme MSTAT-C. The mean differences were adjusted with LSD Test (Gomez and Gomez, 1984).

3.12 Economic analysis

Economic analysis was done to find out the cost effectiveness of different treatments like different levels of spacing and macro nutrient management in cost and return were done in details according to the procedure of Alam *et al*., (1989).

3.13. Analysis of total cost of production

All the material and non-material input cost, interest on fixed capital of land and miscellaneous cost were considered for calculating the total cost of production.

3.14. Gross income

Gross income was calculated on the basis of grain and green pod sale. The price was assumed on the basis of local market value.

3.15. Net return

Net return was calculated by deducting the total production cost from gross income for each treatment combination.

3.16. Benefit cost ratio (BCR)

The economic indicator BCR was calculated by the following formula for each treatment combination.

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross income per hectare}}{\text{Total cost of production per hectare}}$$

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the influence of spacing and different level of macronutrients on growth and yield of garden pea (*Pisum sativum* L.). Data on different growth characters yield and yield related characters were recorded. The findings of the experiment have been presented and discussed with the help of table and graphs and possible interpretations were given under the following headings:

4.1 Growth parameters

4.1.1 Plant height (cm)

Significant variation was found on plant height of garden pea at different growth stages affected by different plant spacing (Table 1 and Appendix V). The highest plant height (35.1, 56.5, 79.1 and 86.0 cm at 30, 45, 60 and 75 DAS, respectively) was found from the plant spacing S_1 (30 cm × 10 cm) which was significantly different from other treatments. The lowest plant height (25.5, 43.4, 62.7 and 70.7 cm at 30, 45, 60 and 75 DAS, respectively) was recorded from the plant spacing S_3 (30 cm × 30 cm). This result indicated that lower plant spacing showed higher plant height, this might be due to cause of lower sunlight intensity. Similar result was also observed by Murade *et al.* (2014) who found higher plant with the spacing of 30 cm ×10 cm compared to 45 cm × 10 cm.

Different macro nutrient treatments showed significant variation on plant height of garden pea at different growth stages (Table 2 and Appendix V). The highest plant height (32.1, 52.1, 75.9 and 82.9 cm at 30, 45, 60 and 75 DAS, respectively) was recorded from the macro nutrient treatment T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) whereas the lowest plant height (27.4, 46.3, 67.4 and 75.6 cm at 30, 45, 60 and 75 DAS,respectively) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}) which was statistically identical with T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-}

[1]). This result indicated that plant height was increased with the increment of plant nutrients to at a certain level. Because excess nutrition might be toxic to plants. Similar result was also observed by Dubey *et al*. (2012) for garden pea.

Table 1. Plant height of garden pea as influenced by different plant spacing.

Treatment	Plant height (cm)			
	30 DAS	45 DAS	60 DAS	75 DAS
S_1	35.1 a	56.5 a	79.1 a	86.0 a
S_2	28.7 b	47.7 b	70.6 b	77.9 b
S_3	25.5 c	43.4 c	62.7 c	70.7 c
CV(%)	6.3	7.3	9.8	10.3
$LSD_{0.05}$	0.54	0.68	0.56	0.62

Means in a colum followed by same letter do not differ significantly of 5% level.

S_1 (30 cm × 10cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm)

Table 2. Plant height of garden pea as influenced by different level of macronutrients

Treatment	Plant height (cm)			
	30 DAS	45 DAS	60 DAS	75 DAS
T_0	27.4 c	46.3 d	67.4 d	75.6 c
T_1	29.6 b	48.7 c	69.3 c	75.6 c
T_2	32.1 a	52.1 a	75.9 a	82.9 a
T_3	29.9 b	49.7 b	70.7 b	78.6 b
CV(%)	6.3	7.3	9.8	10.3
$LSD_{0.05}$	0.62	0.79	0.65	0.71

Means in a colum followed by same letter do not differ significantly of 5% level.

T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1})

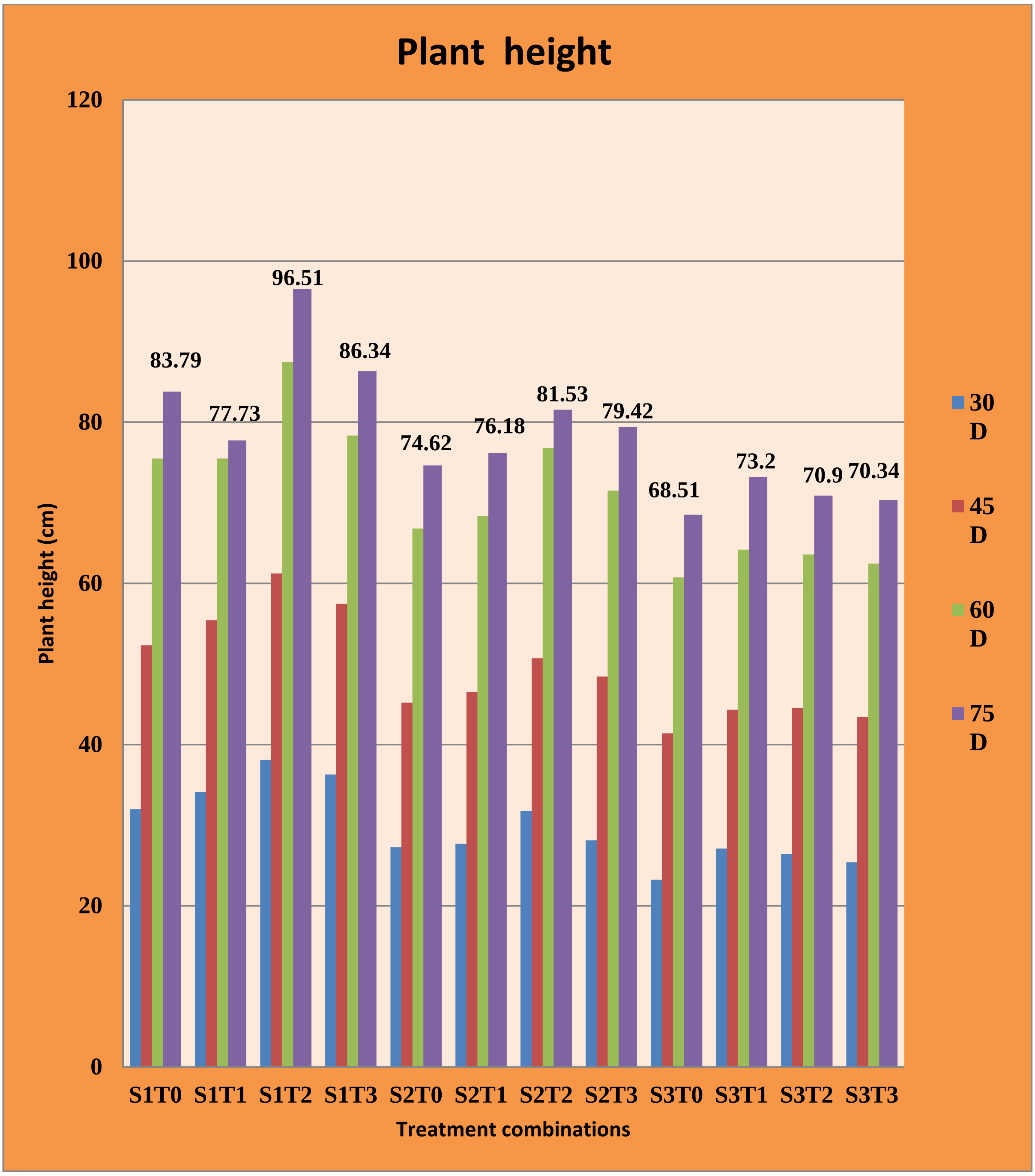

Figure 1: Plant height of garden pea as influenced by combined effect of plant spacing and macro nutrients.

S_1 (30 cm × 10cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm)

T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}).

Treatment combination of plant spacing and macro nutrients showed significant influence on plant height of garden pea at different growth stages

(Fig. 1 and Appendix V). The highest plant height (38.0, 61.2, 87.4 and 96.5 cm at 30, 45, 60 and 75 DAS, respectively) was achieved from the treatment combination of S_1T_2 which was significantly different from other treatment combinations followed by S_1T_3. The lowest plant height (23.2, 41.3, 60.7 and 68.5 cm at 30, 45, 60 and 75 DAS, respectively) was obtained from the treatment combination of S_3T_0.

4.1.2 Number of branches plant^{-1}

Significant variation was found on number of branches plant^{-1} of garden pea at different growth stages affected by different plant spacing (Fig. 2 and Appendix VI). The highest number of branches plant^{-1} (4.0, 5.6, 7.1 and 8.1 at 30, 45, 60 and 75 DAS, respectively) was found from the plant spacing S_2 (30 cm × 20 cm) which was significantly different from other treatments. The lowest number of branches plant^{-1} (3.3, 4.8, 6.4 and 6.8 at 30, 45, 60 and 75 DAS, respectively) was recorded from the plant spacing S_1 (30 cm × 10cm). Optimum plant spacing ensures highest achievement of crop production. Branches is an important factor for higher yield. Correct plant spacing ensures balanced nutrition to the plant and also light, water etc. This result under the present study also might be the same reason. Similar result was also achieved by Murade *et al.* (2014) in black gram.

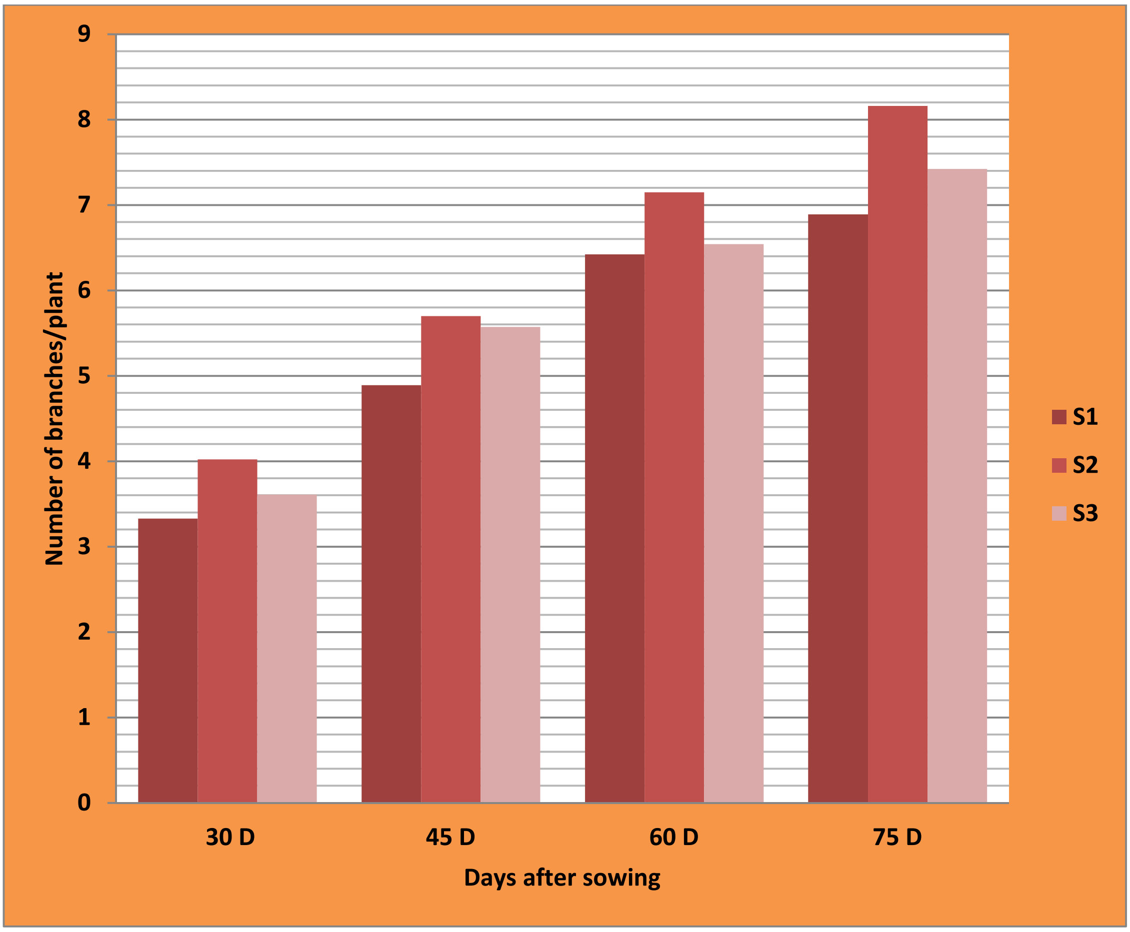

Figure 2. Number of branches plant^{-1} of garden pea as influenced by different plant spacing

S_1 (30 cm × 10cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm).

Different macro nutrient treatments showed significant variation on number of branches plant^{-1}of garden pea at different growth stages (Table 3 and Appendix VI). The highest number of branches plant^{-1} (4.21, 5.99, 7.63 and 8.36 at 30, 45, 60 and 75 DAS, respectively) was recorded from the macro nutrient treatment T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) which was significantly different from other treatments. The lowest number of branches plant^{-1} (2.6, 3.8, 4.7 and 5.4 at 30, 45, 60 and 75 DAS, respectively) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}).Wider plant spacing which intercepted more photosynthetically active radiation owing to better geometric situation that might have resulted in vigorous plant growth and more number of branches and leaves as compared to narrow spacing. Optimum nutrition ensures highest achievement of crop production. Branches can be considered an important factor for higher achievement. Higher branches number can produce higher pods per plant. But excess nutrition might be toxic to plants and resulted lower yield. Under the present study, this might be the main reason of the obtained result on branches per plant. Similar result was also observed by Kharbamon *et al.* (2016) and Brkic *et al*. (2004).

Table 3. Number of branches plant^{-1} of garden pea as influenced by different level of macronutrients

Treatment	Number of branches plant^{-1}			
	30 DAS	45 DAS	60 DAS	75 DAS
T_0	2.6 c	3.8 c	4.7 d	5.4 c
T_1	3.5 b	5.7 b	6.9 c	7.7 b
T_2	4.2 a	5.9 a	7.6 a	8.3 a
T_3	4.1 a	5.9 a	7.4 b	8.3 a
CV(%)	11.9	10.3	11.2	10.6
$LSD_{0.05}$	0.12	0.15	0.13	0.08

Means in a colum followed by same letter do not differ significantly of 5% level.

T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1})

Treatment combination of plant spacing and macro nutrients showed significant influence on number of branches plant^{-1} of garden pea at different growth stages (Fig. 3 and Appendix VI). Results revealed that the highest number of branches plant^{-1} (4.8, 6.4, 8.2 and 9.2 at 30, 45, 60 and 75 DAS, respectively) was achieved from the treatment combination of S_2T_2 which was statistically identical with S_2T_3 at 75 DAS. The lowest number of branches plant^{-1} (2.0, 3.4, 4.8 and 5.0 at 30, 45, 60 and 75 DAS, respectively) was obtained from the treatment combination of S_1T_0 which was significantly different from other treatment combinations.

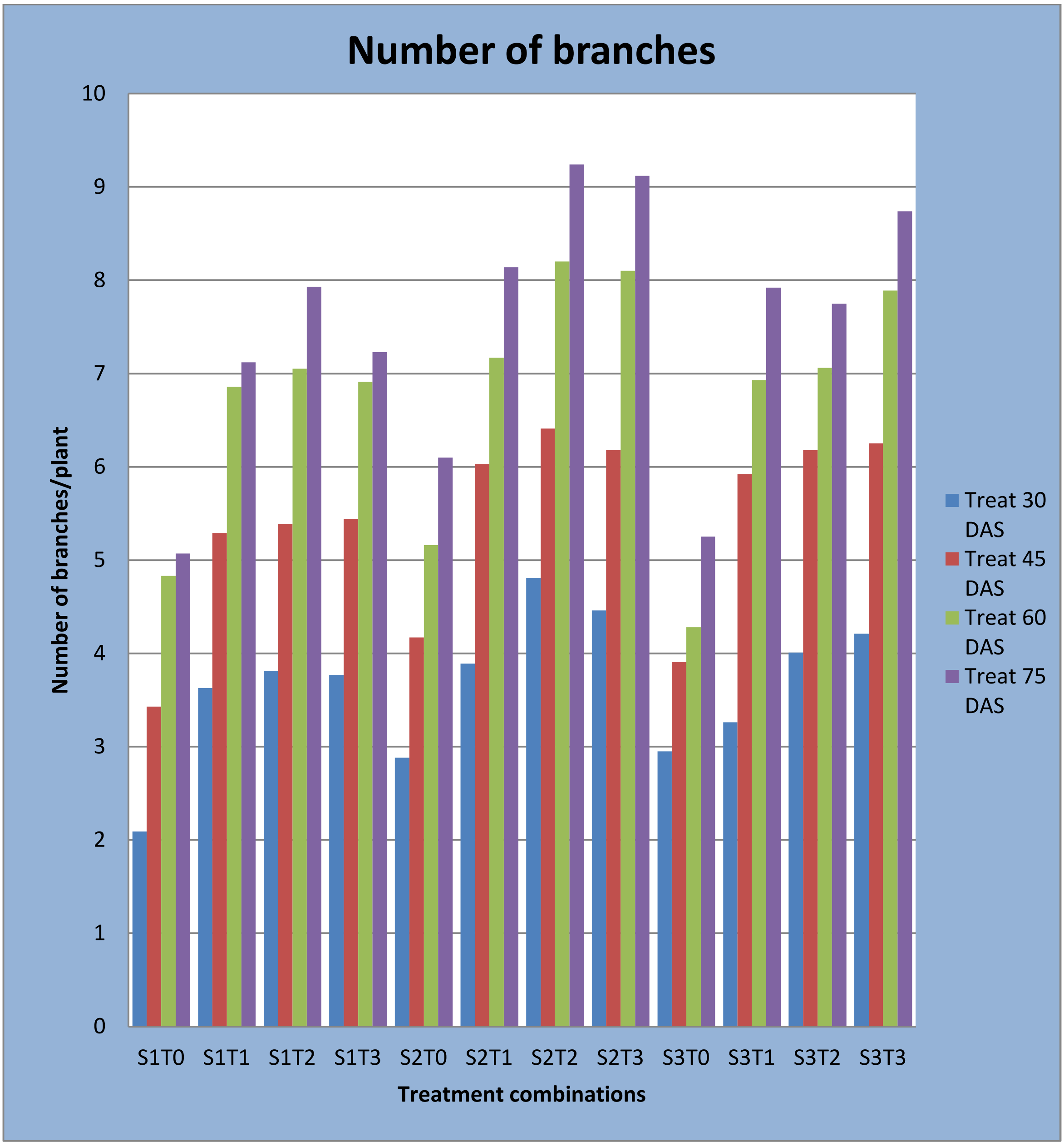

Figure 3. Number of branches plant^{-1} of garden pea as influenced by combined effect of plant spacing and macro nutrients

S_1 (30 cm × 10cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm)

T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}).

4.2 Yield contributing parameters and yield

4.2.1 Days to 50% germination

Non-signification variation was found on days to 50% germination of garden pea affected by different plant spacing (Table 4). However, the highest days to 50% germination (9.4) was found from the plant spacing S_1 (30 cm × 10cm) whereas the lowest days to 50% germination (8.2) was found from the plant spacing S_2 (30 cm × 20 cm).

Different macro nutrient treatments showed non-significant variation on days to 50% germination (Table 5). However, the highest days to 50% germination (9.6) was from control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}) whereas the lowest days to 50% germination (8.3) was found from T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1})

Treatment combination of plant spacing and macro nutrients showed non-significant influence on days to 50% germination (Table 6). The highest days to 50% germination (10.0) was achieved from the treatment combination of S_1T_0. The lowest days to 50% germination (7.1) was obtained from the treatment combination of S_2T_2.

4.2.2 Days to 50% flowering

Signification variation was found on days to 50% flowering of garden pea affected by different plant spacing (Table 4). The highest days to 50% flowering (36.0) was found from the plant spacing S_1 (30 cm × 10cm) whereas the lowest days to 50% flowering (32.8) was found from the plant spacing S_2 (30 cm × 20 cm). Similar result was also observed by Shaukat *et al*. (2012) which supported the present study.

Different macro nutrient treatments showed significant variation on days to 50% flowering (Table 5). The highest days to 50% flowering (36.64) was from control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}) whereas the lowest days to 50% flowering (32.7) was found from T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) which was statistically identical with T_3. Shaukat *et al*. (2012) also showed similar result which supported the present study.

Treatment combination of plant spacing and macro nutrients showed significant influence on days to 50% flowering (Table 6 and Appendix V). The highest days to 50% flowering (37.2) was achieved from the treatment combination of S_1T_0. The lowest days to 50% flowering (31.1) was obtained from the treatment combination of S_2T_2 which was statistically identical with S_2T_3, S_3T_2 and S_3T_3.

4.2.3 Number of pods plant^{-1}

Signification variation was found on number of pods plant^{-1} of garden pea affected by different plant spacing (Table 4 and Appendix VII). The highest number of pods plant^{-1} (20.4) was found from the plant spacing S_2 (30 cm × 20 cm) followed by S_3 (30 cm × 30 cm). The lowest number of pods plant^{-1} (18.2) was recorded from the plant spacing S_1 (30 cm × 10cm). Wider plant spacing which intercepted more photosynthetically active radiation owing to better geometric situation that might have resulted in more number of pods plant^{-1}. Similar result was also observed by Murade *et al.*, (2014) who found higher pods plant^{-1} with wider spacing.

Different macro nutrient treatments showed significant variation on number of pods plant-1 of garden pea (Table 5 and Appendix VII). The highest number of pods plant-1 (24.7) was recorded from the macro nutrient treatment T2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha-1) followed by T3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha-1) whereas the lowest number of pods plant-1 (14.7) was observed from the control treatment T_0 (Control).

Treatment combination of plant spacing and macro nutrients showed significant influence on number of pods plant^{-1} of garden pea (Fig. 4 and Appendix VII). The highest number of pods plant^{-1} (26.8) was achieved from the treatment combination of S_2T_2 which was significantly different from other treatment combinations followed by S_3T_2 and S_1T_2. The lowest number of pods plant^{-1} (13.38) was obtained from the treatment combination of S_1T_0.

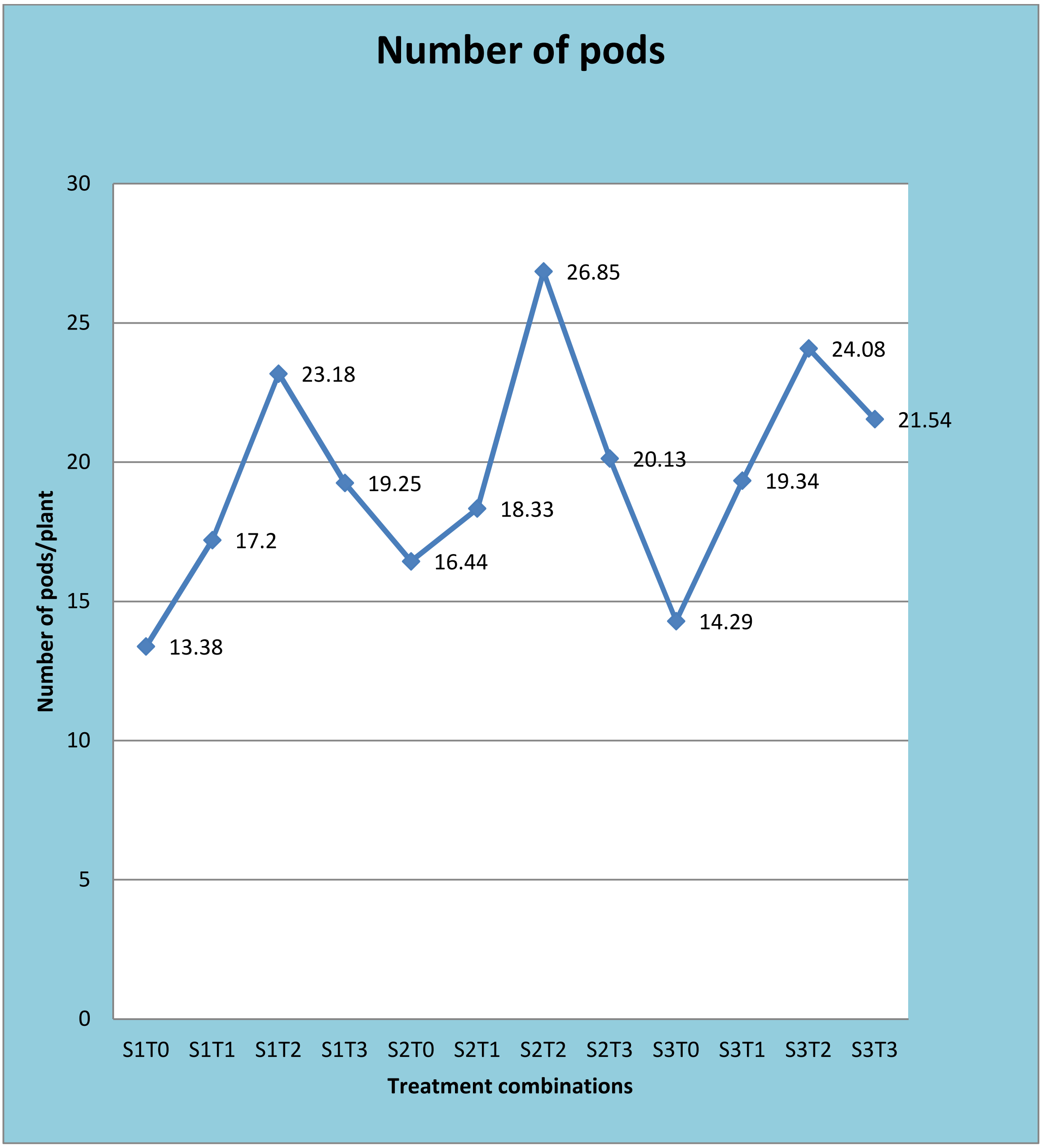

Figure 4. Number of pods plant^{-1} of garden pea as influenced by combined effect of plant spacing and macro nutrients

S_1 (30 cm × 10cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm)

T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1})

4.2.4 Number of seeds pod^{-1}

Signification variation was found on number of seeds pod^{-1} of garden pea affected by different plant spacing (Table 4 and Appendix VIII). The highest number of seeds pod^{-1} (7.4) was found from the plant spacing S_2 (30 cm × 20 cm) followed by S_3 (30 cm × 30 cm). The lowest number of seeds pod^{-1} (6.2) was recorded from the plant spacing S_1 (30 cm × 10cm). Wider spacing ensures more light, nutrients, nutrients than closer spacing. This results showed higher number of seeds pod^{-1} compared to control which might be due to cause of more nutrient available. Similar results was also observed by Tomar *et al.* (2013) and Murade *et al.* (2014) who also found higher pod number with wider spacing.

Table 4. Yield and yield attributes of garden pea garden pea influenced by different plant spacing

Treatment			Yield contributing parameters				
	Days to 50% germin-ation	Days to 50% flowe-ring	No. of pods plant^{-1}	No. of seeds pod^{-1}	Length of pod (cm)	Breadth of pod (cm)	Weight of 10 green pods (g)
S_1	9.4	36.0 a	18.2 c	6.2 c	5.8 c	1.3 c	42.1 b
S_2	8.2	32.8 c	20.4 a	7.4 a	6.8 a	1.4 a	44.4 a
S_3	8.5	33.1 b	19.8 b	6.9 b	6.2 b	1.4 b	42.1 b
CV(%)	6.8	5.8	8.1	9.9	10.5	7.4	8.6
$LSD_{0.05}$	---	0.31	0.47	0.26	0.22	0.03	0.39

Means in a colum followed by same letter do not differ significantly of 5% level.

S_1 (30 cm × 10cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm)

Different macro nutrient treatments showed significant variation on number of seeds pod^{-1} of garden pea (Table 5 and Appendix VIII). The highest number of seeds pod^{-1} (7.5) was recorded from the macro nutrient treatment T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) which was statistically similar with T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}). The lowest number of seeds pod^{-1} (5.6) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}).

Treatment combination of plant spacing and macro nutrients showed significant influence on number of seeds pod^{-1} of garden pea (Table 6 and Appendix VIII). The highest number of seeds pod^{-1} (8.1) was achieved from the treatment combination of S_2T_2 which was statistically similar with S_2T_3. The lowest number of seeds pod^{-1} (5.0) was obtained from the treatment combination of S_1T_0.

Table 5. Yield and yield attributes of garden pea influenced by different level of macronutrients

Treatment	Yield contributing parameters						
	Days to 50% germin-ation	Days to 50% flowe-ring	No. of pods plant^{-1}	No. of seeds pod^{-1}	Length of pod (cm)	Breadth of pod (cm)	Weight of 10 green pods (g)
T_0	9.6	36.6 a	14.7 d	5.6 c	5.4 c	1.3 d	39.9 d
T_1	8.9	33.8 b	18.2 c	7.1 b	6.1 b	1.4 c	42.9 c
T_2	8.3	32.7 c	24.7 a	7.5 a	7.3 a	1.5 a	45.3 a
T_3	8.5	32.8 c	20.3 b	7.2 ab	6.3 b	1.4 b	43.5 b
CV(%)	6.8	5.8	8.1	9.9	10.5	7.4	8.6
$LSD_{0.05}$	---	0.36	0.54	0.30	0.26	0.03	0.33

Means in a colum followed by same letter do not differ significantly of 5% level.

T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1})

4.2.5 Length of pod (cm)

Significant variation was found on length of pod of garden pea affected by different plant spacing (Table 4 and Appendix VII). The highest length of pod (6.8 cm) was found from the plant spacing S_2 (30 cm × 20 cm) followed by S_3 (30 cm × 30 cm). The lowest length of pod (5.8 cm) was recorded from the plant spacing S_1 (30 cm × 10cm). Higher levels of plant nutrients help to increase pod length and wider spacing ensures more plant nutrients than lower spacing. Shaukat *et al*. (2012) found similar results which supported the present finding.

Different macro nutrient treatments showed significant variation on length of pod of garden pea (Table 5 and Appendix VII). The highest length of pod (7.37 cm) was recorded from the macro nutrient treatment T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) followed by T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}). The lowest length of pod (5.4 cm) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}).

Treatment combination of plant spacing and macro nutrients showed significant influence on length of pod of garden pea (Table 6 and Appendix VII). The highest length of pod (8.1 cm) was achieved from the treatment combination of S_2T_2 which was statistically identical with S_3T_2. The lowest length of pod (5.0 cm) was obtained from the treatment combination of S_1T_0 which was statistically similar with S_2T_0.

4.2.6 Breadth of pod (cm)

Significant variation was found on breadth of pod of garden pea affected by different plant spacing (Table 4 and Appendix VII). The highest breadth of pod (1.4 cm) was found from the plant spacing S_2 (30 cm × 20 cm) followed by S_3 (30 cm × 30 cm). The lowest breadth of pod (1.3 cm) was recorded from the plant spacing S_1 (30 cm × 10cm). Similar result was also observed by Shaukat *et al*. (2012).

Different macro nutrient treatments showed significant variation on breadth of pod of garden pea (Table 5 and Appendix VII). The highest breadth of pod (1.5 cm) was recorded from the macro nutrient treatment T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) followed by T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}). The lowest breadth of pod (1.3 cm) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}).

Treatment combination of plant spacing and macro nutrients showed significant influence on breadth of pod of garden pea (Table 6 and Appendix VII). The highest breadth of pod (1.5 cm) was achieved from the treatment combination of S_2T_2 whereas the lowest breadth of pod (1.2 cm) was obtained from the treatment combination of S_1T_0 which was statistically similar with S_1T_1.

4.2.7 Weight of 10 green pods (g)

Significant variation was found on weight of 10 green pods of garden pea affected by different plant spacing (Table 4 and Appendix VII). The highest weight of 10 green pods (44.4 g) was found from the plant spacing S_2 (30 cm × 20 cm). The lowest weight of 10 green pods (42.1 g) was recorded from the plant spacing S_1 (30 cm × 10cm) which was statistically identical with S_3 (30 cm × 30 cm). The present study showed that wider spacing howed higher pod weight compared to lower spacing which might be due to cause of nutrient deficiency occurred with closer spacing. Agarwal *et al.,* (2015) also found similar result with the present study.

Different macro nutrient treatments showed significant variation on weight of 10 green pods of garden pea (Table 5 and Appendix VII). The highest weight of 10 green pods (45.3 g) was recorded from the macro nutrient treatment T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) followed by T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}). The lowest weight of 10 green pods (39.9 g) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}).

Table 6. Yield and yield attributes influenced by combined effect of plant spacing and macro nutrients

Treatment	Yield contributing parameters					
	Days to 50% germin-ation	Days to 50% flowe-ring	Number. of seeds pod^{-1}	Length of pod(cm)	Breadth of pod(cm)	Weight of 10 green pods (g)
S_1T_0	10.0	37.2 a	5.0 h	5.0 e	1.2 f	39.1 h
S_1T_1	9.7	35.8 cd	6.4 ef	5.6 d	1.3 ef	42.2 e
S_1T_2	9.1	35.2 d	7.0 cd	6.2 c	1.4 b	44.2 c
S_1T_3	9.9	35.7 cd	6.6 de	6.3 c	1.4 cd	43.1 d
S_2T_0	9.8	36.5 b	6.0 fg	5.5 de	1.4 cd	40.4 g
S_2T_1	8.2	32.3 f	7.5 bc	7.0 b	1.4 bc	45.3 b
S_2T_2	7.1	31.1 g	8.1 a	8.1 a	1.5 a	46.2 a
S_2T_3	7.6	31.3 g	8.0 ab	6.5 c	1.4 b	45.5 b
S_3T_0	9.9	36.1 bc	5.7 g	5.5 d	1.3 de	40.1 g
S_3T_1	7.8	33.4 e	7.5 bc	5.6 d	1.4 bc	41.2 f
S_3T_2	7.6	31.5 g	7.4 c	7.7 a	1.4 b	45.5 b
S_3T_3	7.9	31.5 g	7.1 cd	6.2 c	1.4 b	41.7 ef
CV(%)	6.8	5.8	9.9	10.5	7.4	8.6
$LSD_{0.05}$	---	0.62	0.53	0.45	0.06	0.58

Means in a colum followed by same letter do not differ significantly of 5% level.

S_1 (30 cm × 10cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm)

T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1})

Treatment combination of plant spacing and macro nutrients showed significant influence on weight of 10 green pods of garden pea (Table 6 and Appendix VII). The highest weight of 10 green pods (46.2 g) was achieved from the treatment combination of S_2T_2 which was significantly different from other treatment combinations. The lowest weight of 10 green pods (39.1 g) was obtained from the treatment combination of S_1T_0.

4.2.8 Weight of green seeds plant^{-1} (g)

Signification variation was found on weight of green seeds plant^{-1} of garden pea affected by different plant spacing (Table 7 and Appendix VIII). The highest weight of green seeds plant^{-1} (18.1 g) was found from the plant spacing S_2 (30 cm × 20 cm) which was statistically identical with S_3 (30 cm × 30 cm). The lowest weight of green seeds plant^{-1} (17.1 g) was recorded from the plant spacing S_1 (30 cm × 10 cm). Similar result was also observed by Tomar *et al.* (2013) and Agarwal *et al.* (2015) which supported the present study.

Different macro nutrient treatments showed significant variation on weight of green seeds plant^{-1} of garden pea (Table 8 and Appendix VIII). The highest weight of green seeds plant^{-1} (19.5 g) was recorded from the macro nutrient treatment T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) which was statistically identical with T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}). The lowest weight of green seeds plant^{-1} (16.3 g) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}).

Treatment combination of plant spacing and macro nutrients showed significant influence on weight of green seeds plant-1 of garden pea (Table 9 and Appendix VIII). The highest weight of green seeds plant-1 (20.9 g) was achieved from the treatment combination of S_2T_2 which was significantly different from other treatment combinations. The lowest weight of green seeds plant-1 (15.3 g) was obtained from the treatment combination of S_1T_0.

4.2.9 Weight of 100 seeds (g)

Significant variation was found on 100 seed weight of garden pea affected by different plant spacing (Table 7 and Appendix VIII). Results showed that the highest 100 seed weight (4.3 g) was found from the plant spacing S_2 (30 cm × 20 cm) whereas the lowest 100 seed weight (3.7 g) was recorded from the plant spacing S_1 (30 cm × 10 cm). The result obtained from the present study was similar with the findings of Agarwal *et al.* (2015) and Murade *et al.* (2014) who reported that higher spacing showed higher 1000 seed weight.

Table 7. The effect of spacing on yield and yield attributes of garden pea.

Treatment	Yield contributing parameters and yield				
	Weight of green seeds $plant^{-1}$ (g)	100 seed weight (g)	% dry matter of plant	Seed yield (t ha^{-1})	Pod yield (t ha^{-1})
S_1	17.1 b	3.7 b	15.1 c	8.3 a	10.6 a
S_2	18.1 a	4.3 a	17.1 b	6.6 b	8.1 b
S_3	17.9 a	4.1 a	17.6 a	6.0 c	6.4 c
CV(%)	10.3	11.9	10.3	11.2	12.7
$LSD_{0.05}$	0.34	0.18	0.42	0.23	0.13

Means in a colum followed by same letter do not differ significantly of 5% level.

S_1 (30 cm × 10cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm)

Different macro nutrient treatments showed significant variation on 100 seed weight of garden pea (Table 8 and Appendix VIII). The highest 100 seed weight (4.3 g) was recorded from the macro nutrient treatment T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) whereas the lowest 100 seed weight (3.64 g) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}).

Treatment combination of plant spacing and macro nutrients showed significant influence on 100 seed weight of garden pea (Table 9 and Appendix VIII). The highest 100 seed weight (5.2 g) was achieved from the treatment combination of S_2T_2 which was statistically identical with S_2T_3 and S_3T_3. The lowest 100 seed weight (3.3 g) was obtained from the treatment combination of S_1T_0.

Table 8. The effect of macronutrients on yield and yield attributes of garden pea.

Treatment	Yield contributing parameters and yield				
	Weight of green seeds $plant^{-1}$ (g)	100 seed weight (g)	% dry matter of plant	Seed yield (t ha^{-1})	Pod yield (t ha^{-1})
T_0	16.3 c	3.6 c	15.1 c	6.0 b	7.7 d
T_1	17.5 b	3.8 b	15.8 b	7.3 a	8.2 c
T_2	19.5 a	4.3 a	17.8 a	7.5 a	9.1 a
T_3	17.6 b	4.5 a	17.8 a	7.3 a	8.5 b
CV(%)	10.3	11.9	10.3	11.2	12.7
$LSD_{0.05}$	0.39	0.21	0.48	0.26	0.15

Means in a colum followed by same letter do not differ significantly of 5% level.

T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1})

4.2.10 Percent (%) dry matter of plant

Signification variation was found on percent (%) dry matter of garden pea affected by different plant spacing (Table 7 and Appendix IX). The highest percent (%) dry matter (17.6%) was found from the plant spacing S_3 (30 cm × 30 cm) whereas the lowest percent (%) dry matter (15.1) was recorded from the plant spacing S_1 (30 cm × 10cm). Similar result was also found from the findings of Tomar *et al.* (2013) which supported the present study.

Different macro nutrient treatments showed significant variation on percent (%) dry matter of garden pea (Table 8 and Appendix IX). The highest percent (%) dry matter (17.8%) was recorded from the macro nutrient treatment T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}) whereas the lowest percent (%) dry matter (15.1%) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}). Supported result on percent (%) dry matter production was also achieved by Brkic *et al.* (2004).

Treatment combination of plant spacing and macro nutrients showed significant influence on percent (%) dry matter of garden pea (Table 9 and Appendix IX). The highest percent (%) dry matter (20.1%) was achieved from the treatment combination of S_3T_3 which was statistically similar with S_2T_2. The lowest percent (%) dry matter (14.4%) was obtained from the treatment combination of S_1T_0.

4.3 Yield parameters

4.3.1 Seed yield (t ha^{-1})

Significant variation was found on seed yield of garden pea affected by different plant spacing (Table 7). The highest seed yield (8.3 t ha^{-1}) was found from the plant spacing S_1 (30 cm × 10 cm) followed by S_2 (30 cm × 20 cm). The lowest seed yield (6.0 t ha^{-1}) was recorded from the plant spacing S_3 (30 cm × 30 cm). Mainly seed yield depends on yield contributing parameters like number of plant populations per square meter, pods per plant, seeds per pod etc. Under the present study lower plant spacing showed highest yield which might be due to cause of higher plant population. Similar result was also observed by Murade *et al.* (2014), Tomar *et al.* (2013) and Agarwal *et al.,* (2015).

Different macro nutrient treatments showed significant variation on seed yield of garden pea (Table 8). The highest seed yield (7.5 t ha^{-1}) was recorded from the macro nutrient treatment T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) which was statistically identical with T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}). The lowest seed yield (6.01 t ha^{-1}) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}). Generally it is known that excess plant nutrients are toxic to plant. So, optimum nutrition is essential for higher production. Similar result was also observed by Brkic *et al.*, (2004), Michalojc *et al.* (1997) and Kharbamon *et al.,* (2016).

Treatment combination of plant spacing and macro nutrients showed significant influence on seed yield of garden pea (Table 9). The highest seed yield (9.2 t ha^{-1}) was achieved from the treatment combination of S_1T_2 which was significantly different from other treatment combinations followed by $S_1T_{1.}$ The lowest seed yield (4.6 t ha^{-1}) was obtained from the treatment combination of $S_3T_{0.}$

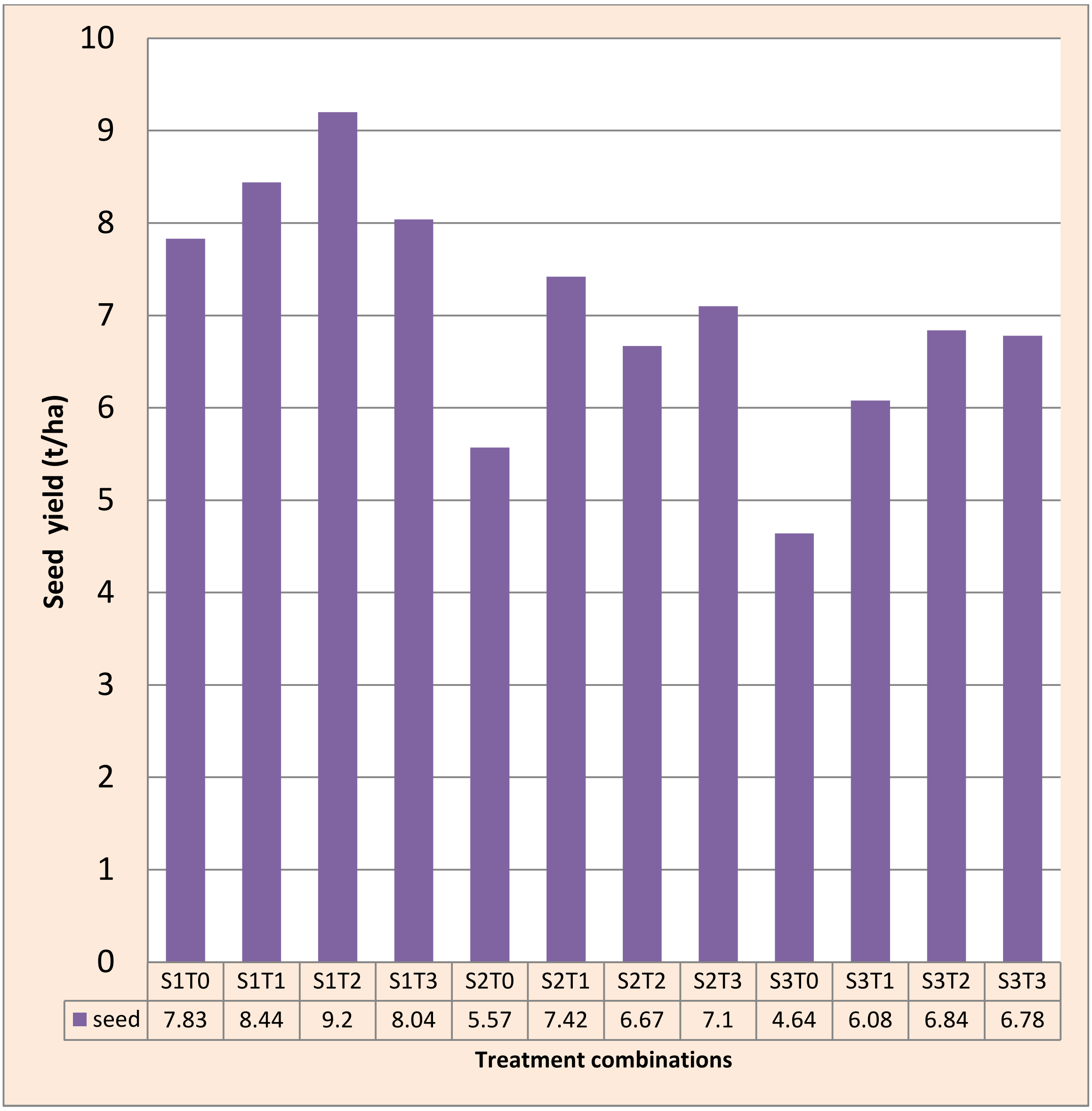

Figure 5. The combined effect of spacing and macronutrients on seed yield (ton/ha)

Means in a colum followed by same letter do not differ significantly of 5% level.

S_1 (30 cm × 10cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm)

T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1})

4.3.2 Pod yield (t ha^{-1})

Significant variation was found on pod yield of garden pea affected by different plant spacing (Table 7). The highest pod yield (10.5 t ha^{-1}) was found from the plant spacing S_1 (30 cm × 10 cm) followed by S_2 (30 cm × 20 cm). The lowest pod yield (6.4 t ha^{-1}) was recorded from the plant spacing S_3 (30 cm × 30 cm).

Similar result was also observed by Tomar *et al.* (2013), Shaukat *et al.* (2012) and Agarwal *et al.* (2015) which supported the present study.

Table 9. The combined effect of spacing and macronutrients on yield and yield attributes of garden pea.

Treatment	Yield contributing parameters and yield			
	Weight of green seeds $plant^{-1}$ (g)	100 seed weight (g)	% dry matter of plant	Pod yield (t ha^{-1})
S_1T_0	15.3 h	3.3 e	14.4 f	9.6 d
S_1T_1	17.2 efg	3.9 bc	16.0 cd	10.3 c
S_1T_2	18.4 bc	4.0 b	15.0 ef	11.8 a
S_1T_3	17.4 def	3.5 de	14.9 ef	10.7 b
S_2T_0	17.0 fg	3.5 de	15.0 ef	7.7 g
S_2T_1	17.2 efg	3.6 cde	15.1 ef	8.1 f
S_2T_2	20.9 a	5.2 a	19.5 ab	8.6 e
S_2T_3	17.3 ef	5.0 a	19.0 b	8.2 f
S_3T_0	16.6 g	4.0 bc	15.4 de	5.9 k
S_3T_1	18.1 cd	3.9 bc	16.3 c	6.2 j
S_3T_2	19.1 b	3.7 bcd	18.7 b	6.9 h
S_3T_3	17.9 cde	5.03 a	20.1 a	6.5 i
CV(%)	10.3	11.9	10.3	12.7
$LSD_{0.05}$	0.68	0.36	0.84	0.27

Means in a colum followed by same letter do not differ significantly of 5% level.

S_1 (30 cm × 10 cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm)

T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1})

Different macro nutrient treatments showed significant variation on pod yield of garden pea (Table 8). The highest pod yield (9.1 t ha^{-1}) was recorded from the macro nutrient treatment T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) followed by T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}). The lowest pod yield (7.7 t ha^{-1}) was observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}). The result obtained from the present study was conformity with the findings of Michalojc *et al*. (1997), Brkic *et al*. (2004) and Kharbamon *et al.* (2016).

Treatment combination of plant spacing and macro nutrients showed significant influence on pod yield of garden pea (Fig. 5 and Appendix VIII). The highest pod yield (11.8 t ha^{-1}) was achieved from the treatment combination of S_1T_2 which was significantly different from other treatment combinations followed by S_1T_3. The lowest pod yield (5.9 t ha^{-1}) was obtained from the treatment combination of S_3T_0 which was significantly different from other treatment combinations.

4.4 Economic analysis of garden pea production

Input costs for land preparation, inorganic fertilizer, organic manure and manpower required for all the operations from seed sowing to harvesting of garden pea were recorded as per plot and converted into cost/hectare. Price of pod was considered as per present market rate basis. The economic analysis presented under the following headings-

4.4.1 Gross return

The combination of spacing and macronutrients dose has different value in terms of gross return under the trial(Table 10).The heist gross return (BDT 354600/ha) was recorded from the treatment combination S_1T_2 and the lowest gross return (BDT 177900/ha) was recorded from the treatment combination S_3T_0.

4.4.2 Net return per hectare

In case of net return, spacing and macronutrient dose of net return under the present trial (Table 10).The highest net return (BDT 236396 /ha) was found from the treatment combination S_1T_2 treatment. The lowest net return (BDT 68418 /ha) was obtained from S_3T_0 treatment.

4.4.3 Benefit Cost Ratio (BCR)

In the combination of spacing and macronutrient dose , the highest benefit Cost ratio (3.00) was recorded from the combination of S_1T_2 treatment (Table 10) and the second highest benefit cost ratio (2.69) was counted from the combination of S_1T_1 treatment. The lowest benefit cost ratio (1.02) was obtained from S_3T_0 treatment. From economic point of view, it is apparent from the above results that the combination of S_1T_2 treatment was better than rest of the combination in garden pea cultivation.

Table 10. Economic analysis of garden pea regarding cost of production per hectare basis

Treatment	Garden pea yield ha^{-1} (t)	Total cost of production	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
S_1T_0	9.6	112837	289800	176963	2.5
S_1T_1	10.3	115521	310500	194979	2.6
S_1T_2	11.8	118204	354600	236396	3.0
S_1T_3	10.7	120888	322800	201912	2.6
S_2T_0	7.7	110600	231000	120400	2.0
S_2T_1	8.1	113284	243000	129716	2.1
S_2T_2	8.6	115968	258900	142932	2.2
S_2T_3	8.2	118652	246300	127648	2.0
S_3T_0	5.9	109482	177900	68418	1.6
S_3T_1	6.2	112166	188700	76534	1.6
S_3T_2	6.9	114850	207300	92450	1.8
S_3T_3	6.5	117533	197700	80167	1.6

Total cost of production was done in details according to the procedure of krishitattik Fasaler utpadon O unnayan (in Bengali) 1989 by Alam (1984).

Total Cost of production = Input Cost (A) + Overhead Cost (B),

Gross return=Marketable yield × Tk ton^{-1}

Net income=Gross income – total cost of production

BCR = Gross return ÷ cost of production

S_1 = 30 cm × 10 cm, S_2 = 30 cm × 20 cm, S_3 = 30 cm × 30 cm

$T_0 = N_0P_0K_0S_0$ (control), $T_1 = N_{15}P_{25}K_{25}S_5$ (kg ha^{-1}), $T_2 = N_{30}P_{50}K_{50}S_{10}$ (kg ha^{-1}), T_3 = $N_{45}P_{75}K_{75}S_{15}$ (kg ha^{-1})

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period of November, 2018 to January, 2019. The experiment consisted of two factors. Factor A: Plant spacing (3 levels) viz. S_1 (30 cm × 10cm), S_2 (30 cm × 20 cm) and S_3 (30 cm × 30 cm) and Factor B: Macro nutrient management (4 levels), T_0 ($N_0P_0K_0S_0$ kg ha^{-1}), T_1 ($N_{15}P_{25}K_{25}S_5$ kg ha^{-1}), T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) and T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters and yield at different days after sowing (DAS) were recorded.

Plant spacing was considered as significant under the present study. On the growth parameters; plant height was highest with lower plant spacing. The highest plant height (35.1, 56.5, 79.1 and 86.09 cm at 30, 45, 60 and 75 DAS, respectively) was found from S_1 (30 cm × 10 cm) whereas the lowest plant height (25.5, 43.4, 62.7 and 70.7 cm at 30, 45, 60 and 75 DAS, respectively) was recorded from S_3 (30 cm × 30 cm). Similarly, highest number of branches plant^{-1} (4.0, 5.6, 7.1 and 8.15 at 30, 45, 60 and 75 DAS, respectively) was found from S_2 (30 cm × 20 cm) but the lowest number of branches plant^{-1} (3.3, 4.8, 6.4 and 6.8 at 30, 45, 60 and 75 DAS, respectively) was recorded from S_1 (30 cm × 10cm). Again, the highest number of pods plant^{-1} (20.44), number of seeds pod^{-1} (7.45), length of pod (6.81 cm), breadth of pod (1.47 cm), weight of 10 green pods (44.42 g), weight of green seeds plant^{-1} (18.1 g) and 100 seed weight (4.3 g) were found from S_2 (30 cm × 20 cm) but the highest percent (%) dry matter (17.6%) was found from S_3 (30 cm × 30 cm). Likewise, the highest seed yield (8.3 t ha^{-1}) and pod yield (10.5 t ha^{-1}) were found from S_1 (30 cm × 10cm). Similarly, the lowest number of pods plant^{-1} (18.2), number of seeds pod^{-1} (6.2), length of pod (5.8 cm), breadth of pod (1.3

cm), weight of 10 green pods (42.1 g), weight of green seeds plant^{-1} (17.1 g), 100 seed weight (3.7 g) and percent (%) dry matter (15.1) were recorded from S_1 (30 cm × 10 cm) whereas the lowest seed yield (6.0 t ha^{-1}) and pod yield (6.4 t ha^{-1}) was recorded from the plant spacing S_3 (30 cm × 30 cm).

Considering macro nutrient application, all the parameters among the treatments were significant. In terms of growth parameters, the highest plant height (32.1, 52.1, 75.9 and 82.9 cm at 30, 45, 60 and 75 DAS, respectively) and number of branches plant^{-1} (4.2, 5.9, 7.6 and 8.3 at 30, 45, 60 and 75 DAS, respectively) were recorded from the T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) treatment whereas the lowest plant height (27.4, 46.3, 67.4 and 75.6 cm at 30, 45, 60 and 75 DAS, respectively) and number of branches plant^{-1} (2.6, 3.8, 4.7 and 5.4 at 30, 45, 60 and 75 DAS, respectively) were observed from control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}). Regarding yield contributing parameters and yield, the highest number of pods plant^{-1} (24.7), number of seeds pod^{-1} (7.5), length of pod (7.3 cm), breadth of pod (1.5 cm), weight of 10 green pods (45.3 g), weight of green seeds plant^{-1} (19.5 g), 100 seed weight (4.32 g), seed yield (7.5 t ha^{-1}) and pod yield (9.1 t ha^{-1}) were recorded from T_2 ($N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1}) but the highest percent (%) dry matter (17.8%) was recorded from T_3 ($N_{45}P_{75}K_{75}S_{15}$ kg ha^{-1}). Similarly, the lowest number of pods plant^{-1} (14.7), number of seeds pod^{-1} (5.6), length of pod (5.4 cm), breadth of pod (1.3 cm), weight of 10 green pods (39.9 g), weight of green seeds plant^{-1} (16.3 g), 100 seed weight (3.6 g), percent (%) dry matter (15.1%), seed yield (6.0 t ha^{-1}) and pod yield (7.7 t ha^{-1}) were observed from the control treatment T_0 ($N_0P_0K_0S_0$ kg ha^{-1}).

In terms of combined effect of plant spacing and macro nutrient management, regarding growth parameters, the highest plant height (38.0, 61.2, 87.4 and 96.5 cm at 30, 45, 60 and 75 DAS, respectively) was achieved from S_1T_2 whereas the lowest plant height (23.2, 41.3, 60.7 and 68.5 cm at 30, 45, 60 and 75 DAS, respectively) was obtained S_3T_0. Again, the highest number of branches plant^{-1}

(4.8, 6.4, 8.2 and 9.2 at 30, 45, 60 and 75 DAS, respectively) was achieved from S_2T_2 whereas the lowest number of branches plant^{-1} (2.0, 3.4, 4.8 and 5.07 at 30, 45, 60 and 75 DAS, respectively) was obtained from S_1T_0. Considering yield contributing parameters and yield, the highest number of pods plant^{-1} (26.8), number of seeds pod^{-1} (8.1), length of pod (8.1 cm), breadth of pod (1.5 cm), weight of 10 green pods (46.2 g), weight of green seeds plant^{-1} (20.9 g) and 100 seed weight (5.2 g) were achieved from S_2T_2 but the highest percent (%) dry matter (20.14%) was achieved from S_3T_3 whereas the highest seed yield (9.2 t ha^{-1}) and pod yield (11.8 t ha^{-1}) were achieved from the treatment combination of S_1T_2. Similarly, the lowest number of pods plant^{-1} (13.3), number of seeds pod^{-1} (5.0), length of pod (5.0 cm), breadth of pod (1.2 cm), weight of 10 green pods (39.1 g), weight of green seeds plant^{-1} (15.3 g), 100 seed weight (3.3 g) and percent (%) dry matter (14.42%) were obtained from S_1T_0 but the lowest seed yield (4.6 t ha^{-1}) and pod yield (5.9 t ha^{-1}) were obtained from S_3T_0.

From the above result it was concluded that the treatment combination of S_1T_2 (30 cm × 10 cm) plant spacing with $N_{30}P_{50}K_{50}S_{10}$ kg ha^{-1} macro nutrients) can be considered as best treatment combinations compared to other treatment combinations in respect of yield and economic point of view.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

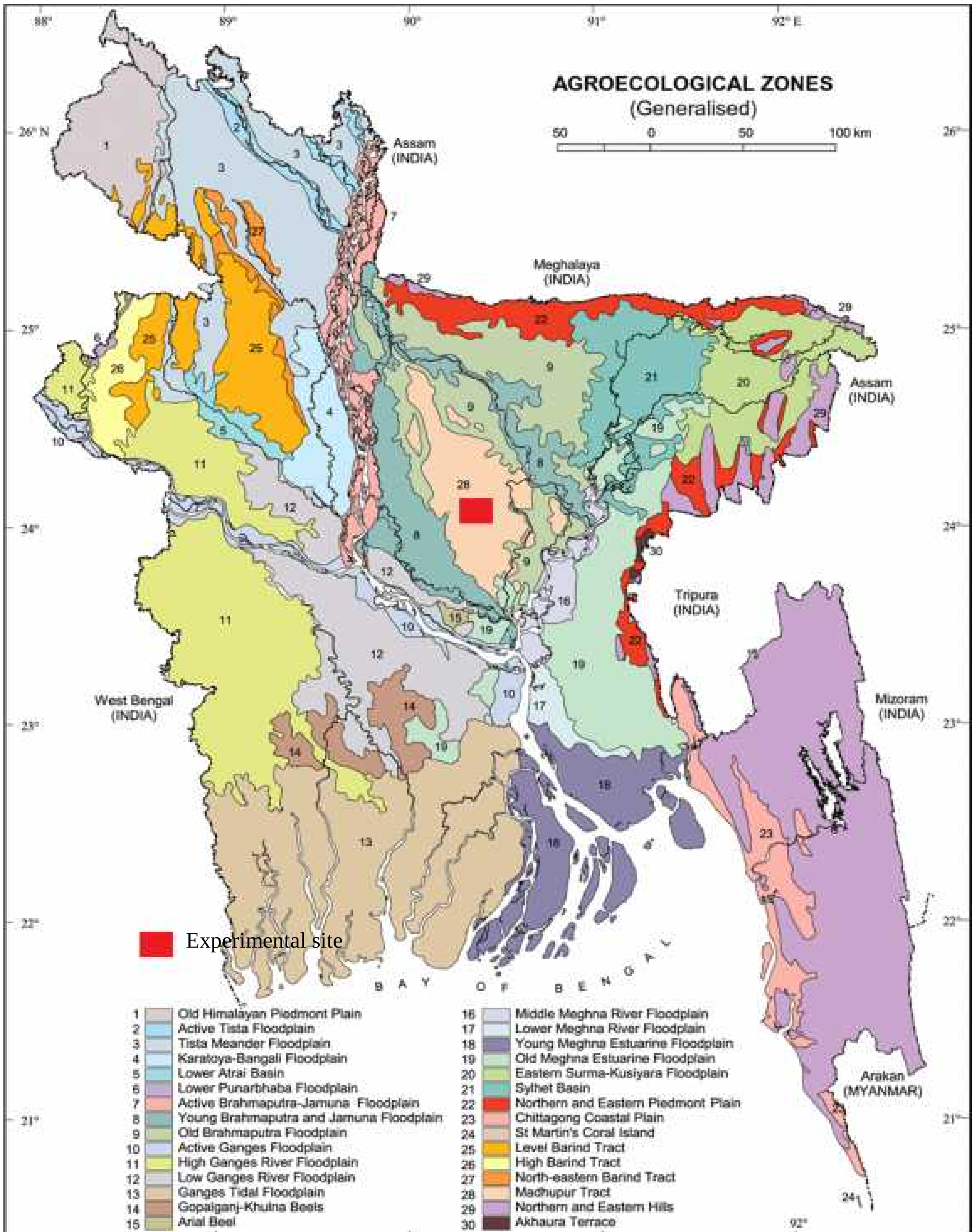


Fig. 6. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2018 to January 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	November	28.60	8.52	18.56	56.75	14.40
2018	December	25.50	6.70	16.10	54.80	0.0
2019	January	23.80	11.70	17.75	46.20	0.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Horticultural Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

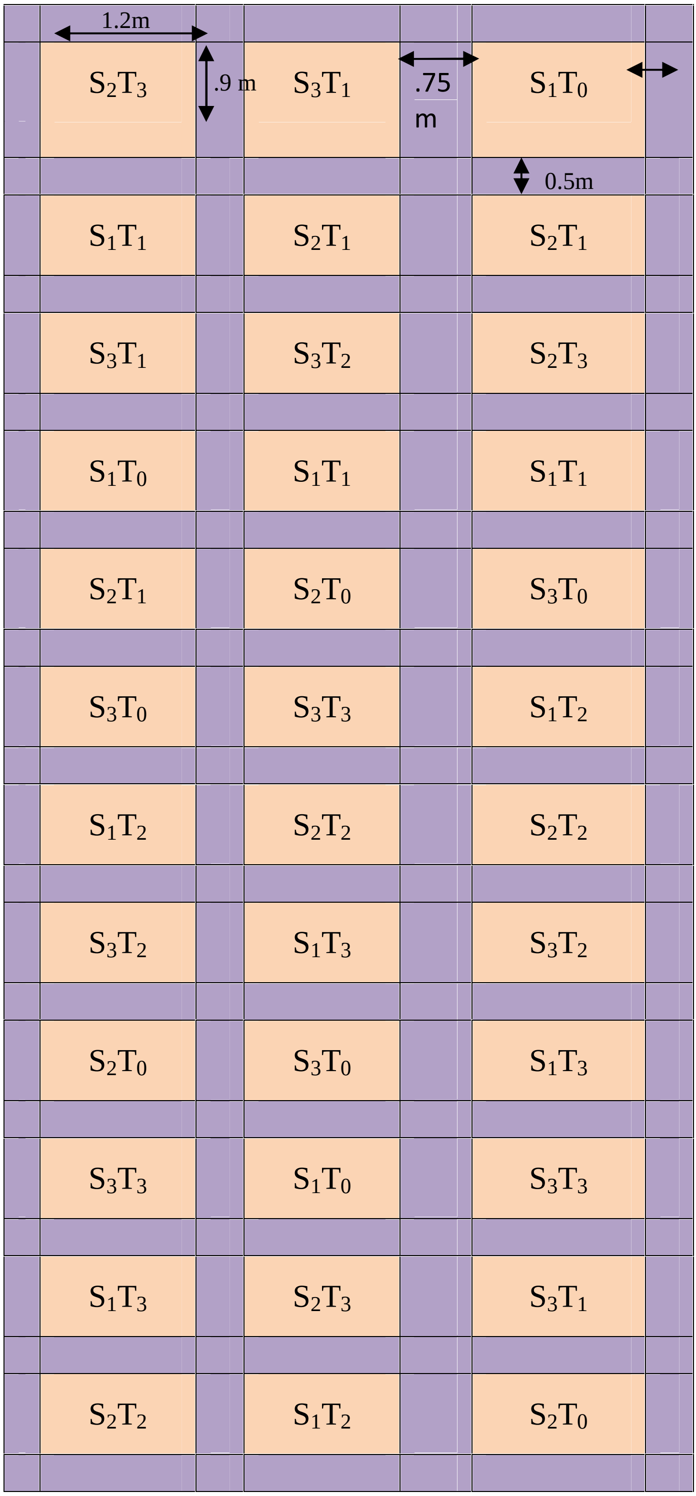
Source: Soil Resource Development Institute (SRDI)

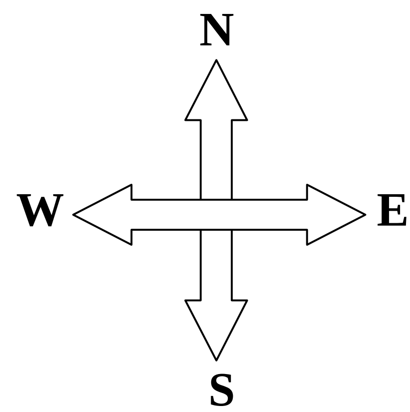
B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
P^H	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (mq/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV . Layout of the experiment field





Plot size: 1.2 m × 0.9 m

Length: 17.3 m

Breadth: 6.6 m

Area: 114.18 Square metre

Factor A: Three levels of spacing

1. $S_{1=}$ 30 cm × 10 cm
2. $S_{2=}$30 cm × 20 cm
3. $S_{3=}$30 cm × 30 cm

Factor B: Four level of macronutrients

Factor B: Macronutrient management

1. $T_0 = N_0P_0K_0S_0$ (control)
2. $T_1 = N_{15}P_{25}K_{25}S_5$ (kg ha^{-1})
3. $T_2 = N_{30}P_{50}K_{50}S_{10}$ (kg ha^{-1})
4. $T_3 = N_{45}P_{75}K_{75}S_{15}$ (kg ha^{-1})

Fig. 7. Layout of the experimental plot

Appendix V. Mean square of plant height

Source of variation	Degrees of freedom (df)	Mean Square of			
		PH30	PH45	PH60	PH75
Replication	2	0.353	0.486	3.021	0.787
Factor A (Spacing)	2	7.767**	13.380**	26.481*	44.896 **
Factor B (Treatment)	3	12.098**	17.015**	29.095*	49.280**
A x B	6	4.026*	12.704*	22.282*	19.005*
Error	22	1.152	4.713	7.458	6.046

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix VI. Mean square of branches per palnt

Source of variation	Degrees of freedom (df)	Mean Square of number of branches per plant			
		NB30	NB45	NB60	NB75
Replication	2	8.902	20.701	0.041	5.472
Factor A (Spacing)	2	87.875**	94.121**	1.262*	101.372**
Factor B (Treatment)	3	85.623**	104.005**	4.093**	125.430**
A x B	6	55.516*	78.951*	1.406*	61.426*
Error	22	17.932	31.059	0.643	21.988

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix VII. Mean square of yield contributing parameters

Source of variation	Degrees of freedom (df)	Mean Square of			
		Number of pod plant^{-1}	Pod length	Pod breadth	Wt of 10 green pod
Replication	2	249.51	2.290	2.108	0.021
Factor A (Spacing)	2	1406.03**	29.637**	64.250**	12.195**
Factor B (Treatment)	3	5201.43**	24.808**	75.811**	9.876**
A x B	6	411.14*	19.771*	35.811*	5.697**
Error	22	132.67	7.142	23.237	1.005

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix VIII. Mean square of yield and yield contributing parameters

Source of variation	Degrees of freedom (df)	Mean Square of							
		Mature wt 10 pod(g)	Seed/ plant	Num-ber of seed/ pod	Green wt 100 seed(g)	Green pod kg/plot	Green pod ton/ha	Seed g/plot	Seed ton/ha
Replication	2	9.99	443.5	0.18	1.20	0.45	1.00	2.55	2.32
Factor A (Spacing)	2	97.01**	24.3**	1.50**	21.68**	44.71*	58.21**	98.93**	33.38**
Factor B	3	82.57**	450.2**	1.25**	78.06**	25.98*	25.51**	89.95**	29.18*
A x B	6	44.30*	64.8**	1.48**	10.93**	14.35*	23.41*	48.76*	20.60*
Error	22	15.54	535.4	0.19	1.91	3.45	4.13	15.44	6.86

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix IX . Mean square of yield contributing parameters

Source of variation	Degrees of freedom (df)	Mean Square of	
		Dry wt 100 seed	Dry matter of 100 g plant(%)
Replication	2	34.17	23.04
Factor A (Spacing)	2	124.40**	126.64**
Factor B (Treatment)	3	101.87**	113.00**
A x B	6	98.16*	59.75*
Error	22	26.97	19.45

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix X: Cost of production of garden pea

A. Input cost (Tk. ha-1)

Treatments	Labor cost	Ploughing cost	Seed cost	Sowing cost	Irrigation	Fertilizer				Subtotal A
						N	P	K	S	
S_1T_0	10000	7000	6000	12000	4000	0	0	0	0	39000
S_1T_1	10000	7000	6000	12000	4000	700	800	600	300	41400
S_1T_2	10000	7000	6000	12000	4000	1400	1600	1200	600	43800
S_1T_3	10000	7000	6000	12000	4000	2100	2400	1800	900	46200
S_2T_0	10000	7000	4000	12000	4000	0	0	0	0	37000
S_2T_1	10000	7000	4000	12000	4000	700	800	600	300	39400
S_2T_2	10000	7000	4000	12000	4000	1400	1600	1200	600	41800
S_2T_3	10000	7000	4000	12000	4000	2100	2400	1800	900	44200
S_3T_0	10000	7000	3000	12000	4000	0	0	0	0	36000
S_3T_1	10000	7000	3000	12000	4000	700	800	600	300	38400
S_3T_2	10000	7000	3000	12000	4000	1400	1600	1200	600	40800
S_3T_3	10000	7000	3000	12000	4000	2100	2400	1800	900	43200

A= input cost (Tk ha^{-1})

B. Overhead cost (Tk. ha-1), Cost of production (Tk. ha-1), Gross return (Tk. ha-1), Net return (Tk. ha-1) and BCR

Treatments	Overhead cost (Tk. ha^{-1})				Subtotal (A)	Total cost of production (A+B)	Garden pea yield ha^{-1} (t)	Gross return (Tk.ha^{-1})	Net return (Tk. ha^{-1})	BCR
	Cost of leased land for 6 months (13% of value of land Tk. 10,00,000/-	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 month (13% of cost $year^{-1}$)	Subtotal (B)						
S_1T_1	65000	2070	7051	74120.55	41400	115521	10.35	310500	194979	2.69
S_1T_2	65000	2190	7214	74404.35	43800	118204	11.82	354600	236396	3.00
S_1T_3	65000	2310	7378	74688.15	46200	120888	10.76	322800	201912	2.67
S_2T_0	65000	1850	6750	73600.25	37000	110600	7.70	231000	120400	2.09
S_2T_1	65000	1970	6914	73884.05	39400	113284	8.10	243000	129716	2.15
S_2T_2	65000	2090	7078	74167.85	41800	115968	8.63	258900	142932	2.23
S_2T_3	65000	2210	7242	74451.65	44200	118652	8.21	246300	127648	2.08
S_3T_0	65000	1800	6682	73482	36000	109482	5.93	177900	68418	1.62
S_3T_1	65000	1920	6846	73765.8	38400	112166	6.29	188700	76534	1.68
S_3T_2	65000	2040	7010	74049.6	40800	114850	6.91	207300	92450	1.80
S_3T_3	65000	2160	7173	74333.4	43200	117533	6.59	197700	80167	1.68

Total cost of production was done in details according to the procedure of krishitattik Fasaler utpadon O unnayan (in Bengali) 1989 by Alam (1984).Total Cost of production = Input Cost (A) + Overhead Cost (B),

Gross return = Marketable yield × Tk $ton^{-1.}$ Net income = Gross income – Total cost of production

BCR = Gross return ÷ cost of production.