EFFECT OF PHOSPHORUS AND PLANT SPACING ON THE GROWTH AND YIELD OF LETTUCE

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Phosphorus and Plant Spacing on the Growth and Yield of Lettuce"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **Ashik Alahi**, Registration No. **04-01474** 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.

Dated: 30/08/2010
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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2008 to February 2009 to find out the effect of phosphorus and plant spacing on the growth and yield of lettuce. The experiment consisted of two factors, such as factor A: 4 levels of phosphorus P_0: 0 kg P_2O_5/ha; P_1: 24 kg P_2O_5/ha; P_2: 48 kg P_2O_5/ha and P_3: 72 kg P_2O_5/ha; factor B: 3 levels of plant spacing; S_1: 40 × 20 cm, S_2: 40 × 25 cm; S_3: 40 × 30 cm. The experiment was laid out in a Randomized Complete Block Design with three replications. Data on growth, yield contributing characteristics and yield were recorded. At 30, 40, 50 and 60 DAT all the highest value of growth parameter and the yield per hectare (5.31 ton, 6.03 ton, 6.61 ton and 7.06 ton) was recorded from P_3. At 30, 40, 50 and 60 DAT the tallest plant was recorded from S_1, maximum number of leaves per plant was recorded from S_2 and the highest yield per hectare (4.58 ton, 5.33 ton, 6.07 ton and 6.51 ton) was observed from S_2. At 30, 40, 50 and 60 DAT highest value for plant height was recorded from P_3S_1 and maximum number of leaves per plant was found from the treatment combination of P_3S_2. The highest yield per hectare (5.95 ton, 6.49 ton, 7.26 ton and 7.68 ton) and the highest benefit cost ratio (2.08) was recorded from P_3S_2 and the lowest was observed from P_0S_3 respectively. So the best results were obtained from the treatment receiving 72 kg P_2O_5/ha with plant spacing 40 × 25 cm.

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LIST OF ABBREVIATED TERMS

ABBREVIATION	FULL NAME
AEZ	Agro-Ecological Zone
et al.	and others
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
°C	Degree Celsius
etc.	Etcetera
FAO	Food and Agriculture Organization of The United Nations
g	Gram
ha	Hectare
kg	Kilogram
mm	Millimeter
MP	Muriate of Potash
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
m^2	Square meter
TSP	Triple Superphosphate
DAT	Days After Transplanting
LSD	Least Significant Difference
CV	Coefficient of Variance

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Lettuce (*Lactuca sativa* L.*)* is annual leafy herb belonging to the family Compositae is one of the most popular salad crops and occupies the largest production area among salad crops in the world. It is popular for its delicate, crispy, texture and slightly bitter taste with milky juice at fresh condition. Lettuce is mainly a cold loving crop and the best temperature for cultivation is 18^0C to 25^0C and the night temperature is 10^0C to 15^0C (Ryder, 1998). It produces a short stem early in the winter season, a cluster of leaves varying considerably in shape, character and colour in different varieties. Lettuce is originated from the Southern Europe and the Western Asia (Rashid, 1999). It mainly grows in temperate regions and in some cases in the tropic and sub-tropic regions of the world. Lettuce is largely produced in the greenhouse in temperate region (Lindquist, 1960).

Lettuce is rich in vitamin A and minerals like calcium and iron. It also contains protein, carbohydrate and vitamin C and in 100 g of edible portion of lettuce contains moisture 93.4 g, protein 2.1 g, fat 0.3 g, minerals 1.2 g, fibre 0.5 g, carbohydrates 2.5 g, calcium 310 mg, phosphorus 80 mg, iron 2.6 mg, vitamin A 1650 I.U., thiamine 0.09 mg, riboflavin 0.13 mg and vitamin C is about 10.0 mg (Gopalan and Balaraman, 1966). It is usually used as salad with tomato, carrot, cucumber or other salad vegetables and often served alone or with dressing. Its nutritive value is not spoiled. Moreover, it is also known as anodyne, sedative, diuretic and expectorant (Kallo, 1986).

Lettuce is a newly introduced crop in our country and getting popularity day by day but its production package is not much known to the Bangladeshi farmers. Among various factors responsible for higher yield, supply of nutrient and production technology play vital role in the production and quality of lettuce. Deficiency of soil nutrient is now considered as one of the major constraints to

successful upland crop production in Bangladesh (Islam and Noor, 1982). The cultivation of lettuce requires proper supply of plant nutrient. Lettuce responds greatly to major essential elements like N, P and K in respect of its growth and yield (Singh *et al*., 1976; Thompson and Kelly, 1988). Its production can be increased by adopting improved management practices.

Fertilizer plays a vital role in proper growth and development of lettuce. Fertilizer application in appropriate time, appropriate dose and proper method is the prerequisite of crop cultivation (Islam, 2003). Generally, chemical fertilizers increase the growth and yield but excessive application of chemical fertilizers in crop production causes health hazards, create problem to the environment including the pollution of soil, air and water. The effect of phosphorus on the formation and translocation of carbohydrates, leaf and root development, reproductive growth and other agronomic characters are well recognized in leafy vegetables. Phosphorus induces earliness in flowering and maturity. Phosphorus also makes its contribution through its favorable effect on flowering and fruiting of lettuce (Buckman and Bradey, 1980).

Plant spacing for lettuce cultivation is an important criterion for attaining maximum vegetative growth and an important aspect of crop production for maximizing the yield. Optimum plant spacing ensures judicious use of natural resources and makes the intercultural operations easier. It helps increase the number of leaves, branches and healthy foliage. Densely planted crop obstruct the proper growth and development. On the other hand, wider spacing ensures the basic nutritional requirements but decrease the total number of plants as well as total yield. Yield may be increased for any crop upto 25% by using optimum spacing in leafy vegetable (Bansal, *et al*., 1995). In Bangladesh, like other management practices, information about plant spacing to be used in lettuce cultivation is insufficient. The farmers of Bangladesh cultivate this crop according to their own choice due to the absence or unavailability of standard production technique. As a result, they do not get satisfactory yield and return from investment.

Considering the above factors, the present experiment was undertaken to study the following objectives-

i. to estimate the effect of phosphorus fertilizer for the growth and development of lettuce
ii. to determine the effect of plant spacing on the growth and development of lettuce
iii. to find out the better combination of phosphorus and plant spacing for the production of lettuce.

Chapter II
Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Lettuce is one of the most important and popular salad vegetables in Bangladesh as well as many countries of the world. The crop has got conventional less concentration by the researchers on various aspects because it is newly introduced crop. A very few studies on the growth and yield of lettuce have been carried out in our country as well as many other countries of the world. Therefore, the research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important informative works and research findings related to phosphorus and plant spacing on lettuce so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.1 Effect of phosphorus on growth and yield of lettuce

An experiment was conducted by Zaman *et al*. (2006) to determine the effect of nitrogen and phosphorus fertilizers (0, 50 and 100 kg P_2O_5/ha) on the productivity of lettuce in terms of leaf and seed yield at Banghabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur, Bangladesh, during November 2000 to April 2001. They reported that the application of phosphorus at the rate of 100 kg/ha significantly increased leaf yield. The interaction effect of nitrogen and phosphorus on leaf yield and yield components was significant. The treatment $N_{100}P_{100}$ produced maximum seed yield (390 kg/ha).

To evaluate the response of lettuce (*Lactuca sativa* L.) to P fertilization in fields with elevated STP levels, 12 trials were conducted during 2002-03 by Johnstone *et al*. (2005). In each trial, four replicate plots receiving the growers' P application were compared with paired plots in which no P was applied. Leaf P was monitored at mid-season and at harvest. At harvest, mean whole and marketable plant mass and percent of marketable plants were recorded. A significant increase in lettuce yield with P fertilization was achieved at only

one trial site, a spring planting with 54 mg/kg P_2O_5; at all other sites, including three with 60 mg/kg P_2O_5, P application resulted in no significant yield increase. Phosphorus application resulted in only a marginal increase in plant P uptake; in the non-responsive fields leaf P concentration of non-fertilized plots was in excess of established sufficiency levels.

An experiment was carried out by Souza *et al*. (2005) from July to September 1996, in Mossoro, Rio Grande do Norte State, Brazil, to evaluate the effect of organic compost on chemical characteristics of lettuce leaves at the second successive cultivation. The first factor consisted of doses of organic compost: 0, 40, 80, 120 and 160 t/ha and the second factor consisted of the presence or absence of mineral fertilizers: 300, 500 and 150 kg/ha of ammonium, simple superphosphate and potassium chloride, respectively. The protein, phosphorus, potassium and magnesium contents in lettuce leaves increased with the doses of organic compost. There was no significant interaction between doses of organic compost and doses of mineral fertilizer on the evaluated traits.

Xu *et al*. (2004) conducted an experiment to assess the effects of fertilization frequency on plant phosphorus and water uptake. Special attention was given to root measurement in order to elucidate the mechanism that relates the fertilization frequency to P uptake and plant growth. Lettuce (*Lactuca sativa* L., cv. Iceberg) grown in pots filled with quartz sand was chosen as a test plant. The experiment comprised six treatments, with two concentrations of P in irrigation water (0.2 mM and 1.0 mM), and three daily fertilization frequencies (one, four and ten). It was found that high irrigation frequency induced a significant increase in plant-P concentration at low solution-P concentration, whereas at high P concentration the effect of irrigation frequency was insignificant. The increases with irrigation frequency of P concentration in lettuce organs and of P influx to the roots, at the low P level, were attributed to the elimination of the depletion zone at the root-soil interface by the supply of fresh nutrient solution, and the enhancement of P uptake.

The response of the lettuce crop to sources of soluble and reactive P fertilizers with slow solubility was evaluated in the presence of liming by Lana *et al.* (2004). The treatments comprised: single superphosphate; thermalphosphate magnesium; triple superphosphate; Fosmag; Arad phosphate rock; and control (without phosphorus). P suppression, yield and plant diameter indicate, as well as all other variables related to plant growth, the importance of P for lettuce development. Significant responses to different P sources were also observed for fresh and dry matter production of aerial parts, fresh mass of roots and level of P in the soil. Best responses in decreasing order were obtained for Fosmag, triple superphosphate, single superphosphate, thermalphosphate magnesium and Arad phosphate rock match sources. Fosmag and triple superphosphate were equivalent for production of root dry mass and diameter of the aerial part.

Lei *et al.* (2004) revealed that the rules of nitrate accumulation in Dian Lake drainage area in intensive cultivation were studied. The effects of P on NO_3 accumulation in soil differ from crops to crops. The fertilizer P input evidently influenced the accumulation of NO_3 in the soil of cultivating pimiento [*Capsicum annuum*], and the increase of fertilizer P input decreased NO_3 accumulation. The effects of P on NO_3 accumulation were different according to the changes of N input. No evident effects were observed on the NO_3 accumulation in the soil of cultivating lettuce with P input.

The effect of different rates and sources of phosphorus on crisphead lettuce production was evaluated in an experiment conducted by Mota *et al.* (2003) in Santo Antonio do Amparo, Minas Gerais, Brazil, from June to September 1998. Treatments comprised: two sources of phosphorus as simple superphosphate (18% P_2O_5) and magnesium thermophosphate (17% P_2O_5) at 4 rates (0, 300, 600 and 900 kg/ha). The total and commercial yields of lettuce, stem length and the circumference of the heads were evaluated. Significant effects among rates and sources were observed for the total and commercial yields. With magnesium thermophosphate, the yield linearly increased. Using 583 kg P_2O_5/ha resulted in a greater stem length (6.75 cm) without impairing

the commercial value. Rates and sources of phosphorus had no significant effects on head circumference.

Wijk (2000) described the results obtained in trials with early head lettuce, cultivated in soils with different 4 levels of phosphorus status combined with 2 rates of P fertilizer dressing, during 1996-98 in Netherlands. The best rate of P fertilizer dressing was strongly linked to the P status of the soil and the cultivation method because of the strong phosphate requirement of lettuce. There was a big response to phosphate fertilization on soils with a low P level regarding yield and yield contributing characters.

Tisselli (1999) reported that maximum rates of organic manure (usually poultry manure) and NPK recommended in 1998 by the crop for use in lettuce crops in Emilia-Romagna, Italy were tabulated. Trials showed that a combination of organic and mineral fertilizers gave higher yield of marketable heads, fewer rejects and a better average weight/head than only mineral.

Sajjan *et al.* (1998) observed that with the application of 150, 75 and 75 kg N, P_2O_5 and K_2O, respectively per ha, under protective irrigated conditions, led to the production of high quality lettuce cv. 'Great Lakes' seeds in terms of germination percentage, root length, shoot length, seedling dry matter accumulation, 1000-seed weight and seedling vigour index.

Bastelaere and Van (1998) stated that different fertilizer treatments with ammonium nitrate (3.5-8 kg/acre), patent potassium (3.5-8 kg/acre) and triple superphosphate (3.65 kg/acre) were carried out during 1997-98 in 6 green houses with lettuce (cvs. 'Completo', 'Alfredo', 'Omega' and 'Samir') in Belgium. Soil analysis was carried out before and after fertilizer applications and at harvest. Ten out of 12 trials showed the greatest crop weights and better crop quality in treatments with equal amounts of ammonium nitrate and patent potassium. Lower crop weights occurred in the treatment with standard fertilizer plus Papaver (46 kg/acre).

Vidigal *et al.* (1997) mentioned that dried pig manure gave the highest yield at 65 days after sowing (54.4 t/ha), an increase of 33.3% above those supplied with NPK, with similar results in a succeeding crop planted on the same ground in late September (39.4% increase over NPK). Napier grass + coffee straw + pig slurry was the best mixture, increasing yields 10.8% and 17.6% above those produced by NPK in 1st and 2nd crops, respectively.

Sanchez and Hout (1995) conducted four field experiments in Florida to compare the relative responses of different lettuce types to P fertilizer application. P was applied at 0, 50, 100, 200 and 300 kg/ha as triple super phosphate. All lettuce types showed large yield and quality responses to P fertilizer because environmental conditions affected yield potential. P rate required for optimal yield varied for lettuce types across experiments.

Hochmuth *et al.* (1994) carried out a field trial in Gainesville, USA in spring 1994, in which crisphead lettuce cv. 'Desert Queen' Plants were grown on beds covered with a polythene mulch and drip system. Yield and yield contributing characters were greatly influenced by P fertilizer under field conditions. P fertilizer application did not increase quality.

Karacal and Turetken (1992) carried out an experiment on the cultivation of lettuce cv. 'Lital' in Turkey. N as ammonium sulphate, ammonium nitrate or urea was applied at 24 kg/da and P (as triple super phosphate) was applied at 0, 8, 16, or 24 kg/da. Average head weight was 497 g for lettuces that received ammonium sulphate, compared with 358 g for those grown without N fertilizer (1 dounum = 2500 m^2).

Sajjan *et al.* (1992) studied that the response of lettuce cv. 'Great lakes' to different dates of transplanting (20 July, 20 August and 20 September) and levels of fertilizer (50:25:25, 75:25:25, 100:50:50, 125:50:50, 150:75:75, and 175:75:75 kg N, P_2O_2 K_2O/ha) during 1988-89. The treatment receiving 175:75:75 kg N, P_2O_5, K_2O/ha gave the highest seed yield and interaction was significant. Significant increase in number of branch/plant, number of

capsule/plant, number of seed/capsule and 1000 seed weight contributed to seed yield.

Rubeiz *et al.* (1992) mentioned that the lack of significant response in yield was due to sufficient levels of soil NO_3-N and available P in the untreated soil. Manure or fertilizer application had no effect on soil EC, pH or available P. Leaf PO–P concentration was not affected by treatments, but leaf NO_3-N at heading was significantly increased by all treatments.

Sajjan *et al.* (1991) reported that seedlings of the lettuce cultivar 'Great Lakes', planted in a sandy clay soil 'in July, Aug. or Sep., received N, P and K at 6 different rates. Data were tabulated on fresh weight in g/plant and head yield in t/ha. The highest yield (17 t/ha) was obtained from plants transplanted on 20 Sep. and fertilized with N at 175, P at 75 and K at 75 kg/ha.

Wilson (1976) conducted an experiment with winter lettuce in which phosphorus was applied at 100, 200 and 300 kg/ha. He noted that maturity was advanced and the yield was increased by higher rates of P.

2.2 Effect of plant spacing on growth and yield of lettuce

A field experiment was conducted by Moniruzzaman (2006) with three levels of spacing (40 × 20 cm, 40 × 30 cm and 40 × 40 cm) and two levels of mulching (mulch and non-mulch) to find out the effect of plant spacing and mulching on yield and profitability of lettuce cv. 'Green Wave' at the Agricultural Research Station, Raikhali. Rangamati Hill District for the two consecutive years during 1999-'00 and 2000-'01. Plant spacing, mulching and their interaction showed significant effect on yield and yield components of lettuce. The highest fresh yield of lettuce was obtained from the closest spacing (40 × 20 cm) that was statistically similar to that recorded of medium spacing (40 × 30 cm) during both the years. The highest yield (25.9 t/ha in 1999-'00 and 28.3 t/ha in 2000-'01 with an average of 27.10 t/ha) was observed in the spacing of 40 × 20 cm with mulch, which was statistically at par with the spacing of 40 × 30 cm with mulch. The results also revealed that higher gross

return (Tk. 216,800) was obtained from the closest spacing in combination with mulch followed by medium spacing (40 × 30 cm) with mulch (Tk. 210,160). The treatment combination of 40 × 30 cm spacing and mulching gave the highest benefit cost ratio (8.84). But the benefit cost ratio (4.22) from the treatment combination of 40 × 20 cm spacing and mulching was less due to the involvement of higher seedling cost.

The effects of spacing, hoeing and mulching on the yield and quality of lettuces under integrated control were determined by Petrikova and Pokluda (2004). Marketable lettuce yields reached 82-99%. Planting density, cultivar and mulching affected the quality of lettuce heads. The quality of lettuce heads were determined by the cultivar, as well as by mulching and hand hoeing. The size of lettuce heads were positively correlated with loose spacing.

A field experiment was carried out by Sodkowski and Rekowska (2003) in Szczecin, Poland during 1998-2000 to study the effects of cultivation method and mulching. The spacing between plants was 25 × 30 cm. The cultivation period was reduced by 8 days on average in the case of direct sowing, and by 3 days in plants cultivated from seedlings produced in the seedbed and the highest yield (6.50 kg/m^2) of crisp lettuce was obtained with this treatment.

Steingrobe and Schenk (1994) reported that seeds of lettuce cv. 'Clarion' were sown in 4 × 4 cm peat blocks and seedlings were planted out 3 weeks later at a spacing of 30 x 30 cm. Seedlings received different amounts of N fertilizer before and after planting. They found that N application increased root growth in the first 3 weeks after planting out, but had no effect on yield.

EL-Hassan, (1990) had grown lettuce cv. 'Dark Green' lettuce on experimental plot in Cairo in the winter seasons of 1987 and 1988. The effects of various planting systems and application of 20 or 40 kg N/feddan (1 feddan = 0.42 ha) on head weight, dry matter content and N content were recorded. The higher N rate and wide spacing (30 cm) gave greater head weight, % dry matter, total N (%) in dry matter and NO_3-N content in fresh leaf midribs. The highest total

and saleable yields and the highest total dry matter content were achieved with the higher N rate, spacing at 10 cm and planting on both sides of the planting ridges.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2008 to February 2009 to find out the effect of phosphorus and plant spacing on the growth and yield of lettuce. The materials and methods that were used for conducting the experiment are presented under the following headings:

3.1 Experimental site

The present experiment was carried out in the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^0 74'$N latitude and $90^0 35'$E longitude and at an elevation of 8.2 m from sea level (Anon., 1989).

3.2 Climate

The climate of the experimental site was subtropical, characterized by three distinct seasons; the winter season from November to February, the pre-monsoon or hot season from March to April and the monsoon season from May to October (Edris *et al*., 1979). Details of the meteorological data during the period of the experiment were collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix I.

3.3 Characteristics of soil

The soil of the experimental area belonging to the Modhupur Tract (UNDP, 1988) under AEZ No. 28. It had shallow red brown 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 and details of the recorded soil characteristics were presented in Appendix II.

3.4 Planting materials

Seeds of lettuce cultivar, 'Grand Raphids' were used in the experiment and the seeds were collected from a commercial seed trader named Manik seed traders, Siddique Bazar, Dhaka.

3.5 Treatment of the experiment

The experiment was conducted to find out the effects of phosphorus and plant spacing on lettuce. The experiment consisted of two factors.

Factor A: 4 levels of phosphorus

i. P_0: 0 kg P_2O_5/ha (Control)
ii. P_1: 24 kg P_2O_5/ha
iii. P_2: 48 kg P_2O_5/ha
iv. P_3: 72 kg P_2O_5/ha

Factor B: 3 levels of plant spacing

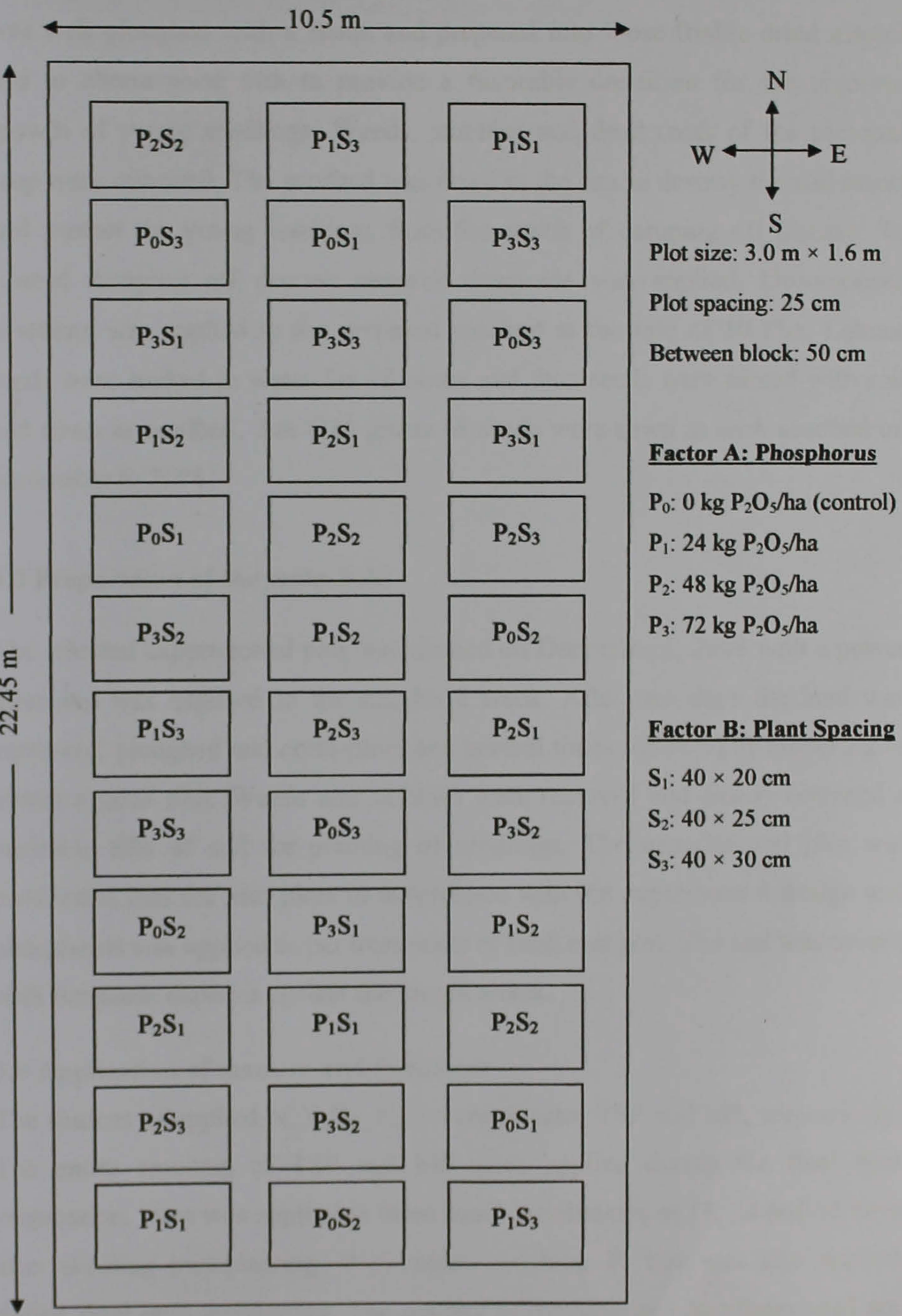
i. S_1: 40 × 20 cm
ii. S_2: 40 × 25 cm
iii. S_3: 40 × 30 cm

There were 12 treatment combinations such as P_0S_1, P_0S_2, P_0S_3, P_1S_1, P_1S_2, P_1S_3, P_2S_1, P_2S_2, P_2S_3, P_3S_1, P_3S_2 and P_3S_3.

3.6 Experimental design and layout

The two factors Randomized Complete Block Design (RCBD) experiment was laid out with three replications. An area of 22.45 m × 10.5 m was divided into three equal blocks. Each block was divided into 12 plots where 12 treatment combinations were allotted at random. There were 36 unit plots and the size of the each unit plot was 3.0 m × 1.6 m. The distance maintained between two blocks and two plots were 0.5 m and 0.25 m, respectively. The seeds were sown with maintaining row to row distance 40 cm and plant to plant distances

20 cm, 25 cm and 30 cm as per plant spacing treatment. The layout of the experiment is shown in Figure 1.



Plot size: 3.0 m × 1.6 m

Plot spacing: 25 cm

Between block: 50 cm

Factor A: Phosphorus

P_0: 0 kg P_2O_5/ha (control)

P_1: 24 kg P_2O_5/ha

P_2: 48 kg P_2O_5/ha

P_3: 72 kg P_2O_5/ha

Factor B: Plant Spacing

S_1: 40 × 20 cm

S_2: 40 × 25 cm

S_3: 40 × 30 cm

Figure 1. Layout of the experimental plot

3.7 Raising of seedlings

The seedlings were raised at the Sher-e-Bangla Agricultural University farm, Dhaka under special care in a 3 m × 1 m size seedbed. The soil of the seedbed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease cupravit fungicide was applied. Decomposed cowdung was applied to the prepared seedbed at the rate of 10 t/ha. Lettuce seeds were soaked in water for 48 hours and then seeds were mixed with soil and sown in seedbed. Ten (10) grams of seeds were sown in each seedbed on November 6, 2008.

3.8 Preparation of the main field

The selected experimental plot was opened on December 1, 2008 with a power tiller and was exposed to the sun for a week. After two days the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil for planting of seedlings. The experimental plot was partitioned into the unit plots in accordance with the experimental design and phosphorus was applied as per treatments of each unit plot. The soil was treated with fungicide cupravit against the fungal attack.

3.9 Application of manure and fertilizers

The sources of applied N, P_2O_5, K_2O were as urea, TSP and MP, respectively. The entire amounts of TSP and MP were applied during the final land preparation. Urea was applied in three equal installments at 15, 30 and 45 days after seedling transplanting. Well-rotten cowdung 10 t/ha was also applied during final land preparation. The amount of manures and fertilizers used are shown in table 1 as recommended by Rashid (1993).

Table 1. Dose and method of application of fertilizers in lettuce field

Fertilizers/ Manure	Dose/ha	Application (%)			
		Basal	15 DAT	30 DAT	45 DAT
Cowdung	10 tons	100	--	--	--
Urea	200 kg	--	33.33	33.33	33.33
TSP	As per treatment	100	--	--	--
MP	125 kg	100	--	--	--

3.10 Transplanting of seedlings in the main field

Healthy and uniform sized seedlings were transplanted in the main field on December 6, 2008. The seedlings were uprooted carefully from the seedbed to avoid any damage to the root system. To minimize the root damage of the seedlings, the seedbed was watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. A considerable number of seedlings were also planted in the border of the experimental plots for gap filling.

3.11 Intercultural operation

When the seedlings established in the beds it was always kept under careful observation. Various intercultural operations viz. irrigation and drainage, gap filling, weeding, top dressing were accomplished for better growth and development of seedlings.

3.11.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after transplanting in every alternate day in the evening upto the 1st harvest. Further irrigation was done as and when needed. Stagnant water was effectively drained out at the time of excess irrigation.

3.11.2 Gap filling

Gap filling was done after six days of transplanting from border side transplanted plant.

3.11.3 Weeding

Weeding was done to keep the plots free from weeds, easy aeration of soil, which ultimately ensured better growth and development. Breaking the crust of the soil was done when needed.

3.11.4 Top dressing

Urea was top-dressed in three equal installments. The fertilizers were applied on both sides of plant rows and mixed well with the soil by hand. Earthing up was done with the help of nirani immediately after top-dressing of nitrogen fertilizer.

3.12 Plant protection

For controlling leaf caterpillars, Nogos @ 1 ml/L water were applied two times at an interval of 10 days starting soon after the appearance of infestation. No remarkable attack of disease was found in lettuce field under study.

3.13 Harvesting

To evaluate yield, four harvesting were done at different growth stages. First harvesting was done at 30 days after transplanting. Second, third and fourth harvesting were done at 40, 50 and 60 days after transplanting, respectively. Different yield contributing data have been recorded from the mean of five harvested plants which were selected at random of each unit plot of every harvesting stage.

3.14 Data collection

Data were recorded on the following parameters from the sample plants during the course of experiment. Five plants were randomly selected from each unit plot for the collection of data. The plants in the outer rows and the extreme end

of the middle rows were excluded from the random selection to avoid the border effect.

3.14.1 Plant height

Plant height was recorded in centimeter (cm) at 30, 40, 50 and 60 days after transplanting (DAT) by using measuring tape. The height was measured from the attachment of the ground level up to the tip of the growing point.

3.14.2 Number of leaves per plant

The total number of leaves per plant was counted. Data were recorded as the average of five plants selected at random from the inner rows of each plot starting from 30 to 60 DAT at 10 days interval.

3.14.3 Length of leaf

The length of leaf was measured by using a meter scale. The measurement was taken from base to tip of the leaf. Average length of leaves was taken from five randomly selected plants from inner rows of each plot. Data were recorded from 30 to 60 DAT at 10 days interval. Mean was expressed in centimeter.

3.14.4 Breadth of leaf

Breadth of leaf was recorded as the average of five leaves selected at random from the plant of inner rows of each plot starting from 30 to 60 DAT at 10 days interval. Thus mean was recorded and expressed in centimeter.

3.14.5 Yield of leaves per plant

Leaves of five randomly selected plants were detached by a sharp knife and fresh weight of leaves was recorded and expressed in gram. Data were recorded as the average of 5 randomly selected plants of inner rows of each plot starting from 30 to 60 DAT at 10 days interval.

3.14.6 Dry matter content in plant

After harvesting, 150 g of leaf sample previously sliced into very thin pieces were put into envelop and placed in oven and dried at 60^0C for 72 hours and it

was observed until constant weight. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight was taken. The dry matter contents of leaves were computed by simple calculation from the weight recorded by the following formula

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

3.14.7 Yield per plot

Yield of lettuce per plot was recorded as the whole plant in every harvest within a plot and was expressed in kilogram. Yield included weight of leaves at different harvesting time.

3.14.8 Yield per hectare

Yield per hectare of lettuce was calculated by converting the weight of plot yield to hectare and was expressed in ton.

3.15 Statistical Analyses

The data obtained for different parameters were statistically analyzed to find out the significance difference of phosphorus fertilization and plant spacing on yield and yield contributing characters of lettuce. The mean values of all the attributes studied were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.16 Economic analyses

The cost of production was analyzed in order to find out the most economic treatment of phosphorus and plant spacing. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 13% in simple rate. Analysis was done according to the procedure of Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio} = \frac{\text{Net return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was carried out to find out the effect of phosphorus fertilization and plant spacing on the growth and yield of lettuce. Data on different growth parameters and yield of lettuce plant were recorded and the analysis of variance (ANOVA) of the data on different growth parameters and yield of lettuce are presented in Appendix III-VI. The results have been presented and discussed, and possible interpretations are given under the following headings:

4.1 Plant height

Plant height of lettuce varied significantly due to the application of different levels of phosphorus at 30, 40, 50 and 60 DAT (Appendix III). At 30, 40, 50 and 60 DAT the tallest plant (17.66 cm, 22.52 cm, 28.08 cm and 29.96 cm) was recorded from P_3 which was statistically similar (17.42 cm, 22.05 cm, 27.23 cm and 29.29 cm) to P_2. Again, the shortest plant (10.41 cm, 12.84 cm, 18.23 cm and 20.33 cm) was observed from P_0 (Table 2). It was revealed that with the increase of the level of phosphorus plant height increased upto a certain level. Phosphorus fertilizer ensured favorable condition for the cell division and helped the elongation of lettuce plant with optimum vegetative growth and the ultimate result was the tallest plant. Mota *et al*. (2003) reported significant response on plant height of lettuce.

Lettuce plant height showed statistically significant variation due to different plant spacing at 30, 40, 50 and 60 DAT (Appendix III). At the different days after transplanting (DAT), the tallest plant (15.84 cm, 20.24 cm, 25.90 cm and 27.49 cm) was recorded from S_1 which was closely followed (14.54 cm, 18.70 cm, 24.28 cm and 26.33 cm) by S_2. On the other hand, at the same DAT the shortest plant (13.35 cm, 17.03 cm, 21.35 cm and 23.31 cm) was found from S_3 (Table 2).

Table 2. Main effect of phosphorus fertilization and plant spacing on plant height and number of leaves per plant of lettuce

Treatments	Plant height (cm) at				Number of leaves per plant at			
	30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Phosphorus fertilizer								
P_0	10.41 c	12.84 c	18.23 c	20.33 c	11.63 c	15.37 c	19.82 c	20.48 c
P_1	12.81 b	17.22 b	21.83 b	23.26 b	13.74 b	19.70 b	22.84 b	23.62 b
P_2	17.42 a	22.05 a	27.23 a	29.29 a	16.90 a	22.30 a	26.20 a	27.61 a
P_3	17.66 a	22.52 a	28.08 a	29.96 a	17.23 a	23.24 a	26.60 a	28.73 a
$LSD_{(0.05)}$	0.784	1.260	1.625	1.359	0.667	1.396	0.980	1.244
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Plant spacing								
S_1	15.84 a	20.24 a	25.90 a	27.49 a	14.03 c	18.98 b	23.92 b	25.40 a
S_2	14.54 b	18.70 b	24.28 b	26.33 a	15.76 a	21.15 a	25.02 a	26.08 a
S_3	13.35 c	17.03 c	21.35 c	23.31 b	14.84 b	20.33 a	22.67 c	23.86 b
$LSD_{(0.05)}$	0.679	1.091	1.408	1.177	0.577	1.209	0.848	1.077
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	5.50	6.91	6.97	5.40	8.58	7.09	9.20	5.07

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha
P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha
P_3: 72 kg P_2O_5/ha

S_1: 40 × 20 cm
S_2: 40 × 25 cm
S_3: 40 × 30 cm

It was revealed that with the increases of spacing plant height showed decreasing trend. In case of closer spacing plant compete for light which helps to elongate plant than the wider spacing. Moniruzzaman (2006) reported similar findings from the closest spacing.

Statistically significant variation was observed due to the combined effect of phosphorus and plant spacing in terms of plant height of lettuce at 30, 40, 50 and 60 DAT (Appendix III). The tallest plant (19.25 cm, 25.91 cm, 31.54 cm and 33.00 cm) was recorded from P_3S_1 at 30, 40, 50 and 60 DAT, respectively. On the other hand, the shortest plant (9.56 cm, 11.67 cm and 17.03 cm) was found from P_0S_2 at 30, 40 and 50 DAT, respectively and 19.84 cm plant height was recorded from P_0S_3 at 60 DAT (Table 3). It was revealed that optimum level of phosphorus and plant spacing ensured the tallest plant.

4.2 Number of leaves per plant

Statistically significant variation was recorded on number of leaves per plant of lettuce due to application of different levels of phosphorus at 30, 40, 50 and 60 DAT (Appendix III). At 30, 40, 50 and 60 DAT the maximum number of leaves per plant (17.23, 23.24, 26.60 and 28.73) was found from P_3 which was statistically similar (16.90, 22.30, 26.20 and 27.61) to P_2, respectively and the minimum number of leaves per plant (11.63, 15.37, 19.82 and 20.48) was obtained from P_0 for same DAT (Table 2). It was revealed that with the increase of phosphorus, number of leaves per plant increase upto a certain level than decrease slowly. The maximum number of leaves per plant was recorded for highest level of phosphorus because phosphorus fertilizer ensures favorable condition for the growth of lettuce. Sajjan *et al*. (1992) reported that P increase number of leaves of lettuce.

Due to different plant spacing varied statistically significant variation was recorded for number of leaves per plant of lettuce at 30, 40, 50 and 60 DAT (Appendix III).

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Table 3. Interaction effect of phosphorus fertilization and plant spacing on plant height and number of leaves per plant of lettuce

Treatments	Plant height (cm) at				Number of leaves per plant at			
	30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
P_0S_1	11.91 ef	14.38 de	19.98 de	20.90 de	10.47 e	14.10 f	19.20 f	20.13 e
P_0S_2	9.56 g	11.67 f	17.03 e	20.26 e	12.13 d	15.37 f	20.23 ef	20.33 e
P_0S_3	9.76 g	12.46 ef	17.67 e	19.84 e	12.30 d	16.63 ef	20.03 ef	20.97 e
P_1S_1	14.23 cd	18.33 c	23.61 c	25.46 bc	13.23 cd	18.60 de	23.57 d	24.60 d
P_1S_2	12.99 de	17.06 c	22.15 cd	23.27 cd	14.10 c	20.37 cd	23.67 d	24.27 d
P_1S_3	11.22 f	16.27 cd	19.74 de	21.06 de	13.90 c	20.13 d	21.30 e	22.00 e
P_2S_1	17.98 ab	22.33 b	28.47 b	30.62 a	15.77 b	20.37 cd	25.70 bc	27.50 bc
P_2S_2	17.33 b	22.42 b	28.51 b	30.58 a	18.67 a	22.93 bc	27.57 a	28.97 ab
P_2S_3	16.95 b	21.41 b	24.72 c	26.68 b	16.27 b	23.60 ab	25.33 cd	26.37 cd
P_3S_1	19.25 a	25.91 a	31.54 a	33.00 a	16.67 b	22.83 bc	27.20 ab	29.37 ab
P_3S_2	18.28 ab	23.67 b	29.42 ab	31.21 a	18.13 a	25.93 a	28.60 a	30.73 a
P_3S_3	15.45 c	18.00 c	23.28 c	25.67 bc	16.90 b	20.97 cd	24.00 cd	26.10 cd
$LSD_{(0.05)}$	1.358	2.183	2.815	2.353	1.155	2.419	1.697	2.154
Significance level	0.05	0.01	0.05	0.01	0.05	0.01	0.01	0.05
CV(%)	5.50	6.91	6.97	5.40	8.58	7.09	9.20	5.07

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha
P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha
P_3: 72 kg P_2O_5/ha

S_1: 40 × 20 cm
S_2: 40 × 25 cm
S_3: 40 × 30 cm

At the different days after transplanting (DAT) the maximum number of leaves per plant (15.76, 21.15, 25.02 and 26.08) was produced by S_2 which was followed by S_3 (14.84, 20.33, 22.67 and 23.86). At the same DAT the minimum number of leaves per plant (14.03, 18.98, 23.92 and 25.40) was recorded from S_1 (Table 2). It was revealed that with the increases of spacing number of leaves per plant also increase. Enough space for vertical and horizontal expansion in the optimum spacing that leads for production of the maximum number of leaves per plant than the closer. Steingrobe and Schenk (1994) also reported similar results earlier.

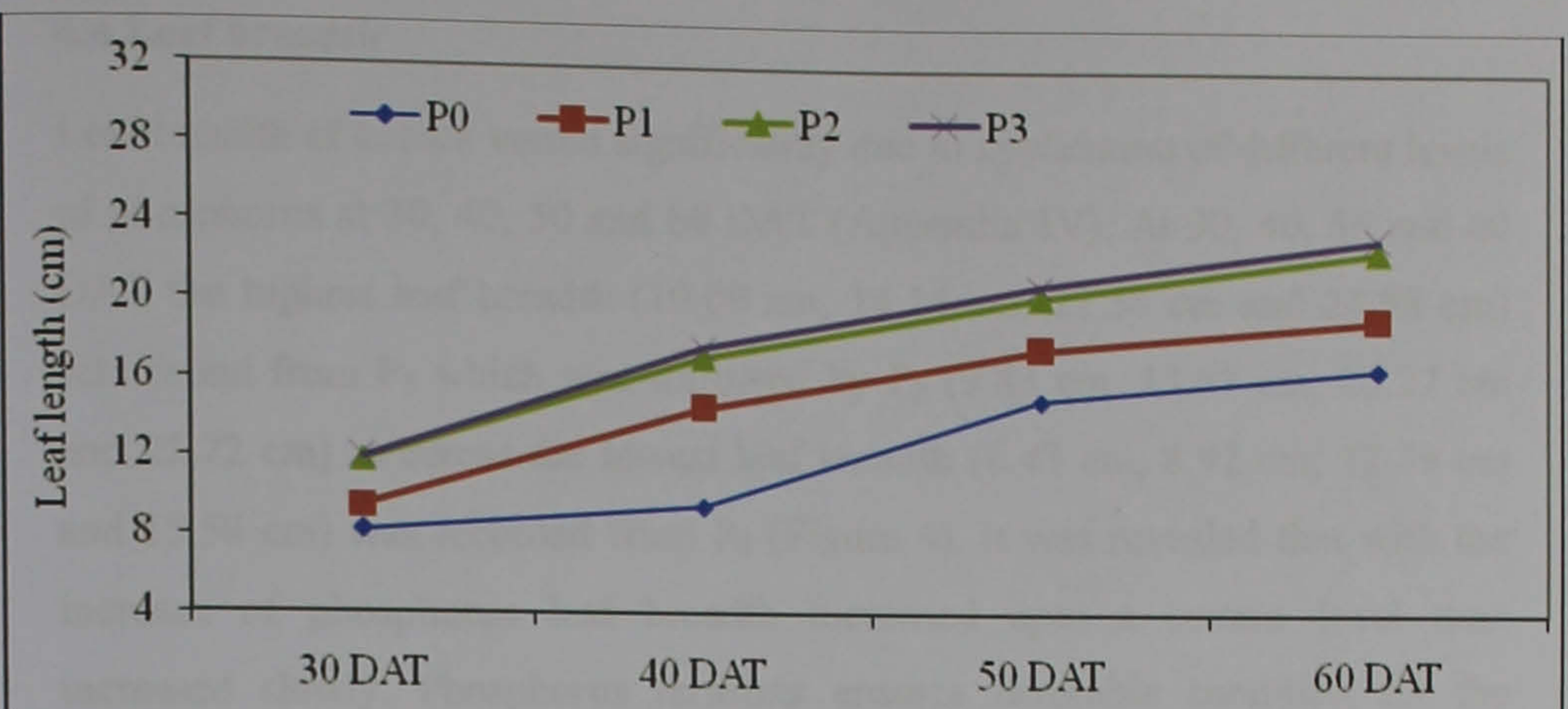
Combined effect of phosphorus and plant spacing showed statistically significant variation in terms of number of leaves per plant of lettuce at 30, 40, 50 and 60 DAT (Appendix III). The maximum number of leaves per plant (18.13, 25.93, 28.60 and 30.73) was found from P_3S_2 at 30, 40, 50 and 60 DAT, respectively where as the minimum number of leaves per plant (10.47, 14.10, 19.20 and 20.13) was obtained from P_0S_1 at 30, 40, 50 and 60 DAT, respectively (Table 3). It was revealed that optimum level of phosphorus and plant spacing ensured the maximum number of leaves per plant.

4.3 Leaf length

Due to application of different levels of phosphorus showed statistically significant variation on leaf length of lettuce at 30, 40, 50 and 60 DAT (Appendix IV). At 30, 40, 50 and 60 DAT the highest leaf length (11.94 cm, 17.62 cm, 20.95 cm and 23.43 cm) was recorded from P_3 which was statistically identical (11.81 cm, 17.17 cm, 20.36 cm and 22.79 cm) to P_2 and the lowest leaf length (8.20 cm, 9.48 cm, 15.01 cm and 16.67 cm) was found from P_0 (Figure 2). It was revealed that with the increase of phosphorus leaf length was increased. Optimum vegetative growth was occurred due to the highest amount of phosphorus fertilizer that leads for the leaf length of lettuce which results was the longest leaf. Rubeiz *et al.* (1992) reported that leaf length would be increased with the application of phosphorus.

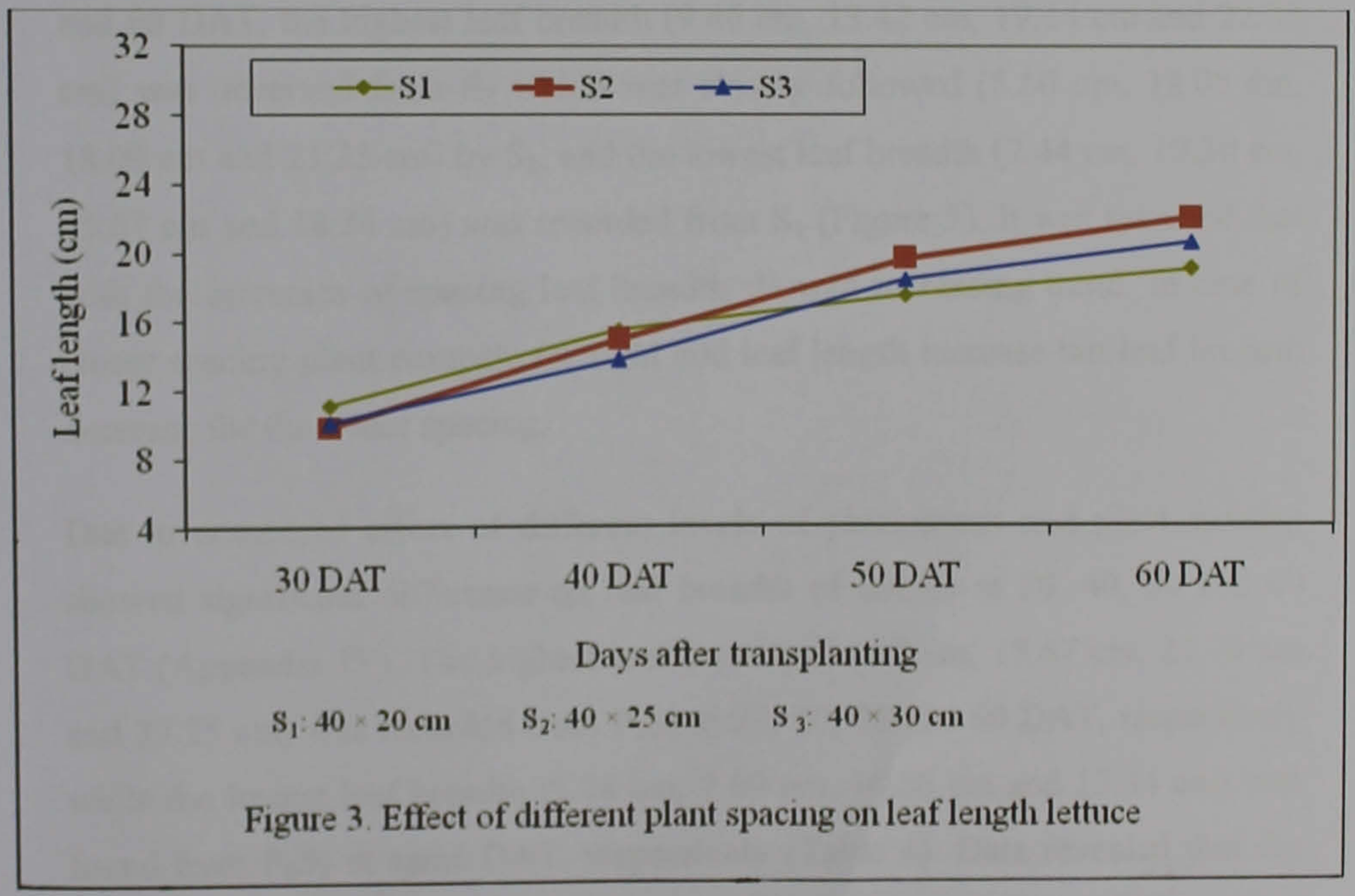
Leaf length of lettuce showed statistically significant differences due to use of different plant spacing at 30, 40, 50 and 60 DAT (Appendix IV). At 30 DAT, the highest leaf length (11.10 cm) was observed from S_1 which was closely followed by S_3 (10.11 cm) and the lowest leaf length (9.86 cm) was recorded from S_2. At 40 DAT, the highest leaf length (15.46 cm) was recorded from S_1 which was statistically identical (14.92 cm) with S_2 and the lowest leaf length (13.75 cm) was found from S_3. At 50 DAT, the highest leaf length (19.63 cm) was recorded from S_2 which was closely followed by S_3 (18.42 cm) and the lowest leaf length (17.47 cm) was recorded from S_1. At 60 DAT, the highest leaf length (21.99 cm) was recorded from S_2 which was closely followed by S_3 (20.57 cm) and the lowest leaf length (19.02 cm) was found from S_1 (Figure 3). It was revealed that with the increases of spacing leaf length showed increasing trend but thereafter a certain period optimum spacing produced the highest leaf length. In case of closer spacing plant compete for light and with the time being leaf length decreases. Sodkowski and Rekowska (2003) reported longest leaf from closer spacing.

Statistically significant variation was recorded due to combined effect of different levels of phosphorus and plant spacing in terms of leaf length of lettuce at 30, 40, 50 and 60 DAT (Appendix IV). The highest leaf length 12.79 cm and 18.69 cm was found from P_3S_1 at 30 and 40 DAT, respectively and the lowest leaf length 7.41 cm and 8.47 cm was observed from P_0S_2 at same DAT, respectively. At 50 and 60 DAT the highest leaf length 22.45 cm and 25.82 cm was recorded from P_3S_2, respectively and the lowest leaf length 14.23 cm and 15.53 cm was obtained from P_0S_1 at same DAT, respectively (Table 4). Results revealed that the optimum level of phosphorus and plant spacing ensured the highest leaf length with maximum vegetative growth.



P_0: 0 kg P_2O_5/ha P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha P_3: 72 kg P_2O_5/ha

Figure 2. Effect of phosphorus on leaf length of lettuce



S_1: 40 × 20 cm S_2: 40 × 25 cm S_3: 40 × 30 cm

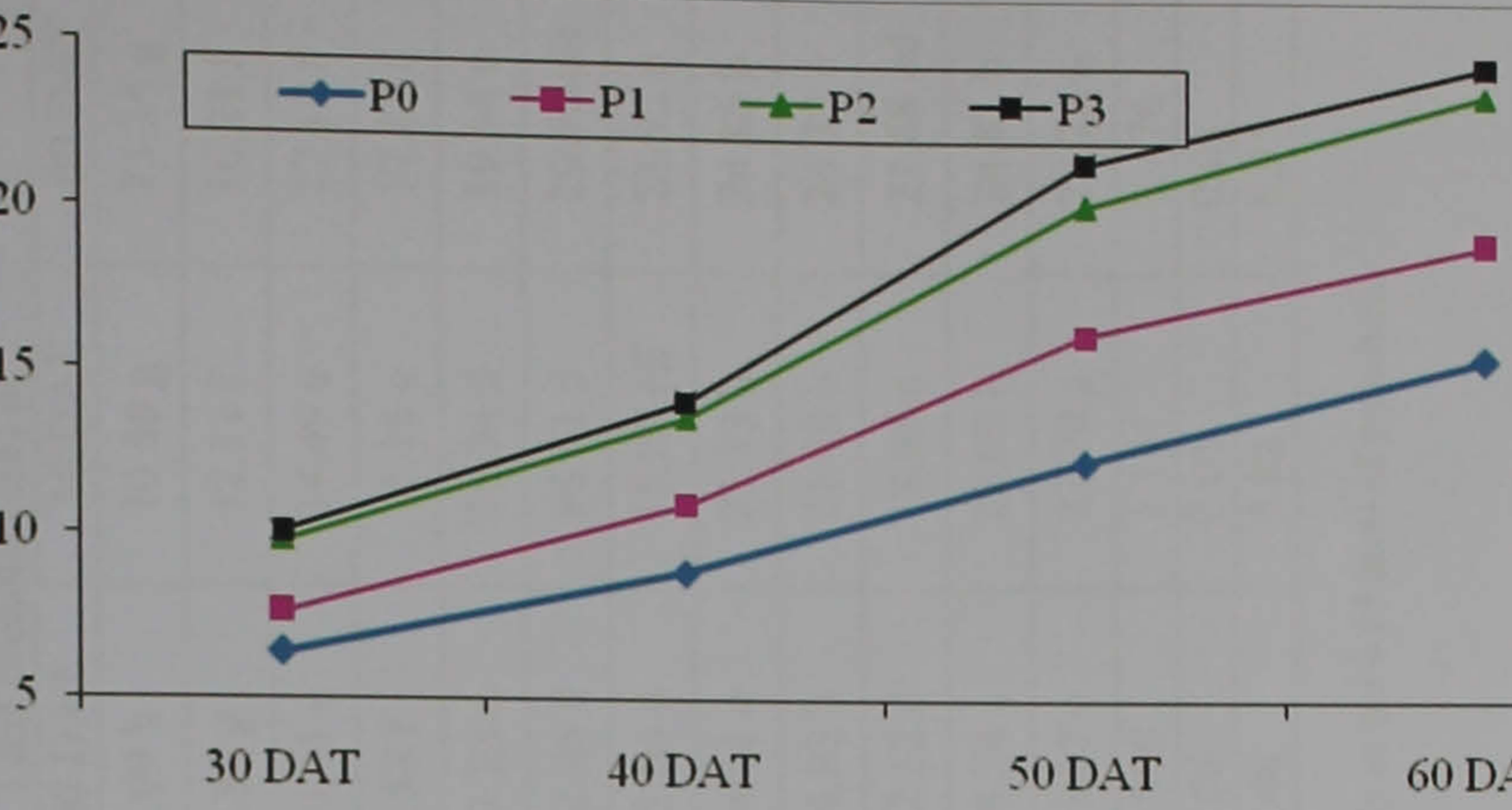
Figure 3. Effect of different plant spacing on leaf length lettuce

4.4 Leaf breadth

Leaf breadth of lettuce varied significantly due to application of different levels of phosphorus at 30, 40, 50 and 60 DAT (Appendix IV). At 30, 40, 50 and 60 DAT the highest leaf breadth (10.09 cm, 14.14 cm, 21.58 cm and 24.58 cm) was found from P_3 which was followed by P_2 (9.83 cm, 13.67 cm, 20.27 cm and 23.72 cm) whereas the lowest leaf breadth (6.43 cm, 8.92 cm, 12.39 cm and 15.58 cm) was recorded from P_0 (Figure 4). It was revealed that with the increase of phosphorus leaf breadth increased upto a certain level than increased slowly. Phosphorus fertilizer ensures favorable condition for the growth of lettuce with optimum vegetative growth and the ultimate results was the highest leaf breadth. Rubeiz *et al.* (1992) reported that leaf breadth was increased with the higher level of phosphorus application.

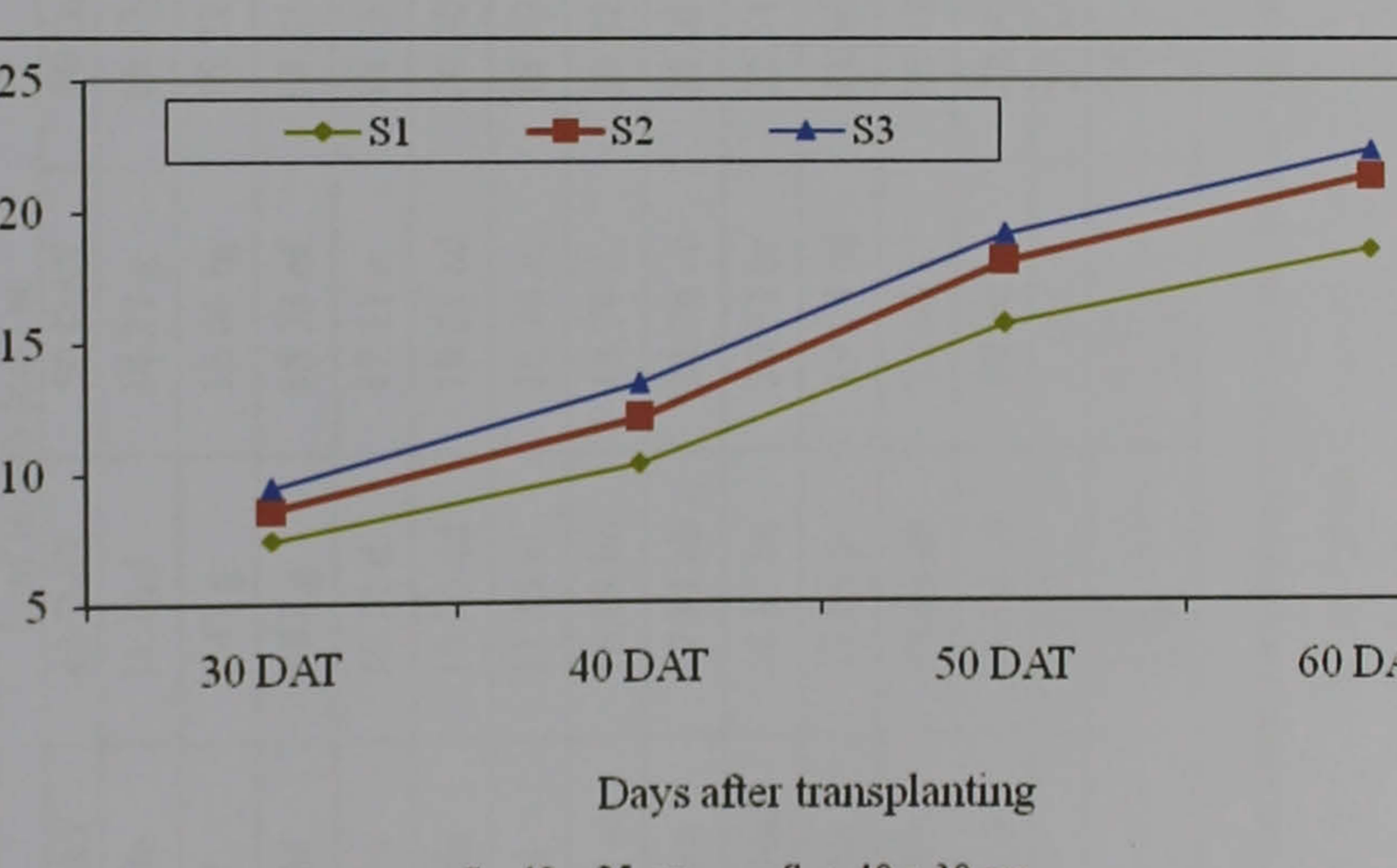
Statistically significant variation was observed on lettuce leaf breadth in different plant spacing at 30, 40, 50 and 60 DAT (Appendix IV). At 30, 40, 50 and 60 DAT, the highest leaf breadth (9.46 cm, 13.42 cm, 19.14 cm and 22.35 cm) was observed from S_3 which was closely followed (8.60 cm, 12.08 cm, 18.09 cm and 21.35 cm) by S_2, and the lowest leaf breadth (7.44 cm, 10.30 cm, 15.67 cm and 18.54 cm) was recorded from S_1 (Figure 5). It was revealed that with the increases of spacing leaf breadth showed increasing trend. In case of closer spacing plant compete for light and leaf length increase but leaf breadth decrease for the wider spacing.

Due to combined effect of different levels of phosphorus and plant spacing showed significant difference on leaf breadth of lettuce at 30, 40, 50 and 60 DAT (Appendix IV). The highest leaf breadth (11.07 cm, 15.67 cm, 23.70 cm and 27.25 cm) was recorded from P_3S_3 at 30, 40, 50 and 60 DAT, respectively while the lowest leaf breadth (5.14 cm, 7.09 cm, 10.56 cm and 13.34 cm) was found from P_0S_1 at same DAT, respectively (Table 4). Data revealed that the optimum level of phosphorus and plant spacing ensured the highest leaf breadth with the maximum vegetative growth.



P_0: 0 kg P_2O_5/ha P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha P_3: 72 kg P_2O_5/ha

Figure 4. Effect of phosphorus on leaf breadth of lettuce



S_1: 40 × 20 cm S_2: 40 × 25 cm S_3: 40 × 30 cm

Figure 5. Effect of plant spacing on leaf breadth of lettuce

Table 4. Interaction effect of phosphorus fertilization and plant spacing on leaf length and leaf breadth of lettuce

Treatments	Leaf length (cm) at				Leaf breadth (cm) at			
	30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
P_0S_1	9.06 de	11.16 f	14.23 g	15.53 e	5.14 f	7.09 h	10.56 g	13.34 g
P_0S_2	7.41 f	8.47 g	15.06 fg	16.23 de	6.59 e	8.85 g	12.11 f	16.21 f
P_0S_3	8.12 ef	8.81 g	15.73 ef	18.25 cd	7.56 d	10.81 e	14.49 e	17.19 f
P_1S_1	10.67 c	15.11 d	17.11 e	18.18 cd	6.59 e	9.53 f	15.16 e	17.23 f
P_1S_2	8.52 de	15.26 cd	19.21 cd	20.90 b	7.76 d	11.23 e	16.84 d	19.54 e
P_1S_3	9.28 d	13.35 e	16.76 e	18.59 c	8.63 c	12.26 d	16.91 d	20.56 de
P_2S_1	11.88 ab	16.88 bc	18.79 d	20.81 b	8.85 c	12.06 d	18.00 cd	21.92 c
P_2S_2	12.48 a	17.81 ab	21.78 ab	25.03 a	10.07 b	14.01 c	21.33 b	24.86 b
P_2S_3	11.06 bc	16.82 bc	20.51 bc	22.54 b	10.59 ab	14.93 b	21.48 b	24.39 b
P_3S_1	12.79 a	18.69 a	19.74 cd	21.56 b	9.19 c	12.52 d	18.95 c	21.68 cd
P_3S_2	11.05 bc	18.14 ab	22.45 a	25.82 a	10.01 b	14.24 c	22.09 b	24.81 b
P_3S_3	11.98 ab	16.02 cd	20.66 bc	22.90 b	11.07 a	15.67 a	23.70 a	27.25 a
$LSD_{(0.05)}$	0.947	1.517	1.345	2.051	0.772	0.500	1.141	1.176
Significance level	0.01	0.05	0.05	0.05	0.05	0.05	0.01	0.01
CV(%)	8.40	6.09	10.29	5.90	11.36	9.48	6.82	8.35

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha
P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha
P_3: 72 kg P_2O_5/ha

S_1: 40 × 20 cm
S_2: 40 × 25 cm
S_3: 40 × 30 cm

4.5 Fresh weight of plant

Fresh weight of lettuce plant showed statistically significant variation due to the application of different levels of phosphorus at 30, 40, 50 and 60 DAT (Appendix V). At 30, 40, 50 and 60 DAT the maximum fresh weight of plant (212.89 g, 242.10 g, 266.23 g and 284.92 g) was obtained from P_3 which was statistically similar (207.75 g, 232.03 g, 258.70 g and 274.74 g) to P_2, respectively. On the other hand, the minimum fresh weight of plant (109.98 g, 148.28 g, 176.09 g and 196.52 g) was found from P_0 (Table 5). It was revealed that with the increase of phosphorus fresh weight of plant increase due to optimum vegetative growth. Phosphorus fertilizer ensures favorable condition for the growth of lettuce with optimum vegetative growth and the ultimate results was the highest fresh weight per plant. Lana *et al*. (2004) reported significant responses to different P sources were also observed for fresh parts.

Fresh weight of lettuce plant showed statistically significant variation due to the use of different plant spacing at 30, 40, 50 and 60 DAT (Appendix V). At all observations the maximum fresh weight of plant (195.29 g, 231.58 g, 264.92 g and 286.92 g) was observed from the widest spacing (S_3) which was closely followed (183.00 g, 213.16 g, 242.79 g and 260.42 g) by S_2 at 30, 40, 50 and 60 DAT, respectively, while at the same DAT the minimum fresh weight of plant (125.36 g, 155.31 g, 172.64 g and 188.58 g) was found from S_1 (Table 5). It was revealed that with the increases of spacing fresh weight of plant showed increasing trend. In case of wider spacing plant receive enough light and space that leads to the attained maximum fresh weight of plant.

Combined effect of different levels of phosphorus and plant spacing showed significant variation on fresh weight of lettuce plant at 30, 40, 50 and 60 DAT (Appendix V). The maximum fresh weight of plant (249.66 g, 287.38 g, 324.71 g and 353.38 g) was found from P_3S_3 at 30, 40, 50 and 60 DAT, respectively whereas, the minimum fresh weight of plant (80.28 g, 138.64 g, 158.08 g and

Table 5. Main effect of phosphorus fertilization and plant spacing on yield per plant and dry matter content (%) of lettuce

Treatments	Fresh weight (g/plant) at				Dry matter content (%) at			
	30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Phosphorus fertilizer								
P_0	109.98 c	148.28 c	176.09 c	196.52 c	7.21 c	7.64 c	9.30 c	10.33 c
P_1	140.91 b	177.67 b	206.12 b	225.04 b	8.26 b	9.37 b	10.55 b	12.44 b
P_2	207.75 a	232.03 a	258.70 a	274.74 a	9.22 a	10.43 a	11.92 a	13.02 a
P_3	212.89 a	242.10 a	266.23 a	284.92 a	9.46 a	10.53 a	12.10 a	13.37 a
$LSD_{(0.05)}$	12.76	19.36	16.52	15.15	0.362	0.375	0.404	0.424
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Plant spacing								
S_1	125.36 c	155.31 c	172.64 c	188.58 c	7.98 b	8.73 c	10.22 c	11.20 b
S_2	183.00 b	213.16 b	242.79 b	260.42 b	8.67 a	9.65 b	11.06 b	12.72 a
S_3	195.29 a	231.58 a	264.92 a	286.92 a	8.96 a	10.11 a	11.62 a	12.95 a
$LSD_{(0.05)}$	11.05	16.77	14.31	13.12	0.313	0.325	0.350	0.367
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	7.77	9.90	7.45	6.32	10.34	8.04	11.77	8.53

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha
P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha
P_3: 72 kg P_2O_5/ha

S_1: 40 × 20 cm
S_2: 40 × 25 cm
S_3: 40 × 30 cm

Table 6. Interaction effect of phosphorus fertilization and plant spacing on yield per plant and dry matter content (%)of lettuce

Treatments	Fresh weight (g/plant) at				Dry matter content (%) at			
	30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
P_0S_1	80.28 e	138.64 ef	158.08 e	177.13 gh	6.60 g	6.93 d	8.59 h	9.29 f
P_0S_2	113.46 d	146.25 def	170.09 de	191.23 fgh	6.95 g	7.38 d	9.23 gh	10.25 e
P_0S_3	136.21 c	159.96 cdef	200.11 d	221.19 de	8.09 ef	8.62 c	10.08 ef	11.44 d
P_1S_1	104.96 d	128.78 f	148.02 e	166.84 h	7.77 f	8.71 c	9.88 fg	11.54 d
P_1S_2	152.29 bc	195.61 bc	228.95 c	246.07 cd	8.48 de	9.51 b	10.64 de	12.93 c
P_1S_3	165.46 b	208.61 b	241.39 c	262.22 c	8.53 de	9.90 b	11.13 cd	12.84 c
P_2S_1	155.55 bc	174.63 bcde	192.27 d	206.29 ef	8.74 cde	9.51 b	10.92 cd	11.86 d
P_2S_2	237.87 a	251.08 a	290.35 b	307.06 b	9.71 ab	11.11 a	12.24 a	13.87 ab
P_2S_3	229.82 a	270.39 a	293.49 b	310.87 b	9.23 bc	10.68 a	12.60 a	13.33 bc
P_3S_1	160.63 b	179.19 bcd	192.18 d	204.05 efg	8.81 cd	9.76 b	11.48 bc	12.10 d
P_3S_2	228.38 a	259.71 a	281.78 b	297.33 b	9.55 ab	10.62 a	12.15 ab	13.84 ab
P_3S_3	249.66 a	287.38 a	324.71 a	353.38 a	10.01 a	11.23 a	12.67 a	14.17 a
$LSD_{(0.05)}$	22.09	33.53	28.62	26.23	0.627	0.649	0.700	0.734
Significance level	0.05	0.01	0.01	0.01	0.05	0.05	0.05	0.05
CV(%)	7.77	9.90	7.45	6.32	10.34	8.04	11.77	8.53

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha
P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha
P_3: 72 kg P_2O_5/ha

S_1: 40 × 20 cm
S_2: 40 × 25 cm
S_3: 40 × 30 cm

177.13 g) was obtained from P_0S_1 (Table 6). It was revealed that optimum level of phosphorus and plant spacing ensured maximum vegetative growth that ensured highest fresh weight of plant.

4.6 Dry matter content of plant

Due to the application of different levels of phosphorus differ significantly on dry matter content of plant at 30, 40, 50 and 60 DAT (Appendix V). At 30, 40, 50 and 60 DAT the maximum dry matter content of plant (9.46%, 10.53%, 12.10% and 13.37%) was recorded from P_3 which was statistically similar to P_2 (9.22%, 10.43%, 11.92% and 13.02%) and the minimum dry matter content of plant (7.21%, 7.64%, 9.30% and 10.33%) was obtained from P_0 which was followed by P_1 (8.26%, 9.37%, 10.55% and 12.44%) for the same date (Table 5). It was revealed that with the increase of phosphorus dry matter content of plant increase. Phosphorus fertilizer ensures favorable condition for the growth of lettuce with optimum vegetative growth with highest assimilation of dry matter and the ultimate results was the highest dry matter content in plant. Lana *et al*. (2004) reported significant responses to different P sources for dry matter production.

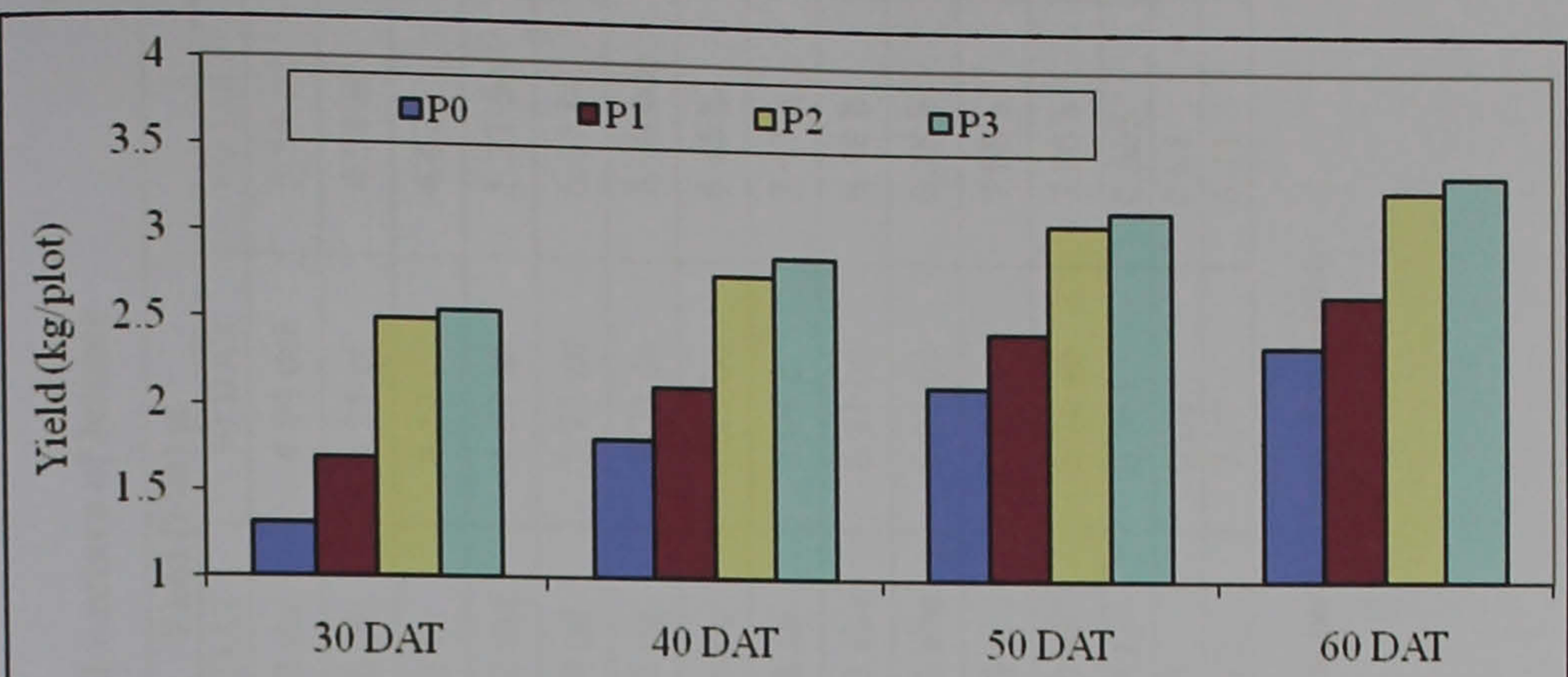
Dry matter content of plant differed significantly due to different plant spacing at 30, 40, 50 and 60 DAT (Appendix V). At 30,40,50 and 60 DAT the maximum dry matter content of plant (8.96%, 10.11%, 11.62% and 12.95%) was found from S_3 which was statistically similar to S_2 (8.67%, 9.65%, 11.06% and 12.72%) respectively. Again, at the same DAT the minimum dry matter content of plant (7.98%, 8.73%, 10.22% and 11.20%) was recorded from S_1, respectively (Table 5). It was revealed that with the increases of spacing dry matter content of plant showed increasing trend. In case of wider spacing plant received enough light and space that leads to the attained maximum assimilation of nutrients that leads to attain the highest dry matter content of plant.

A significant variation was recorded due to combined effect of different levels of phosphorus and plant spacing in terms of dry matter content of plant at 30, 40, 50 and 60 DAT (Appendix V). The maximum dry matter content of plant (10.01%, 11.23%, 12.67% and 14.17%) was observed from P_3S_3 at 30, 40, 50 and 60 DAT, respectively and the minimum dry matter content of plant (6.60%, 6.93%, 8.59% and 9.29%) was found from P_0S_1 at 30, 40, 50 and 60 DAT, respectively (Table 6). It was revealed that optimum level of phosphorus and plant spacing ensured maximum vegetative growth that ensured the highest dry matter content of plant with maximum assimilation of different nutrients.

4.7 Yield per plot

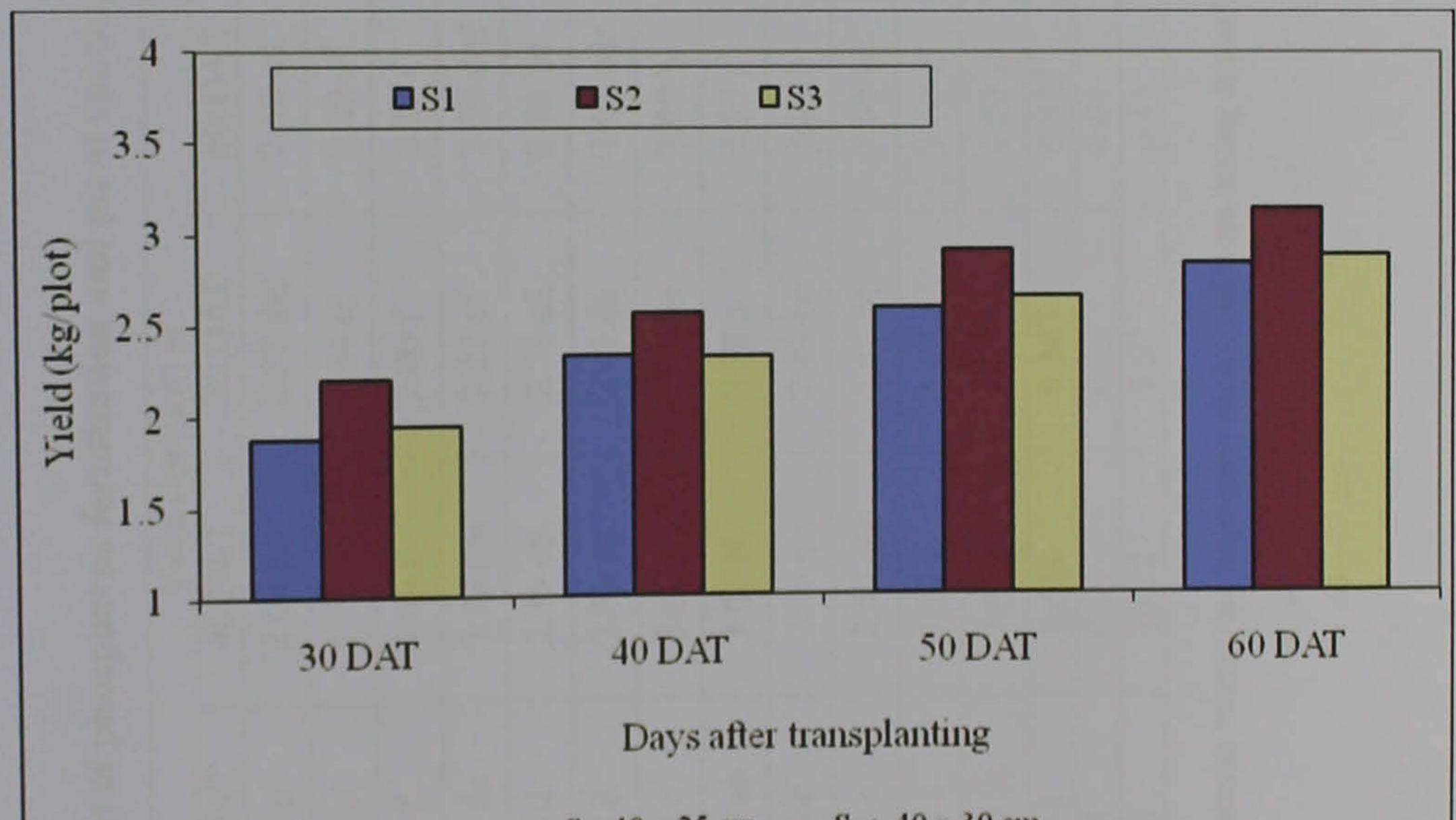
Significant variation was recorded in terms of yield per plot of lettuce due to the application of different levels of phosphorus at 30, 40, 50 and 60 DAT (Appendix VI). At 30, 40, 50 and 60 DAT, the highest yield per plot (2.55 kg, 2.89 kg, 3.17 kg and 3.39 kg) was obtained from P_3 which was statistically similar (2.50 kg, 2.78 kg, 3.10 kg and 3.30 kg) with P_2. On the other hand, the lowest yield per plot (1.31 kg, 1.81 kg, 2.14 kg and 2.39 kg) was recorded from P_0 (Figure 6). It was revealed that with the increase of phosphorus vegetative growth of lettuce also increased that ensured the highest yield per plot. Wijk (2000) reported response to phosphate fertilization on soils with a low P level regarding yield of lettuce.

Different plant spacing showed significant variation on yield per plot of lettuce at 30, 40, 50 and 60 DAT (Appendix VI). At the different days after transplanting (DAT) the maximum yield per plot (2.20 kg, 2.56 kg, 2.91 kg and 3.13 kg) was obtained from S_2. On the other hand, at the same DAT the lowest yield per plot (1.88 kg, 2.32 kg, 2.59 kg and 2.83 kg) was recorded from S_1 respectively which was statistically identical (1.95 kg, 2.32 kg, 2.65 kg and 2.87 kg) to S_3 at 30, 40, 50 and 60 DAT, respectively (Figure 7). It was revealed that with the increases of spacing individual weight per plant increase.



P_0: 0 kg P_2O_5/ha P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha P_3: 72 kg P_2O_5/ha

Figure 6. Effect of phosphorus on yield per plot of lettuce



S_1: 40 × 20 cm S_2: 40 × 25 cm S_3: 40 × 30 cm

Figure 7. Effect of different plant spacing on yield per plot of lettuce

Table 7. Interaction effect of phosphorus fertilization and plant spacing on yield per plot and hectare of lettuce

Treatments	Yield (kg/plot) at				Yield (t/ha) at			
	30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
P_0S_1	1.36 ef	2.08 de	2.37 def	2.66 cd	2.84 ef	4.33 de	4.94 def	5.54 cd
P_0S_2	1.36 ef	1.76 ef	2.04 ef	2.29 ef	2.84 ef	3.66 ef	4.25 ef	4.78 ef
P_0S_3	1.20 f	1.60 f	2.00 f	2.21 f	2.51 f	3.33 f	4.17 f	4.61 f
P_1S_1	1.57 de	1.93 def	2.22 ef	2.50 def	3.28 de	4.02 def	4.63 ef	5.21 def
P_1S_2	1.83 d	2.35 cd	2.75 cd	2.95 bc	3.81 d	4.89 cd	5.72 cd	6.15 bc
P_1S_3	1.65 d	2.09 de	2.41 de	2.62 cde	3.45 d	4.35 de	5.03 de	5.46 cde
P_2S_1	2.33 c	2.62 bc	2.88 bc	3.09 b	4.86 c	5.46 bc	6.01 bc	6.45 b
P_2S_2	2.74 ab	3.01 ab	3.38 a	3.57 a	5.71 ab	6.28 ab	7.04 a	7.43 a
P_2S_3	2.30 c	2.70 abc	2.93 bc	3.11 b	4.79 c	5.63 abc	6.11 bc	6.48 b
P_3S_1	2.41 c	2.69 abc	2.88 bc	3.06 b	5.02 c	5.60 abc	6.01 bc	6.38 b
P_3S_2	2.85 a	3.12 a	3.48 a	3.68 a	5.95 a	6.49 a	7.26 a	7.68 a
P_3S_3	2.50 bc	2.87 ab	3.25 ab	3.53 a	5.20 bc	5.99 ab	6.76 ab	7.36 a
$LSD_{(0.05)}$	0.268	0.411	0.367	0.321	0.557	0.857	0.763	0.665
Significance level	0.05	0.05	0.01	0.01	0.05	0.05	0.01	0.01
CV(%)	7.83	10.12	7.97	6.41	7.83	10.12	7.97	6.41

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P_2O_5/ha
P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha
P_3: 72 kg P_2O_5/ha

S_1: 40 × 20 cm
S_2: 40 × 25 cm
S_3: 40 × 30 cm

Due to less number of plant total plot yield reduced but optimum spacing ensured the highest yield with the maximum vegetative growth and considerable number of plant.

Statistically significant differences were observed due to combined effect of different levels of phosphorus and plant spacing in terms of yields per plot of lettuce at 30, 40, 50 and 60 DAT (Appendix VI). The highest yield per plot (2.85 kg, 3.12 kg, 3.48 kg and 3.68 kg) was found from P_3S_2 at 30, 40, 50 and 60 DAT, respectively. While, the lowest yields per plot (1.20 kg, 1.60 kg, 2.00 kg and 2.21 kg) was recorded from the treatment combination of P_0S_3 at 30, 40, 50 and 60 DAT, respectively (Table 7). It was revealed that optimum level of phosphorus and plant spacing ensured maximum vegetative growth and the allocation of optimum number of plants that leads to produce the highest yield per plot.

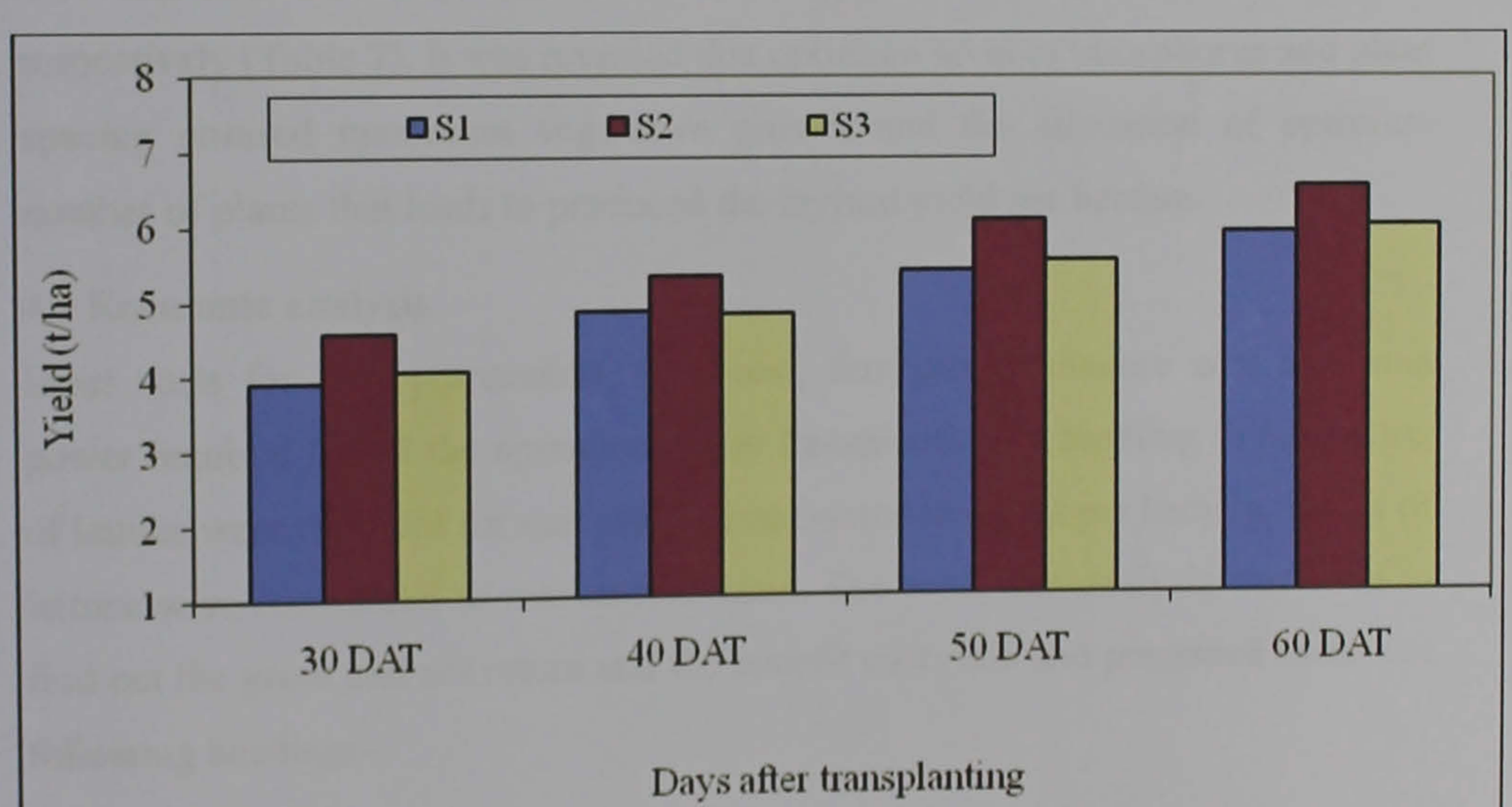
4.8 Yield per hectare

Different level of phosphorus varied significantly on yield per hectare of lettuce at 30, 40, 50 and 60 DAT (Appendix VI). At 30, 40, 50 and 60 DAT the highest yield per hectare (5.31 ton, 6.03 ton, 6.61 ton and 7.06 ton) was found from P_3 which was statistically similar (5.20 ton, 5.79 ton, 6.46 ton and 6.87 ton) to P_2, respectively and the lowest yield per hectare (2.73 ton, 3.77 ton, 4.45 ton and 4.97 ton) was recorded from P_0 for same DAT, respectively (Figure 8). It was revealed that with the increase of phosphorus vegetative growth of lettuce also increased resulting the highest yield per hectare. Zaman *et al.* (2006) reported that application of phosphorus at the rate of 100 kg/ha significantly increased leaf yield.

Statistically significant variation was observed on yield per hectare of lettuce due to different plant spacing at 30, 40, 50 and 60 DAT (Appendix VI). At the different days after transplanting (DAT) the maximum yield per hectare (4.58 ton, 5.33 ton, 6.07 ton and 6.51 ton) was observed from S_2 whereas, at the same DAT the lowest yield per hectare (3.92 ton, 4.82 ton, 5.39 ton and 5.89 ton) was

P_0: 0 kg P_2O_5/ha P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha P_3: 72 kg P_2O_5/ha

Figure 8. Effect of phosphorus on leaf yield per hectare of lettuce



S_1 : 40 × 20 cm S_2: 40 × 25 cm S_3: 40 × 30 cm

Figure 9. Effect of plant spacing on yield per hectare of lettuce

recorded from S_1, respectively which was statistically identical (4.07 ton, 4.85 ton, 5.52 ton and 5.98 ton) to S_3 at 30, 40, 50 and 60 DAT, respectively (Figure 9). It was revealed that with the increases of spacing individual weight per plant increased but due to the less number of plant total yield per hectare decreased. Moniruzzaman (2006) reported that the highest yield (25.9 t/ha in 1999-'00 and 28.3 t/ha in 2000-'01 with an average of 27.10 t/ha) was observed in the spacing of 40 × 20 cm with mulch, which was statistically at per with the spacing of 40 × 30 cm.

Different levels of phosphorus and plant spacing showed significant variation due to combined effect of phosphorus fertilizer and plant spacing on yield per hectare of lettuce at 30, 40, 50 and 60 DAT (Appendix VI). The highest yield per hectare (5.95 ton, 6.49 ton, 7.26 ton and 7.68 ton) was recorded from P_3S_2 at 30, 40, 50 and 60 DAT, respectively and the lowest yield per hectare (2.51 ton, 3.33 ton, 4.17 ton and 4.61 ton) was found from P_0S_3 at 30, 40, 50 and 60 DAT, respectively (Table 7). It was revealed that optimum level of phosphorus and plant spacing ensured maximum vegetative growth and the allocation of optimum number of plants that leads to produced the highest yield per hectare.

4.9 Economic analysis

Input costs for land preparation, seed cost, fertilizer & manure cost and man power required for all the operations from transplanting of seedling to harvesting of lettuce were recorded for unit plot and converted into cost per hectare. Prices of lettuce were considered as market rate basis. The economic analysis was done to find out the gross and net return and the benefit cost ratio and presented under the following headings-

4.9.1 Gross return

In the combination of phosphorus fertilizer and plant spacing showed different gross return under the trial (Table 8). The highest gross return (Tk. 3,28,560/ha) was obtained from P_3S_2 and the second highest gross return (Tk. 3,17,520/ha) was obtained from P_2S_2. The lowest gross return (Tk. 1,75,440/ha) was found from P_0S_3.

Table 8. Cost and return of lettuce cultivation as influenced by phosphorus fertilization and plant spacing

Treatment	Cost of production (Tk./ha)	Yield at harvest				Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
		30 DAT	40 DAT	50 DAT	60 DAT			
P_0S_1	1,02,815	2.84	4.33	4.94	5.54	2,11,800	1,08985	1.06
P_0S_2	1,02,815	2.84	3.66	4.25	4.78	1,86,360	83,545	0.81
P_0S_3	1,02,815	2.51	3.33	4.17	4.61	1,75,440	72,625	0.71
P_1S_1	1,04,045	3.28	4.02	4.63	5.21	2,05,680	1,01,635	0.98
P_1S_2	1,04,045	3.81	4.89	5.72	6.15	2,46,840	1,42,795	1.37
P_1S_3	1,04,045	3.45	4.35	5.03	5.46	2,19,480	1,15,435	1.11
P_2S_1	1,05,275	4.86	5.46	6.01	6.45	2,73,360	1,68,085	1.60
P_2S_2	1,05,275	5.71	6.28	7.04	7.43	3,17,520	2,12,245	2.02
P_2S_3	1,05,275	4.79	5.63	6.11	6.48	2,76,120	1,70,845	1.62
P_3S_1	1,06,505	5.02	5.60	6.01	6.38	2,76,120	1,69,615	1.59
P_3S_2	1,06,505	5.95	6.49	7.26	7.68	3,28,560	2,22,055	2.08
P_3S_3	1,06,505	5.20	5.99	6.76	7.36	3,03,720	1,97,215	1.85

Market price of lettuce @ Tk. 12,000/t

P_0: 0 kg P_2O_5/ha
P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha
P_3: 72 kg P_2O_5/ha

S_1: 40 × 20 cm
S_2: 40 × 25 cm
S_3: 40 × 30 cm

4.9.2 Net return

In case of net return, different treatment combinations showed different values of net return (Table 8). The highest net return (Tk. 2,22,055/ha) was obtained from P_3S_2 and the second highest net return (Tk. 2,12,245/ha) was obtained from P_2S_2. The lowest net return (Tk. 72,625/ha) was obtained from P_0S_3.

4.9.3 Benefit cost ratio (BCR)

The combination of phosphorus fertilizer and plant spacing showed different benefit cost ratio in different treatment combinations (Table 8). The highest benefit cost ratio (2.08) was performed from P_3S_2 and the second highest benefit cost ratio (2.02) was estimated from P_2S_2. The lowest benefit cost ratio (0.71) was obtained from P_0S_3. From the economic point of view, it is apparent that P_3S_2 was the more profitable than the rest of the treatment combinations for lettuce cultivation.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2008 to February 2009 to find out the effect of phosphorus and plant spacing on the growth and yield of lettuce. The experiment consisted of two factors. Factor A: 4 levels of phosphorus P_0: 0 kg P_2O_5/ha (Control); P_1: 24 kg P_2O_5/ha; P_2: 48 kg P_2O_5/ha and P_3: 72 kg P_2O_5/ha; factor B: 3 levels of plant spacing, S_1: 40 × 20 cm, S_2: 40 × 25 cm; S_3: 40 × 30 cm. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters and yield at different days after transplanting (DAT) were recorded.

At 30, 40, 50 and 60 DAT the tallest plant (17.66 cm, 22.52 cm, 28.08 cm and 29.96 cm) was recorded from P_3, at the same time the shortest plant (10.41 cm, 12.84 cm, 18.23 cm and 20.33 cm) was observed from P_0. The maximum number of leaves per plant (17.23, 23.24, 26.60 and 28.73) was found from P_3 and the minimum number (11.63, 15.37, 19.82 and 20.48) was obtained from P_0. The highest leaf length (11.94 cm, 17.62 cm, 20.95 cm and 23.43 cm) was observed from P_3 again, the lowest (8.20 cm, 9.48 cm, 15.01 cm and 16.67 cm) was found from P_0. At 30, 40, 50 and 60 DAT and the highest leaf breadth (10.09 cm, 14.14 cm, 21.58 cm and 24.58 cm) was found from P_3 whereas the lowest (6.43 cm, 8.92 cm, 12.39 cm and 15.58 cm) was recorded from P_0. At 30, 40, 50 and 60 DAT the maximum fresh weight of plant (212.89 g, 242.10 g, 266.23 g and 284.92 g) was obtained from P_3 while the minimum (109.98 g, 148.28 g, 176.09 g and 196.52 g) was found from P_0 and the maximum dry matter content of plant (9.46%, 10.53%, 12.10% and 13.37%) was recorded from P_3 again, the minimum (7.21%, 7.64%, 9.30% and 10.33%) was recorded from P_0. At 30, 40, 50 and 60 DAT the highest yield per hectare (5.31 ton, 6.03

ton, 6.61 ton and 7.06 ton) was found from P_3 and the lowest (2.73 ton, 3.77 ton, 4.45 ton and 4.97 ton) was recorded from P_0, respectively.

At 30, 40, 50 and 60 DAT the tallest plant (15.84 cm, 20.24 cm, 25.90 cm and 27.49 cm) was recorded from S_1, while the shortest (13.35 cm, 17.03 cm, 21.35 cm and 23.31 cm) was found from S_3 and the maximum number of leaves per plant (15.76, 21.15, 25.02 and 26.08) was obtained from S_2 and the minimum (14.03, 18.98, 23.92 and 25.40) was recorded from S_1. At 30 DAT, the highest leaf length (11.10 cm) was observed from S_1, while the lowest (9.86 cm) was recorded from S_2. At 40 DAT, the highest leaf length (15.46 cm) was recorded from S_1 and the lowest (13.75 cm) was found from S_3. At 50 DAT, the highest leaf length (19.63 cm) was recorded from S_2 and the lowest (17.47 cm) was recorded from S_1. At 60 DAT, the highest leaf length (21.99 cm) was recorded from S_2 and the lowest (19.02 cm) was found from S_1. At 30, 40, 50 and 60 DAT, the highest leaf breadth (9.46 cm, 13.42 cm, 19.14 cm and 22.35 cm) was observed from S_3, again the lowest (7.44 cm, 10.30 cm, 15.67 cm and 18.54 cm) was recorded from S_1 and the maximum fresh weight of plant (195.29 g, 231.58 g, 264.92 g and 286.92 g) was observed from S_3 while at the same DAT the minimum (125.36 g, 155.31 g, 172.64 g and 188.58 g) was found from S_1. The maximum dry matter content of plant (8.96%, 10.11%, 11.62% and 12.95%) was found from S_3, while the minimum (7.98%, 8.73%, 10.22% and 11.20%) was recorded from S_1, respectively and the maximum yield per hectare (4.58 ton, 5.33 ton, 6.07 ton and 6.51 ton) was observed from S_2, whereas the lowest (3.92 ton, 4.82 ton, 5.39 ton and 5.89 ton) was recorded from S_1.

The tallest plant (19.25 cm, 25.91 cm, 31.54 cm and 33.00 cm) was recorded from P_3S_1 at 30, 40, 50 and 60 DAT, respectively and the shortest plant (9.56 cm, 11.67 cm and 17.03 cm) was found from P_0S_2 at 30, 40 and 50 DAT, respectively and 19.84 cm plant height was recorded from P_0S_3 at 60 DAT. The maximum number of leaves per plant (18.13, 25.93, 28.60 and 30.73) was found from P_3S_2 again, the minimum number (10.47, 14.10, 19.20 and 20.13)

was attained from P_0S_1. The highest leaf length (12.79 cm and 18.69 cm) was found from P_3S_1 at 30 and 40 DAT, respectively and the lowest (7.41 cm and 8.47 cm) was observed from P_0S_2 at same DAT, respectively. At 50 and 60 DAT the highest leaf length (22.45 cm and 25.82 cm) was recorded from P_3S_2, respectively and the lowest (14.23 cm and 15.53 cm) was obtained from P_0S_1. The highest leaf breadth (11.07 cm, 15.67 cm, 23.70 cm and 27.25 cm) was recorded from P_3S_3 at 30, 40, 50 and 60 DAT, respectively while the lowest (5.14 cm, 7.09 cm, 10.56 cm and 13.34 cm) was found from P_0S_1. The maximum fresh weight of plant (249.66 g, 287.38 g, 324.71 g and 353.38 g) was found from P_3S_3 whereas the minimum (80.28 g, 138.64 g, 158.08 g and 177.13 g) was obtained from P_0S_1. The maximum dry matter content of plant (10.01%, 11.23%, 12.67% and 14.17%) was observed from P_3S_3 and the minimum (6.60%, 6.93%, 8.59% and 9.29%) was found from P_0S_1. The highest yield per hectare (5.95 ton, 6.49 ton, 7.26 ton and 7.68 ton) was recorded from P_3S_2 again, the lowest (2.51 ton, 3.33 ton, 4.17 ton and 4.61 ton) was observed from P_0S_3.

The highest benefit cost ratio (2.08) was obtained from P_3S_2 and the lowest benefit cost ratio (0.71) was obtained from P_0S_3. From the economic point of view, it is apparent that P_3S_2 was the more profitable than rest of the treatment combinations for lettuce cultivation.

The overall findings of this research can be summarized as follows:

1. Application of 72 kg P_2O_5/ha in combination with 40 × 25 cm plant spacing may be considered for better growth and higher yield of lettuce.

2. Another levels of phosphorus and different other plant spacing can be included for further optimization.

3. Regional trial of the key findings of this research is of prime requisite for final recommendation.

Chapter VI

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Appendices

APPENDICES

Appendix I. Characteristics of Sher-e-Bangla Agricultural University (SAU) Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	SAU Farm, Dhaka
AEZ	Madhupur 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

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

*** Source**: SRDI

Appendix II. Monthly record of air temperature, relative humidity, rainfall and Sunshine of the experimental site during the period from November 2008 to February 2009

Month	*Air temperature (°c)		*Relative humidity (%)	*Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2008	25.82	16.04	78	00	6.8
December, 2008	22.4	13.5	74	00	6.3
January, 2009	24.5	12.4	68	00	5.7
February, 2009	27.1	16.7	67	30	6.7

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka-1212

Appendix III. Analysis of variance of the data on plant height and number of leaves per plant of lettuce as influenced by phosphorus fertilization and plant spacing

Source of variation	Degrees of freedom	Mean square							
		Plant height (cm) at				Number of leaves per plant at			
		30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.335	0.028	1.080	0.161	0.148	0.872	0.011	1.254
Phosphorus (A)	3	114.206**	187.219**	194.991**	197.315**	64.338**	111.843**	90.954**	129.165**
Plant spacing (B)	2	18.673**	30.740**	63.686**	55.824**	8.942**	14.485**	16.590**	15.492**
Interaction (A×B)	6	1.923*	9.690**	8.115*	6.228**	1.278*	6.905**	3.556**	4.394*
Error	22	0.643	1.662	2.764	1.931	0.465	2.040	1.004	1.618

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on length and breadth of leaf of lettuce as influenced by phosphorus fertilization and plant spacing

Source of variation	Degrees of freedom	Mean square							
		Leaf length (cm) at				Leaf breadth (cm) at			
		30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.184	1.312	0.107	0.323	0.031	0.070	0.251	0.456
Phosphorus (A)	3	30.069**	125.603**	66.953**	90.361**	27.848**	53.516**	155.378**	158.714**
Plant spacing (B)	2	5.136**	9.195**	14.032**	26.523**	12.345**	29.371**	38.182**	46.785**
Interaction (A×B)	6	1.435**	2.513*	1.784*	4.533*	0.905*	0.211*	1.887**	1.626**
Error	22	0.313	0.803	0.631	1.467	0.208	0.087	0.454	0.482

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on fresh weight of plant and dry matter content of lettuce as influenced by phosphorus fertilization and plant spacing

Source of variation	Degrees of freedom	Mean square							
		Fresh weight of plant (g) at				Dry matter content (%) at			
		30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	18.506	151.629	59.826	158.382	0.039	0.016	0.024	0.134
Phosphorus (A)	3	23084.72**	17914.85**	16713.69**	15680.32**	9.439**	16.212**	15.413**	16.730**
Plant spacing (B)	2	16728.04**	19008.04**	27855.52**	31068.65**	3.085**	5.936**	5.986**	10.841**
Interaction (A×B)	6	448.205*	1338.877**	1638.285**	1964.320**	0.363*	0.388*	0.898*	0.488*
Error	22	170.256	392.192	285.594	240.015	0.137	0.147	0.171	0.188

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on yield per plot and hectare of lettuce as influenced by phosphorus fertilization and plant spacing

Source of variation	Degrees of freedom	Mean square							
		Yield (kg/plot) at				Yield (t/ha) at			
		30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.005	0.021	0.006	0.026	0.022	0.093	0.026	0.112
Phosphorus (A)	3	3.367**	2.431**	2.263**	2.079**	14.612**	10.549**	9.823**	9.024**
Plant spacing (B)	2	0.328**	0.222*	0.357**	0.310**	1.424**	0.963*	1.548**	1.346**
Interaction (A×B)	6	0.092*	1.119*	0.171**	0.201**	0.0983*	0.918*	0.741**	0.872**
Error	22	0.025	0.059	0.047	0.036	0.108	0.256	0.203	0.154

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VII. Cost and Return analysis for lettuce cultivation as influenced by phosphorus fertilization and plant spacing

A. Input cost

Treatment Combination	Labour cost	Ploughing cost	Seed cost (Tk)	Irrigation	Weeding cost	Pesticides Cost	Manure and fertilizers				Sub Total (A)
							Cowdung	Urea	Potassium	Phosphorus	
P_0S_1	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	0.00	54800.00
P_0S_2	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	0.00	54800.00
P_0S_3	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	0.00	54800.00
P_1S_1	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	1100.00	55900.00
P_1S_2	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	1100.00	55900.00
P_1S_3	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	1100.00	55900.00
P_2S_1	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	2200.00	57000.00
P_2S_2	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	2200.00	57000.00
P_2S_3	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	2200.00	57000.00
P_3S_1	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	3300.00	58100.00
P_3S_2	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	3300.00	58100.00
P_3S_3	11000.00	6000.00	3500.00	4000.00	3000.00	2500.00	20000.00	1600.00	3200.00	3300.00	58100.00

P_0: 0 kg P_2O_5/ha
P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha
P_3: 72 kg P_2O_5/ha

S_1: 40 × 20 cm
S_2: 40 × 25 cm
S_3: 40 × 30 cm

Appendix VII. Contd.

B. Overhead cost (Tk./ha)

Treatment Combination	Cost of lease of land for 6 months (13% of value of land Tk. 6,00000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 13% of cost/year	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
P_0S_1	39000	2740	6275	48015	102815
P_0S_2	39000	2740	6275	48015	102815
P_0S_3	39000	2740	6275	48015	102815
P_1S_1	39000	2795	6350	48145	104045
P_1S_2	39000	2795	6350	48145	104045
P_1S_3	39000	2795	6350	48145	104045
P_2S_1	39000	2850	6425	48275	105275
P_2S_2	39000	2850	6425	48275	105275
P_2S_3	39000	2850	6425	48275	105275
P_3S_1	39000	2905	6500	48405	106505
P_3S_2	39000	2905	6500	48405	106505
P_3S_3	39000	2905	6500	48405	106505

P_0: 0 kg P_2O_5/ha
P_1: 24 kg P_2O_5/ha
P_2: 48 kg P_2O_5/ha
P_3: 72 kg P_2O_5/ha

S_1: 40 × 20 cm
S_2: 40 × 25 cm
S_3: 40 × 30 cm