IMPACT OF SPACING AND POTASSIUM ON YIELD AND YIELD ATTRIBUTES IN CHILLI

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*This is to certify that the thesis entitled, **"IMPACT OF SPACING AND POTASSIUM ON YIELD AND YIELD ATTRIBUTES IN CHILLI"** 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 **MASTER OF SCIENCE IN HORTICULTURE,** embodies the result of a piece of bonafide research work carried out by **RUMAN BARI TRISHA** Registration No**. 11-04267** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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ABSTRACT

An experiment was carried out in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to April 2018. The experiment consisted of two factors *viz.* 3 levels of plant spacing; S_1: 45 cm × 30 cm; S_2 : 45 cm × 45 cm and S_3: 45 cm × 60 cm and 4 levels of potassium; K_0: 0 kg/ha (Control); K_1: 60 kg K ha^{-1}; K_2: 90 kg K ha^{-1} and K_3: 120 kg K ha^{-1}. The experiment was laid out in Randomized Complete Block Design with three replications. Data on different growth, yield contributing characters and yield at different days after transplanting (DAT) were recorded. Individually plant spacing and potassium had significant effect on growth, yield contributing parameters and yield parameters of chilli. Plant spacing, S_2 showed highest fruit yield (21.46 t ha^{-1}). Regarding potassium application, K_2 gave highest fruit yield (20.37 t ha^{-1}). Combined effect of plant spacing and potassium also showed significant effect on growth and yield of chilli. Results revealed that the highest fruit yield (24.62 t ha^{-1}) was achieved from the treatment combination of S_2K_2 where the lowest fruit yield plant was obtained from the treatment combination of S_1K_0 (16.20 t ha^{-1}). Regarding economic analysis, the highest BCR (3.52) was achieved from the treatment combination of S_2K_2 with higher gross return (Tk. 369300 ha^{-1}) and net return (Tk. 264462 ha^{-1}) where the lowest BCR (1.98) was observed from the treatment combination of S_3K_0 . So, it can be concluded that spacing 45 cm × 45 cm with 90 kg K ha^{-1} is suitable for chilli cultivation.

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LIST OF ABBREVIATIONS

AEZ	=	Agri Ecological Zone
ANOVA	=	Analysis of Variance
BBS	=	Bangladesh Bureau of Statistics
ppm	=	Perts per million
ha	=	Hectare
J.	=	Journal
Sci.	=	Scientific
DF	=	Degree of freedom
Agric.	=	Agriculture
et al.	=	And others
FAO	=	Food and Agricultural Organization of United Nation
g	=	Gram
Int.	=	International
MS	=	Mean Square
Hort.	=	Horticultural
LSD	=	Least Squares Means
ml	=	Milliliter
NS	=	Non-significant
Soc.	=	Society
SRDI	=	Soil Resource Development Institution
SAS	=	Statistical Analysis
DAT	=	Day After Transplanting
SE	=	Standard Error
NAR	=	Net Assimilation Rate
RGR	=	Relative Growth Rate
LAI	=	Leaf Area Index

CHAPTER I

INTRODUCTION

Chilli plants botanically referred to as genus *Capsicum*, belongs to family solanaceae, having diploid species with mostly 2n = 2x = 24 chromosomes, but wild species with 2n = 2x = 26 chromosomes have been reported (Pickersgill, 1991) and is cultivated as an annual crop worldwide. The domestication of chilli first occurred in Central America, most likely in Mexico, with secondary centers in Guatemala and Bulgaria (Salvador, 2002). India, Mexico, Japan, Ethiopia, Uganda, Nigeria, Thailand, Turkey, Indonesia, China and Pakistan are the major chilli growing countries. It is also known as hot pepper, capsicum, marich, green pepper etc. It is an important spice as well as vegetable crop, where both ripe and unripe fruits are used for culinary, salad and processing purposes. Its extract is used in pharmaceutical industry for colouring the drugs.

Chilli is an excellent source of vitamin A and C. Being richest source of vitamin C, it is sometimes referred as capsule of vitamin C (Durust *et al*., 1997). The pungency in chilli is due to an alkaloid capsaicin ($C_9Hi_4O_2$) which is a digestive stimulant. It contains high nutritive value with 1.29 mg/100 g protein, 11 mg/100 g calcium, 870 I.U vitamins-A, 175 mg ascorbic acid, 0.06 mg thiamine, 0.03 mg riboflavin, 0.55 niacin per 100 g edible fruit and 321mg per 100 g of vitamin C (Agarwal *et al*., 2007). They have beta carotene which is as much as that found in spinach of 180 mg per 100 g (Olivier *et al.*, 1981).

Chilli is one of the vegetable crops which has tremendous export potential and help farmers in solving their problems of dependence on traditional crops. Depending on yield and consumers preference, a number of chilli genotypes are being cultivated throughout the Bangladesh. Winter chilli contributes about 90 % of its total production. In Bangladesh, chilli crops occupies 103.24 thousand hectare of land with a production of 137 thousand metric tones (BBS, 2017). Moreover, new processing units have established in the past which have encouraged the cultivation of chilli in the country.

For commercial production of vegetable crops in many regions of the world, the use of plant spacing has become an important cultural practice to maximize nutrient use efficiency by the plant and to improve the growth (Sharma and Kumar, 2017). Successful cultivation of any crop depends in several factors. Plant spacing is of the important aspects for production system of different crops. Optimum plant spacing ensures proper growth and development of plant resulting maximum yield of crop and economic use of land (Islam *et al.*, 2011).

Fertilizers offer the best means of increasing yield, quality and maintaining soil fertility. Three major nutrients viz., nitrogen, phosphorous in general and potassium in particular are essential for increasing yield and quality of chillies (Irutharayaraj and Kulandaivelu, 1973). Solanaceous crops have high K demand and the harvested fruit removes a large amount of K from soil. Input of K fertilizer to these crops is much less than amounts removed. Potassium is one of the major macronutrient, contributing upto 6% of plant dry weight (Hartz *et al.*, 1999) called it as a quality nutrient. Adequate K nutrition has also been associated with increased yields, fruit size increased soluble solids and ascorbic acid concentrations, improved fruit colour, increased shelf life, and shipping quality in many horticultural crops (Lester *et al.*, 2007).

Potassium is involved in a number of biochemical and physiological processes vital to plant growth, yield, quality and stress (Marschner, 1995) in addition to stomatal regulation, transpiration and photosynthesis. K is also involved in photo phosphorylation, transportation of photoassimilates from source tissues via phloem to sink tissues, turgour maintenance and stress tolerance (Pettigrew, 2008). It has also been shown that potassium plays a key role in activation of more than 60 enzyme systems in plants. In addition to this wide spread use of nitrogenous fertilizers only has increased susceptibility of plants to diseases and pests which can be countered by optimum potassium nutrition (Dev, 1989).

Keeping in view the importance of spacing and potassium in enhancing yield and quality of chilli, an investigation has been carried out for the following objectives:

1. To determine suitable spacing for higher growth and yield of chilli;

2. To find out the optimum level of potassium fertilizers for maximum yield of chilli and

3. To measure the combined effect of different spacing and potassium fertilizer for successful growth and yield of chilli.

CHAPTER II

REVIEW OF LITERATURE

Chilli is the most important vegetable crop in the world. It responses sensitivity to various factors like plant nutrition, population density, temperature, humidity, light intensity and moisture for proper growth and yield. Researchers have tried to find optimum environment for better production by conducting different experiments modifying the environmental factors or application of cultural practices. Some relevant research works are reviewed here to get an impression which are common in agreement or disagreement.

2.1 Literature on plant spacing

Thakur *et al*. (2018) carried out an experiment to study the effect of plant spacing on growth, flowering, fruiting and yield of capsicum (*Capsicum annuum* L.) hybrid buffalo. There were three levels of spacing 45 cm × 30 cm (4.4 plants/m^2), 45 cm × 45 cm (2.94 plants/m^2) and 45 cm × 60 cm (2.22 plants/m^2) and three levels of numbers of shoots per plant *viz*. two shoots, three shoots and four shoots. Among the different spacing level, the spacing S_1 (45 cm × 30 cm) recorded maximum plant height (137.46 cm), yield (82.13t/ha.) and spacing S_1 (45 cm × 30 cm) showed the early flower initiation as well as 50 percent flowering (52.24 days). Maximum number of leaves (122.29), leaf area (97.24), number of branches (9.39), number of flower per plant (10.74), number of days for fruit set (66.20), least number of days to first harvest (89.06 days), fruit weight (185.31g), number of fruit per plant (18.48), yield per plant(3.38 kg.) was recorded under S_3 (45 cm × 60 cm) and higher B:C ratio (5.60) was recorded under S_2 rest of treatments.

Sharma and Kumar (2017) conducted a field study to investigate growth and yield of chilli as influenced by growing conditions and spacing. There were two different growing conditions *viz*. low tunnel and open field conditions and three levels of spacing *viz*. 60 × 30 cm, 60 × 45 cm, 60 × 60 cm. The plant spacing had significant variation in almost all the growth and yield components; number of branches/plant, number of fruits/plant, and yield/plant were increased with the increasing of plant spacing but plant height was found to be significantly increased with the decreasing plant spacing.

Bai and Sudha (2015) conducted an experiment to assess the optimum spacing requirement of chilli grown inside greenhouse. Treatments consisted of three spacing *viz*., 45 × 45 cm, 50 × 50 cm and 55 × 55 cm in the greenhouse condition and it was compared with chilli grown under open field condition with spacing of 45 × 45 cm. Results revealed that chilli performed better under greenhouse condition than under open condition during rainy season. Spacing had significant influence on the growth and yield of chilli under green house condition. Spacing of 50 × 50 cm recorded highest yield followed by 55 × 55 cm.

Fatemi *et al.* (2012) evaluated the response of sweet pepper (*Capsicum annuum* L.) to plant density under field conditions. Plant density at four levels (20 × 50 cm, 30 × 50 cm, 20 × 100 cm and 30 × 100 cm). Plant height, lateral stem number, leaf chlorophyll content, yield and vitamin C were assessed at immature and mature stages. The results showed that vegetative growth characteristics (plant height, lateral stem number and leaf dry matter) and reproductive factors (fruit volume, fruit weight and plant yield) decreased with increasing plant density but total yield increased with increasing plant density. The highest and lowest total yields were obtained by plant density 20 × 50 cm and 30 ×100 cm, respectively.

Islam *et al*. (2011) carried out a field experiment to investigate growth and yield of sweet pepper as influenced by spacing. There were three levels of spacing *viz*. 50×50 cm, 50×40 cm and 50×30 cm. The plant spacing had significant variation in almost all the growth and yield components except pericarp thickness. Number of branches per plant, number of leaves per plant, stem girth, number of fruits per plant, days to first harvest, fruit length, individual fruit weight, yield per plant were found to be significantly increased with the increasing of plant spacing but plant height at different stages, number of fruits per plot, days to 50% flowering, fruit breadth, yield per plot and yield per hectare were found to be significantly increased with the decreasing plant spacing. Considering the yield of fruits per hectare, cost of production and net return, 50×30 cm spacing appeared to be recommendable for the cultivation of sweet pepper.

Aminifard *et al.* (2010) conducted a study to determine the effects of different plant densities (20 × 50 cm, 30 × 50 cm, 20 × 100 cm and 30 × 100 cm) on plant growth characteristics and fruit yield of paprika pepper (*Capsicum annuum* L.) in open field. Plant height, leaf chlorophyll content, flower number, yield, fruit and seed number, 1000 seed weight and vitamin C were assessed at immature and mature stage. The results indicated that vegetative growth characteristics viz. plant height, lateral stem length and leaf chlorophyll content reduced as plant density increased. The highest lateral stem number and leaf number were obtained in plant density 30 × 100 cm. Plant density affected the flowering factors viz. node number to first flower, days to first flowering and flower number. The days to first flowering increased as plant density increased. It was observed that fruit volume, fruit average weight, plant yield and seed number decreased with increasing plant density but total yield per hectare increased with increasing plant density. The highest and lowest of yield per ha were obtained by 20 × 50 cm and 30 × 100 cm spacing, respectively. Also plant density significantly affected the vitamin C. The highest and lowest vitamin C was observed in 30 × 100 cm and 30 × 50 cm spacing, respectively.

Khasmakhi *et al.* (2009) carried out an experiment with three plant densities (30,000; 42,000, and 78,000 plants ha^{-1}) with an in-row spacing of 0.45, 0.30 or 0.15 m between plants in rows 0.8 m apart. The 42,000 plants per hectare density produced suitable vegetative growth, best yield and did not have any significant negative effects on bell pepper quality.

Chaudhary *et al.* **(**2007) studied the effect of spacing (45 × 50, 60 × 50 and 75 × 50 cm) on the growth and yield of *Capsicum annuum* var. *grossum* on sandy loam soil in Uttar Pradesh during 2000-01 and 2001-02. Decreasing spacing treatments from

75 × 50 to 60 × 50 cm improved the yield without adversely affecting the yield attributes. Maximum fruit yield per hectare was recorded under 60× 50 cm spacing.

Lee *et al.* (2006) conducted an experiment to determine the effects of planting distance (in-row spacings of 30, 45, 60 and 70 cm) on jalapeno pepper **(***Capsicum annuum* cv**.** *Sierra fuego*) and the effects of plant types (erect, semispreading and spreading). They reported that there were no significant differences in fruit characteristics such as fruit length, fruit width and sugar contents. The number of fruits and yield per plant increased with increase in row spacings but the total yield per unit area was highest at the lowest in-row spacing of 30 cm regardless of plant type.

Shabnam *et al.* **(**2004) studied the effect of row spacing (60, 70 or 80 cm) on the growth characteristics of chilli. The row spacing had a significant effect on the number of days to edible maturity and plant height. The greatest number of days to edible maturity (80.22) and plant height (88.96 cm) were recorded for wider row spacing (80 cm), while the lowest number of days to edible maturity (78.00) and plant height (85.18 cm) were recorded for a row spacing of 60 cm.

Buczkowska (2004) investigated the effect of plant density (5.88, 4.17, 3.33 and 2.27 plants/m^2) on the growth and yield of sweet pepper cv Mino in experiments conducted during 2001-03 in Poland. The highest average marketable yield (4.06 kg/m^2) was obtained at a density of 5.88 plants/m^2.

Dasgan and Abak (2003) grown the pepper **(***Capsicum annuum* L.) cultivars, Amazon-Long Green and Balo bell-shape type in the winter cultivation period in a glasshouse. A constant space of 80 cm between rows with different within row spacings (45 cm, 30 cm and 15 cm) were maintained to optimize plant density. Wider within row spacing increased the number of leaves. However, the individual leaf blade area was higher for narrower within row spacings. While higher plant densities reduced photosynthetically active radiation, they increased the leaf area index at fruiting level. In order to obtain high yields an assumption of 80 × 15 cm is suggested for peppers. When expensive seed is used then a 80 × 30 cm spacing might be more economical. However, plant density did not affect fruit quality characteristics, such as fruit weight, length, diameter, volume, dry matter, total soluble solids and the pH of the flesh in either cultivar.

Faiza *et al.* (2002) conducted a field experiment to study the effects of different plant spacing (25, 30, 35, 40 and 45 cm) on the growth and yield of sweet pepper cv. Yellow Wonder at the Agriculture Research Station (North), Mingora, Swat, Pakistan, during spring 2001. Plant spacing significantly affected plant height (41.00 cm), number of branches (7.78) and number of fruits (18.61) at 45 cm spacing, while minimum values of these parameters were recorded when plants were spaced at 25 cm. Maximum (25.98 t) and minimum (20.17 t) yield per hectare were observed in plants spaced 35 and 45 cm apart, respectively. The results showed that better performance in growth and yield were obtained when plants were spaced at 35 cm.

Aliyu (2002) conducted a field trials with pepper (*Capsicum annuum*) cv. L5962-2 between 1991 and 1993 at Samam, Nigeria, to study the effect of N (0, 80, 160, 240 and 360 kg/ha), P (0, 22 and 44 kg/ha) and plant density (20000, 40000 and 60000 plants/ha) on the growth and dry fruit yield. Using the classical approach, growth analysis indices were derived at fortnightly intervals. Leaf area index and relative growth rate as well as aerial phytomass showed a positive significant response to N application, whilst net assimilation rate was significant only at 10 weeks after transplanting. The effects of P and plant density on dry weights and growth analysis indices were less marked. Significant increases in the yield both per plant and per hectare were obtained up to 240 kg N/ha. Application of P at 22 kg P/ha was adequate for dry fruit yield. Although yield per plant decreased with increasing density, the yield/ha increased up to 60000 plants/ha.

Arora *et al.* (2002) conducted a field experiments comprising of six plant densities and four irrigation levels to study their effect on shoot-root growth and fruit yield in chilli cv. HC-44 during 1994 and 1995. Among various levels of plant densities tested D_5 (24 plants/plot) produced maximum dry weight of leaves, root length and root biomass whereas D_4 (60 plants/plot) produced maximum fruit yield (q/ha). Among the irrigation levels tested 13 (ID/CPE ratio of 1.0) gave maximum diy weight of leaves and fruit yield (q/ha) while 12 (ID/CPE ratio of 0.75) gave maximum root length and root biomass. The interaction effect of plant density and irrigation levels showed that D_{413} (60 plants/pot with irrigation level having ID/CPE ratio of 0.75) resulted in maximum yield of red ripe fruits while least was recorded in D_{513} (24 plants/plant with ID/CPE ratio of 1.0).

A field experiment was conducted to study the effects of different nitrogen rates (0, 50, 100, 150, 200 and 250 kg ha^{-1}) and plant spacing (25, 30, 35, 40, and 45 cm) on the growth and yield of sweet pepper (*Capsicum* sp.)cv. Yellow Wonder at the Agriculture Research Station (North), Mingora, Swat, Pakistan, during spring 2001 (Faiza *et al.,* 2002). Plant height (41.60 cm), number of branches (9.13), and yield ha^{-1} (30.82 t) were recorded with the application of 150 kg N/ha. Maximum fruiting (18.20) was observed in 100 kg N ha^{-1}. Plant spacing significantly affected plant height (41.00cm), number of branches (7.78) and number of fruits (18.61) at 45 cm spacing, while minimum values of these parameters were recorded when plants were spaced at 25 cm. Maximum (25.98 t) and minimum (20.17 t) yield ha^{-1} were observed in plants spaced 35 and 45 cm apart, respectively. The interaction between different levels of nitrogen and plant spacing showed significant effect on most of the parameters. The results showed that better performance in growth and yield were obtained when plants were supplied with 150 kg N ha^{-1} and spaced at 35 cm under the climatic conditions of Swat.

Viloria *et al.* (2001) conducted an experiment to determine the effect of different levels of nitrogen, phosphorus and potassium (NPK), and density of plants on pepper vegetative growth. Four doses of NPK (0-0-0; 172-0-0; 137- 50-83 and 180-55-124 kg/ha) and two plant densities (6 and 8 plants/m^2) were evaluated 36, 58, 80 and 102 days after transplanting. NPK at 180-55-124 kg/ha recorded the highest diameter, fresh weight and dry weight of the stem. Fresh and dry weight of the leaves were the highest with 137-50-83 and ISO- 551-124 NPK/ha. Dry and fresh weight decreased with increasing plant density. Plant diameter and height, branching weight, and fresh and dry weights of the leaves were a function of plant age and were demonstrated by linear equations.

Dobromilska (2000) studied the effect of spacing and planting method in a 3 year long experiment under unheated plastic tunnel on the yield of sweet pepper. The seedlings were planted at a density of 50 × 40 cm, 50 × 50 cm and 50 × 60 cm in single or double rows. Plants grown at 50 × 40 cm in double rows produced the highest total fruit yields and yields of first class fruits. However, the commercial quality of fruits based on mean weight and thickness of pericarp was lower at the highest planting density.

Cavero *et al.* **(**2001) grown paprika pepper **(***Capsicum annuum* L.) on raised beds in double rows 0.35 cm apart. Plants were thinned within the row to establish densities ranging from 13,333 to > 50,000 plants/ha. Yield of paprika pepper increased as plant density increased but plant densities >200,000 plants/ha resulted in only small increases in yield. Fruit number and dry fruit weight/plant decreased with increasing plant populations, and weight/fruit decreased slightly. The increase in yield/ha as plant density increased was a result of increased numbers of fruits/ha. Plant densities in the range of 15,000 to 20,000 plants/ha were optimal.

Capsicum annuum var. *grossum* cv. California Wonder was sown at different densities (60 × 30, 60 × 45 and 60 × 60 cm spacing) and was supplied with 4 N rates (0, 50, 100 and 150 kg/ha) and 3 P rates (0, 50 and 100 kg/ha) in a field study conducted at C oi mb atore, Tamil Nadu, India . Leaf Area Index (LAI) was the highest at 60 × 45 cm spacing. Net assimilation rate (NAR), relative growth rate (RGR) and crop growth rate (CGR) increased as population densities increased and were the highest at 60 × 30 cm spacing. Harvest index was the highest at 60 × 60 cm spacing. LAI, total chlorophyll content and harvest index were the highest when 150 kg N/ha + 100 kg P/ha was applied. NAR, RGR and CGR were not affected by N and P rates (Maya *et al.*, 1999).

Kim *et al.* (1999) investigated the effect of planting density (2479-6198 plants/1000 m^2) on growth, yield and fruit quality of *Capsicum* cultivars Pungchon (upright) and Shinbaram (spreading), grown in tunnels. Seedlings were planted in 2-rows on a raised- bed, either facing each other or alternating, and were spaced 20, 30, 40 or 50 cm apart. Planting systems and distances did not significantly alter plant height, main stem length, fruit length, fruit diameter or thickness of pericarp. However, increasing the distance from 20 to 50 cm increased stem diameter. Planting distance, but not the planting pattern, affected fruit number/plant. Total yield increased as planting density increased in Pungchon, but not in Shinbaram. Some differences were found in fruit powder chromaticity, ASTA colour and the concentrations of capsaicinoids and sugars, but no consistent conclusion, ascribed solely to planting patterns and distances, could be drawn. Since increasing planting density did not reduce fruit size or the quality of pepper powder, it is an acceptable way to increase the yield of tunnel-grown capsicum.

Ravanappa *et al.* (1998) investigated the effect of plant density (60 × 30, 60 × 45, 60×60, 75× 30, 75 × 45, or 75 × 60 cm) on growth and yield of 3 green chilli cultivars (Nagavi, Kadrolli and Pusa Jwala) using factorial design at Dharwad, India, during summer 1991 and Kharif season (monsoon) 1992. Significant cultivar and treatment differences were noticed. The variety Nagavi produced the highest number of branches of all orders, fresh weight and dry weight of plants, and the highest green fruit yield. The highest plant density treatment (60 × 30 cm) produced the highest yield/ha, while the lowest plant density treatment (75 × 60 cm) produced the highest DW, FW, number of branches and yields/plant.

Viloria *et al.* (1998) conducted a field trial in 1995 in Venezuela with *Capsicum annuum* cv. Jupiter. Seedling of 35 days old were transplanted in raised beds (18 × 1.2 × 0.40 m), filled with a mixture of soil, horse manure, sand and coconut fiber (2:1:1:1, by volume). Plant spacing's of 10, 15 and 20 cm were used, with rows 60 cm apart. Height and diameter of main stem, height, fresh and dry weight of shoots, fresh and dry weight of leaves, number of primary and secondary branches, and number of flower blossoms in these branches were measured at 35 and 80 days after transplanting. With the reduction of the planting distance from 20 × 60 to 10 × 60 cm, the values of the parameters evaluated decreased significantly, except for stem heights. Age (days after planting) was statistically significant for all the variables except the height of the main stem, which showed that the period between 35 and 80 days after transplanting is determinant on the growth of the bell pepper plant structures. The responses of growth variables were explained by multiple exponential and linear equations.

2.2 Literature on potassium

Idan (2016) investigated the present study entitled effect of potassium on yield of pepper (*Capsicum annuum* L.) cv. charisma under protected cultivation. The experiment was carried with the treatments of T_1 (0), T_2 (10), T_3 (15), T_4 (20) kg potassium sulfate per poly house (504 m^2). The highest number of fruits (22.10), fruit weight (184.10 g), yield per plant (4.07 kg) and total yield per poly house (3.25 tones) was obtained in T_4.

Khan *et al*. (2014) conducted an experiment to observe the influence of nitrogen and potassium levels on chillies (*Capsicum annuum* L.). Different levels of nitrogen (0, 60, 120 and 180 kg ha^{-1}) and potassium (0, 30, 40 and 50 kg ha^{-1}) were investigated. The maximum number of fruits $plant^{-1}$ (47.7), fruit length (5.76 cm), seeds $fruit^{-1}$ (109) and higher yield (7.102 tons ha^{-1}) were recorded with 50 kg K ha^{-1} which was statistically at par with 40 kg K ha^{-1} except for fruit length. Application of 180-40 kg N-K_2O ha^{-1} are recommended for better growth and yield of chillies.

Bhuvaneswari *et al*. (2013) studied the effects of nitrogen and potassium on the growth and yield of capsicum. The treatments were 4 levels of N (0, 25, 50 and 75 kg ha^{-1} designated as N_0 , N_{25}, N_{50}, and N_{75}, respectively) and 3 levels of K (0, 30 and 60 kg ha^{-1} designated as K_0, K_{30} and K_{60}, respectively). Plant height at first flowering and number of branches at first harvest increased significantly increasing levels of K up to the treatment K_1 (30 kg K ha^{-1}), whereas plant height and number of branches at final harvest and number fruits yield per plant enhanced significantly up to the treatment K_2 (60 kg K ha^{-1}). Considering the combined effect of nitrogen and potassium, the maximum plant height at final harvest were obtained from N_3K_2 (75 kg N +60 kg K ha^{-1}). Maximum number of fruits per plant was also found in the treatment combination N_3K_2 (75 kg N + 60 kg K ha^{-1}).

Bidari and Hebsur (2011) stated that the amount of potassium needed for production of quality vegetables exceeds the amount needed for maximum production. Potassium deficiency symptoms appeared first in oldest leaves which develop scorch, curled margins, brown margins. Potassium balances acid-sugar ratio in fruits. In tomato and red chillies potassium deficiency lead to irregular fruit colour development. Increasing rates of K fertilization resulted in increased lycopene and capsanthin synthesis in tomato and chilli fruits respectively.

El-Bassiony *et al.* (2010) reported significant increase in all growth characters of sweet pepper with increase in potassium rates from 50 to 200 kg fed^{-1}. Maximum plant height (46.77 cm), leaf number $plant^{-1}$ (201.75), branch number $plant^{-1}$ (9.44) were recorded with application of 200 kg potassium fed^{-1}. Application of potassium at the rate of 200 kg fed^{-1} produced maximum fruit length (10.12 cm), fruit diameter (6.85 cm), fruit weight (157 g $plant^{-1}$) and total fruit yield (8.64 t/Fed) in sweet pepper.

Rubio *et al.* (2010) observed that marketable fruit yield in sweet pepper was reduced by 25% at highest potassium level of 14 m mol l^{-1}. Application of 7 m mol l^{-1} of K+ produced marketable fruit yield of 2,100 g $plant^{-1}$ which was significantly higher than at 12 m mol l^{-1} of K^+.

Shivakumar *et al.* (2010) found that in chilli increasing doses of potassium upto 300 kg K_2O ha^{-1} recorded consistent increase in the yield. However, with further increase in the potassium level beyond 300 kg K_2O ha^{-1}, the yield showed declining trend.

Bharamappa *et al.* (2009) reported that application of 150 kg K_2O ha^{-1} in combination with 300 kg N and 150 kg P_2O_5 ha^{-1} recorded maximum plant height

(91.26 cm), number of branches plant^{-1} (25.97), number of leaves plant^{-1} (251.20), leaf area index (1.21), total dry matter plant^{-1} (71.40 g) and stem girth (1.01 cm) in chilli. Increasing levels of potassium in combination with nitrogen and phosphorous increased the yield attributes in chilli. Maximum fruit length (10.35 cm), fruit girth (0.80 cm) and dry fruit weight plant^{-1} (85.96 g) were recorded with 150 kg K_2O ha^{-1} in combination with 300 kg N and 150 kg P_2O_5 ha^{-1}.

Data and Jana (2009) found that application of 100 kg K_2O ha^{-1} in combination with 200 kg N and 100 kg P_2O_5 ha^{-1} significantly improved the plant height (76.7 cm), primary branches plant^{-1} (7.7) and individual fruit weight (2.51 g) in chilli. However, significantly highest fruit number plant^{-1} (133) was recorded with 75 kg K_2O ha^{-1} in combination with 150 kg N and 75 kg P_2O_5 ha^{-1}. Data and Jana (2009) also recorded significantly highest chilli yield (10.6 t ha^{-1}) with application of 150 percent of recommended dose of NPK (100:50:50 kg NPK ha^{-1}).

Prabhavati *et al.* (2008) reported that in chilli maximum number of fruits picking^{-1} (36.74) and weight of 100 dry fruits (131.74 g) was recorded when potassium was applied at 75 kg K_2O ha^{-1}. In an investigation undertaken to study the influence of potassium on yield of chilli. Significantly highest dry fruit yield (10.71 q ha^{-1}) was also recorded when potassium was applied at 75 kg K_2O ha^{-1}.

Hari *et al.* (2007) while studying the effect of potassium levels (0, 30, 60 and 90 kg K_2O ha^{-1}) on yield and nutrient uptake in paprika under irrigated conditions on red loam soils, of Andhra Pradesh reported that increased levels of potassium significantly increased the dry pod yield with highest yield (17.64 q ha^{-1}) at 90 kg K_2O ha^{-1}.

Hiremath *et al.* (2006) found higher number of fruit plant^{-1}, fruit length, fruit width and fruit weight in paprika with highest fertility level of 225:112.5:112.5 kg NPK ha^{-1} + 25 t FYM ha^{-1} compared to lower fertility levels. Working on chilli Bose *et al.* (2006) reported that potassium application at 150 kg K_2O ha^{-1} produced significantly highest fruit length (6 cm), fruit weight (1.9 g) and seeds fruit^{-1} (57).

Bose *et al.* (2006) reported that application of potassium at 90 kg K_2O ha^{-1} in tomato produced maximum plant height (77.90 cm), basal girth (4.80 cm), days to 50% flowering (40) and truss $plant^{-1}$ (24). They also reported that potassium application at the rate of 190 kg K_2O ha^{-1} produced maximum tomato fruit weight of 102.80 g.

Ditschar and Ivanova (2005) observed that with increasing doses of potassium upto 450 kg K_2O ha^{-1}, the yield of chilli increased to 14 t ha^{-1}. Thakre *et al.* (2005) conducted field experiment to find out the effect of potassium on yield and quality of brinjal and reported that application of 25 kg K_2O ha^{-1} produced the highest fresh fruit yield of 144.52 q ha^{-1} which was at par with 50 kg K_2O ha^{-1} (140.60 q ha^{-1}). Shankar and Sumangala (2005) reported that application of potassium at 50 kg ha^{-1} resulted in significantly higher chilli yield.

Ananthi *et al.* (2004) reported that potassium application at 60 kg K_2O ha^{-1} increased fruit number $plant^{-1}$, fruit length and fruit weight in chilli.

Ramakrishna and Palled (2004) found that application of 75 kg K_2O ha^{-1} in combination with 150 kg N and 75 kg P_2O_5 ha^{-1} significantly increased the number of fruits $plant^{-1}$ (90.25) and fruit weight $plant^{-1}$ (45.46 g) over other fertility levels. However, 100-seed weight of chilli remained unaffected. Application of 75 kg K_2O ha^{-1} in combination with 150 and 75 kg N and P_2O_5 ha^{-1}, respectively also significantly increased the fruit yield in chilli (11.76 q ha^{-1}) over other fertility levels.

Ramakrishna and Palled (2005) reported significant increase in leaf area index of chilli (2.01) with application of potassium at 75 kg K_2O ha^{-1} in combination with 150 kg N and 25 kg P_2O_5 ha^{-1}.

Shetty *et al.* (2003) stated that dry fruit yield in chilli did not show any significant improvement with increasing levels of potassium beyond recommended dose of 50 kg K_2O ha^{-1}.

Wuzhang (2002) reported that potassium fertilization significantly increased the fruit yield of egg plant, tomato, sweet pepper and chilli.

Mohanty *et al.* (2001) reported that among three levels of potassium viz., 0, 30 and 60 kg K_2O ha^{-1}, 30 kg K_2O ha^{-1} dose recorded the highest number of fruits $plant^{-1}$ in chilli cv. Utkal Rashmi.

Chattopadhyay *et al.* (2000) did not find any significant variation in growth and fruit characters of potato at different potassium levels. Thakur *et al.* (2000) also reported that increasing levels of potassium in combination with bioregulators and bioextracts significantly affected plant height, leaf area index, transpiration rate and osmolarity in bell pepper.

Gupta and Senger (2000) found that potassium application exhibited pronounced effect in improving vegetative growth of tomato. Maximum number of fruits $plant^{-1}$ (35.20) and average fruit weight (93.50 g) were recorded with potassium application at 60 kg ha^{-1}.

Singh *et al.* (2000) reported that increasing levels of potassium increased the number of marketable fruits $plant^{-1}$ in tomato hybrids with hybrid Menka recording maximum number of marketable fruits $plant^{-1}$ (26.58). Similarly average fruit weight increased with increasing levels of potassium.

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 October 2017 to April 2018 to study the impact of spacing and potassium on yield and yield attributes in chilli. 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 airtemperature, 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 spice crop; chilli was considered for the present study. Seed of Anmol F_1 hybrid chilli variety was used. It is an Indian chilli variety.

3.5 Experimental details

3.5.1 Treatments

The experiment comprised of two factors.

Factor A: Spacing – Three plant spacing

S_1=45 cm × 30 cm

S_2=45 cm × 45 cm

S_3=45 cm × 60 cm

Factor B: Potassium (K) – Four K levels

K_0=0 kg ha^{-1} (Control)

K_1=60 kg ha^{-1}

K_2=90 kg ha^{-1}

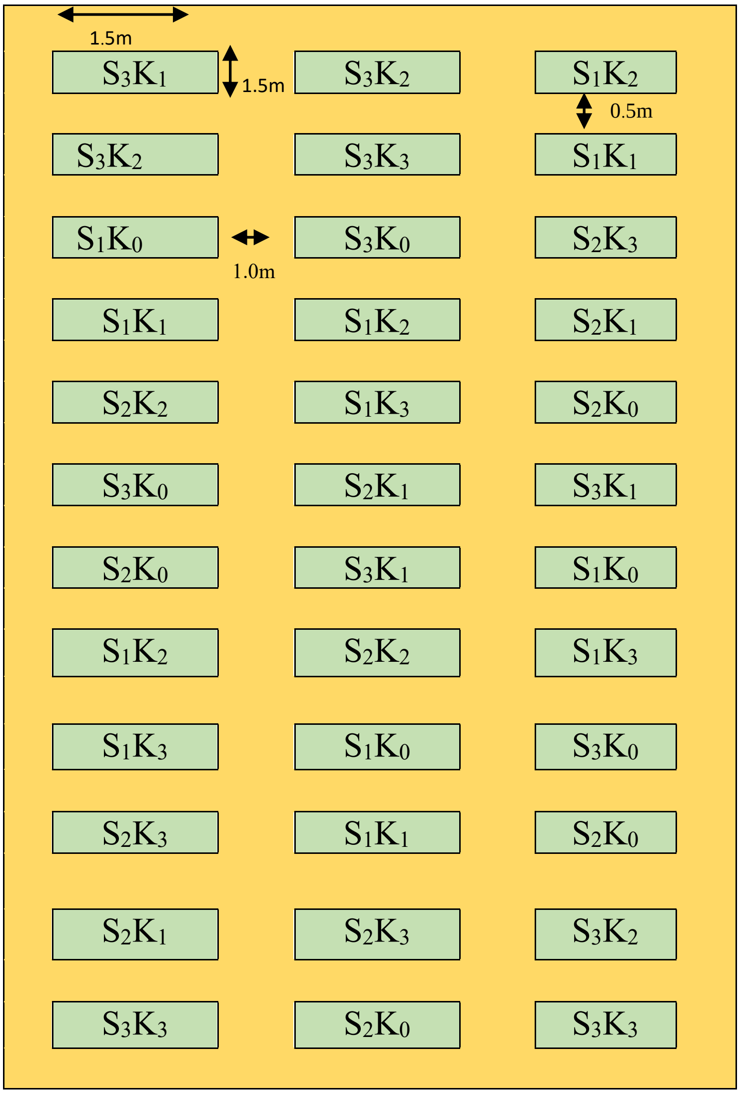
K_3= 120 kg ha^{-1}

Treatment combinations - 12 treatment combinations

S_1K_0, S_1K_1, S_1K_2, S_1K_3, S_2K_0, S_2K_1, S_2K_2, S_2K_3, S_3K_0, S_3K_1, S_3K_2 and S_3K_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 combination of plant spacing and different potassium levels. The 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot 1.5 m × 1.5 m (= 2.25 m^2). The distance between blocks and plots were 1.0 m and 0.5 m respectively. The layout of the experiment field is presented here.



Legend:

Plot length: 1.5m

Plot breadth: 1.5m

Plot size=1.5m×1.5m=2.25m^2

Distence between blocks =1.0

Distance between plots =.5m

Fig. 1. Lay out of experimental plot.

3.6 Variety used and seed collection

Anmol F_1 hybrid chilli variety was used for the present study. Seeds were collected from Siddiq Bazar, Dhaka, Bangladesh.

3.6.1 Raising of seedlings

The land selected for nursery bed was well drained and were sandy loam type soil. The area was well prepared and converted into loose friable and dried mass to obtain fine tilth. All weeds and dead roots were removed and the soil was mixed with well rotten cowdung at the rate of 5 kg/bed. Seed bed size was 3m × 1m raised above the ground level. One bed was prepared for raising the seedlings. Five grams of seeds were sown inthe seed bed on 5 November, 2017. After sowing, the seeds were covered with light soil. Complete germination of the seeds took place with 5 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. No chemical fertilizer was used in the seed bed.

3.7 Preparation of the main field

The plot selected for the experiment was opened in the first week of December, 2017 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 6 December 2017. The individual plots were made by making ridges around each plot to restrict lateral runoff of irrigation water.

3.8 Fertilizers and manure application

The Nitrogen, Phosphorus and Borax fertilizer were applied according to Krishi Projukti Hat Boi through urea, Triple super phosphate and boron respectively. Cowdung also used as organic manure. Potassium (K) was applied through MoP as per treatment. Nutrient doses used under the present study are presented as follows:

Nutrients	Manures/fertilizers	Doses ha^{-1}
-	Cowdung	10 ton
N	Urea	210 kg
P	TSP	330 kg
K	MoP	As per treatment
B	Borax	5kg

One third (1/3) of whole amount of Urea and full amount of TSP, one forth (1/4) of MoP and full amount of cowdung and Borax were applied at the time of final land preparation. The remaining Urea was top dressed in two equal installments- at 25 days after transplanting (DAT) and 50 DAT respectively and remaining MoP was given in three installments- at 20, 40 and 60 DAT.

3.9 Transplanting of seedlings

Healthy and uniform sized 25 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 6 December, 2017. Three plant spacing was maintained according to the treatments. The seed bed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

3.10 Intercultural operations

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

3.10.1 Gap filling and weeding

When the seedlings were established, the soil around the base of each seedling was pulverized. A few gaps filling were done by healthy plants from the border whenever it was required. Weeds of different types were controlled manually as and when necessary.

3.10.2 Irrigation

Irrigation was done at three times. The first irrigation was given in the field at 25 days after transplanting (DAT) through irrigation channel. The second irrigation was given at the stage of maximum vegetative growth stage (35 DAT). The final irrigation was given at the stage of fruit formation (50 DAT).

3.10.3 Plant protection

The crop was infested with cutworm, leaf hopper and others. The insects were controlled successfully by spraying Malathion 57 EC @ 2ml /L water. The insecticide was sprayed fortnightly from a week after transplanting to a week before first harvesting. During foggy weather precautionary measures against fungal diseases of chilli was taken by spraying Dithane M-45 @ 2 g/L.

3.11 Harvesting and cleaning

Fruits were harvested at 3 days intervals during maturity to ripening stage. Harvesting was started from 10 March, 2018 and completed by 28 April, 2018.

3.12 Data collection

Five plants were selected randomly from each unit plot for recording data on crop parameters and the yield of chilli was taken plot wise.

3.13 Procedure of recording data

3.13.1 Growth parameters

3.13.1.1Plant height

The height of plant was recorded in centimeter (cm) at different days after transplanting of crop duration. Data were recorded as the average of 5 plants selected at random from each plot. The height was measured from the ground level to the tip of the leaves by meter scale. Data was taken at 45, 60 and 75 days after transplanting (DAT).

3.13.1.2 Number of leaves plant^{-1}

Number of leaves per plant was counted at different days after sowing of crop duration. Leaves number per plan twas recorded from randomly selected 5 plants by counting all leaves and mean was calculated. Data was taken at 45, 60 and 75 days after transplanting (DAT).

3.13.1.3 Number of branches per plant

At different days after transplanting (DAT) i.e. at 45, 60 and 75 DAT, all the primary branches were counted from 5 plants of each plot and their average value was taken as number of branches per plant.

3.13.1.4 Stem diameter

Diameter of stem in centimeter (cm) was recorded from 5 selected plants of each plot at different days after transplanting (at 45, 60 and 75 DAT) at the base portion of the plant with a slide calipers. The average value is termed as stem diameter.

3.13.2 Yield contributing parameters

3.13.2.1 Days to 1st flowering

Days to first (1st) flowering was recorded from the date of transplanting to when 1st flower is appeared in the plant.

3.13.2.2 Days to 1st harvest

Days to 1st harvest was calculated also from the date of transplanting up to the attainment of edible fruit maturity stage.

3.13.2.3 Fruit length

The length of the fruit was measured with a digital slide calipers in centimeter from the neck of the fruit to the bottom of the fruit. It was measured from each plot and their average was calculated in centimeter.

3.13.2.4 Fruit diameter

Breadth of the fruits were measured at the middle portion of 20 randomly selected fruits from each plot with the slide calipers in centimeter and then their average was taken as the breadth of the fruits.

3.13.3 Yield parameters

3.13.3.1 Number of fruits plant^{-1}

Total fruit number was counted from 5 selected plants from 1st to last harvest and average number was calculated as number of fruits per plant.

3.13.3.2 Single fruit weight

From first harvest to last harvest total fruit number and weight was counted from 5 plants to determine single fruit weight. By using the following formula, single fruit weight was calculated and expressed in gram.

$$\text{Weight of individual fruit (g)} = \frac{\text{Total weight of fruits from 5 selected plants (g)}}{\text{Total number of fruits from 5 selected plants}}$$

3.13.3.3 Number of seeds fruit^{-1}

At first 20 marketable fruits were randomly selected and total seeds were counted. The average number was calculated and termed as number of seeds fruit^{-1}.

3.13.3.4 Fruit yield plant^{-1}

Total fruit yield was counted from 5 selected plants from 1st to last harvest and average yield was calculated as fruit yield per plant and was expressed in gram.

3.13.3.5 Fruit yield per hectare

To calculate fruit yield per ha; at first a pan scale balance was used to take the weight of fruits per plot. It was measured by totaling of fruit yield from 5 selected plants from each unit plot during the period from first to final harvest and then it converted to per plot yield and was expressed in kilogram. After collection of per plot yield, it was converted to ton per hectare by the following formula:

$$\text{Fruit yield per hectare (ton)} = \frac{\text{Fruit yield per plot (kg)} \times 10000 \text{ m}^2}{\text{Plot size (m}^2) \times 1\,000 \text{ kg}}$$

3.14 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

3.15 Economic analysis

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

3.15.1 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. Total cost of production (input cost, overhead cost), gross return, net return and BCR are presented in Appendix X.

3.15.2 Gross income

Gross income was calculated on the basis of mature fruit sale. The price of chilli was assumed to be Tk. 15/kg basis of local market value.

3.15.3 Net return

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

3.15.4 Benefit cost ratio (BCR)

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

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

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CHAPTER IV

RESULTS AND DISCUSSION

The experiment was carried out to find out the effect of potassium and plant spacing on growth and yield of chilli. Data on different growth parameters and yield of chilli plant was recorded and analyzed with MSTAT program. The results have been presented and discussed, and possible interpretations are given under the following headings:

4.1 Plant height

Statistically significant variation on plant height of chilli was shown due to different plant spacing at 45, 60 and 75 DAT (Appendix IV). At different days after transplanting (DAT) the tallest plant (32.12, 40.66 and 59.51 cm at 45, 60 and 75 DAT respectively) was recorded from S_1 (45 cm × 30 cm) treatment. On the other hand, the shortest plant (26.94, 33.29 and 46.03 cm at 45, 60 and 75 DAT, respectively) was found from S_3 (Fig. 2). Results under the present experiment found that closer spacing showed higher plant height where higher plant spacing showed lower plant height because of closer spacing plant compete for light which helps to elongate plant than the wider spacing. Fatemi *et al.* (2012) reported similar findings from the closest spacing.

Plant height of chilli varied significantly due to different levels of potassium (Appendix IV). At all the growth stages, the tallest plant (31.00, 39.44 and 57.58 cm at 45, 60 and 75 DAT, respectively) was recorded from K_3 (120 kg K/ha) which was statistically similar with K_2 (90 kg K ha^{-1}) at 45 and 60 DAT. Again, the shortest plant (27.44, 33.87 and 48.61 cm at 45, 60 and 75 DAT, respectively) was observed from control treatment, K_0 (Fig. 3). It was revealed that with the higher doses of potassium level, increase plant height, where no potassium application showed lowest plant height at all growth stages. Potassium fertilizer ensured favorable condition for the elongation of chilli plant with optimum vegetative growth and the ultimate results was the tallest plant. Similar results were observed by Sharma and Kumar (2017), Bai and Sudha (2015) and Boroujerdnia and Ansari (2007).

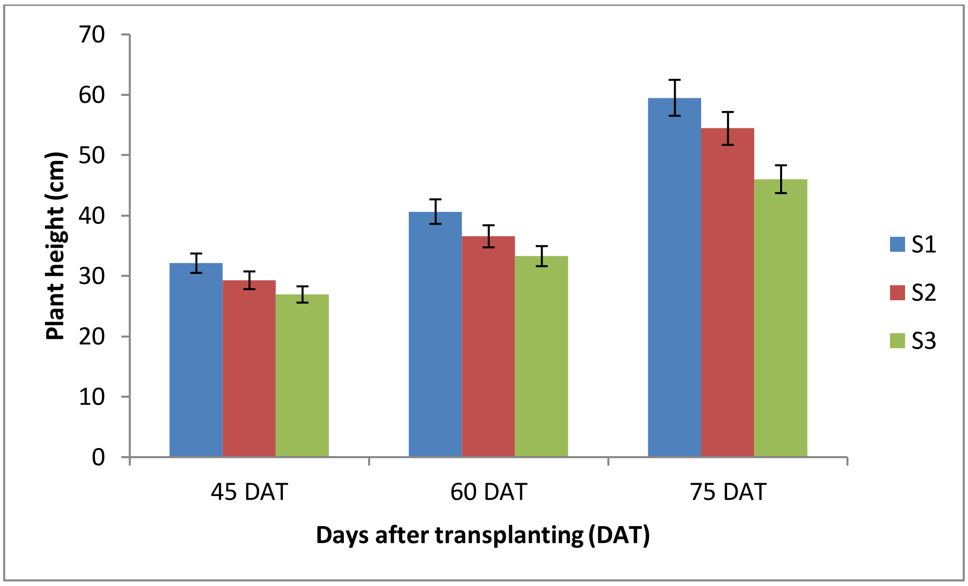

Fig. 2. Effect of spacing on plant height of chilli

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm

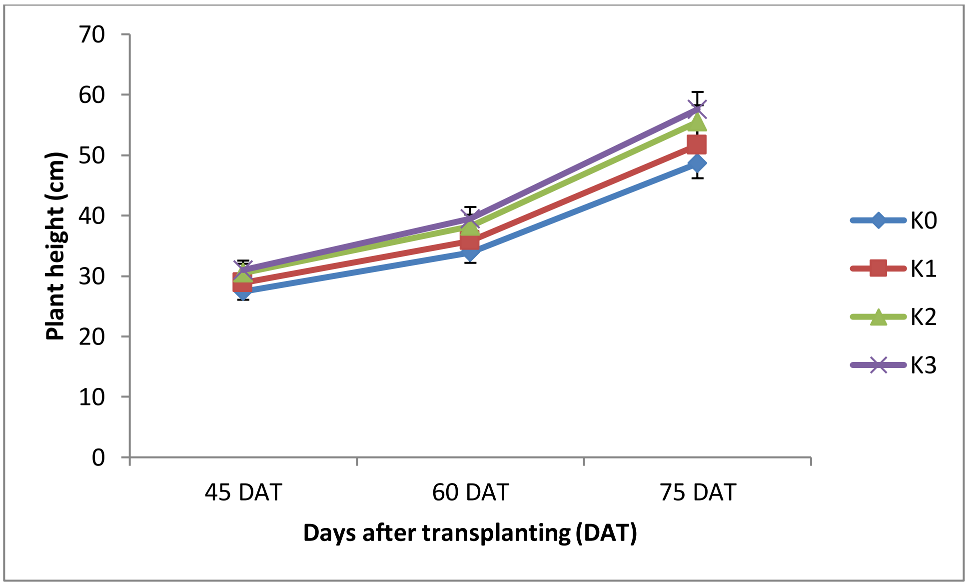

Fig. 3. Effect of potassium on plant height of chilli

K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Table 1. Combined effect of spacing and potassium on plant height of chilli

Treatments	Plant height (cm)		
	45 DAT	**60 DAT**	**75 DAT**
S_1K_0	28.54 cd	35.21 de	50.93 ef
S_1K_1	30.77 b	38.31 c	57.40 cd
S_1K_2	34.31 a	42.67 b	61.45 b
S_1K_3	34.88 a	46.44 a	68.28 a
S_2K_0	27.33 de	33.89 efg	50.62 ef
S_2K_1	29.31 c	36.20 d	52.62 e
S_2K_2	29.53 c	37.64 c	55.84 d
S_2K_3	31.00 b	38.56 c	58.67 c
S_3K_0	26.44 e	32.51 g	44.27 g
S_3K_1	26.55 e	32.89 g	44.88 g
S_3K_2	27.67 de	34.42 ef	49.18 f
S_3K_3	27.11 e	33.32 fg	45.78 g
$LSD_{0.05}$	1.196	1.303	2.205
CV(%)	11.86	13.54	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

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm
K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Significant variation was observed due to interaction effect of potassium and plant spacing in terms of plant height of chilli at 45, 60 and 75 DAT (Appendix IV). The tallest plant (34.88, 46.44 and 68.28 cm at 45, 60 and 75 DAT, respectively) was recorded from S_1K_3. The combination of S_1K_2 also showed higher plant height but significantly different from S_1K_3. The shortest plant (26.44, 32.51 and 44.27 cm at 45, 60 and 75 DAT, respectively) was found from S_3K_0 which was statistically identical with S_3K_1 (Table 1).

4.2 Number of leaves plant^{-1}

Significant variation was found for number of leaves per plant due to different plant spacing at 45, 60 and 75 DAT (Appendix V). At different days after transplanting (DAT) the maximum number of leaves per plant (40.19, 81.25 and 87.92 at 45, 60 and 75 DAT, respectively) was obtained from S_3 (45 cm × 60 cm) which was closely followed by S_2 (Fig.4). At the same condition, the minimum number of leaves plant^{-1} (34.67, 70.17 and 70.83 at 45, 60 and 75 DAT, respectively) was recorded from S_1 (45 cm × 30 cm). It was revealed that with the increases of spacing, number of leaves per plant also increased. Enough space for vertical and horizontal expansion in the optimum spacing that leads for production of maximum number of leaves per plant than the closer spacing. El-Bassiony *et al.* (2010) also reported similar results earlier.

Significant variation was recorded for number of leaves plant^{-1} of chilli with application of different levels of potassium at 45, 60 and 75 DAT (Appendix V). At 45, 60 and 75 DAT the maximum number of leaves plant^{-1} was 40.55, 83.42 and 91.22, respectively which was obtained from K_3 (120 kg K/ha) and the minimum number of leaves plant^{-1} (33.63, 66.89 and 65.44 at 45, 60 and 75 DAT respectively) was found from K_0 (Fig. 5). It was revealed that the higher doses of potassium level showed higher number of leaves plant^{-1} where no potassium application showed the lowest at all growth stages. Maximum number of leaves plant^{-1} was recorded for highest level of potassium because potassium fertilizer ensures favorable condition for the growth of chilli. Similar findings were observed by Bharamappa *et al.* (2013).

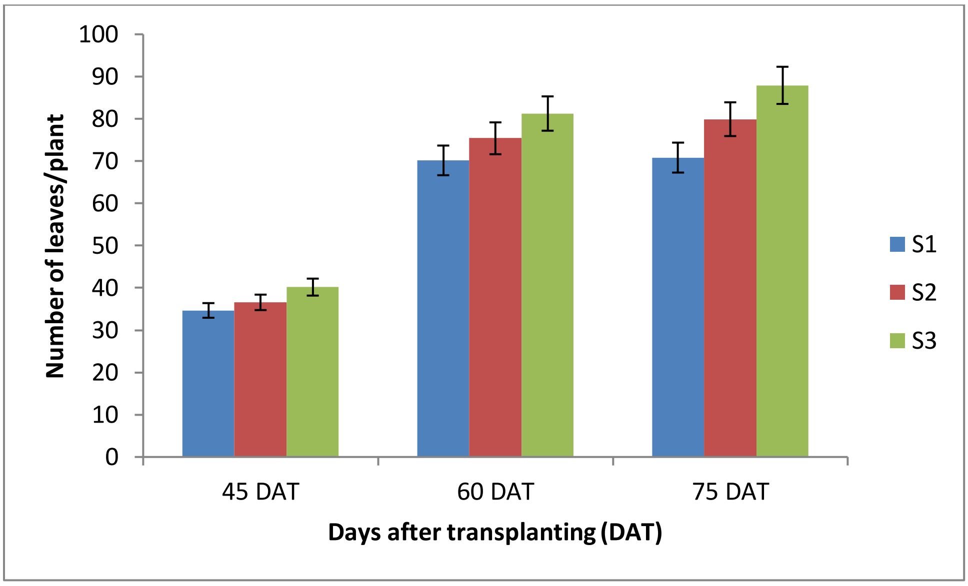

Fig. 4. **Effect of spacing on number of leaves plant^{-1} of chilli**

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm

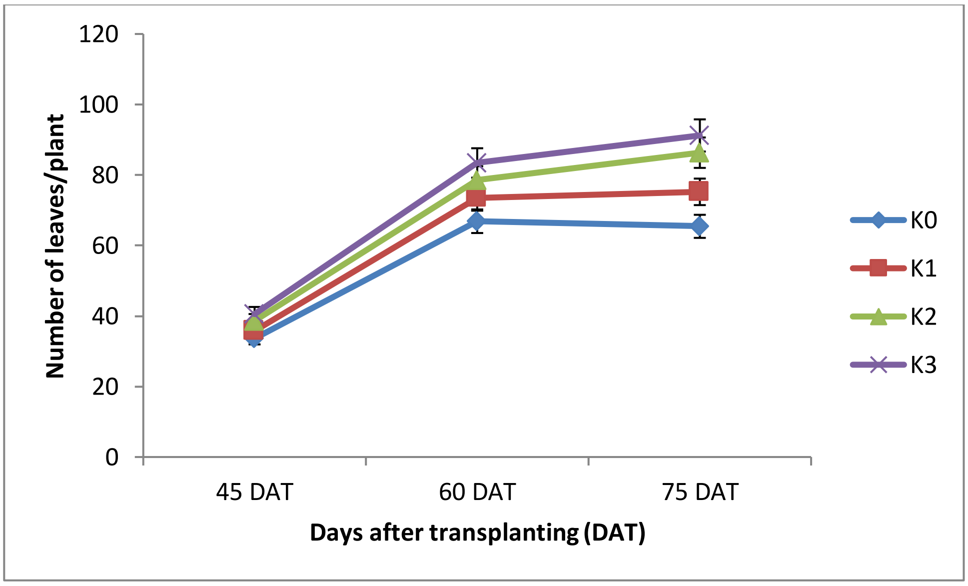

Fig. 5. Effect potassium on number of leaves plant^{-1} of chilli

K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Table 2. Combined effect of spacing and potassium on number of leaves plant^{-1} of Chilli

Treatments	Number of leaves plant^{-1}		
	45 DAT	60 DAT	75 DAT
S_1K_0	32.00 f	65.00 g	63.33 h
S_1K_1	34.56 e	68.33 fg	65.67 gh
S_1K_2	35.67 de	72.33 de	74.33 f
S_1K_3	36.44 de	75.00 d	80.00 de
S_2K_0	34.22 e	65.67 g	64.33 h
S_2K_1	35.78 de	74.00 d	76.33 ef
S_2K_2	37.22 cd	80.00 bc	88.67 c
S_2K_3	39.11 c	81.93 b	90.33 c
S_3K_0	34.67 e	70.00 ef	68.67 g
S_3K_1	37.00 cd	78.33 c	83.67 d
S_3K_2	43.00 b	83.33 b	96.00 b
S_3K_3	46.11 a	93.33 a	103.30 a
$LSD_{0.05}$	2.021	3.265	3.841
CV(%)	9.49	12.87	5.35

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

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm
K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Interaction effect of potassium and plant spacing showed significant difference among the treatments in terms of number of leaves per plant of chilli at 45, 60 and 75 DAT (Appendix V). The maximum number of leaves plant^{-1} (46.11, 93.33 and 103.30 at 45, 60 and 75 DAT, respectively) was found from S_3K_3. The treatment combination of S_3K_2 also showed higher number of leaves plant^{-1} but significantly different from S_3K_3 (Table 2). Again, the minimum number of leaves plant^{-1} (32.00, 65.00 and 63.33 at 45, 60 and 75 DAT, respectively) was attained from S_1K_0. It was revealed that optimum level of potassium and plant spacing ensured maximum number of leaves plant^{-1}.

4.3 Number of branches plant^{-1}

Number of branches per plant of chilli was significantly varied between S_2 and S_3. But number of branches per plant of chilli was significantly influenced due to different plant spacing at 45, 60 and 75 DAT (Appendix VI). The highest number of branches per plant (7.64, 12.94 and 14.19 at 45, 60 and 75 DAT, respectively) was observed from S_3 (45 cm × 60 cm) which was statistically identical with S_2 (45 cm × 45 cm) and the lowest number of branches per plant (6.39, 10.89 and 11.56) was recorded from S_1 (Fig. 6). It was revealed that with the increases of spacing number of branches per plant of chilli showed increasing trend. In case of closer spacing plant compete for light and with the time being leaf length decreased. Islam *et al.* (2011) reported number of branches per plant of chilli increase with the increase of plant spacing.

Application of different levels of potassium showed statistically significant variation for number of branches per plant of chilli at different days after transplanting (Appendix VI). At 45, 60 and 75, DAT the highest number of branches per plant was 7.75, 13.11 and 14.37, respectively which was achieved from K_3 (120 kg K/ha). Again, the lowest number of branches per plant (6.00, 10.56 and 10.96 at 45, 60 and 75 DAT, respectively) was found from K_0 (Fig. 7). Results showed that higher doses of potassium cause higher number of branches per plant. Optimum vegetative growth was occurred due to higher amount of potassium fertilizer that leads for the growth of chilli and the ultimate results was the highest number of branches. The results obtained earlier by Boroujerdnia and Ansari (2007) was similar with the present study.

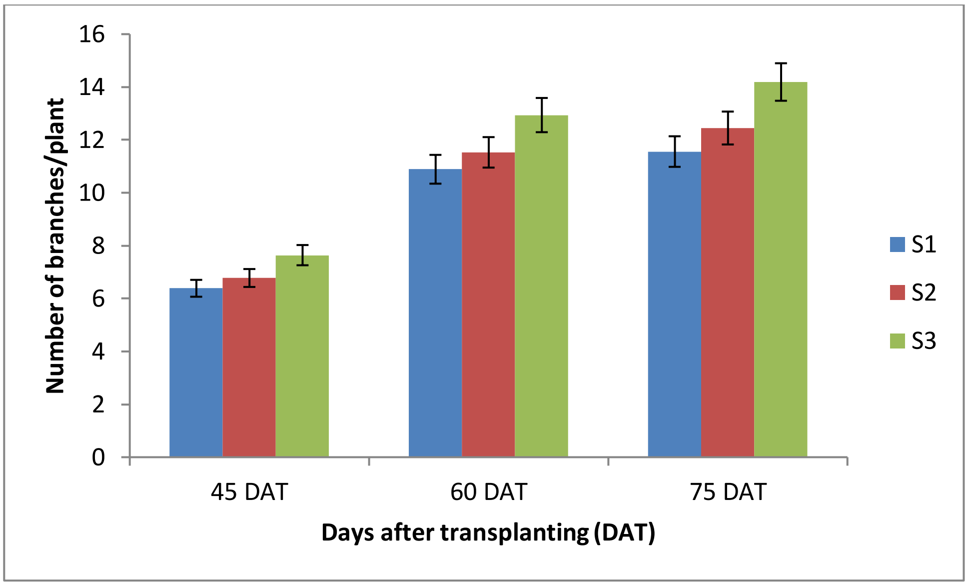

Fig. 6. Effect of spacing on number of branches plant^{-1} of chilli

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm

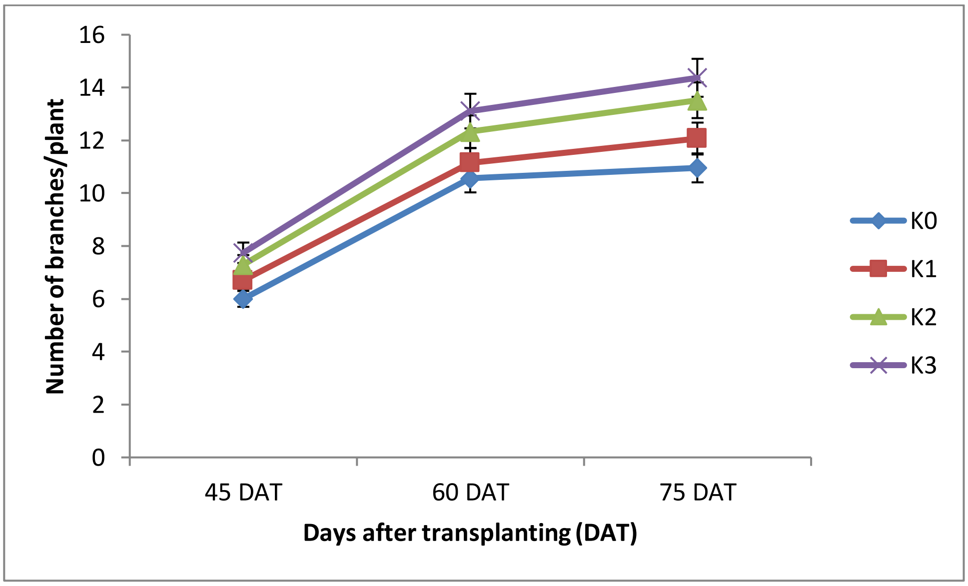

Fig. 7. Effect of potassium on number of branches plant^{-1} of chilli

K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Table 3. Combined effect of spacing andpotassium on number of branches plant^{-1} of chilli

Treatments	Number of branches plant^{-1}		
	45 DAT	60 DAT	75 DAT
S_1K_0	5.67 g	10.33 f	10.45 i
S_1K_1	6.22ef	10.56 f	11.22 gh
S_1K_2	6.66 de	11.22 de	12.00 ef
S_1K_3	7.00 cd	11.44 de	12.56 de
S_2K_0	5.78fg	10.44 f	10.78 hi
S_2K_1	6.78d	11.22 de	12.22 def
S_2K_2	7.11 cd	12.22 c	13.33 c
S_2K_3	7.45 c	12.22 c	13.45 c
S_3K_0	6.56 de	10.89 ef	11.67 fg
S_3K_1	7.11 cd	11.66 cd	12.78 d
S_3K_2	8.11 b	13.56 b	15.22 b
S_3K_3	8.79 a	15.66 a	17.11 a
$LSD_{0.05}$	0.497	0.559	0.541
CV(%)	13.57	12.78	8.49

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

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm
K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Statistically significant variation was recorded due to interaction effect of potassium and plant spacing in terms of number of branches per plant of chilli at 45, 60 and 75 DAT (Appendix VI). The highest number of branches (8.79, 15.66 and 17.11 at 45, 60 and 75 DAT, respectively) was found from S_3K_3 (Table 3). The lowest leaf length (5.67, 10.33 and 10.45 cm at 45, 60 and 75 DAT, respectively) was obtained from S_1K_0. The treatment combination of S_2K_0 also showed lower leaf length but significantly different from S_2K_3. Data revealed that optimum level of potassium and plant spacing ensured the highest number of branches with maximum vegetative growth.

4.4 Stem diameter

Stem diameter of chilli was significantly varied due to different plant spacing at 45, 60 and 75 DAT (Appendix VII). The highest stem diameter (0.67, 0.82, and 1.01 cm at 45, 60 and 75 DAT, respectively) was observed from S_3 (45 cm × 60 cm) and the lowest stem diameter (0.58, 0.72 and 0.81 cm) was recorded from S_1 (Fig. 8). It was revealed that with the increases of spacing stem diameter showed increasing trend. In case of closer spacing plant compete for light and with the time being stem diameter decreases.

Application of different levels of potassium showed statistically significant variation for stem diameter of chilli at different days after transplanting (Appendix VII). At 45, 60 and 75 DAT, the highest leaf breadth was 0.70, 0.83 and 1.04 cm respectively which was achieved from K_3 (120 kg K/ha). Again, the lowest stem diameter (0.56, 0.69 and 0.76 cm at 45, 60 and 75 DAT, respectively) was found from K_0 (Fig. 9). Results showed that higher doses of potassium cause higher stem diameter. Optimum vegetative growth was occurred due to higher amount of potassium fertilizer that leads for the growth of chilli and the ultimate results was the widest leaf. The results obtained earlier by Boroujerdnia and Ansari (2007) was similar with the present study.

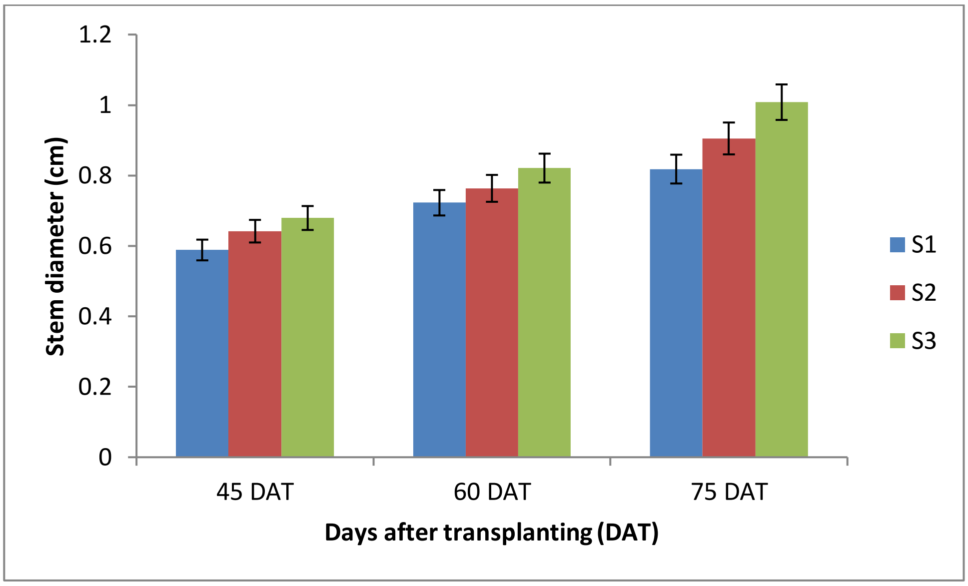

Fig. 8. Effect of spacing on stem diameter of chilli

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm

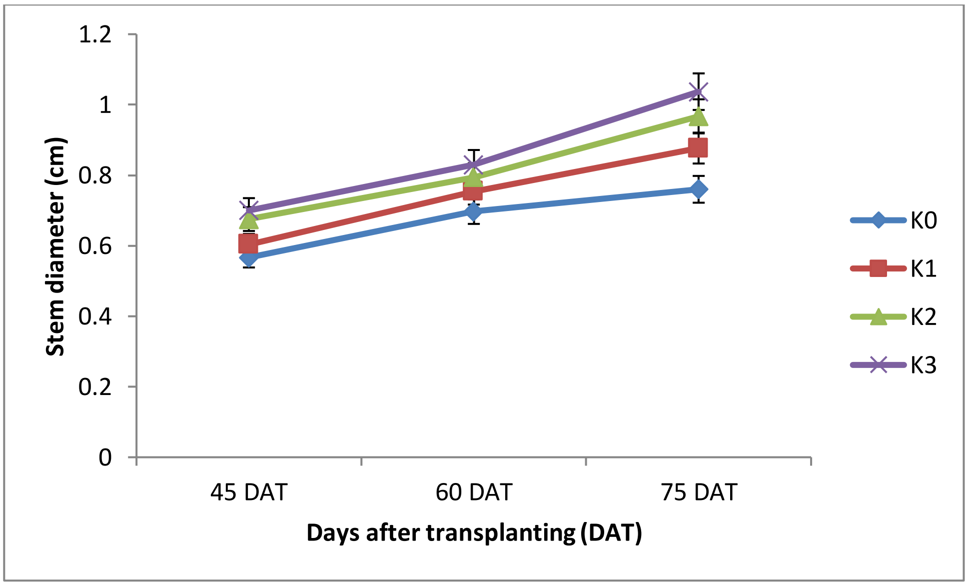

Fig. 9. Effect of potassium on stem diameter of chilli

K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Table 4. Combined effect of spacing and potassium on stem diameter of chilli

Treatments	Stem diameter (cm)		
	45 DAT	60 DAT	75 DAT
S_1K_0	0.56 e	0.63 d	0.70 g
S_1K_1	0.57 e	0.73 c	0.80ef
S_1K_2	0.60 de	0.74 c	0.84ef
S_1K_3	0.63 cd	0.79bc	0.93 cd
S_2K_0	0.57 e	0.72 c	0.78 f
S_2K_1	0.61 de	0.74 c	0.88 de
S_2K_2	0.68bc	0.79bc	0.96 cd
S_2K_3	0.71 ab	0.80bc	1.00 c
S_3K_0	0.58 de	0.74 c	0.80 f
S_3K_1	0.63 cd	0.79bc	0.95 cd
S_3K_2	0.75 a	0.86 ab	1.10 b
S_3K_3	0.76 a	0.90 a	1.18 a
$LSD_{0.05}$	0.054	0.076	0.076
CV(%)	3.23	9.08	4.66

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

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm
K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Statistically significant variation was recorded due to interaction effect of potassium and plant spacing in terms of stem diameter of chilli at different growth stages (Appendix VII). The highest stem diameter (0.76, 0.90 and 1.18 cm at 45, 60 and 75 DAT, respectively) was found from S_3K_3 which was statistically identical with S_3K_2 at 45 DAT (Table 4). The lowest stem diameter (0.56, 0.63 and 0.70 cm at 45, 60 and 75 DAT, respectively) was obtained from S_1K_0. The combination of S_2K_0 and S_3K_0 also showed lower stem diameter but significantly different from S_3K_3 at 45, 60 and 75 DAT. Data revealed that optimum level of potassium and plant spacing ensured the highest stem diameter with maximum vegetative growth.

4.5 Yield contributing parameters

4.5.1 Days to 1st flowering

Days to 1st flowering of chilli showed statistically significant variation due different plant spacing (Appendix VIII). The maximum days to 1st flowering (43.33) was obtained from S_3 (45 cm × 60 cm) which was significantly different from all other treatments. On the other hand, the minimum days to 1st flowering was 40.08 and found from S_2 (45 cm × 45 cm) which was statistically identical with S_1 (Table 5).

Significant variation was found on days to 1st flowering of chilli due to different levels of potassium application (Appendix VIII) .It was found that days to 1st flowering was maximum (44.67), obtained from control treatment, K_0 (Table 5) which was significantly different from all other treatments. On the other hand, the minimum days to 1st flowering (39.44) was found from K_2 (90 kg K ha^{-1}).

Different plant spacing and potassium levels showed statistically significant variation on days to 1st flowering of chilli (Appendix VIII). Results revealed that the maximum days to 1st flowering (45.67) was obtained from the treatment combination of S_3K_0 which was significantly different from all other treatment combinations. On the other hand, the minimum days to 1st flowering (37.33) was found from the treatment combination of S_2K_2 which was statistically identical with S_1K_2 (Table 6).

4.5.2 Days to 1st harvest

In Chilli, yield contributing parameter, days to 1st harvest varied significantly due to different levels of plant spacing (Appendix VIII). The maximum days to 1st harvest (78.42) was obtained from S_3 (45 cm × 60 cm) which was significantly different from all other treatments where the minimum days to 1st harvest (73.50) was found from S_2 (Table 5).

Different potassium levels showed statistically significant variation on days to 1st harvest (Appendix VIII). The maximum days to 1st harvest, (75.78) was obtained from K_3 (120 kg K ha^{-1}) which was statistically identical with K_1 (60 kg K ha^{-1}) and control treatment, K_0 (Table 5). On the other hand, the minimum days to 1st harvest (74.56) was found from K_2 (90 kg K ha^{-1}).

Combined effect of plant spacing and potassium levels showed statistically significant variation on days to 1st harvest of chilli (Appendix VIII). The maximum days to 1st harvest of chilli (80.00) was obtained from S_3K_3 which was significantly identical (79.33) with the treatment combination of S_3K_2. On the other hand, the minimum days to1st harvest was 71.33 and found from S_2K_2 which was significantly different from all other treatment combinations (Table 6).

4.5.3 Fruit length

Variation in fruit length of chilliwas statistically significant due to different plant spacing (Appendix VIII). The maximum fruit length (6.82 cm) was obtained from S_3 (45 cm × 60 cm) which was significantly different from all other treatments. The minimum fruit length (6.10 cm) was found from S_1 (Table 5).

Application of different levels of potassium showed statistically significant variation on fruit length of chilli (Appendix VIII). The maximum fruit length (6.85 cm) was obtained from K_2 (90 kg K ha^{-1}) which was significantly different from allother treatments. The minimum fruit length (5.92 cm) was and found from control treatment, K_0 (Table 5).

Different combination of plant spacing and potassium levels showed statistically significant variation on fruit length of chilli (Appendix VIII). The maximum fruit length (7.24 cm) was obtained from S_3K_2 which was statistically identical (7.18cm) with the treatment combination of S_3K_1. On the other hand, the lowest fruit length (5.85 cm) was found from S_1K_0 which was statistically similar with S_2K_0 and S_3K_0 (Table 6).

4.5.4 Fruit diameter

Different plant spacing showed significant variation on fruit diameter of chilli (Appendix VIII). Results revealed that the highest fruit diameter (0.55 cm) was obtained from S_3 (45 cm × 60 cm) which was significantly different from other treatments. The lowest fruit diameter (0.43 cm) was found from S_1 (Table 5). It was revealed that in case of wider spacing plant receive enough light and nutrients which leads to attain maximum yield contributing characters like fruit diameter of plant. Similar result was also observed by Sharma *et al.* (2017).

Different levels of potassium application showed statistically significant variation on fruit diameter of chilli (Appendix VIII). Results revealed that the highest fruit diameter (0.57 cm) was obtained from K_2 (90 kg K ha^{-1}) which was significantly different from all other treatments. The lowest fruit diameter (0.39 cm) was obtained from control treatment, K_0 (Table 5). The results obtained earlier by Boroujerdnia and Ansari (2007) were similar with the present study.

Table 5. Effect of spacing and potassium on yield contributing parameters of chilli

Treatments	Yield contributing parameters			
	Days to 1st flowering	Days to 1st harvest	Fruit length (cm)	Fruit diameter (cm)
Effect of spacing				
S_1	40.67 b	74.42 b	6.10 c	0.43 c
S_2	40.08 b	73.50 c	6.53 b	0.51b
S_3	43.33 a	78.42 a	6.82 a	0.55 a
$LSD_{0.05}$	0.614	0.891	0.114	0.027
CV(%)	11.37	9.69	5.33	6.74
Effect of potassium				
K_0	44.67 a	75.67 a	5.92 c	0.39 c
K_1	40.78 b	75.78 a	6.58 b	0.52 b
K_2	39.44 c	74.56 b	6.85 a	0.57 a
K_3	40.56 b	75.78 a	6.58 b	0.50 b
$LSD_{0.05}$	0.556	0.508	0.054	0.044
CV(%)	11.37	9.69	5.33	6.74

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

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm
K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Table 6. Effect of spacing and potassium and their combination on yield contributing parameters of chilli

Treatments	Yield contributing parameters			
	Days to 1st flowering	Days to 1st harvest	Fruit length (cm)	Fruit diameter (cm)
S_1K_0	44.33 b	74.33 d	5.85 g	0.38 g
S_1K_1	41.67 c	76.00 c	6.13ef	0.43efg
S_1K_2	37.67 f	73.00 e	6.27 de	0.48 de
S_1K_3	39.00 e	74.33 d	6.15ef	0.44ef
S_2K_0	44.00 b	74.67 d	5.91fg	0.40fg
S_2K_1	40.33 d	75.00 d	6.44 d	0.51 cd
S_2K_2	37.33 f	71.33 f	7.05 ab	0.60 ab
S_2K_3	38.67 e	73.00 e	6.72 c	0.52 cd
S_3K_0	45.67 a	78.00 b	6.00fg	0.40fg
S_3K_1	40.33 d	76.33 c	7.18 a	0.61 a
S_3K_2	43.33 b	79.33 a	7.24 a	0.64 a
S_3K_3	44.00 b	80.00 a	6.88bc	0.55bc
$LSD_{0.05}$	0.9624	0.8799	0.227	0.053
CV(%)	11.37	9.69	5.33	6.74

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

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm
K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Fruit diameter of chilli was significantly influenced by combined effect of different plant spacing and potassium levels (Appendix VIII). The highest fruit diameter (0.64 cm) was obtained from S_3K_2 which was statistically identical (.63cm) with S_3K_1. The minimum fruit diameter (0.38 cm) was found from S_1K_0 which was statistically similar with the treatment combination of S_2K_0, S_1K_1 and S_3K_0. Interaction effect of different levels of potassium application and plant spacing showed statistically significant variation for yield of different yield contributing parameters of chilli. It might be due to cause of optimum level of potassium and plant spacing ensured maximum vegetative growth that ensured highest fruit diameter.

4.6 Yield parameters

4.6.1 Number of fruits plant^{-1}

Number of fruits plant^{-1} was found statistically significant due to the application of different levels of plant spacing (Appendix IX). Results revealed that the highest number of fruits plant^{-1} (509.9) was obtained from S_3 (45 cm × 60 cm) which was significantly different from all other treatments followed by S_2 (45 cm × 45 cm). The minimum number of fruits plant^{-1} (415.9) was found from S_1 (Table 7). It was revealed that in wider spacing, plants have enough light and space for growth, there was no compitition for nutrients and thats why number of fruits per plant was increased. Sharma and Kumar (2017) and Hari *et al.* (2007) were found similar results.

Significant variation was found on number of fruits plant^{-1} due to the application of different levels of potassium (Appendix IX). Results showed that the maximum number of fruits plant^{-1} (516.80) was obtained from K_2 (90 kg K ha^{-1}) which was significantly different from all other treatments followed by K_1 (60 kg K ha^{-1}). On the other hand, the minimum number of fruits plant^{-1} (385.00) was achieved from control treatment, K_0 (Table 7).

Number of fruits plant^{-1} was significantly influenced by combined effect of different plant spacing and potassium levels (Appendix IX). Results signified that the highest number of fruits per plant (567.80) was obtained from S_3K_2 which was significantly different from all other treatment combinations followed by S_3K_1. The lowest number of fruits plant^{-1} (367.20) was observed S_1K_0 which was also significantly different from all other treatment combinations followed by S_2K_0 (Table 8).

4.6.2 Single fruit weight

Non-significant influence was observed among the plant spacing treatment regarding single fruit weight of chilli (Appendix IX). However, the maximum single fruit weight (1.92 g) was obtained from S_3 (45 cm × 60 cm) and the minimum single fruit weight (1.88 g) was found from S_1 (Table 7).

Different levels of potassium application showed significant variation on single fruit weight (Appendix IX). The highest single fruit weight (1.97 g) was obtained from K_2 (90 kg K ha^{-1}) which was significantly different from other treatments. The lowest single fruit weight (1.79 g) was found from control treatment, K_0 (Table 7).

Single fruit weight of chilli was statistically influenced by combined effect of different plant spacing and potassium levels (Appendix IX). Results showed that the highest single fruit weight (1.99 g) was obtained from the treatment combination of S_3K_2 which was statistically identical with S_2K_2. The lowest single fruit weight (1.75 g) was found from the treatment combination of S_1K_0 followed by S_3K_0 (Table 8).

4.6.3 Number of seeds fruit^{-1}

Number of seeds per fruit was significantly influenced by different plant spacing (Appendix IX). The maximum number of seeds fruit^{-1} (76.96) was obtained from S_3 (45 cm × 60 cm) treatment followed by S_2 (45 cm × 45 cm). The minimum number of seeds fruit^{-1} (59.79) was observed from the treatment, S_1 (Table 7).

Different levels of potassium application showed significant variation on number of seeds fruit^{-1} (Appendix IX). Results indicated that the highest number of seeds fruit^{-1} (78.95) was obtained from K_2 (90 kg K ha^{-1}) which was significantly different from others followed by K_3 (120 kg K ha^{-1}). The lowest number of seeds fruit^{-1} (53.54) was found from the control treatment, K_0 (Table 7).

Combined effect of different plant spacing and potassium levels demonstrated significant variation on number of seeds fruit^{-1} of chilli (Appendix IX). It was observed that the highest number of seeds fruit^{-1} (88.40) was obtained from the treatment combination of S_3K_2 which was statistically similar with the treatment combination of S_3K_1. On the other hand, the lowest number of seeds fruit^{-1} (50.40) was obtained from the treatment combination of S_1K_0 followed by S_2K_0 (Table 8).

4.6.4 Fruit yield plant^{-1}

Significant variation on fruits yield plant^{-1} of chilli was found, affected by different plant spacing (Appendix IX). The highest fruits yield plant^{-1} (982.20 g) was obtained from S_3 (45 cm × 60 cm) which was significantly different from all other treatments followed by S_2 (45 cm × 45 cm). The lowest fruits yield plant^{-1} (784.40 g) was found from the treatment S_1 (Table 7). It was revealed that the wider spacing facilitated plants to develop properly with less inter and intra plant competition for utilizing the available resources resulting higher yield per plant. On the other hand, in higher population density reduced yield per plant might be attributed to lesser fruit yield per plant. The result of the present experiment is in agreement with the findings of Ravanappa *et al.* (1998).

Different levels of potassium application showed statistically significant variation on fruit yield plant^{-1} (Appendix IX). The maximum fruit yield plant^{-1} (1018.00 g) was obtained from K_2 (90 kg K ha^{-1}) which was significantly different from other treatments followed by K_1 (60 kg K ha^{-1}). The minimum fruit yield plant^{-1} (690.70 g) was found from control treatment, K_0 (0 kg K ha^{-1}) followed by K_3 (Table 7).

Combined effect of different plant spacing and potassium levels showed significant variation on yield plant^{-1} of chilli (Appendix IX). Results showed that the highest fruits yield plant^{-1} (1129.00g) was obtained from the treatment combinations of S_3K_2 which was significantly different from all other treatment combination followed by S_3K_1. The lowest fruit yield plant^{-1} (642.70g) was found from S_1K_0 followed by S_2K_0 (Table 8).

4.6.5 Fruit yield

Fruit yield of chilli under the present study was significantly influenced by different plant spacing (Appendix IX). Results revealed that the highest fruit yield (21.46 t ha^{-1}) was obtained from plant spacing, S_2 (45 cm × 45 cm) which was significantly different from other treatments followed by S_1 (45 cm × 30 cm). The lowest yield (14.38 t ha^{-1}) was found from the spacing treatment, S_3 (Table 7). It might be revealed that with the increases of spacing yield contributing parameters per plant basis showed better performance because of wider spacing, plant receive enough light and nutrients which leads to attain higher resultper plant. But highest yield was not achieved with wider spacing due to cause of lower plant population. Lower plant spacing represents higher plant population and therefore incase of lower performance of per plant yield with closer spacing, per hectare yield was higher than wider spacing. Similar result was also observed by Sharma *et al.* (2017).

Different levels of potassium application showed significant variation on fruit yield of chilli (Appendix IX). The highest fruit yield (20.37 t ha^{-1}) was obtained from the treatment K_2 (90 kg K ha^{-1}) which was significantly different from all other treatments followed by K_3 (120 kg K ha^{-1}). On the other hand, the lowest fruit yield (15.44 t ha^{-1}) was found from control treatment, K_0 (Table 7). It was revealed that with potassium application, different yield parameters such as number of fruits plant^{-1}, fruit yield plant^{-1} and single fruit weight increased with the increase of K application to certain level and resulted higher fruit from K_2 (90 kg K ha^{-1}) compared to other treatments. It is also known that the excess amount of nutrients hamper yield parameters and yield. The results obtained earlier by Boroujerdnia and Ansari (2007) is similar with the present study.

Table 7. Effect of spacing and potassium on yield parameters of chilli

Treatments	Yield parameters				
	Number of fruits $plant^{-1}$	Single fruit weight (g)	Number of seeds $fruit^{-1}$	Fruit yield per plant(g)	Fruit yield (t ha^{-1})
Effect of spacing					
S_1	415.90 c	1.88	59.79 c	784.40 c	18.85 b
S_2	472.00 b	1.89	71.47 b	892.40 b	21.46 a
S_3	509.90 a	1.92	76.96 a	982.20 a	14.38 c
$LSD_{0.05}$	3.783	0.046	1.439	3.596	1.316
CV(%)	12.18	3.98	7.47	12.91	8.54
Effect of potassium					
K_0	385.00 d	1.79 c	53.54 c	690.70 d	15.44 d
K_1	484.60 b	1.91 b	73.34 b	925.00 b	17.55 c
K_2	516.80 a	1.97 a	78.95 a	1018.o0. a	20.37 a
K_3	477.30 c	1.91 b	71.81 b	912.00 c	19.55 b
$LSD_{0.05}$	4.258	0.054	1.649	3.392	0.631
CV(%)	12.18	3.98	7.47	12.91	8.54

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

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm
K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Table 8. Effect of spacing and potassium and their combination on yield parameters of chilli

Treatments	Yield parameters				
	Number of fruits plant^{-1}	Single fruit weight (g)	Number of seeds fruit^{-1}	Fruit yield plant^{-1} (g)	Fruit yield (t ha^{-1})
S_1K_0	367.20 l	1.75 h	50.40 h	642.70 l	16.20 fg
S_1K_1	418.50 i	1.89 d	60.27 f	788.70 i	17.62 de
S_1K_2	448.30 g	1.93 c	66.70 e	864.30 g	18.48 d
S_1K_3	429.70 h	1.96 b	61.80 f	842.00 h	23.10 b
S_2K_0	381.70 k	1.84 f	54.33 g	702.00 k	16.76 ef
S_2K_1	478.60 f	1.87 e	74.38 d	894.00 f	20.60 c
S_2K_2	534.30 c	1.98 a	81.75 bc	1060.00 c	24.62 a
S_2K_3	493.20 e	1.85 ef	75.42 d	914.00 e	23.85 ab
S_3K_0	406.00 j	1.79 g	55.90 g	727.30 j	13.36 h
S_3K_1	556.70 b	1.96 b	85.36 ab	1092.00 b	14.42 h
S_3K_2	567.80 a	1.99 a	88.40 a	1129.00 a	15.56 g
S_3K_3	509.10 d	1.92 c	78.20 cd	980.00 d	14.16 h
$LSD_{0.05}$	7.753	0.017	3.729	7.949	1.092
CV(%)	12.18	3.98	7.47	12.91	8.54

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

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm
K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

Combined effect of different plant spacing and potassium levels showed significant variation on fruit yield of chilli (Appendix IX). It was found that the highest fruit yield of (24.62 t ha^{-1}) was achieved from the treatment combination of S_2K_2 which was statistically similar (23.85 t ha^{-1}) with the treatment combination of S_2K_3. Similarly, the lowest fruit yield (13.36 t ha^{-1}) was found from S_3K_0 which was statistically identical with the treatment combination of S_3K_1 and S_3K_3 (Table 8).

4.7 Economic analysis

Economic analysis is included total cost of production, gross return (Tk. ha^{-1}), net return (Tk. ha^{-1}) and finally benefit cost ration (BCR). Results indicated that the highest BCR (3.52) was achieved from the treatment combination of S_2K_2 with higher gross return (Tk. 369300 ha^{-1}) and net return (Tk. 264462 ha^{-1}) followed by the treatment combination of S_2K_3, S_1K_3 and S_2K_1 with BCR (3.38, 3.24 and 2.97, respectively) (Table 9 and Appendix X). The lowest BCR (1.98) was observed from the treatment combination of S_3K_0 with lowest gross return (Tk. 200400 ha^{-1}) and net return (Tk. 99275 ha^{-1}) followed by S_3K_1, S_3K_2 and S_3K_3.

It was revealed that optimum level of potassium and plant spacing ensured higher yield performance which resulted highest return. From economic point of view, it is apparent from the above results that S_2K_2 was the more profitable than rest of the treatment combinations for Chilli crop.

Table 9. Economic analysis of chilli production as influenced by plant spacing and potassium fertilizer

Treatments	Economic analysis				
	Fruit yield ($t\ ha^{-1}$)	**Total cost of production**	**Gross return ($Tk.\ ha^{-1}$)**	**Net return ($Tk.\ ha^{-1}$)**	**BCR**
S_1K_0	16.20	103309	243000	139691	2.35
S_1K_1	17.62	105056	264300	159244	2.52
S_1K_2	18.48	105930	277200	171270	2.62
S_1K_3	23.10	106803	346500	239697	3.24
S_2K_0	16.76	102217	251400	149183	2.46
S_2K_1	20.60	103964	309000	205036	2.97
S_2K_2	24.62	104838	369300	264462	3.52
S_2K_3	23.85	105711	357750	252039	3.38
S_3K_0	13.36	101125	200400	99275	1.98
S_3K_1	14.42	102872	216300	113428	2.10
S_3K_2	15.56	103746	233400	129654	2.25
S_3K_3	14.16	104619	212400	107781	2.03

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm
K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2= 90 kg ha^{-1}, K_3 = 120 kg ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment consisted of two factors *viz*. Factor A: 3 levels of plant spacing; S_1 (45 cm × 30 cm), S_2 (45 cm × 45 cm) and S_3 (45 cm × 60 cm) and Factor B: 4 levels of potassium; K_0: 0 kg/ha (control); K_1: 60 kg K ha^{-1}; K_2: 90 kg K ha^{-1} and K_3: 120 kg K ha^{-1}. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield contributing characters and yield at different days after transplanting (DAT) were recorded.

Different plant spacing had significant effect on growth, yield and yield parameters of chilli crop under the present study. At 45, 60 and 75 DAT the tallest plant (32.12, 40.6 and 59.51 cm, respectively) was recorded from closer spacing; S_1 (45 cm × 30 cm) where the shortest plant (26.96, 33.29 and 46.03 cm, respectively) was found from wider spacing, S_3 (45 cm × 60 cm). Again, at 45, 60 and 75 DAT, the maximum number of leaves $plant^{-1}$ (40.19, 81.25 and 87.92 respectively), number of branches $plant^{-1}$ (7.64, 12.94 and 14.19 cm, respectively) and stem diameter (0.67, .82 and 1.01cm respectively) were obtained from S_3 (45 cm × 60 cm) where the lowest number of leaves $plant^{-1}$ (34.67, 70.17 and 70.83 respectively) was recorded from S_1 (45 cm × 30 cm), branches $plant^{-1}$ (6.39, 10.89 and 10.56 cm, respectively) and stem diameter (0.58, 0.72 and 0.81) cm respectively were recorded from S_1 (45 cm × 30 cm).

Regarding, yield contributing parameters and yield parameters, maximum days to 1^{st} flowering (43.33) and days to 1^{st} harvest (78.42) were obtained from S_3 (45 cm × 60 cm) where the minimum days to 1^{st} flowering (40.08) and days to 1^{st} harvest (73.50) were found from S_2 (45 cm × 45 cm). similarly, the highest fruit length (6.83 cm), fruit diameter (0.55 cm), number of fruits $plant^{-1}$ (509.90), fruits yield $plant^{-1}$ (982.20 g) and number of seeds $fruit^{-1}$ (76.96) were obtained from S_3 (45 cm × 60 cm) treatment but the highest fruit yield (21.46 t ha^{-1}) was obtained from plant spacing, S_2 (45 cm × 45 cm). The lowest fruit length (6.10 cm), fruit diameter (0.43 cm), minimum number of fruits plant^{-1} (415.90), fruits yield plant^{-1} (784.40 g) and number of seeds fruit^{-1} (59.79) were achieved from S_1 (45 cm × 30 cm) treatment but the lowest yield (14.38 t ha^{-1}) was found from the spacing treatment, S_3 (45 cm × 60 cm).

Potassium effect was considered significant under the present study. On the growth parameters; plant height, number of leaves plant^{-1}, number of branches plant^{-1} and stem diameter were highest with higher potassium doses at 120 kg/ha (K_3). At 45, 60 and 75 DAT the tallest plant (31.00, 39.44 and 57.58 cm, respectively), maximum number of leaves plant^{-1} (40.55, 83.42 and 91.22 respectively), highest number of branches (7.75, 13.11 and 14.37 cm, respectively) and highest stem diameter (0.70, 0.83 and 1.04 cm, respectively) were found from K_3 (120 kg K ha^{-1}). But at 45, 60 and 75 DAT the shortest plant (27.44, 33.87 and 48.61 cm, respectively), minimum number of leaves plant^{-1} (33.63, 66.89 and 65.44 respectively), lowest number of branches plant^{-1} (6.00, 10.56 and 10.96 cm respectively) and lowest stem diameter (0.56, 0.69 and .76 cm, respectively) were recorded from control treatment, K_0 (0 kg K ha^{-1}). Yield contributing parameters and yield parameters were also significantly influenced by different doses of potassium application.

Results revealed that the highest fruit length (6.85 cm) and fruit diameter (0.57 cm) and also minimum days to 1st flowering (39.44 days) and days to 1st harvest (74.56) were obtained from K_2 (90 kg K ha^{-1}) treatment where the lowest fruit length (5.92 cm) and fruit diameter (0.39 cm) and also maximum days to 1st flowering (44.67) were obtained from control treatment, K_0 (0 kg K ha^{-1}) but maximum days to 1st harvest (75.78) was obtained from K_3 (120 kg K ha^{-1}). The highest number of fruits plant^{-1} (516.80), fruit yield plant^{-1} (1018.00 g), number of seeds fruit^{-1} (78.95), single fruit weight (1.97 g) and fruit yield (20.37 t ha^{-1}) were also obtained from the treatment K_2 (90 kg K ha^{-1}) where the lowest number of fruits plant^{-1} (385.00), fruit yield plant^{-1} (690.70 g), number of seeds fruit^{-1} (53.54), single fruit weight (1.79 g) and fruit yield (15.44 t ha^{-1}) were found from control treatment, K_0 (0 kg K ha^{-1}).

Interaction of spacing potassium had significant effect on growth, yield and yield contributing characters of chilli crop. Results showed that at 45, 60 and 75 DAT, the tallest plant (34.88, 46.44 and 68.28 cm, respectively) was recorded from K_3S_3 where the shortest plant (26.44, 32.51 and 44.27 cm, respectively) was found from K_0S_3. Again, at 45, 60 and 75 DAT, the maximum number of leaves plant^{-1} (46.11, 93.33 and 103.3 respectively), highest number of branches (8.79, 15.66 and 17.11 cm, respectively), highest stem diameter (0.76, 0.90 and 1.18 cm, respectively) was found from K_3S_2. On the other hand, at 45, 60 and 75 DAT, the lowest number of leaves plant^{-1} (34.22, 65.67 and 64.33, respectively), number of branches (5.66, 10.33 and 10.45 cm respectively), stem diameter (0.57, 0.72 and 0.78 cm, respectively) were found from S_1K_0.

In terms of yield contributing parameters and yield of chilli, the highest fruit length (7.24 cm), fruit diameter (0.64 cm), number of fruits plant^{-1} (567.80), fruits yield plant^{-1} (1129.00 g), number of seeds fruit^{-1} (88.40), and single fruit weight (1.99 g) were obtained from the treatment combination of S_3K_2 but the highest fruit yield of (24.62 t ha^{-1}) was achieved from the treatment combination of S_2K_2. The lowest fruit length (5.85 cm), fruit diameter (0.38 cm), number of fruits plant^{-1} (367.20), fruit yield plant^{-1} (642.7 g) and number of seeds fruit^{-1} (50.40) were obtained from the treatment combination of S_1K_0.

Regarding economic analysis, the highest BCR (3.52) was achieved from the treatment combination of S_2K_2 with higher gross return (Tk. 369300 ha^{-1}) and net return (Tk. 264462 ha^{-1}) where the lowest BCR (1.98) was observed from the treatment combination of S_3K_0 with lowest gross return (Tk. 200400 ha^{-1}) and net return (Tk. 99275 ha^{-1}).

From economic point of view, it is apparent from the above results that S_2K_2 was the most profitable than rest of the treatment combinations for chilli cultivation.

The results revealed that, the yield of chilli was gradually decreased when the plants get wider space for vegetative growth. Among the spacing, 45 cm × 45 cm showed the best result for the yield of chilli. Also from the present experimental results, it has been found that the potassium dose 90 kg per hectare gave the highest result in growth, yield parameters as well as yield. Therefore, the results suggest that the combintion of spacing and potassium such as 45 cm × 45 cm and 90 kg potassium per hectare is suitable for the higher yield production of chilli.

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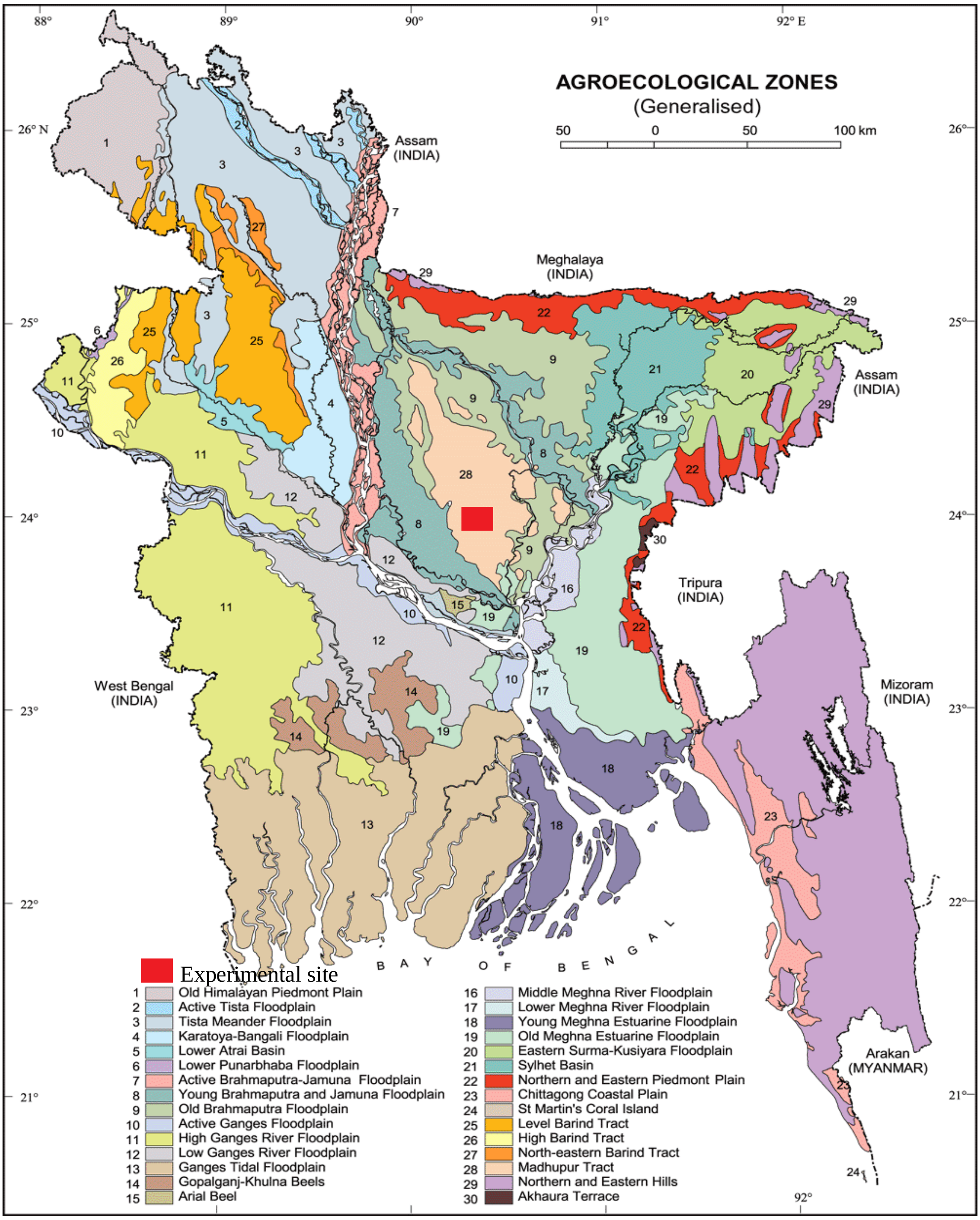
APPENDICES

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



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

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture 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
％ Sand	27
％Silt	43
%Clay	30
Textural class	Silty Clay Loam（ISSS）
pH	5.6
Organic carbon（％）	0.45
Organic matter（％）	0.78
Total N（％）	0.03
Available P（ppm）	20
Exchangeable K（me/100 g soil）	0.1
Available S（ppm）	45

Source：Soil Resource Development Institute（SRDI）

Appendix III . Monthly records of air temperature, relative humidity and rainfall the period from October 2017 to February 2018.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2017	October	30.42	16.24	23.33	68.48	52.60
2017	November	28.60	8.52	18.56	56.75	14.40
2017	December	25.50	6.70	16.10	54.80	0.0
2018	January	23.80	11.70	17.75	46.20	0.0
2018	February	22.75	14.26	18.51	37.90	0.0

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

Appendix IV. Analysis of variance of spacing and potassium and their combination on plant height of chilli

Sources of variation	Degrees of Freedom	Mean square of Plant height (cm)		
		45 DAT	60 DAT	75 DAT
Replication	2	2.961	3.801	5.360
Factor A (spacing)	2	80.720*	163.631*	556.854*
Factor B (potassium)	3	23.603*	55.902*	143.652*
A×B	6	5.587**	15.622*	33.621*
Error	22	12.19	24.882	11.696

* Significant at 5% level of probability ; ** Significant at 1% level of probability

Appendix V. Analysis of variance of spacing and potassium and their combination on number of leaves plant^{-1} of chilli

Sources of variation	Degrees of Freedom	Mean square of number of leaves plant^{-1}		
		45 DAT	60 DAT	75 DAT
Replication	2	8.564	8.564	2.028
Factor A (spacing)	2	94.530*	94.530*	876.78*
Factor B (potassium)	3	84.162*	84.162*	119.908*
A×B	6	11.879*	11.879*	55.891*
Error	22	12.425	12.425	18.146

* Significant at 5% level of probability ; ** Significant at 1% level of probability

Appendix VI. Analysis of variance of spacing and potassium and their combination on number of branches plant^{-1} of chilli

Sources of variation	Degrees of Freedom	Mean square of number of branches plant^{-1}		
		45 DAT	60 DAT	75 DAT
Replication	2	2.754	3.204	3.021
Factor A (spacing)	2	4.937*	13.278*	21.590*
Factor B (potassium)	3	5.133*	11.905*	20.586*
A×B	6	0.206*	2.392*	2.262*
Error	22	0.786	2.559	1.169

* Significant at 5% level of probability ; ** Significant at 1% level of probability

Appendix VII. Analysis of variance of spacing and potassium and their combination on stem diameter of chilli

Sources of variation	Degrees of Freedom	Mean square of stem diameter (cm)		
		45 DAT	60 DAT	75 DAT
Replication	2	0.009	0.007	0.002
Factor A (spacing)	2	0.025**	0.029*	0.109*
Factor B (potassium)	3	0.035*	0.029*	0.129*
A×B	6	0.003*	0.002**	0.006**
Error	22	0.017	0.005	0.002

* Significant at 5% level of probability ; ** Significant at 1% level of probability

Appendix VIII. Analysis of variance of spacing and potassium and their combination on yield contributing parameters of chilli

Sources of variation	Degrees of Freedom	Mean square of yield contributing parameters			
		Days to 1st flowering	Days to 1st harvest	Fruit length (cm)	Fruit diameter (cm)
Replication	2	0.444	0.028	0.002	0.002
Factor A (spacing)	2	36.022*	82.023*	1.595*	0.042**
Factor B (potassium)	3	46.761*	3.185*	1.423**	0.052**
A×B	6	9.657*	8.880*	0.177*	0.004**
Error	22	0.323	0.270	0.007	0.001

* Significant at 5% level of probability ; ** Significant at 1% level of probability

Appendix IX . Analysis of variance of spacing and potassium and their combination on yield parameters of chilli

Sources of variation	Degrees of Freedom	Mean square of yield parameters				
		Number of fruits per plant	Fruit yield per plant (g)	Number of seeds per fruit	Single fruit weight (g)	Fruit yield (t ha^{-1})
Replication	2	5.961	12.583	5.528	0.001	0.757
Factor A (spacing)	2	268.605*	1176.253*	922.908*	.002^{NS}	153.972*
Factor B (potassium)	3	288.274*	1730.333*	1091.77*	0.048**	43.745*
A×B	6	18.623*	100.583*	59.219*	0.007*	12.000*
Error	22	10.966	28.038	26.849	0.003	0.416

* Significant at 5% level of probability ; ** Significant at 1% level of probability ; NS- Non significant

Appendix X: Cost of production of chilli per hectare

A. Input cost (Tk. ha^{-1})

Treatment	Cultivation with labor	Chilli seed cost	Pesticide cost	Irrigation cost	Cowdung/ compost cost	Fertilizer				Seed bed preparation and seed sowing cost	Transplanting cost	Sub-total (A)
						Urea	TSP	MP	Borax			
S_1K_0	12000	6000	3000	2500	3000	3360	8250	0	400	3000	15000	56510
S_1K_1	12000	6000	3000	2500	3000	3360	8250	1600	400	3000	15000	58110
S_1K_2	12000	6000	3000	2500	3000	3360	8250	2400	400	3000	15000	58910
S_1K_3	12000	6000	3000	2500	3000	3360	8250	3200	400	3000	15000	59710
S_2K_0	12000	5000	3000	2500	3000	3360	8250	0	400	3000	15000	55510
S_2K_1	12000	5000	3000	2500	3000	3360	8250	1600	400	3000	15000	57110
S_2K_2	12000	5000	3000	2500	3000	3360	8250	2400	400	3000	15000	57910
S_2K_3	12000	5000	3000	2500	3000	3360	8250	3200	400	3000	15000	58710
S_3K_0	12000	4000	3000	2500	3000	3360	8250	0	400	3000	15000	54510
S_3K_1	12000	4000	3000	2500	3000	3360	8250	1600	400	3000	15000	56110
S_3K_2	12000	4000	3000	2500	3000	3360	8250	2400	400	3000	15000	56910
S_3K_3	12000	4000	3000	2500	3000	3360	8250	3200	400	3000	15000	57710

S_1 = 45 cm × 30 cm, S_2 = 45 cm × 45 cm, S_3 = 45 cm × 60 cm

K_0 = 0 kg ha^{-1} (Control), K_1 = 60 kg ha^{-1}, K_2 = 90 kg ha^{-1}, K_3 = 120 kg 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})				Sub-total (A)	Total cost of production (A+B)	Yield ha^{-1} (ton)	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
	Cost of leased land for 6 months (8% of value of land Tk. 10,00,000/-	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 month (8% of cost year^{-1})	Subtotal (B)						
S_1K_0	40000	2825.5	3973	46798.92	56510	103309	16.20	243000	139691	2.35
S_1K_1	40000	2905.5	4041	46946.12	58110	105056	17.62	264300	159244	2.52
S_1K_2	40000	2945.5	4074	47019.72	58910	105930	18.48	277200	171270	2.62
S_1K_3	40000	2985.5	4108	47093.32	59710	106803	23.10	346500	239697	3.24
S_2K_0	40000	2775.5	3931	46706.92	55510	102217	16.76	251400	149183	2.46
S_2K_1	40000	2855.5	3999	46854.12	57110	103964	20.60	309000	205036	2.97
S_2K_2	40000	2895.5	4032	46927.72	57910	104838	24.62	369300	264462	3.52
S_2K_3	40000	2935.5	4066	47001.32	58710	105711	23.85	357750	252039	3.38
S_3K_0	40000	2725.5	3889	46614.92	54510	101125	13.36	200400	99275	1.98
S_3K_1	40000	2805.5	3957	46762.12	56110	102872	14.42	216300	113428	2.10
S_3K_2	40000	2845.5	3990	46835.72	56910	103746	15.56	233400	129654	2.25
S_3K_3	40000	2885.5	4024	46909.32	57710	104619	14.16	212400	107781	2.03

Selling cost= 15.00 tk^{-1} kg; S_1=45 cm × 30 cm, S_2=45 cm × 45 cm, S_3=45 cm × 60 cm; K_0=0 kg ha^{-1} (Control), K_1 =60 kg ha^{-1}, K_2 =90 kg ha^{-1}, K_3=120 kg ha^{-1}

Plate 1: Photograph showing experimental field

Plate 2: Photograph showing plant spacing using in plot

Plate 3: Photograph showing data collection procedure

Plate 4: Phtograph showing measuring fruit weight

Plate 5: Photograph showing fruit size

Plate 6: Photograph showing harvested fruits