RESPONSE OF OKRA TO DIFFERENT DOSES OF K-FERTILIZER AND SPACING

BY

SAMUTSU JASH CHAKMA

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APPROVED BY:

Prof. Asim Kumar Bhadra
Department of Agricultural Botany
SAU, Dhaka
Supervisor

Prof. Dr. Md. Moinul Haque
Department of Agricultural Botany
SAU, Dhaka
Co-Supervisor

Dr. Md. Ashabul Hoque
Associate Professor
&
Chairman
Examination Committee

DEPARTMENT OF AGRICULTURAL BOTANY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/

CERTIFICATE

This is to certify that the thesis entitled **'Response of Okra to Different Doses of K-fertilizer and Spacing'** submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Agricultural Botany,** embodies the result of a piece of bonafide research work carried out by **Samutsu Jash Chakma**, Registration No. 07-02572 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Date:
Dhaka, Bangladesh

Asim Kumar Bhadra
Professor
Department of Agricultural Botany
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

DEDICATED
TO
MY BELOVED PARENTS

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The Author

EFFECT OF SPACING AND POTASSIUM FERTILIZER ON THE GROWTH AND YIELD OF OKRA

ABSTRACT

The experiment was carried out at the Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from April to August 2014 to find out the effect of spacing and potassium fertilizer on the growth and yield of okra. The test crop used in the experiment was BARI Dherosh-1. The experiment consisted of two factors: Factor A: Plant spacing (3 levels) as-S_1: 50 cm × 30 cm, S_2: 50 cm × 40 cm, S_3: 50 cm × 50 cm and Factor B: Potassium fertilizer (3 levels) as- K_0: 0 kg K_2O/ha (control), K_1: 120 kg K_2O/ha and K_2: 150 kg K_2O/ha. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth parameters, yield attributing characters and yield of okra was recorded and statistically significant variations were observed for different treatments. For spacing, at 20, 40 and 60 DAS, the tallest plants (25.29, 62.88 and 91.29 cm) were recorded from S_2, while at the same DAS, the shortest plants (18.84, 56.46 and 81.85 cm) were measured from S_1. The highest weight of individual fruit (17.06 g) was recorded from S_2, whereas the lowest weight of individual fruit (14.29 g) was recorded from S_1. The highest yield per hectare (16.23 ton) was observed from S_2, whereas the lowest yield per hectare (13.34 ton) from S_1. For potassium fertilizer, at 20, 40 and 60 DAS the tallest plants (25.29, 63.81 and 91.20 cm) were recorded from K_2, whereas the shortest plants (18.16, 54.65 and 81.41 cm) were found from K_2. The highest weight of individual fruit (17.10 g) was recorded from K_2 whereas, the lowest weight of individual fruit (13.93 g) was found from K_0. The highest yield per hectare (16.26 ton) was recorded from K_2, while the lowest yield per hectare (13.18 ton) was found from K_0. Due to interaction effect of plant spacing and levels of potassium fertilizer the tallest plants (29.42, 67.65 and 96.93 cm) were recorded from S_2K_2 and, the shortest plants (16.91, 53.25 and 80.13 cm) were recorded from S_1K_0. The highest weight of individual fruit (18.44 g) was recorded from S_2K_2, whereas the lowest weight of individual fruit (13.47 g) was obtained from S_1K_0. The highest yield per hectare (18.00 ton) was recorded from S_2K_2, while the lowest yield per hectare (11.35 ton) was observed from S_1K_0. From the findings it was revealed that 50 cm × 40 cm plant spacing with 150 kg K_2O/ha was the best combination for attaining the highest yield contributing characters and yield of okra.

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CHAPTER I

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] is a popular vegetable belongs to the family Malvaceae and locally known as "Dherosh" or "Bhindi". It is an annual vegetable crop grown from seed in tropical and sub-tropical parts of the world (Tahkur and Arora, 1986). It is well distributed throughout the Indian sub continent and East Asia (Rashid, 1990). Okra is specially valued for its tender and delicious edible pods which are rich sources of vitamins and minerals. Tender green pods of okra contains approximately 86.1% water, 2.2% protein, 0.2% fat, 9.7% carbohydrate, 1.0% fibre and 0.8% ash (Purseglove, 1987). The pods have some medicinal value with mucilaginous preparation which may used as plasma replacement or blood volume expander (Savello *et al.,* 1980). In Bangladesh the total production of okra is about 246 thousand tons which was produced from 7287.5 hectare of land in the year 2010 with average yield about 3.38 t/ha (BBS, 2011) which is very low compared to that of other developed countries where the yield is as high as 7.0-12.0 t/ha (Yamaguchi, 1998).

In Bangladesh, vegetable production is not uniform round the year and it is plenty in winter but less in quantity in the summer season. Around 30% of total vegetables are produced during *kharif* season and around 70% in the *rabi* season (Anon., 1993). Therefore, as vegetable okra can get an importance in *kharif* season as well as summer season in our country context. There are variations of the per capita consumption of vegetables in SAARC countries, where they were 69 g in Pakistan, 120 g in Srilanka, and 135 g in India and all are higher than that of Bangladesh. Although, many dietitians prescribed that the daily requirements of vegetables for an adult person is approximately 285 g (Rampal and Gill, 1990). Therefore, there is a big gap between the requirement and consumption of per capita vegetable in Bangladesh. As a result, malnutrition is very much evident in our country. Successful okra production may contribute partially in solving vegetable scarcity of summer season for the Bangladeshi people.

The low yield of okra in Bangladesh however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties in appropriate time, fertilizer management, disease and insect infestation, improper or limited irrigation facilities and other appropriate agronomic practices. Among the different reasons fertilizer management is the important factor that greatly affects the growth, development and yield of this crop. The application of fertilizers influences the physical and chemical properties of soil and enhanced the biological activities. Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). To attain considerable production and quality yield for any crop it is necessary to ensure proper management the availability of essential nutrient in proper doses. Generally, a large amount of fertilizer is required for the growth and development of vegetable crops (Opena *et al.*, 1988). So, the management of fertilizer especially nitrogen and phosphorus is the important factor that greatly affects the growth, development and yield of okra.

Adjustment of proper plant spacing in the okra field is important to ensure maximum utilization of solar energy by the crop and reduce evaporation of soil moisture. Nutrient availability in the soil also depends on plant spacing. So, optimum plant spacing should be maintained to exploit maximum natural resources such as nutrients, sunlight, soil moisture etc. and to ensure satisfactory yield. Plant spacing also directly affect the quality, proper growth of the plant, the pods as are desired as well as yield (Singh and Kanwar, 1995).

Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). The cultivation of vegeatble crops requires proper supply of plant nutrient. Okra responds greatly to major essential elements like N, P and K for its growth and yield (Thompson and Kelly, 1988). Potassium as an inorganic fertilizer and plays a vital role for proper growth and development of okra. Application of potassium in appropriate time, dose and proper method is prerequisite for any crop cultivation.

Generally, a large amount of potassium is required for the growth of leafy vegetable (Opena *et al.*, 1988). For that the management of fertilizers especially potassium is the important factor that greatly affects the growth, development and yield of okra.

Considering the above mentioned facts and based on the prior observation, an investigation was undertaken with the following objectives:

- To determine the suitable spacing for the improved/desired growth and yield of okra;
- To determine the optimum levels of potassium for desired/improved on the growth and yield of okra;
- To find out the suitable combination of spacing and potassium fertilizer dose for ensuring the optimum growth and higher yield of okra.

CHAPTER II

REVIEW OF LITERATURE

In Bangladesh, okra is a very important vegetable crop and it is specially valued for its tender and delicious edible pods. Different management practices influence the growth and yield of okra. Among them plant spacing and management of fertilizer especially potassium is the important factor that greatly affects the growth, development and yield of okra. So it is important to assess the effect of spacing and potassium for the optimum growth and yield of okra. However, very limited research reports on the performance of okra in response to spacing and potassium have been done in various parts of the world including Bangladesh and the work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works conducted at home and abroad in this aspect have been reviewed under the following headings:

2.1 Effect of spacing on growth and yield of okra

Gupta *et al.* (1981) conducted an experiment to study the response of okra to varying levels of plant spacing (60 × 20, 60 × 30 and 60 × 40 cm) and graded levels of nitrogen and phosphorus on sandy loam soil poor in organic carbon, medium in available phosphorus and rich in available potassium during kharif season at the Indian Institute of Horticultural Research, Bangalore. They stated that the closest spacing (60 × 20 cm) gave consistently higher yields.

Palaniswamy *et al.* (1986) studied the influence of date of sowing and spacing on seed quality of okra cv. Pusa Sawani. The seeds were sown at monthly intervals between March and November with 60 × 30 cm, or 60 × 20 cm spacing. They obtained the best quality seed in March, April and May sowing.

Singh *et al.* (1986) conducted a two-year trial on the effect of planting dates and spacing on seed production of okra cv. Pusa Sawani. The seeds were sown on 15 and 30th day of June and July at 60 × 30 cm, 45 × 30 cm and 30 × 30 cm spacing.

The seed yield in both the years was the highest (1.94-2.11 t/ha) in plots sown on 15 June with a plant spacing of 60 × 30 cm.

Rasgoti *et al.* (1987) conducted a trial for 3 years with the Sel. 6-2, planted at 45 x 40 cm, 60 × 40 cm and 75 × 40 cm spacing treated with at 45, 60 and 75 kg N/ha. They recorded the highest seed yield at 60 × 40 cm spacing receiving 60 kg N/ha (1184 kg/ha). They also found no appreciable effect on 1000 seed weight and germination percentage at different spacing.

Khan and Jaiswal (1988) found significant effect on seed yield per hectare due to spacing, nitrogenous fertilizer and fruit pickings. They obtained the highest seed yield (833-902 kg/ha) at close spacing (30 × 15 cm) with the highest amount of nitrogen (150 kg/ha) and edible pods picked twice.

Singh *et al.* (1988) investigated the effect of sowing dates and spacing on the yield and quality of okra seed. Four sowing dates (20 June to 4 August) and plant spacing were compared. The maximum seed yield was obtained when the crop was grown at 45 × 30 cm and sown on June 20 (1844.12 kg/ha).

In an experiment Saha *et al.* (1989) studied the effect of plant spacing 80 × 10 cm, 80 × 20 cm and 80 × 40cm and picking interval (1, 3 and 5days) on the growth and yield of okra cv. Pusa Sawani at the Horticulture farm of Bangladesh Agricultural University, Mymensingh. The fresh weight of plant and number and weight of fruits per plant increased significantly with an increase in plant spacing. However, the yield per hectare decreased with the increasing plant spacing. The highest yield was obtained at spacing of 80 × 10 cm (7.15 t/ha) while the minimum yield recorded from wide spacing of 80 × 40 cm (3.23 t/ha). Picking interval had no effect on the yield per hectare, but the fruit length was influenced significantly. Longer fruits (12.31 cm) were obtained at five days picking interval and a minimum length (9.39 cm) was obtained by picking interval on the yield and other yield components.

Mondal *et al.* (1989) conducted an experiment to investigate the effect of dates and inter row spacing on the growth and yield of okra cv. Pusa Sawani. They obtained the highest number of fruits per plant and fruit yield per unit area when seeds were sown on 20 April. The closest spacing of okra plantation resulted in the lowest number of fruit and quality of fruit per plant but the highest fruit yield per hectare. The highest level of NPK and closer spacing gave the maximum yield of okra and number of fruits per plant increased with the increase of fertilizer levels and spacing (Abdul and Araf, 1986).

Singh (1990) conducted an experiment to study the effect of spacing on okra. Okra seeds were sown at 40 × 20 cm, 40 × 30 cm, 50 × 20 cm, 50 × 30 cm, 40 × 40 cm and 50 × 40 cm spacing. He reported that the highest fruit yield (6037 kg/ha) with the closest spacing (40 × 20 cm) but the maximum fruit weight (35.58 g) and fruit length (19.06 cm) were recorded with the widest spacing (50 × 40 cm). In another experiment seeds of the okra cv. Pusa Sawani and Sel-2-2 were sown in early June, October and January to produce autumn, winter and summer crops respectively. The seeds were sown at 30 × 5 cm, 30 × 10 cm, 30 × 15 cm and 30 × 20 cm. The highest pod yield was obtained with the closest spacing and in the summer season (1851 kg/ha). The treatment had no appreciable effect on pod quality (Gadakh *et al.*, 1990).

An experiment was conducted by Birbal *et al.* (1995) to study the Effect of spacing and nitrogen on fruit yield of okra (*Abelmoschus esculentus* L. Moench.) cv. Varsha Uphar. Seeds of okra cv. Varsha Uphar were sown on a sandy loam soil at 30 × 30, 45 × 30, 45 × 45, 60 × 20 or 60 × 30 cm, with N applied at 0, 50, 100 or 150 kg/ha. The tallest plants (109.2 cm) were obtained with spacing at 30 × 30 cm. The number of branches/plant (2.5) was highest at 45 × 45 cm. Application of N at 100 and 150 kg/ha resulted in taller plants and more branches/plant than that at 0 and 50 kg/ha. Spacing did not affect the number of days to 50% flowering, but N at 100 and 150 kg/ha delayed it by 4.5 and 6.0 days, respectively, compared with no N. Number of fruits/plant, individual fruit weight and yield/plant were highest with 45 × 45 and 60 × 30 cm; these parameters were also increased by N at 100 kg/ha. Yield/ha was highest with spacing at 60 × 20 cm (138.9 q/ha); 45 × 30 cm gave a similar yield.

An experiment was conducted by Raghav (1996) to study influence of dates of sowing and plant spacing on the growth and yield of okra. In this study 4 sowing dates (21 February or 1, 11 or 21 March) and 3 plant spacing (15 × 30, 30 × 30 or 45 × 30 cm) on the growth and yield of okra cv. Pusa Sawani were investigated. Results from the 1992 and 1993 seasons were pooled. Plant height was greatest with sowing on 1 March and at the closest spacing. Green pod yield was highest with sowing on 1 March (57.32 q/ha) and at the widest spacing (47.67 q/ha).

In field trials in 1989-91 was conducted by Saimbhi *et al.* (1997) at Ludhiana and Jalandhar, India, to study the effect of plant spacing on fruit yield in okra. They were grown plants of okra cv. Punjab-7 in spring at 45 × 25, 45 × 20 or 45 × 15 cm on the flat or on ridges, while in the rainy season plants were grown on the flat at 3 row spacing (30, 45 or 60 cm) and 2 plant spacing (15 or 30 cm). Fruit yield increased as plant spacing decreased in both spring and rainy seasons. The highest fruit yields in spring (45 × 15 cm) and rainy (30 × 15 and 45 × 15 cm) seasons were significantly higher than those at the recommended row and plant spacing (45 × 25 and 60 × 30 cm in spring and rainy seasons, respectively). The 45 × 15 cm spacing was considered most suitable for okra cultivation in both spring and rainy seasons, as a closer row spacing of 30 cm in the rainy season would make fruit picking difficult.

Amjad *et al.* (2001) conducted field experiment in Faisalabad, Pakistan with okra cultivar Sabz pari grown at 15, 30 or 45 cm; with a distance between rows of 60 cm. Phosphorous was applied at 0.33 or 66 kg/ha at the time of sowing. Phosphorous did not have any significant effect on days to first flowering and plant height at flowering, while these parameters were significantly affected by the planting geometry. Plants spaced at 30 and 45 cm took significantly lesser number of days to flower than those planted at 15 cm. However, plant height was maximum at 15 cm spacing, green pod length was maximum at plant spacing 45 cm. Number of green pods per plant and average weight per green pod were significantly affected by plant spacing. Both were highest with the widest spacing of 45 cm.

Field studies were conducted by Sajjan *et al.* (2002) in Bagalkot, Karnataka, India, to elucidate the effect of sowing date (15 June, 15 July (kharif), 15 November and 15 December (rabi)), spacing (60 × 20, 60 × 30 and 60 × 40 cm) and nitrogen rates (100, 125 and 150 kg/ha) on the yield attributes and seed yield of okra cv. Arka Anamika during the 1998 kharif season and 1998-99 rabi season. Sowing on 15 July coupled with 60 × 30 cm spacing and 150 kg N/ha recorded the highest yield attributes of branches per plant, fruits per plant, 100-seed weight, length and girth of fruits, processed seed recovery and processed yield (1139.7 kg/ha) in the kharif season. However, for the 15 November sowing, with the same spacing (60 × 30 cm) and nitrogen rate (150 kg N/ha), the highest seed yield of 745.3 kg/ha was recorded.

Effect of row spacing on growth and yield of okra was studied by Leghari *et al.* (2003) on clay loam soil at Latif Experimental Farm, Sindh Agriculture University, Tandojam Pakistan. The results exhibited that all the yield components and yields were significantly affected by plant spacing. Number of pods and pod yield per plant also revealed significant response to row spacing only. Results also demonstrated that plants grown at 30 cm plant spacing with 50 cm row spacing produced taller plants and maximum branches. Maximum pods and pod yield/plant were produced by 50 cm inter spacing with 60 cm intra spacing. But higher pod yield per unit area was recorded under lowest inter and intra row spacing i.e. 30 cm plant to plant and 50 cm row to row spacing under agro- climatic conditions of Tandojam.

Bajpai *et al.* (2004) carried out an experiment with okra cv. Parbhani Kranti in Kanpur, India, consisting of three spacing i.e. 20 cm × 15 cm (S_1), 30 cm × 15 cm (S_2) and 45 cm × 15 cm (S_3) and three sowing dates i.e. 5 February (D_1), 20 February (D_2) and 5 March (D_3). Plant populations per plot, number of leaves per plant, plant height, plant diameter, flowering date, fruiting date, number of fruits per plant, pod length, pod diameter data were recorded. The plant population and growth were highest in S_2D_2 treatment.

A field experiment was conducted by Maurya *et al.* (2013) on okra to determine the optimum plant spacing (30 cm × 45 cm, 60 cm × 30 cm and 60 cm × 45 cm) and picking interval regime which would promote the maximum yield with quality fruits of okra cv. 'Clemson Spineless' and reported the thickest (2.50 cm) stem diameter, greatest (41.86 cm) leaf diameter and maximum (1.72) number of branches per plant and the highest (415.60 g) yield per plant was recorded at the widest (60 cm × 45 cm) spacing. However, the yield per hectare was decreased with the increasing plant spacing. The highest (147.20 cm) plant height and (18.96 tons) yield per hectare was obtained in the closest spacing (45 cm × 30 cm).

The effects of various intra-row spacing on yield and yield components of okra variety; Clemson Spineless was evaluated by Madisa *et al.* (2015) at Botswana College of Agriculture in Sebele. The treatments consisted of five intra-row spacings of 30, 45, 60, 75 and 90 cm for treatments 1-5 respectively. Generally, a significant treatment effect was revealed for plant height with narrower plant spacing of 30 cm significantly increasing the plant height. Wider plant spacing of 90 cm significantly increased the plant weight, number of branches and leaves. A non significant treatment effect was observed for stem diameter, fruit length and diameter, number of flowers and fruits. Based on the results wider intra-row spacing of 90 cm is recommended for okra production.

2.2 Effect of potassium on growth and yield of okra

Mani and Ramanathan (1980) carried out an experiment to study the effect of nitrogen and potassium on the yield of okra. There were 5 levels of N (0, 20, 40, 60 and 80 kg/ha) and 5 levels of K_2O (0, 15, 30, 45 and 60 kg/ha). Nitrogen fertilization significantly increased yield. The highest K level (60 kg/ha) increased yield by 149.2% over the control and combined application of 80 kg N/ha with either 30 kg or 60 kg K_2O/ha produced maximum yields (17.2 t/ha and 17.5 t/ha respectively).

Adelana (1985) reported that significant responses were obtained to 20-40 kg N, 20 kg P and 20-30 kg K/ha at two sites in the derived savanna and at one site in the forest zone.

Abdul and Aarf (1986) carried out subsequently two trails with okra cv. Batrra and it was grown with 5 levels of fertilizers i.e. 100, 250, 300, 350 and 400 kg NPK/ donum (1338 m^2). The maximum okra yield (12.23 t/donum) was obtained with 400 kg NPK. The numbers of pods/plant was increased slightly by increasing fertilizers levels and to a maximum of 400 kg, but there was no significant effect on average pod weight.

Mishra and Pandey (1987) conducted trails with okra CV. Pusa Sawani, with N and K_2O which were each applied at 0, 40, 80 and120 kg/ha. N at 80 kg/ha significantly increased the number of fruits/plant, 1000 seed weight and the seed yield of okra. Application of K above 120 kg/ha adversely affected, plant height, number of branches per plant, pod length, yield per plant as well as fruit yield. Interaction effect was significant with 80 kg/ha N and 40 kg K_2O/ha giving the highest seed yield and it was 15.47 q/ha.

Lenka *et al.* (1989) investigated a field trail with three replicates with N (as urea) applied at 4 levels (0, 50, 75, 100 kg/ha), P_2O_5 at 2 levels (30 and 60 kg/ha) and K_2O at a constant 40 kg/ha. They stated that N and P significantly increased plant height, yield and its attributes. Application of 100 kg N/ha and 30 kg P_2O_5/ha gave a satisfactory seed yield (7.60 q/ha).

Rain and Lal (1990) conducted a field experiment in Bapalta, Andhra Pradesh, India and studied the growth and development of okra cultivars (Parbhani Kranti, Arka Anamika and Pussa Sawani) in response to 4 fertilizer levels(0-0-0, 50-25-25, 100-50-50 and 150-75-75 kg N, P_2O_5, K_2O/ha respectively). Results showed that leaf area, index (LAI) and leaf area duration (LAD) were significantly influenced at all stages by cultivers, fertilizer levels and their interaction effects. Among cultivars, Pusa Sawani showed the maximum leaf area, LAI and LAD. However, Arka Anamika showed significantly superior performance with respect to plant height, number of leaves, and number of nodes and yield per plant. The highest fertilizer level resulted in maximum leaf area, LAI and LAD, which gradually increased up to 60 days after sowing (DAS). Dry matter increased and also influenced significantly by cultivars, fertilizer levels and their combination. Harvest index (HI) was also influenced by cultivars, fertilizer levels and their interaction. Arka Anamicka, with a moderate vegetative growth and high Net Assimilation Rate (NAR), had the highest Harvest Index (HI) values. Among the fertilizer levels, maximum HI was recorded by 100-50-50 kg NPK/ha.

Naik and Srinivas (1992) conducted field experiments with cv. Pusa Sawani in the rainy seasons of 1985 and 1986 on a sandy loam with low available P in soil, applying P at 30, 60 or 90 kg P_2O_5/ha. All the P and 40 kg K_2O/ha were applied before sowing of okra seeds. The highest seed yields were obtained with 90 kg P_2O_5/ha and 40 kg K_2O/ha (11.89 and 10.71 q/ha in 1985 and 1986, respectively). Other parameters (fruit length, fruit diameter, number of fruits/plant, number of seeds/fruit and 1000-seed weight) were also generally highest with the highest rate of fertilizer application.

An experiment was conducted by Bhai and Sing (1998) at Palampur, India to investigate the effect of K application rate (50, 70 or 90 kg/ha). They reported that

K application significantly increased the plant height, number of nodes per plant yield of okra.

Rani *et al.* (1999) conducted a field experiment in Bapatla, Andra Pradesh, India, during 20 March – 8 July 1997 studied the growth and development of 3 okra cultivars (Parbhani Kranti, Arka Anamika and Pusa Sawani) in response to 4 fertilizer levels (0-0-0, 50-25-25,100-50-50 and 150-75-75 kg N, P_2O_5 and K_2O/ha respectively). Results showed that leaf area, leaf area index (LAI) and leaf area duration (LAD) were significantly influenced at all stages by cultivars, fertilizer levels and their interaction effects. Among the cultivars, Pusa Sawani showed the maximum leaf area, LAI and LAD. However, Arka Anamika showed significantly superior performance with respect to plant height, number of leaves, number of nodes and yield per plant. Harvest index (HI) was also influenced by cultivars fertilizer levels and their interactions. Arka Anamika, with a moderate vegetable growth and high NAR, bad the highest HI values. Among the fertilizer levels, maximum HI was recorded by 100-50-50 kg NPK/ha.

The seed quality (SQ) and yield (SY) of okra cv. Parbhani Kranti were studied by Chattopadhyay and Sahana (2000) during *kharif* seasons of 1998-99 in West Bengal, India. Five N rates (0, 60, 80, 100 and 120 kg/ha) were tested against 4 P rates (0, 40, 60 and 80 kg/ha). Urea (50% of the total N dose), single superphosphate and muriate of potash (50 kg K_2O) were applied basally. The remaining urea was applied 30 days after sowing. Most of the SQ and SY parameters improved significantly with increasing rates of N and P, the optimum N and P rates, being 100 and 60 kg/ha, respectively. Germination percentage and 100-seed weight were not significantly affected by N or P, while P had no significant effect on fruit length.

Gowda *et al.* (2001) conducted a field experiment in Bangalore, Karnataka, India during summer season to determine the response of okra cultivars Arka Anamika, Varsha and Vishal to 3 NPK fertilizer rates (125:75:60 kg/ha, 150:100:75 kg/ha and 175:125:100 kg/ha). The highest dry matter production in leaves (20.40 g), stems (35.17 g), roots (18.03 g), fruits (31.11 g) and whole plants (104.71 g) was recorded with 175:125:100 kg NPK/ha treatments. Varsha recorded significantly higher dry matter production in leaves (17.48 g), stems (31.44 g), roots (17.61 g), fruits (29.98 g) and whole plants (96.51 g) compared to the other cultivars. In the interaction effect, the highest total dry matter production (1111.48 g/plant) was recorded in Varsha supplemented with 175:125:100 kg NPK/ha, which was at per with Arka Anamika supplemented with 175:125:100 kg NPK/ha. Comparative data on the effect of varying fertilizer rates, cultivars and their interaction on the length, diameter and yield of fruits are tabulated.

Prabu and Pramanik (2002) conducted an experiment in Parbhani, Maharashtra, India, during the summer season of 2001 to investigate the effects of organic fertilizers at 0, 1/3, 2/3 and full rate (N: P: K at 100: 50: 50 kg/ha), in the presence or absence of farmyard manure (FYM at 10 t/ha), and bio-fertilizers (un inoculated; *Azospirillum* + phosphate sollubilizing bacteria, and *Azospirillum* + vesicular arbuscular mycorrhiza) on the performance of okra cultivar Parbhani Kranti. Result showed that the treatment 2/3 recommended NPK dose + FYM + *Azospirillum* vesicular arbuscular mycorrhiza produced the highest yield.

Gowda *et al.* (2002) conducted a study in the summer season oin Bangalore, Karnataka, India to investigate the effects of different fertilizer levels (N:P:K at 125:75:60, 150:100:75 and 175:125:100 kg/ha) on okra cultivers Arka Anamica, Varsha and Vishal. Dry matter accumulation and nutrient (N, P and K) accumulation increased with increasing fertilizer levels. The highest fertilizer level resulted in the highest nutrient uptake. Varsha showed the highest nutrient uptake and accumulation in leaves and fruits at the highest level of fertilizer.

Aslam and Bose (2003) reported that excessive use of nitrogen fertilizers is a factor of nitrate accumulation in vegetable, which cause health problems to the consumers. A study was conducted to assess the effect of NPK fertilizers on NO_3 accumulation in okra (*Abelmoschus esculentus*) and carrot (*Daucus carota*) at Ayub Agricultural Research Instute, Faisalabad, Pakistan. For okra five (0, 100, 150, 175 and 200 kg N/ha) and two P_2O_5 rates (0, 75 kg/ha) were tested with 60 kg K_2O/ha as basal dose. Increasing fertilizer rates increased NO_3 concentration over the control in okra. Additionally, the doses of NPK fertilizers applied in this study did not pose health hazards to the consumers.

Bamel and Sing (2003) conducted a plot experiment to study the effect of different fertilizer sources on *M. incognita* in okra under greenhouse condition. Better plant growth and reduced nematode damage when a combination of N, P, K and Zn fertilizers was applied at recommended dose. Individually, murate of potash and potassium sulfate at higher doses recorded maximum plant growth. Ammonium sulfate and gypsum reduced nematode reproduction significantly compared to other treatments. All the fertilizers except calcium nitrate, murate of potash and potassium sulfate, showed reduction in nematode damage with a corresponding increase in their dose.

Two field experiments were conducted by El-Shaikh (2005) at the Experimental Farm of Sohag, South Valley University, Egypt, during 2003 and 2004 to investigate the effects of phosphorus (22.5, 30.0, 37.5 and 45 kg P_2O_5/fed) and potassium fertilizers on the growth, yield and quality of two okra cultivars (El-Balady and Golden Coast). Applying high levels, i.e. 37.5 and 45 kg K_2O/fed, of phosphorus significantly improved the most studied characters.

Field experiments were conducted by Sunita *et al.* (2006) for two consecutive years at the Feirsa Agricultural University, Ranchi, Jharkhand, India, to determine the effects of intercrop and NPK fertilizer application on the performance of okra (cv. Arka Anamika). Treatments comprised: two intercrops (cowpea and French bean) and five fertilizer rates (0, 25, 50, 75 and 100% recommended dose of NPK). The results revealed that treatment with 100% recommended dose of fertilizers recorded higher okra equivalent yield (153.16 q/ha) and net returns (Rs. 30,709.91/ha) than the rest of the fertilizer rates. The best performance of okra in terms of yield, number of fruits per plant, fruit weight and plant height were observed with 100% recommended dose of fertilizer.

A field experiment was conducted by Khan *et al.* (2007) in 1999 in Medziphema, Nagaland, India, on a sandy loam soil having 5.3 pH, 4.5% organic carbon, 208.0 kg/ha available N, 12.3 kg P_2O_5/ha and 189.6 kg K_2O/ha to study the response of okra to biofertilizers and K application in terms of growth, yield and leaf nutrient (N, P and K) status. The treatments consisted of five levels of K (0, 30, 60, 90 and 120 kg/ha) and four levels of biofertilizers. The application of K and biofertilizers significantly increased the growth and yield. The optimum K requirement was found to be 60 kg/ha, along with Azotobacter in foothills of Nagaland.

A study was conducted by Omotoso and Shittu (2007) to determine the effect of NPK fertilizer application rates and method of application on growth and yield of okra (*Abelmoschus esculentus* (L.) Moench) at the Teaching and Research Farm, University of Ado-Ekiti. Okra seed variety LD88 were treated to three levels of NPK fertilizer rates (0, 150 and 300 kg NPK ha^{-1}) and two methods of fertilizer application. Treatments were arranged in a split-plot design with fertilizer application method as main plot factor and NPK rates as sub-plot factor. The treatments were replicated three times to give a total of eighteen experimental field plots. The result indicated that the fertilizer NPK significantly increase growth parameters (plant height, leaf area, root length, number of leaves), yield and yield components with optimum yield of okra obtained from NPK @ 150 kg ha^{-1}.

The study was designed by Achebe *et al.* (2013) to investigate the effect of different levels of N.P.K fertilizer on six cultivars of Okra (*Abelmoschus esculentus*). Data collected at different sampling periods included plant height, total leaf area, number of pods and fresh weight of pods. The application of N.P.K 20:10:10 at 250kg/ha level was significantly different from others in growth and yield parameters. Higher mean values were observed with 250kg/ha level followed by 150kg/ha. Cultivar LD –88 performed better in number of pods and fresh pod weight. Other cultivars had areas where they performed well. The application of 250kg/ha level of N.P.K.20:10:10 fertilizer is appropriate in attaining high pod yield in Asaba and Cultivar LD-88 showed the best performance in Asaba soil.

Field studies were carried out by Iyagba *et al.* (2013) at the Federal University of Technology, Owerri, Nigeria to determine the response of okra (*Abelmoschus esculentus* (L.) Moench) to NPK fertilizer rates at different weeding regimes. Okra seeds variety, NHAe47-4 were treated to four levels of NPK fertilizer rates (0, 100, 200 and 300 kg ha^{-1}) and five weeding regimes. Plant height and leaf area were in the increasing order of 0>100>200>300 kg ha^{-1}. More flowers/plant were obtained by applying 300kg ha^{-1} of NPK while the least number of flowers/plant aborted was obtained with the application of 200 and 300 kg ha^{-1} in both years. Among the weeded plots, okra plots applied with 300 kg ha^{-1} of NPK fertilizer produced the highest fruit yield (26.50 t ha^{-1}) which was not significantly different with the application of 200 kg ha^{-1} of NPK fertilizer in both years.

From above reviewed results it was found that plant spacing and potassium fertilizers and their interaction effect are indispensable for the production system of okra and play a vital role to increase the yield and yield attributes, providing other factors are not limiting. Among the macronutrients, N and P are used largely by the okra plants. Physio-morphological and biological development of okra plants depends on the suitable plant spacing and judicious application potassium on growth and yield of okra plant.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out during the period from April to August 2014 to find out the effect of spacing and potassium fertilizer on the yield and yield components of okra. The materials and methods those were used for conducting the experiment have been presented in this chapter. This chapter includes a short description of the location of experimental site, climate and soil condition of the experimental plot, materials used for the experiment, design of the experiment, data collection procedure and procedure of data analysis.

3.1 Location

The experiment was carried out at the Horticulture Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka. It was located in 24.09 ^{0}N latitude and 90.26 ^{0}E longitude. The altitude location was 8 m from the sea level.

3.2 Climate

Experimental site is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months from April to September and scanty rainfall during the rest period of the year. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix I.

3.3 Soil characteristics

Selected land of the experimental field was medium high land in nature with adequate irrigation facilities and remained utilized for crop production during the previous season. The soil is belonged to the Modhupur Tract (UNDP, 1988) under AEZ No. 28. The soil texture of the experimental soil was sandy loam. The nutrient status of the farm soil under the experimental plot within a depth of 0-20 cm were collected and analyzed in the Soil Research and Development Institute Dhaka, and results have been presented in Appendix II.

3.4 Planting materials

The test crop used in the experiment was BARI Dherosh-1.

3.5 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Plant spacing (3 levels) as

i S_1: 50 cm × 30 cm

ii. S_2: 50 cm × 40 cm

iii. S_3: 50 cm × 50 cm

Factor B: Potassium fertilizer (3 levels) as

i. K_0: 0 kg K_2O/ha (control)

ii. K_1: 120 kg K_2O/ha

iii. K_2: 150 kg K_2O/ha

There were 9 (3 × 3) treatments combination such as S_1K_0, S_1K_1, S_1K_2, S_2K_0, S_2K_1, S_2K_2, S_3K_0, S_3K_1 and S_3K_2.

3.6 Collection of seeds

The seeds of okra were collected from Siddique Bazar, Dhaka. The seeds were leveled with 98% purity and 95% germination percentage and preserved in air tied packet.

3.7 Land preparation

The plot selected for conducting the experiment was opened in the third week of March, 2014 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil was obtained for sowing okra seeds. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. The soil was treated with insecticides (cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhabiting insects such as cutworm and mole cricket.

3.8 Application of manure and fertilizers

Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) were used as a source of nitrogen, phosphorous, and potassium, respectively. Manures and fertilizers thoset were applied to the experimental plot have been presented in the Table 1. The total amount of cowdung, TSP and MP was applied as basal dose at the time of final land preparation dated at 28 March, 2014. Urea was applied at 15, 30 and 45 days after sowing (DAS).

Table 1. Dose and method of fertilizers application in okra field (Fertilizer Recommendation Guide, BARC, 2005)

Fertilizers	Dose/ha	Application (%)			
		Basal	15 DAS	30 DAS	45 DAS
Cowdung	10 tons	100	--	--	--
Nitrogen (as urea)	120 kg	--	33.33	33.33	33.33
P_2O_5 (as TSP)	50 kg	100	--	--	--
K_2O (as MP)	As per treatment	100	--	--	--

3.9 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 195.0 m^2 with length 19.5 m and width 10 m. The total area was divided into three equal blocks. Each block was divided into 9 plots where 9 treatments combination of spacing potassium fertilizer and were allotted at random. There were 27 unit plots altogether in the experiment. The size of each plot was 2.0 m × 1.5 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. The spacing was maintained as per treatment. The layout of the experimental plot has been shown in Figure 1.

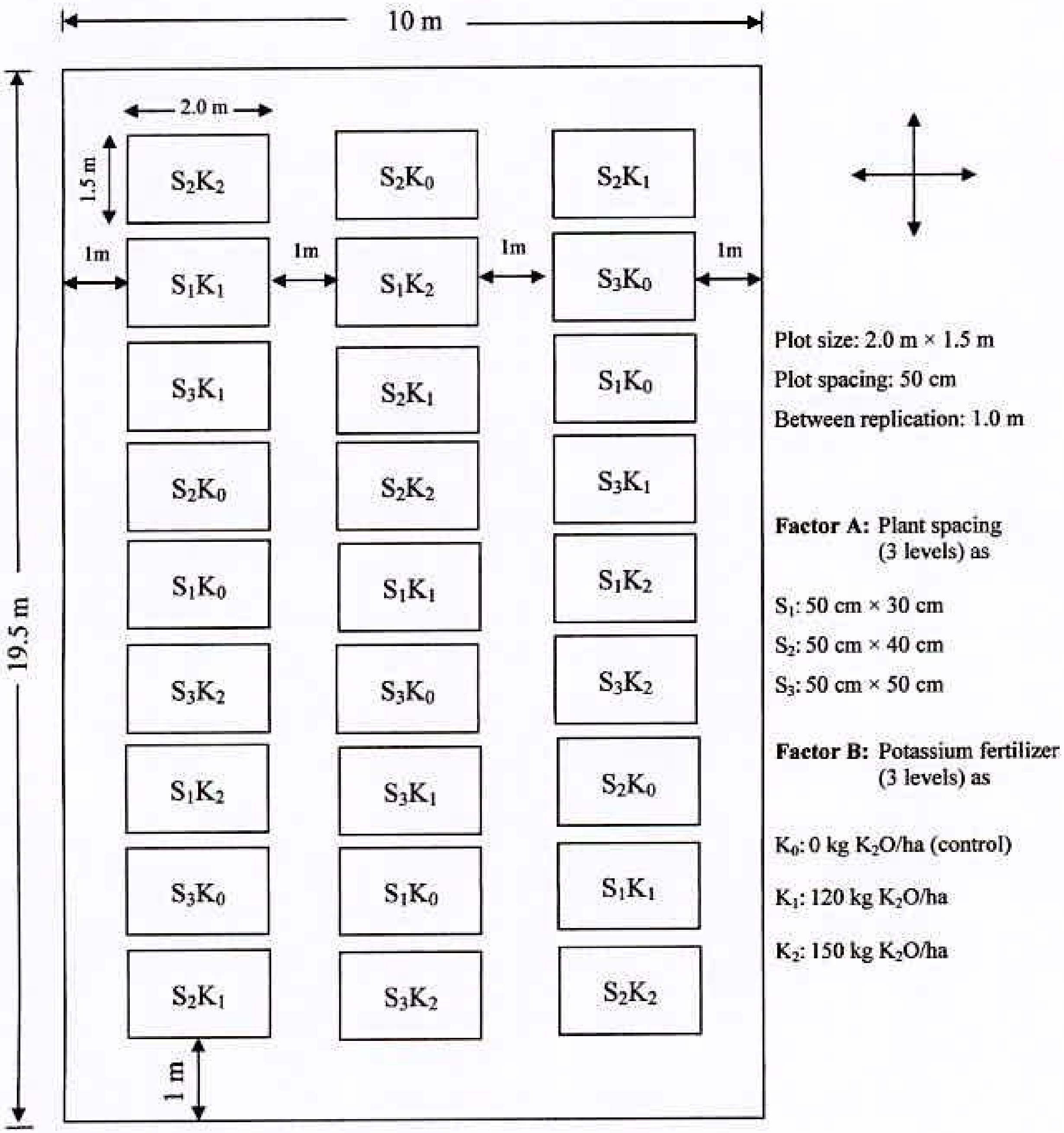

Figure 1. Field layout of the experimental plot

3.10 Seeds sowing

The okra seeds were sown in the main field on 03 April in 2014. Seeds were treated with Bavistin before sowing the seeds to control the seed borne diseases. The seeds were sown in rows having a depth of 2-3 cm with maintaining distance as per treatment.

3.11 Intercultural operation

After raising seedlings, various intercultural operations such as gap filling, weeding, earthing up, irrigation pest and disease control etc. were accomplished for better growth and development of the okra seedlings.

3.11.1 Gap filling

The seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after germination and such seedlings were replaced by new seedlings. Replacement was done with healthy seedling in the afternoon having a boll of earth which was also planted on the same date by the side of the unit plot. The seedlings were irrigated for 7 days starting from germination to their proper establishment.

3.11.2 Weeding

The weeding was done in three times by nirani with roots at 15, 30 and 45 days after sowing to keep the plots free from weeds.

3.11.3 Irrigation

Light watering was given by a watering pot at every morning and afternoon and it was continued for a week for rapid and well establishment of the germinated seedlings.

3.11.4 Pest and disease control

Insect infestation was a serious problem during the period of establishment of seedings in the field. In spite of Cirocarb 3G applications during final land preparation few young plants were damaged due to attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban 29

EC @ 3%. Some discolored and yellowish diseased leaves were also collected from the plant and removed from the field.

3.12 Harvesting

Fruits were harvested at 5 days interval based on eating quality at soft and green condition. Harvesting was started from 09 May, 2014 and was continued up to August 2014.

3.13 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, except yields of plots, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth; yield attributes and yields as affected by different treatments of the experiment. Data on plant height, diameter of stem, number of leaves, number of branches per plant, length of petiole, number of internode per plant, length of internode and leaf area were collected at 20, 40 and, 60 days after sowing (DAS). All other yield contributing characters and yield parameters such as days to flowering, number of flower buds/plant, number of pods per plant, weight of individual pods, length of pod, diameter of pod, yield per plot was also recorded as per the suitable time of optimum performance of okra plants.

3.13.1 Plant height

Plant height was measured from sample plants in centimeter from the ground level to the tip of the longest stem and mean value was calculated. Plant height was also recorded at 20 days interval starting from 20 days after sowing (DAS) upto 60 days to observe the growth rate of plants.

3.13.2 Stem diameter

Stem diameter was measured from sample plants with a slide calipers in centimeter from the three part of plant and mean value was calculated. Stem diameter was recorded at 20 days interval starting from 20 days after sowing (DAS) upto 60 days to observe the growth rate of plants.

3.13.3 Number of leaves per plant

The total number of leaves per plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot from 20 DAS to 60 DAS at 20 days interval.

3.13.4 Length of petiole

Length of petiole was measured from sample plants in centimeter from the one side to another side of petiole of the longest petiole and mean value was calculated. Length of petiole was also recorded at 20 days interval starting from 20 days after sowing (DAS) upto 60 days to observe the growth rate of plants.

3.13.5 Number of internode per plant

The total number of internode per plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot from 20 DAS to 60 DAS at 20 days interval.

3.13.6 Length of internode

Length of internode was measured from sample plants in centimeter from one side to another side of internode and mean value was calculated. Length of internode was also recorded at 20 days interval starting from 20 days after sowing (DAS) upto 60 days to observe the growth rate of plants.

3.13.7 Leaf area

Leaf length and leaf breadth was measured from sample leaves in centimeter and leaf area was measured by multiplying leaf length and leaf breadth. Leaf area was also recorded at 20 days interval starting from 20 days of sowing upto 60 days to observe the growth rate of plants.

3.13.8 Days required for 50% flowering

Days required for 50% flowering was counted from the date of sowing to the initiation of 50% flower bud and was recorded.

3.13.9 Number of flower buds per plant

The number of flower buds per plant was counted from the sample plants and the average number of flower buds produced per plant were recorded.

3.13.10 Number of pods per plant

The number of pods per plant was counted from the sample plants and the average number of pods produced per plant was recorded on the basis of pods per plant.

3.13.11 Pod length

The length of pod was measured with a slide calipers from the tip of the fruit to base of 10 selected marketable fruits from each plot and their average was taken and expressed in cm.

3.13.12 Pod diameter

Diameter of pod was measured at the middle portion of 10 selected marketable fruit from each plot with a slide calipers and their average was taken and expressed in cm.

3.13.13 Weight of individual pods

The weight of individual pod was measured with a digital weighing machine from 10 selected marketable fruits from each selected plots and their average was taken and expressed in gram.

3.13.14 Yield per plot

Yield of okra per plot was recorded as the whole fruit per plot and was expressed in kilogram.

3.13.15 Yield per hectare

Yield per hectare of okra fruits was calculated by converting the weight of plot yield into hectare and was expressed in ton.

3.14 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for plant spacing and potassium fertilizer on growth and yield of okra. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the means of treatment combinations was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was carried out to find out the effect of spacing and potassium fertilizer on the growth and yield of okra. Data on different growth parameters, yield contributing characters and yield of okra was recorded. The analyses of variance (ANOVA) of the data on the parameters have been presented in Appendix III-VII. The results have been presented and discussed, and possible interpretations have been given under the following headings:

4.1 Plant height

Plant height of okra varied significantly for different plant spacing at 20, 40, and 60 DAS (Appendix III). The tallest plant (25.29, 62.88 and 91.29 cm) was recorded from S_2 (50 cm × 40 cm) which was statistically similar (23.40, 61.33 and 89.43 cm) to S_3 (50 cm × 30 cm) at 20, 40 and 60 DAS, respectively, while at the same DAS, the shortest plant (18.84, 56.46 and 81.85 cm) was measured from S_1 (50 cm × 30 cm) (Figure 2). It was revealed that with the increase of spacing plant height showed increasing trend upto certain level than decreased. In case of closer spacing plant compete for light and other macro and micro nutrients. Closer spacing greatly effect plant growth that produced comparatively shorter plants than wider spacing. On the other way excess wider spacing do not create the competition within the species and produce comparatively shorter plant than the suitable spacing. Leghari *et al.* (2003) demonstrated that plants grown at 30 cm plant spacing with 50 cm row spacing produced taller plants.

Effect of levels of potassium fertilizer differed significantly for plant height of okra at 20, 40 and 60 DAS (Appendix III). At 20, 40 and 60 DAS the tallest plant (25.29, 63.81 and 91.20 cm) was recorded from K_2 (150 kg K_2O/ha) which was statistically identical (24.08, 62.22 and 89.96 cm) to K_1 (120 kg K_2O/ha), respectively, whereas the shortest plant (18.16, 54.65 and 81.41 cm) was found from K_2 (0 kg K_2O/ha) (Figure 3). Mishra and Pandey (1987) reported that application of K above 120 kg/ha adversely affected plant height.

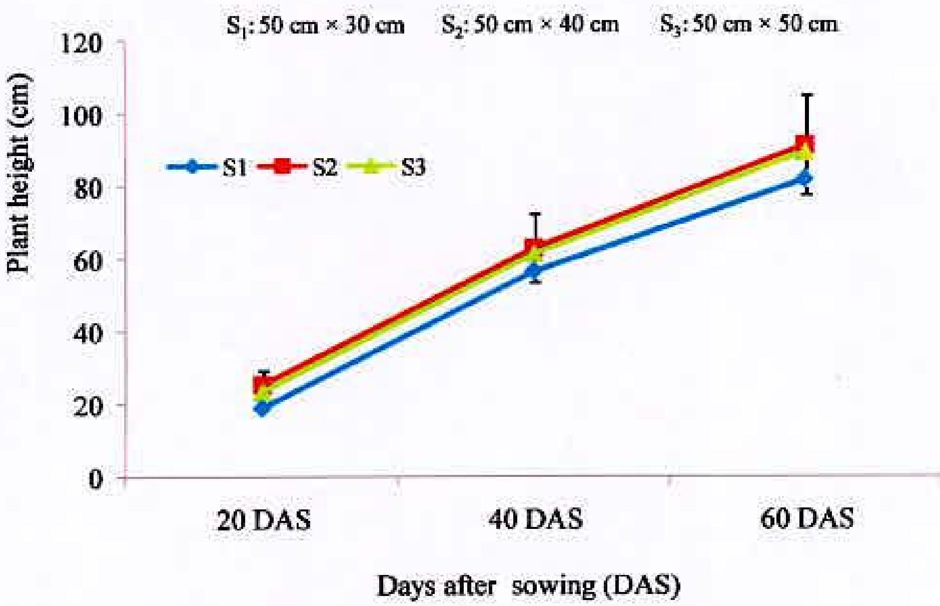

Figure 2. Effect of different plant spacing on plant height of okra. Vertical bars represent LSD value.

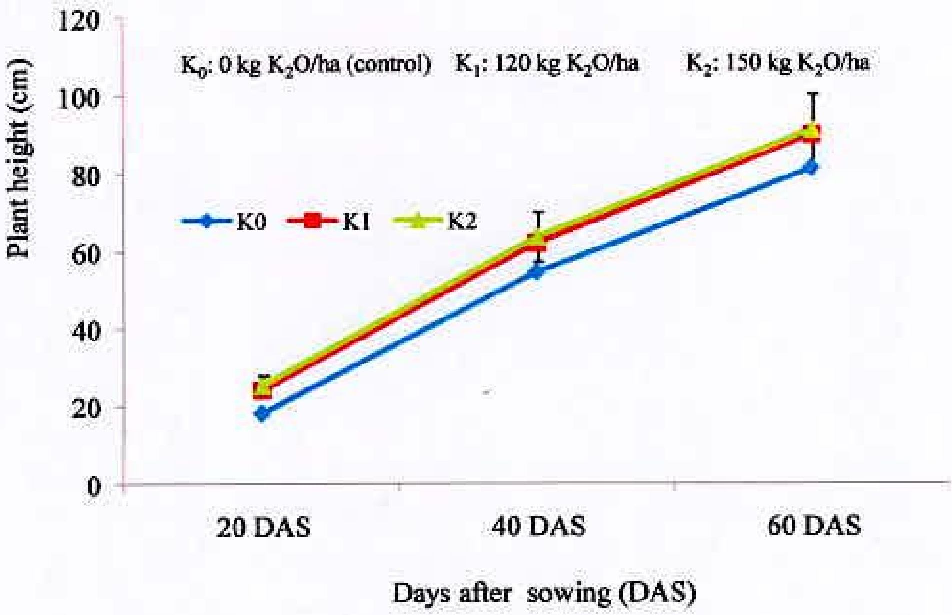

Figure 3. Effect of different levels of potassium on plant height of okra. Vertical bars represent LSD value.

Statistically significant variation was recorded due to interaction effect of plant spacing and levels of potassium fertilizer in terms of plant height of okra at 20, 40 and 60 DAS (Appendix III). The longest plant (29.42, 67.65 and 96.93 cm) was recorded from S_2K_2 (50 cm × 40 cm and 150 kg K_2O/ha) at 20, 40 and 60 DAS, respectively. On the other hand, the shortest plant (16.91, 53.25 and 80.13 cm) was recorded from S_1K_0 (50 cm × 30 cm and 0 kg K_2O/ha) (Table 2). Probably 50 cm × 40 cm and 150 kg K_2O/ha treatment combination was suitable for the growth and development of okra for that tallest plant was recorded for this combination.

4.2 Stem diameter

Statistically significant variation was recorded for stem diameter of okra due to different plant spacing at 20, 40, and 60 DAS (Appendix III). The highest stem diameter (1.53, 1.69 and 2.11 cm) was found from S_2 which was statistically similar (1.48, 1.60 and 2.08 cm) to S_3 at 20, 40 and 60 DAS, respectively, again at the same DAS, the lowest stem diameter (1.27, 1.33 and 1.92 cm) was recorded from S_1 (Figure 4). Wider spacing do not create and competition within the species and produce comparatively thinner stem than the suitable spacing on the other hand optimum plant spacing should be maintained to exploit maximum natural resources such as nutrients, sunlight, soil moisture etc. and to ensure highest stem diameter.

Stem diameter of okra differed significantly due to the application of levels of potassium fertilizer at 20, 40 and 60 DAS (Appendix III). At 20, 40 and 60 DAS the highest stem diameter (1.54, 1.69 and 2.16 cm) was observed from K_2 which was statistically similar (1.50, 1.65 and 2.12 cm) to K_1, respectively, while the lowest stem diameter (1.24, 1.29 and 1.83 cm) was obtained from K_0 (Figure 5).

Interaction effect of plant spacing and levels of potassium fertilizer showed statistically significant variation in terms of stem diameter of okra at 20, 40 and 60 DAS (Appendix III). The highest stem diameter (1.69, 1.94 and 2.27 cm) was found from S_2K_2 at 20, 40 and 60 DAS, respectively, whereas the lowest stem diameter (1.17, 1.20 and 1.76 cm) was recorded from S_1K_0, respectively (Table 2).

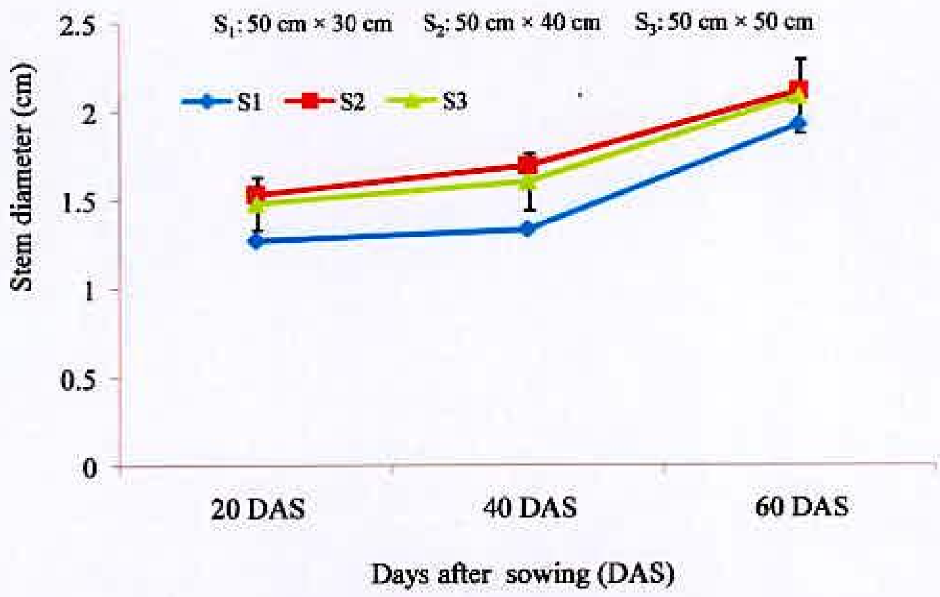

Figure 4. Effect of different plant spacing on stem diameter of okra. Vertical bars represent LSD value.

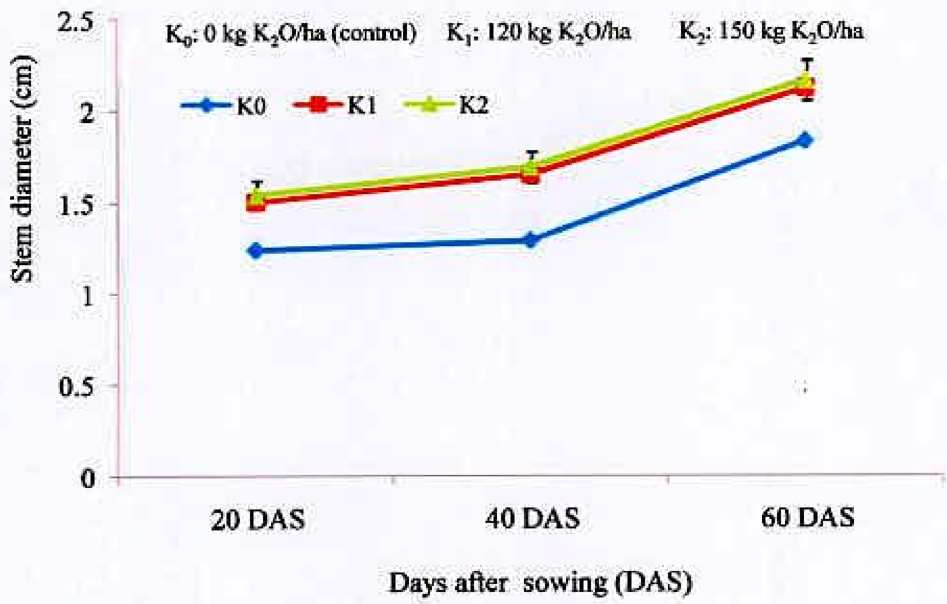

Figure 5. Effect of different levels of potassium on stem diameter of okra. Vertical bars represent LSD value.

Table 2. Interaction effect of plant spacing and potassium fertilizer on plant height and stem diameter at different days after sowing (DAS) of okra

Treatment	Plant height (cm) at			Stem diameter (cm) at		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
S_1K_0	16.91 e	53.25 c	80.13 b	1.17 b	1.20 e	1.76 e
S_1K_1	21.19 cd	58.64 b	84.06 b	1.36 b	1.52 cd	2.02 b
S_1K_2	18.44 de	57.50 bc	81.35 b	1.28 b	1.28 e	1.98 bc
S_2K_0	20.00 de	56.48 bc	83.10 b	1.31 b	1.37 de	1.88 cd
S_2K_1	26.46 ab	64.52 a	93.83 a	1.60 a	1.75 ab	2.20 a
S_2K_2	29.42 a	67.65 a	96.93 a	1.69 a	1.94 a	2.27 a
S_3K_0	17.57 de	54.21 bc	80.99 b	1.23 b	1.30 e	1.85 de
S_3K_1	24.60 bc	63.49 a	91.99 a	1.56 a	1.67 bc	2.16 a
S_3K_2	28.02 ab	66.29 a	95.32 a	1.65 a	1.84 ab	2.22 a
$LSD_{(0.05)}$	3.759	4.504	7.097	0.187	0.197	0.110
CV(%)	9.65	4.32	4.68	7.65	7.45	3.28

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

S_1: 50 cm × 30 cm — K_0: 0 kg K_2O/ha (control)

S_2: 50 cm × 40 cm — K_1: 120 kg K_2O/ha

S_3: 50 cm × 50 cm — K_2: 150 kg K_2O/ha

4.3 Number of leaves/plant

Different plant spacing varied significantly for number of leaves/plant of okra for at 20, 40, and 60 DAS (Appendix IV). The maximum number of leaves/plant (8.29, 28.24 and 51.16) was recorded from S_2 which was statistically similar (7.89, 27.62 and 49.56) to S_3 at 20, 40 and 60 DAS, respectively, again at the same DAS, the minimum number of leaves/plant (6.93, 24.22 and 46.93) was obtained from S_1 (Table 3). It was revealed that with the increases of spacing number of leaves per plant also increases upto a certain level after that decreases.

Levels of potassium fertilizer showed statistically significant variation for number of leaves/plant of okra at 20, 40 and 60 DAS (Appendix IV). At 20, 40 and 60 DAS the maximum number of leaves/plant (8.27, 28.93 and 52.47) was found from K_2 which was statistically similar (8.04, 27.33 and 50.40) to K_1, respectively, whereas the minimum number of leaves/plant (6.89, 23.82 and 44.78) was observed from K_0 (Table 3). It revealed that with the increase of potassium number of leaves per plant showed increasing trend then decreased.

Statistically significant variation was found due to interaction effect of plant spacing and levels of potassium fertilizer in terms of number of leaves/plant of okra at 20, 40 and 60 DAS (Appendix IV). The maximum number of leaves/plant (9.00, 31.07 and 55.47) was obtained from S_2K_2 at 20, 40 and 60 DAS, respectively. On the other hand, the minimum number of leaves/plant (6.67, 22.60 and 43.53) was found from S_1K_0, respectively (Table 4). Probably S_2K_2 (50 cm × 40 cm and 150 kg K_2O/ha) treatment combination was suitable for the growth and development of okra for that highest number of leaves/plant was recorded for this treatment combination.

Table 3. Effect of plant spacing and potassium fertilizer on number of leaves per plant at different days after sowing (DAS) of okra

Treatment	Number of leaves per plant at		
	20 DAS	40 DAS	60 DAS
Plant spacing			
S_1	6.93 b	24.22 b	46.93 b
S_2	8.29 a	28.24 a	51.16 a
S_3	7.98 a	27.62 a	49.56 a
$LSD_{(0.05)}$	0.381	1.715	1.994
CV(%)	4.92	6.43	4.05
Level of potassium			
K_0	6.89 b	23.82 b	44.78 c
K_1	8.04 a	27.33 a	50.40 b
K_2	8.27 a	28.93 a	52.47 a
$LSD_{(0.05)}$	0.381	1.715	1.994
CV(%)	4.92	6.43	4.05

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

S_1: 50 cm × 30 cm — K_0: 0 kg K_2O/ha (control)

S_2: 50 cm × 40 cm — K_1: 120 kg K_2O/ha

S_3: 50 cm × 50 cm — K_2: 150 kg K_2O/ha

Table 4. Interaction effect of plant spacing and potassium fertilizer on number of leaves per plant at different days after sowing (DAS) of okra

Treatment	Number of leaves per plant at		
	20 DAS	40 DAS	60 DAS
S_1K_0	6.67 b	22.60 b	43.53 e
S_1K_1	7.13 b	25.00 b	48.93 cd
S_1K_2	7.00 b	25.07 b	48.33 cd
S_2K_0	7.20 b	24.93 b	46.27 de
S_2K_1	8.67 a	28.73 a	51.73 bc
S_2K_2	9.00 a	31.07 a	55.47 a
S_3K_0	6.80 b	23.93 b	44.53 e
S_3K_1	8.33 a	28.27 a	50.53 bc
S_3K_2	8.80 a	30.67 a	53.60 ab
$LSD_{(0.05)}$	0.659	2.971	3.454
CV(%)	4.92	6.43	4.05

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

S_1: 50 cm × 30 cm — K_0: 0 kg K_2O/ha (control)

S_2: 50 cm × 40 cm — K_1: 120 kg K_2O/ha

S_3: 50 cm × 50 cm — K_2: 150 kg K_2O/ha

4.4 Length of petiole

Length of petiole of okra varied significantly for different plant spacing at 20, 40, and 60 DAS (Appendix V). The highest length of petiole (13.86, 25.67 and 35.61 cm) was recorded from S_3 which was statistically similar (13.66, 25.26 and 34.72 cm) to S_2 at 20, 40 and 60 DAS, respectively, while at the same DAS, the lowest length of petiole (11.10, 17.20 and 28.78 cm) was observed from S_1 (Table 5).

Significant variation was recorded for different levels of potassium fertilizer in terms of length of petiole of okra at 20, 40 and 60 DAS (Appendix V). At 20, 40 and 60 DAS the highest length of petiole (13.67, 25.24 and 36.03 cm) was found from K_2 which was statistically similar (13.23, 24.68 and 34.33 cm) to K_1, respectively, while the lowest (11.72, 18.20 and 28.75 cm) from K_0 (Table 5).

Statistically significant variation was recorded due to interaction effect of plant spacing and levels of potassium fertilizer in terms of length of petiole of okra at 20, 40 and 60 DAS (Appendix V). The highest length of petiole (15.28, 29.00 and 40.39 cm) was found from S_3K_2 at 20, 40 and 60 DAS, respectively, while, the lowest length (11.03, 16.16 and 27.55 cm) from S_1K_0, respectively (Table 6). Probably S_3K_2 (50 cm × 50 cm and 150 kg K_2O/ha) treatment combination was suitable for the growth and development of okra for that longest petiole was recorded for this treatment combination.

4.5 Leaf area

Leaf area varied significantly for different plant spacing at 20, 40, and 60 DAS (Appendix V). The highest leaf area (44.62 cm^2, 56.77 cm^2 and 79.63 cm^2) was observed from S_3 which was statistically similar (43.35 cm^2, 56.24 cm^2 and 78.39 cm^2) to S_2 at 20, 40 and 60 DAS, respectively, while at the same DAS, the lowest leaf area (34.83 cm^2, 51.82 cm^2 and 68.89 cm^2) was found from S_1 (Table 5).

Levels of potassium fertilizer differed significantly for leaf area of okra at 20, 40 and 60 DAS (Appendix V). At 20, 40 and 60 DAS the highest leaf area (44.63 cm^2, 58.60 cm^2 and 80.22 cm^2) was found from K_2 which was statistically similar (42.49 cm^2, 57.00 cm^2 and 76.79 cm^2) to K_1, respectively. Again, the lowest leaf area (35.67 cm^2, 49.24 cm^2 and 69.90 cm^2) was obtained from K_0 (Table 5).

Table 5. Effect of plant spacing and potassium fertilizer on length of petiole and leaf area at different days after sowing (DAS) of okra

Treatment	Length of petiole (cm) at			Leaf area (cm^2) at		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Plant spacing						
S_1	11.10 b	17.20 b	28.78 b	34.83 b	51.82 b	68.89 b
S_2	13.66 a	25.26 a	34.72 a	43.35 a	56.24 a	78.39 a
S_3	13.86 a	25.67 a	35.61 a	44.62 a	56.77 a	79.63 a
$LSD_{(0.05)}$	0.999	1.881	2.403	2.780	2.697	3.064
CV(%)	7.76	8.29	7.28	6.80	4.91	4.05
Level of potassium						
K_0	11.72 b	18.20 b	28.75 b	35.67 b	49.24 b	69.90 c
K_1	13.23 a	24.68 a	34.33 a	42.49 a	57.00 a	76.79 b
K_2	13.67 a	25.24 a	36.03 a	44.63 a	58.60 a	80.22 a
$LSD_{(0.05)}$	0.999	1.881	2.403	2.780	2.697	3.064
CV(%)	7.76	8.29	7.28	6.80	4.91	4.05

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

S_1: 50 cm × 30 cm K_0: 0 kg K_2O/ha (control)

S_2: 50 cm × 40 cm K_1: 120 kg K_2O/ha

S_3: 50 cm × 50 cm K_2: 150 kg K_2O/ha

Table 6. Interaction effect of plant spacing and potassium fertilizer on length of petiole and leaf area at different days after sowing (DAS) of okra

Treatment	Length of petiole (cm) at			Leaf area (cm^2) at		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
S_1K_0	11.03 c	16.16 c	27.55 c	31.87 d	47.40 d	65.93 d
S_1K_1	11.45 c	17.25 bc	30.00 c	36.83 cd	54.44 b	70.48 cd
S_1K_2	10.82 c	18.20 bc	28.79 c	35.78 cd	53.62 bc	70.26 cd
S_2K_0	12.23 bc	20.08 b	30.10 c	37.76 c	51.35 bcd	71.96 c
S_2K_1	13.47 ab	27.15 a	35.15 b	43.09 b	56.20 ab	77.82 b
S_2K_2	15.28 a	28.53 a	38.90 ab	49.19 a	61.17 a	85.39 a
S_3K_0	11.91 bc	18.36 bc	28.59 c	37.38 c	48.96 cd	71.82 c
S_3K_1	14.76 a	29.64 a	37.85 ab	47.54 ab	60.34 a	82.07 ab
S_3K_2	14.92 a	29.00 a	40.39 a	48.93 a	61.01 a	85.01 a
$LSD_{(0.05)}$	1.730	3.258	4.162	4.815	4.672	5.308
CV(%)	7.76	8.29	7.28	6.80	4.91	4.05

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

S_1: 50 cm × 30 cm

S_2: 50 cm × 40 cm

S_3: 50 cm × 50 cm

K_0: 0 kg K_2O/ha (control)

K_1: 120 kg K_2O/ha

K_2: 150 kg K_2O/ha

Statistically significant variation was recorded due to interaction effect of plant spacing and levels of potassium fertilizer in terms of leaf area of okra at 20, 40 and 60 DAS (Appendix V). The highest leaf area (49.19 cm^2, 61.17 cm^2 and 85.39 cm^2) was recorded from S_2K_2 at 20, 40 and 60 DAS, respectively. Again, the lowest leaf area (31.87 cm^2, 47.40 cm^2 and 65.93 cm^2) was observed in S_1K_0, respectively (Table 6).

4.6 Number of internode/plant

Different plant spacing showed statistically significant differences for number of internode/plant of okra at 20, 40, and 60 DAS (Appendix VI). The maximum number of internode/plant (7.45, 15.91 and 21.76) was recorded from S_2 which was statistically similar (7.33, 15.84 and 21.34) to S_3 at 20, 40 and 60 DAS, respectively, whereas at the same DAS, the minimum number of internode/plant (5.13, 12.83 and 17.92) was recorded from S_1 (Table 7). It was revealed that with the increases of spacing number of internodes showed increasing trend upto certain level than decreases. Leghari *et al.* (2003) demonstrated that plants grown at 30 cm plant spacing with 50 cm row spacing produced highest number of nodes.

Number of internode/plant of okra varied significantly for levels of potassium fertilizer at 20, 40 and 60 DAS (Appendix VI). At 20, 40 and 60 DAS the maximum number of internode/plant (7.54, 16.27 and 21.32) was recorded from K_2 which was statistically similar (7.16, 15.40 and 21.07) to K_1, respectively. On the other hand, the minimum number of internode/plant (5.20, 12.17 and 17.57) was found from K_0 (Table 7).

Interaction effect of plant spacing and levels of potassium fertilizer showed statistically significant variation in terms of number of internode/plant of okra at 20, 40 and 60 DAS (Appendix VI). The maximum number of internode/plant (8.83, 18.24 and 23.75) was recorded from S_2K_2 at 20, 40 and 60 DAS, respectively, whereas the minimum number of internode/plant (5.08, 12.17 and 17.57) was recorded from S_1K_0, respectively (Table 8).

Table 7. Effect of plant spacing and potassium fertilizer on number of internode and length of internode at different days after sowing (DAS) of okra

Treatment	Number of internode at			Length of internode (cm) at		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Plant spacing						
S_1	5.13 b	12.83 b	17.92 b	3.02 b	5.42 b	11.51 b
S_2	7.45 a	15.91 a	21.76 a	3.77 a	7.52 a	13.00 a
S_3	7.33 a	15.84 a	21.34 a	3.88 a	7.55 a	13.14 a
$LSD_{(0.05)}$	0.499	0.822	0.701	0.264	0.614	0.628
CV(%)	7.53	5.54	3.45	7.46	8.99	5.01
Level of potassium						
K_0	5.20 b	12.91 c	18.64 b	2.88 b	5.46 c	10.98 b
K_1	7.16 a	15.40 b	21.07 a	3.89 a	7.09 b	13.20 a
K_2	7.54 a	16.27 a	21.32 a	3.90 a	7.95 a	13.46 a
$LSD_{(0.05)}$	0.499	0.822	0.701	0.264	0.614	0.628
CV(%)	7.53	5.54	3.45	7.46	8.99	5.01

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

S_1: 50 cm × 30 cm — K_0: 0 kg K_2O/ha (control)

S_2: 50 cm × 40 cm — K_1: 120 kg K_2O/ha

S_3: 50 cm × 50 cm — K_2: 150 kg K_2O/ha

Table 8. Interaction effect of plant spacing and potassium fertilizer on number of internode and length of internode at different days after sowing (DAS) of okra

Treatment	Number of internode at			Length of internode (cm) at		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
S_1K_0	5.08 c	12.17 c	17.57 d	2.41 e	4.90 c	10.64 c
S_1K_1	5.14 c	13.15 c	18.48 cd	3.52 bc	5.32 c	12.19 b
S_1K_2	5.17 c	13.18 c	17.70 d	3.12 cd	6.05 c	11.71 bc
S_2K_0	5.28 c	13.31 c	18.87 cd	2.75 de	6.02 c	11.21 bc
S_2K_1	7.87 b	16.19 b	22.68 ab	4.20 a	7.65 b	13.55 a
S_2K_2	8.83 a	18.24 a	23.75 a	4.36 a	8.90 a	14.23 a
S_3K_0	5.23 c	13.26 c	19.48 c	3.47 bc	5.46 c	11.10 bc
S_3K_1	8.48 ab	16.87 ab	22.05 b	3.95 ab	8.30 ab	13.86 a
S_3K_2	8.63 ab	17.40 ab	22.50 ab	4.22 a	8.89 a	14.45 a
$LSD_{(0.05)}$	0.864	1.424	1.214	0.458	1.064	1.088
CV(%)	7.53	5.54	3.45	7.46	8.99	5.01

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

S_1: 50 cm × 30 cm K_0: 0 kg K_2O/ha (control)

S_2: 50 cm × 40 cm K_1: 120 kg K_2O/ha

S_3: 50 cm × 50 cm K_2: 150 kg K_2O/ha

4.7 Length of internode

Length of internode of okra varied significantly for different plant spacing at 20, 40, and 60 DAS (Appendix VI). The highest length of internode (3.88, 7.55 and 13.14 cm) was obtained from S_3 which was statistically similar (3.77, 7.52 and 13.00 cm) to S_2 at 20, 40 and 60 DAS, respectively, again at the same DAS, the lowest length of internode (3.02, 5.42 and 11.51 cm) was found from S_1 (Table 7). It was revealed that with the increases of spacing length of internode increasing trend upto certain level than decreases.

Length of internode of okra showed statistically significant variation for different levels of potassium fertilizer at 20, 40 and 60 DAS (Appendix VI). At 20, 40 and 60 DAS the highest length of internode (3.90, 7.95 and 13.46 cm) was observed from K_2 which was statistically similar (3.89, 7.09 and 13.20 cm) to K_1, respectively, whereas the lowest length of internode (2.88, 5.46 and 10.98 cm) was recorded in K_0 (Table 7).

Plant spacing and levels of potassium fertilizer showed statistically significant variation due to their interaction effect of in terms of length of internode of okra at 20, 40 and 60 DAS (Appendix VI). The highest length of internode (4.36, 8.90 and 14.23 cm) was found from S_2K_2 at 20, 40 and 60 DAS, respectively. On the other hand, the lowest length of internode (2.41, 4.90 and 10.64 cm) was observed from S_1K_0, respectively (Table 8).

4.8 Days required for the 1st flowering

Days required for the 1st flowering of okra varied significantly for different plant spacing (Appendix VII). The highest days required for the 1st flowering (45.67) was recorded from S_3, which was statistically similar (44.44) to S_1, while the lowest days (41.67) was found from S_2 (Figure 6). Wider spacing do not create and competition within the species that prolong vegetative period.

Statistically significant variation was recorded for levels of potassium fertilizer in terms of days required for the 1st flowering of okra (Appendix VII). The highest days required for the 1st flowering (47.44) were obtained from K_0 while, the lowest days (41.67) was recorded from K_2 which was similar (42.67) to K_1 ((Figure 7).

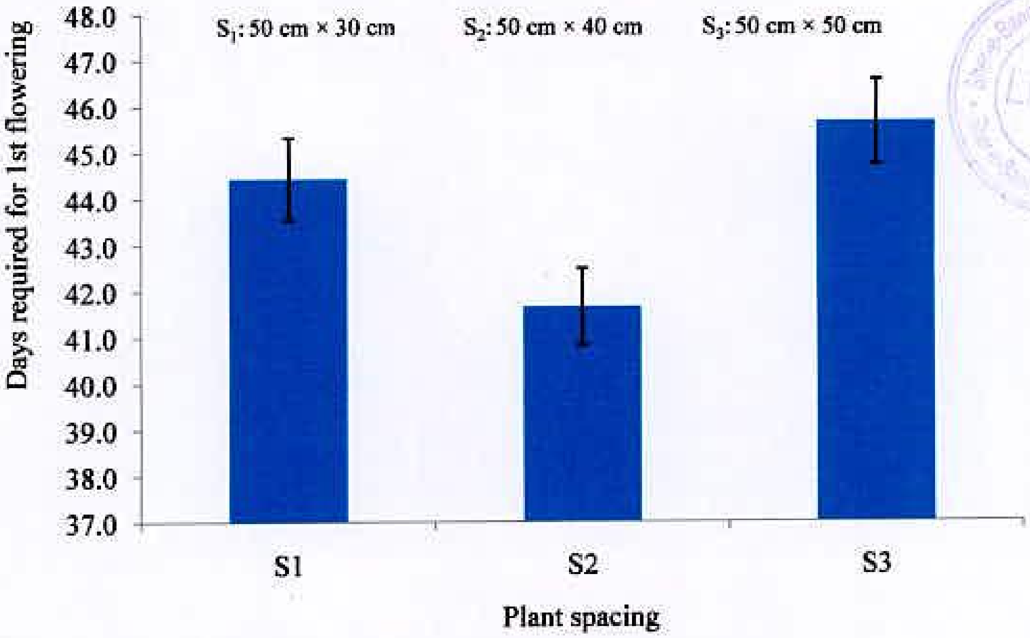

Figure 6. Effect of different plant spacing on days required for 1st flowering of okra. Vertical bars represent LSD value.

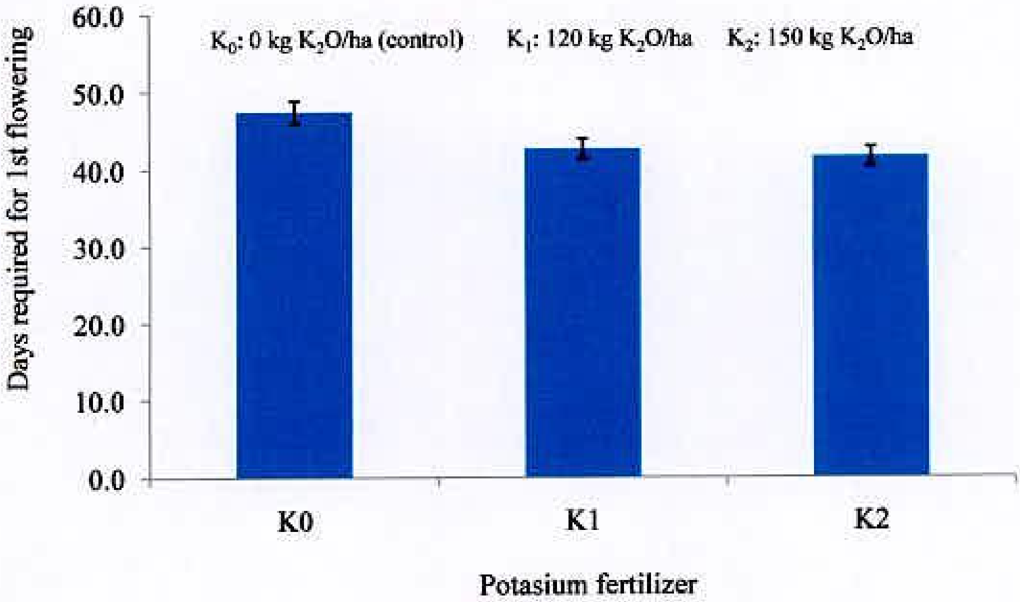

Figure 7. Effect of different levels of potassium on days required for 1st flowering of okra. Vertical bars represent LSD value.

Days required for the 1st flowering showed statistically significant variation due to interaction effect of plant spacing and levels of potassium fertilizer (Appendix VII). The highest days required for the 1st flowering (56.00) was obtained from S_1K_0, again the lowest days (30.00) was found from S_1K_2 ((Figure 8).

4.9 Flower buds/plant

Flower buds/plant of okra showed significant differences for different plant spacing (Appendix VII). The maximum flower buds/plant (44.98) was recorded from S_2 which was statistically similar (42.69) to S_3. On the other hand, the minimum (37.31) was recorded from S_1 (Table 9). Optimum plant spacing should be maintained to exploit maximum natural resources such as nutrients, sunlight, soil moisture etc. and to ensure highest flower buds/plant.

Significant variation was recorded for flower buds/plant of okra for the application of different levels of potassium fertilizer (Appendix VII). The maximum flower buds/plant (46.31) was observed from K_2 which was similar (44.82) to K_1, while the minimum (33.84) was obtained from K_0 (Table 9).

Flower buds/Plant showed statistically significant variation due to interaction effect of plant spacing and levels of potassium fertilizer (Appendix VII). The maximum flower buds/plant (51.13) was observed from S_2K_2. On the other hand, the minimum (32.47) was found from S_1K_0 (Table 10). Probably S_2K_2 (50 cm × 40 cm and 150 kg K_2O/ha) treatment combination was suitable for the growth and development of okra for that highest number of flower buds/plant was recorded for this treatment combination.

4.10 Pods/plant

Statistically significant variation was recorded for pods/plant of okra due to the application of different plant spacing (Appendix VII). The maximum pods/plant (43.67) was recorded from S_2 which was closely followed (37.73) by S_3, whereas the minimum (30.76) was observed from S_1 (Table 9).

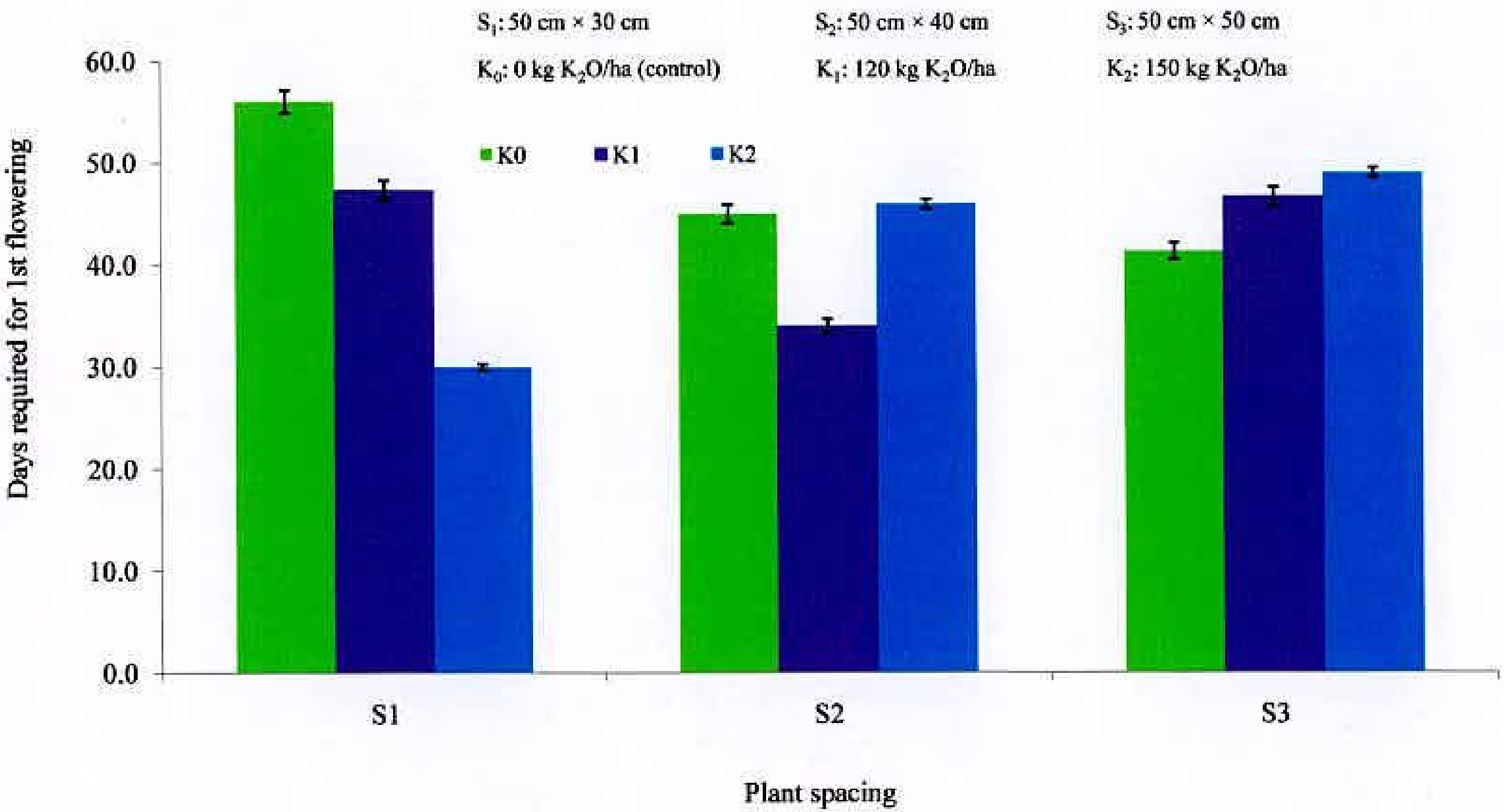

Figure 8. Interaction effect of different plant spacing and levels of potassium fertilizer on days required for 1st flowering of okra. Vertical bars represent LSD value.

Table 9. Effect of plant spacing and potassium fertilizer on yield contributing characters and yield of okra

Treatment	Number of flower buds/plant	Number of pods/plant	Pod length (cm)	Pod diameter (cm)	Weight of individual pod (g)	Pod yield/hectare (ton)
Plant spacing						
S_1	37.31b	30.76 c	13.93 b	1.46 b	14.29 b	13.34 b
S_2	44.98 a	43.67 a	16.15 a	1.95 a	17.06 a	16.23 a
S_3	42.69 a	37.73 b	16.63 a	1.87 a	16.43 a	15.70 a
$LSD_{(0.05)}$	2.857	4.075	1.216	0.105	1.097	1.250
CV(%)	6.86	10.91	7.81	5.97	6.90	8.29
Level of potassium						
K_0	33.84 b	29.71 b	13.92 b	1.55 c	13.92 b	13.18 b
K_1	44.82 a	40.04 a	15.87 a	1.80 b	16.75 a	15.84 a
K_2	46.31 a	42.40 a	16.93 a	1.93 a	17.10 a	16.26 a
$LSD_{(0.05)}$	2.857	4.075	1.216	0.105	1.097	1.250
CV(%)	6.86	10.91	7.81	5.97	6.90	8.29

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

S_1: 50 cm × 30 cm K_0: 0 kg K_2O/ha (control)

S_2: 50 cm × 40 cm K_1: 120 kg K_2O/ha

S_3: 50 cm × 50 cm K_2: 150 kg K_2O/ha

Table 10. Interaction effect of plant spacing and potassium fertilizer on yield contributing characters and yield of okra

Treatment	Number of flower buds/plant	Number of pods/plant	Pod length (cm)	Pod diameter (cm)	Weight of individual pod (g)	Pod yield/hectare (ton)
S_1K_0	32.47 d	29.73 c	13.00 c	1.36 f	13.47 b	11.35 d
S_1K_1	40.93 bc	32.00 c	15.44 b	1.56 de	14.41 b	15.08 bc
S_1K_2	38.53 c	30.53 c	13.35 bc	1.47 ef	14.98 b	13.60 cd
S_2K_0	36.07 cd	32.40 c	15.47 b	1.69 d	14.62 b	12.19 d
S_2K_1	47.73 a	48.53a	14.52 bc	1.96 bc	18.12 a	16.93 ab
S_2K_2	51.13 a	50.07 a	18.47 a	2.20 a	18.44 a	18.00 a
S_3K_0	33.00 d	27.00 c	13.28 bc	1.58 de	13.68 b	15.99 ab
S_3K_1	45.80 ab	39.60 b	17.63 a	1.88 c	17.72 a	15.53 bc
S_3K_2	49.27 a	46.60 ab	18.98 a	2.14 ab	17.87 a	17.17 ab
$LSD_{(0.05)}$	4.949	7.058	2.106	0.182	1.901	2.165
CV(%)	6.86	10.91	7.81	5.97	6.90	8.29

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

S_1: 50 cm × 30 cm

S_2: 50 cm × 40 cm

S_3: 50 cm × 50 cm

K_0: 0 kg K_2O/ha (control)

K_1: 120 kg K_2O/ha

K_2: 150 kg K_2O/ha

Significant variation was recorded due to the application of levels of potassium fertilizer for pods/plant of okra (Appendix VII). The maximum pods/plant (42.40) was found from K_2 which was similar (40.04) to K_1, whereas the minimum (29.71) was recorded from K_0 (Table 9).

Statistically significant variation was recorded due to interaction effect of plant spacing and levels of potassium fertilizer in terms of pods/plant (Appendix VII). The maximum pods/plant (50.07) was found from S_2K_2, again the minimum (29.73) was observed from S_1K_0 (Table 10). Probably S_2K_2 (50 cm × 40 cm and 150 kg K_2O/ha) treatment combination was suitable for the growth and development of okra for that highest number of pods/plant was recorded for this treatment combination.

4.11 Pod length

Pod length of okra showed statistically significant differences for different plant spacing (Appendix VII). The longest pod (16.63 cm) was observed from S_2 which was statistically similar (16.15 cm) to S_3. On the other hand, the shortest pod (13.93 cm) was found from S_1 (Table 9). Optimum plant spacing should be maintained to exploit maximum natural resources such as nutrients, sunlight, soil moisture etc. and to ensure longest pod.

Levels of potassium fertilizer differed significantly for pod length of okra (Appendix VII). The longest pod (16.93 cm) was observed from K_2 which was similar (15.87 cm) to K_1 whereas, the shortest pod (13.92 cm) was recorded from K_0 (Table 9). Mishra and Pandey (1987) reported that application of K above 120 kg/ha adversely affected pod length.

Statistically significant variation was recorded due to interaction effect of plant spacing and levels of potassium fertilizer in terms of pod length (Appendix VII). The longest pod (18.47 cm) was recorded from S_2K_2 while the shortest pod (13.00 cm) was recorded from S_1K_0 (Table 10). Probably S_2K_2 (50 cm × 40 cm and 150 kg

K_2O/ha) treatment combination was suitable for the growth and development of okra for that longest pod was recorded for this treatment combination.

4.12 Pod diameter

Significant variation was recorded for pod diameter of okra for different plant spacing (Appendix VII). The highest pod diameter (1.95 cm) was recorded from S_2 which was statistically similar (1.87 cm) to S_3, whereas the lowest pod diameter (1.46 cm) was recorded from S_1 (Table 9).

Pod diameter of okra showed statistically significant variation for different levels of potassium fertilizer (Appendix VII). The highest pod diameter (1.93 cm) was recorded from K_2 which was closely followed (1.80 cm) by K_1 whereas, the lowest pod diameter (1.55 cm) was found from K_0 (Table 9).

Interaction effect of plant spacing and levels of potassium fertilizer showed statistically significant variation in terms of pod diameter (Appendix VII). The highest pod diameter (2.20 cm) was recorded from S_2K_2, whereas the lowest pod diameter (1.36 cm) was obtained from S_1K_0 (Table 10). Probably S_2K_2 (50 cm × 40 cm and 150 kg K_2O/ha) treatment combination was suitable for the growth and development of okra for that highest pod diameter was recorded for this treatment combination.

4.13 Weight of individual fruit

Significant variation was recorded for weight of individual fruit of okra for different plant spacing (Appendix VII). The highest weight of individual fruit (17.06 g) was recorded from S_2 which was statistically similar (16.43 g) to S_3, whereas the lowest weight (14.29 g) from S_1 (Table 9). Optimum plant spacing should be maintained to exploit maximum natural resources such as nutrients, sunlight, soil moisture etc. and to ensure highest weight of individual fruit.

Weight of individual fruit of okra showed statistically significant variation for different levels of potassium fertilizer (Appendix VII). The highest weight of individual fruit (17.10 g) was recorded from K_2 which was closely followed (16.75

g) by K_1 whereas, the lowest weight of individual fruit (13.93 g) was found from K_0 (Table 9). Mishra and Pandey (1987) reported that application of K above 120 kg/ha adversely affected weight of individual fruit.

Interaction effect of plant spacing and levels of potassium fertilizer showed statistically significant variation in terms of weight of individual fruit (Appendix VII). The highest weight of individual fruit (18.44 g) was recorded from S_2K_2, whereas the lowest weight of individual fruit (13.47 g) from S_1K_0 (Table 10). Probably S_2K_2 (50 cm × 40 cm and 150 kg K_2O/ha) treatment combination was suitable for the growth and development of okra for that highest weight of individual fruit was recorded for this treatment combination.

4.14 Yield per plot

Yield per plot of okra showed statistically significant differences for different plant spacing (Appendix VII). The highest yield per plot (4.87 kg) was obtained from S_2 which was statistically similar (4.71 kg) to S_3, whereas the lowest yield per plot (4.00 kg) was recorded from S_1 (Figure 9). It was revealed that highest plant spacing ensure highest vegetative growth and the ultimate results would be the highest yield of okra. Mishra and Pandey (1987) reported that application of K above 120 kg/ha adversely affected yield per plant. Bhai and Sing (1998) reported that K application significantly increased the yield per plant.

Levels of potassium fertilizer differed significantly for yield per plot of okra (Appendix VII). The highest yield per plot (4.88 kg) was recorded from K_2 which was statistically identical (4.75 kg) to K_1, while the lowest yield per plot (3.95 kg) was found from K_0 (Figure 10).

Statistically significant variation was recorded due to interaction effect of plant spacing and levels of potassium fertilizer in terms of yield per plot (Appendix VII). The highest yield per plot (5.40 kg) was recorded from S_2K_2, while the lowest yield per plot (3.40 kg) from S_1K_0 (Figure 11). Probably S_2K_2 (50 cm × 40 cm and 150 kg K_2O/ha) treatment combination was suitable for the growth and development of okra for that highest yield per plot was recorded for this treatment combination.

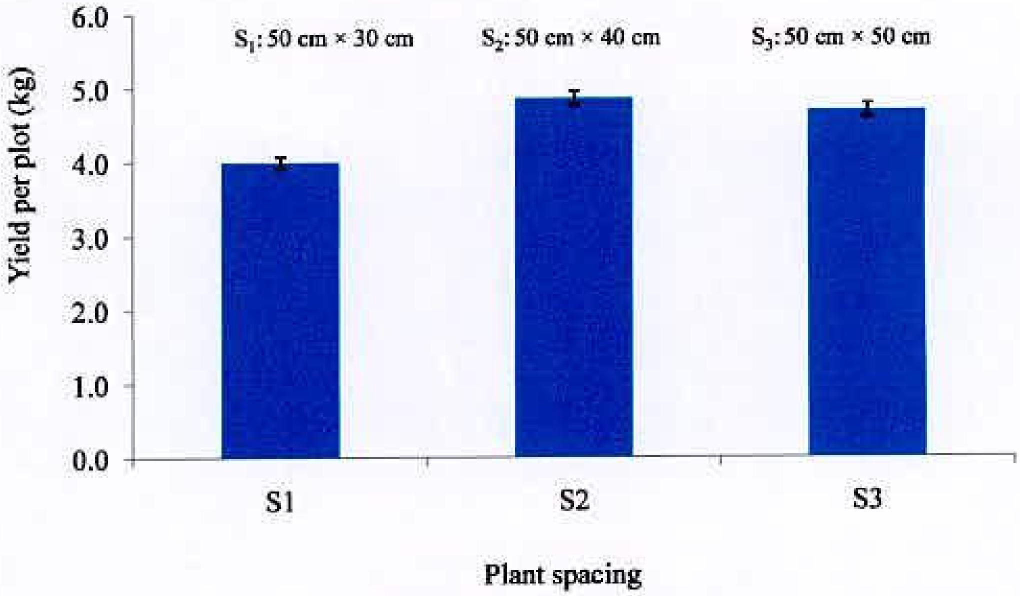

Figure 9. Effect of different plant spacing on yield per plot of okra. Vertical bars represent LSD value.

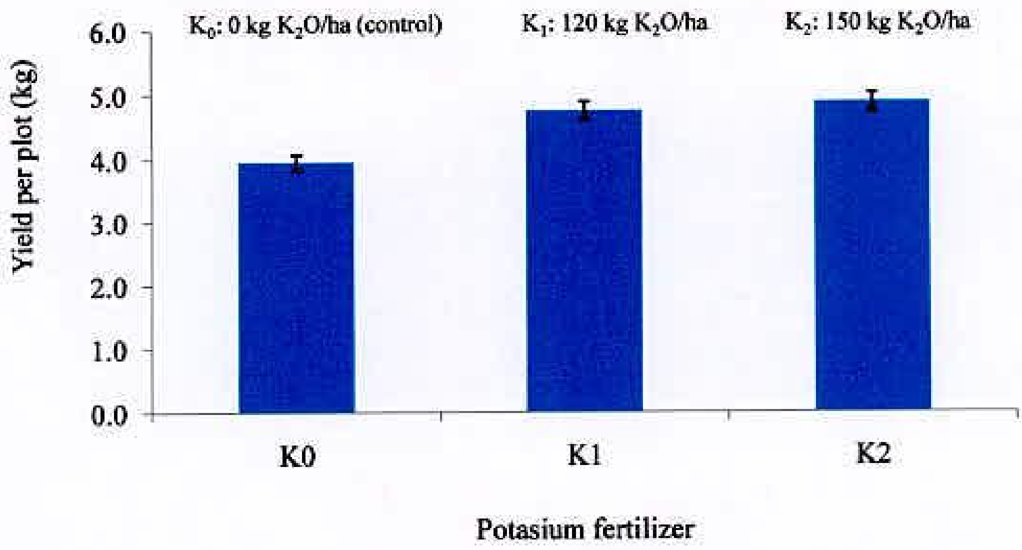

Figure 10. Effect of different levels of potassium on yield per plot of okra. Vertical bars represent LSD value.

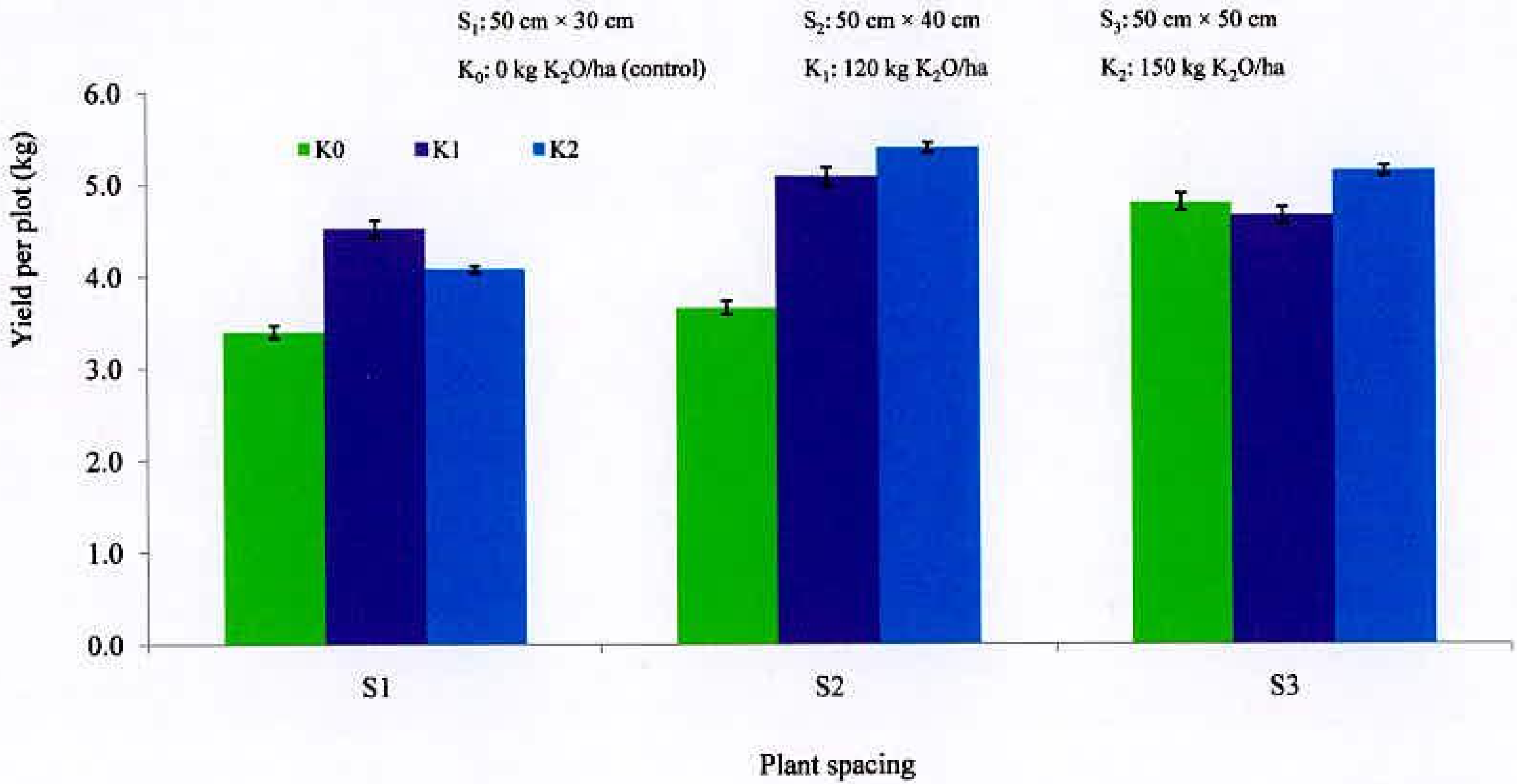

Figure 11. Interaction effect of different plant spacing and levels of potassium fertilizer on yield per plot of okra. Vertical bars represent LSD value.

4.15 Yield per hectare

Different plant spacing showed statistically significant variation for yield per hectare of okra (Appendix VII). The highest yield per hectare (16.23 ton) was observed from S_2 which was statistically similar (15.70 ton) to S_3, whereas the lowest yield per hectare (13.34 ton) was attained from S_1 (Table 9).

Statistically significant variation was recorded due to the application of levels of potassium fertilizer for yield per hectare of okra (Appendix VII). The highest yield per hectare (16.26 ton) was recorded from K_2 which was statistically identical (15.84 ton) to K_1, while the lowest yield per hectare (13.18 ton) was found from K_0 (Table 9). Mishra and Pandey (1987) reported that application of K above 120 kg/ha adversely affected yield contributing characters as well as fruit yield.

Plant spacing and levels of potassium fertilizer showed statistically significant variation due to their interaction effect in terms of yield per hectare (Appendix VII). The highest yield per hectare (18.00 ton) was recorded from S_2K_2, while the lowest yield per hectare (11.35 ton) was observed from S_1K_0 (Table 10).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at the Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from April to August 2014 to find out the effect of spacing and potassium fertilizer on the growth and yield of okra. The test crop used in the experiment was BARI Dherosh-1. The experiment consisted of two factors: Factor A: Plant spacing (3 levels) as-S_1: 50 cm × 30 cm, S_2: 50 cm × 40 cm, S_3: 50 cm × 50 cm and Factor B: Potassium fertilizer (3 levels) as- K_0: 0 kg K_2O/ha (control), K_1: 120 kg K_2O/ha and K_2: 150 kg K_2O/ha. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth parameters, yield contributing characters and yield of okra was recorded and statistically significant variation was observed for different treatment.

For spacing, at 20, 40 and 60 DAS, the tallest plant (25.29, 62.88 and 91.29 cm) was recorded from S_2, while at the same DAS, the shortest plant (18.84, 56.46 and 81.85 cm) was measured from S_1. The highest stem diameter (1.53, 1.69 and 2.11 cm) was found from S_2, again at the same DAS, the lowest stem diameter (1.27, 1.33 and 1.92 cm) was recorded from S_1. The maximum number of leaves/plant (8.29, 28.24 and 51.16) was recorded from S_2, again at the same DAS, the minimum number of leaves/plant (6.93, 24.22 and 46.93) was obtained from S_1. The highest length of petiole (13.86, 25.67 and 35.61 cm) was recorded from S_3, while at the same DAS, the lowest length of petiole (11.10, 17.20 and 28.78 cm) was observed from S_1. The highest leaf area (44.62 cm^2, 56.77 cm^2 and 79.63 cm^2) was observed from S_3, while at the same DAS, the lowest leaf area (34.83 cm^2, 51.82 cm^2 and 68.89 cm^2) was recorded from S_1. The maximum number of internode/plant (7.45, 15.91 and 21.76) was recorded from S_2, whereas at the same DAS, the minimum number of internode/plant (5.13, 12.83 and 17.92) was recorded from S_1. The highest length of internode (3.88, 7.55 and 13.14 cm) was obtained from S_3 again at the same DAS, the lowest length of internode (3.02, 5.42 and 11.51 cm) was found from S_1.

The highest days required for the 1st flowering (45.67) was recorded from S_3, while the lowest days (41.67) was found from S_2. The maximum flower buds/plant (44.98) was recorded from S_2 and the minimum (37.31) was recorded from S_1. The maximum pods/plant (43.67) was recorded from S_2, whereas the minimum (30.76) was observed from S_1. The longest pod (16.63 cm) was observed from S_2 and the shortest pod (13.93 cm) was found from S_1. The highest pod diameter (1.95 cm) was recorded from S_2, whereas the lowest pod diameter (1.46 cm) was recorded from S_1. The highest weight of individual fruit (17.06 g) was recorded from S_2, whereas the lowest weight of individual fruit (14.29 g) was recorded from S_1. The highest yield per plot (4.87 kg) was obtained from S_2, whereas the lowest yield per plot (4.00 kg) was recorded from S_1. The highest yield per hectare (16.23 ton) was observed from S_2, whereas the lowest yield per hectare (13.34 ton) from S_1.

For potassium fertilizer, at 20, 40 and 60 DAS the tallest plant (25.29, 63.81 and 91.20 cm) was recorded from K_2, whereas the shortest plant (18.16, 54.65 and 81.41 cm) was found from K_2. At 20, 40 and 60 DAS the highest stem diameter (1.54, 1.69 and 2.16 cm) was observed from K_2, while the lowest stem diameter (1.24, 1.29 and 1.83 cm) was obtained from K_0. At 20, 40 and 60 DAS, the maximum number of leaves/plant (8.27, 28.93 and 52.47) was found from K_2, whereas the minimum number of leaves/plant (6.89, 23.82 and 44.78) was observed from K_0. At 20, 40 and 60 DAS the highest length of petiole (13.67, 25.24 and 36.03 cm) was found from K_2, while the lowest length of petiole (11.72, 18.20 and 28.75 cm) was obtained from K_0. At 20, 40 and 60 DAS the highest leaf area (44.63 cm^2, 58.60 cm^2 and 80.22 cm^2) was found from K_2 again, the lowest leaf area (35.67 cm^2, 49.24 cm^2 and 69.90 cm^2) was obtained from K_0. At 20, 40 and 60 DAS the maximum number of internode/plant (7.54, 16.27 and 21.32) was recorded from K_2 and, the minimum number of internode/plant (5.20, 12.17 and 17.57) was found from K_0. At 20, 40 and 60 DAS the highest length of internode (3.90, 7.95 and 13.46 cm) was observed from K_2, whereas the lowest length of internode (2.88, 5.46 and 10.98 cm) in K_0.

The highest days required for the 1st flowering (47.44) were obtained from K_0 while, the lowest days (41.67) was recorded from K_2. The maximum flower buds/plant (46.31) was observed from K_2, while the minimum (33.84) was obtained from K_0. The maximum pods/plant (42.40) was found from K_2 whereas the minimum (29.71) was recorded from K_0. The longest pod (16.93 cm) was observed from K_2, whereas the shortest pod (13.92 cm) was recorded from K_0. The highest pod diameter (1.93 cm) was recorded from K_2 whereas, the lowest pod diameter (1.55 cm) was found from K_0. The highest weight of individual fruit (17.10 g) was recorded from K_2 whereas, the lowest weight of individual fruit (13.93 g) was found from K_0. The highest yield per plot (4.88 kg) was recorded from K_2 while the lowest yield per plot (3.95 kg) was found from K_0. The highest yield per hectare (16.26 ton) was recorded from K_2 while the lowest yield per hectare (13.18 ton) was found from K_0.

Due to interaction effect of plant spacing and levels of potassium fertilizer the longest plant (29.42, 67.65 and 96.93 cm) was recorded from S_2K_2 and, the shortest plant (16.91, 53.25 and 80.13 cm) was recorded from S_1K_0. The highest stem diameter (1.69, 1.94 and 2.27 cm) was found from S_2K_2 at 20, 40 and 60 DAS, respectively, whereas the lowest stem diameter (1.17, 1.20 and 1.76 cm) was recorded from S_1K_0. The maximum number of leaves/plant (9.00, 31.07 and 55.47) was obtained from S_2K_2 at 20, 40 and 60 DAS, respectively and, the minimum number of leaves/plant (6.67, 22.60 and 43.53) was found from S_1K_0. The highest length of petiole (15.28, 29.00 and 40.39 cm) was found from S_3K_2 at 20, 40 and 60 DAS and, the lowest length of petiole (11.03, 16.16 and 27.55 cm) was recorded from S_1K_0. The highest leaf area (49.19 cm^2, 61.17 cm^2 and 85.39 cm^2) was recorded from S_2K_2 at 20, 40 and 60 DAS, respectively again, the lowest leaf area (31.87 cm^2, 47.40 cm^2 and 65.93 cm^2) was observed in S_1K_0. The maximum number of internode/plant (8.83, 18.24 and 23.75) was recorded from S_2K_2 at 20, 40 and 60 DAS, respectively, whereas the minimum number of internode/plant (5.08, 12.17 and 17.57) was recorded from S_1K_0. The highest length of internode (4.36, 8.90 and 14.23 cm) was found from S_2K_2 at 20, 40 and 60 DAS and, the lowest length of internode (2.41, 4.90 and 10.64 cm) was observed from S_1K_0, respectively.

The highest days required for the 1st flowering (56.00) was obtained from S_1K_0, again the lowest days (30.00) was found from S_1K_2. The maximum flower buds/plant (51.13) was observed from S_2K_2 and the minimum (32.47) was found from S_1K_0. The maximum pods/plant (50.07) was found from S_2K_2, again the minimum (29.73) was observed from S_1K_0 (Table 10). The longest pod (18.47 cm) was recorded from S_2K_2 while the shortest pod (13.00 cm) was recorded from S_1K_0. The highest pod diameter (2.20 cm) was recorded from S_2K_2, whereas the lowest pod diameter (1.36 cm) was obtained from S_1K_0. The highest weight of individual fruit (18.44 g) was recorded from S_2K_2, whereas the lowest weight of individual fruit (13.47 g) was obtained from S_1K_0. The highest yield per plot (5.40 kg) was recorded from S_2K_2, while the lowest yield per plot (3.40 kg) was recorded from S_1K_0. The highest yield per hectare (18.00 ton) was recorded from S_2K_2, while the lowest yield per hectare (11.35 ton) was observed from S_1K_0.

From the findings it was revealed that 50 cm × 40 cm plant spacing with 150 kg K_2O/ha was the best combination for attaining the highest yield contributing characters and yield of okra, keeping the amount of other fertilizer and manures as usual mentioned in the page 19.

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from April to August, 2014

Month (2014)	*Air temperature (^0C)		*Relative humidity (%)	*Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
April	34.2	23.4	61	112	8.1
May	34.7	25.9	70	185	7.8
June	35.4	22.5	80	577	4.2
July	36.0	24.6	83	563	3.1
August	36.0	23.6	81	319	4.0

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

Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

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

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix III. Analysis of variance of the data on plant height and stem diameter at different days after sowing (DAS) of okra as influenced by different plant spacing and potassium fertilizer

Source of variation	Degrees of freedom	Mean square					
		Plant height (cm) at			Stem diameter (cm) at		
		20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Replication	2	0.443	3.595	10.400	0.011	0.000	0.002
Plant spacing (A)	2	98.789**	101.141**	225.184**	0.174**	0.309**	0.097**
Potassium fertilizer (B)	2	131.063**	215.713**	255.962**	0.249**	0.437**	0.290**
Interaction (A×B)	4	18.833*	13.951*	41.441*	0.023*	0.068**	0.024*
Error	16	4.717	6.770	16.813	0.012	0.013	0.004

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

Appendix IV. Analysis of variance of the data on number of leaves per plant at different days after sowing (DAS) of okra as influenced by different plant spacing and potassium fertilizer

Source of variation	Degrees of freedom	Mean square		
		Number of leaves per plant at		
		20 DAS	40 DAS	60 DAS
Replication	2	0.053	2.766	3.290
Plant spacing (A)	2	4.538**	42.188**	40.895**
Potassium fertilizer (B)	2	4.924**	61.517**	142.499**
Interaction (A×B)	4	0.642**	4.048*	5.908*
Error	16	0.145	2.946	3.982

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

Appendix V. Analysis of variance of the data on length of petiole and leaf area at different days after sowing (DAS) of okra as influenced by different plant spacing and potassium fertilizer

Source of variation	Degrees of freedom	Mean square					
		Length of petiole (cm) at			Leaf area (cm^2) at		
		20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Replication	2	0.333	2.509	1.767	1.320	0.589	0.284
Plant spacing (A)	2	21.341**	204.981**	123.964**	255.058**	66.597**	310.714**
Potassium fertilizer (B)	2	9.412**	137.831**	130.600**	197.197**	225.749**	248.286**
Interaction (A×B)	4	3.291*	23.618**	24.030**	20.390*	14.372*	25.576*
Error	16	0.999	3.542	5.783	7.738	7.285	9.403

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

Appendix VI. Analysis of variance of the data on number of internode and length of internode at different days after sowing (DAS) of okra as influenced by different plant spacing and potassium fertilizer

Source of variation	Degrees of freedom	Mean square					
		Number of internode at			Length of internode (cm) at		
		20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Replication	2	0.532	0.444	0.214	0.141	0.224	0.030
Plant spacing (A)	2	15.365**	27.831**	40.067**	1.974**	13.409**	7.305**
Potassium fertilizer (B)	2	14.239**	27.395**	19.711**	3.108**	14.327**	16.662**
Interaction (A×B)	4	3.475**	3.609**	4.362**	0.315**	1.498*	1.159*
Error	16	0.249	0.677	0.492	0.070	0.378	0.395

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

Appendix VII. Analysis of variance of the data on yield contributing characters and yield as influenced by different plant spacing and potassium fertilizer

Source of variation	Degrees of freedom	Mean square							
		Days required to 1st flowering	Number of flower buds/plant	Number of pods/plant	Pod length (cm)	Pod diameter (cm)	Weight of individual pod (g)	Pod yield/plot (kg)	Pod yield/hectare (ton)
Replication	2	6.704	3.530	35.797	0.443	0.005	0.100	0.033	0.368
Plant spacing (A)	2	37.815*	139.406**	375.89**	18.691**	0.614**	19.036**	1.917**	21.302**
Potassium fertilizer (B)	2	85.815**	417.219**	410.00**	21.023**	0.352**	27.267**	2.263**	25.146**
Interaction (A×B)	4	309.648**	23.737*	88.65**	11.771**	0.052**	2.452*	0.730**	8.108**
Error	16	10.287	8.175	16.627	1.480	0.011	1.206	0.141	1.564

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