EFFECT OF POTASSIUM AND PHOSPHORUS ON GROWTH AND YIELD OF OKRA IN ROOFTOP AND FIELD

ISTIMUM MIMI

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENTAL SCIENCE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY,

DHAKA-1207

DECEMBER, 2021

EFFECT OF POTASSIUM AND PHOSPHORUS ON GROWTH AND YIELD OF OKRA IN ROOFTOP AND FIELD

BY

ISTIMUM MIMI

REGISTRATION NO.19-10182

A Thesis

Submitted to the Faculty of Agriculture,

Sher-e-Bangla Agricultural University, Dhaka

In partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

IN

AGROFORESTRY AND ENVIRONMENTAL SCIENCE

SEMESTER: JULY-DECEMBER, 2021

Approved by:

Dr. Md. Forhad Hossain
Professor
Supervisor

Dr. Jubayer-Al-Mahmud
Professor
Co-Supervisor

Dr. Nasrin Sultana
Chairman
Examination Committee

Department of Agroforestry and Environmental Science
Sher-e-Bangla Agricultural University
Dhaka- 1207, Bangladesh

CERTIFICATE

This is to certify that the thesis enlightens, **"EFFECT OF POTASSIUM AND PHOSPHORUS ON GROWTH AND YIELD OF OKRA IN ROOFTOP AND FIELD"** submitted to the faculty of agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGROFORESTRY AND ENVIRONMENTAL SCIENCE** embodies the result of a piece of bonafide research work conducted by **ISTIMUM MIMI**, Registration no. **19-10182** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Date: DECEMBER, 2021
Dhaka, Bangladesh

Dr. Md. Forhad Hossain
Professor
Supervisor

Dedicated

To

My Beloved Parents

ACKNOWLEDGEMENTS

At first I gratefully express my sincere gratitude to ***Almighty Allah****, who kindly enabled me to complete this research work and preparation of this thesis. I also deem it a great pleasure to express my profound gratitude to* ***my respected parents****, who entitled me to much hardship for pursuing studies, receiving proper education.*

I would like to express my heartfelt respect and deepest sense of gratitude to my honorable Supervisor, ***Professor Dr. Md. Forhad Hossain****, Department of Agroforestry and Environmental Science,Sher-e Bangla Agricultural University, Dhaka,for his sincere guidance, scholastic supervision, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis.*

I feel proud to express my sincere appreciation and profound respect to my honorable Co-Supervisor, ***Associate Professor Dr. Jubayer-Al-Mahmud,*** *Department of Agroforestry and Environmental Science, Sher-e Bangla Agricultural University, Dhaka,for his valuable and helpful suggestions during the research work and cooperation in preparing the thesis.*

I express my sincere respect to the ***Chairman, Associate Professor Dr. Nasrin Sultana*** *and all the teachers of Department of Agroforestry and Environmental Science, Sher-e Bangla Agricultural University, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.*

Finally, sincere and deepest appreciation to my beloved siblings and my friends who inspired best of their prayer, great sacrifice and helped by hard work during my research work.

The Author

EFFECT OF POTASSIUM AND PHOSPHORUS ON GROWTH AND YIELD OF OKRA IN ROOFTOP AND FIELD

ABSTRACT

An experiment was conducted at two locations, the roof of the Biotechnology Department and Agroforestry research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during April 2021 to September 2021 to study the effect of potassium and phosphorus on the growth and yield of okra on rooftop and field. The experiment was conducted in RCBD design with three replications. The MSTAT-C computer package was used for processing and analysis of data. The mean differences were adjusted by Duncan's Multiple Range Test at 5% level of significance. Three levels of Potassium K_0: 0 kg K_2O ha^{-1}, K_1: 50 kg K_2O ha^{-1}, K_2: 80 kg K_2O ha^{-1} and three levels of phosphorous P_0: 0 kg P_2O_5 ha^{-1}, P_1: 80 kg P_2O_5 ha^{-1}, P_2: 120 kg P_2O_5 ha^{-1}were used as treatments in this experiment. The results showed that application of different levels of potassium plus phosphorus, significantly influenced the growth and yield of okra. In both locations, the maximum mean values were recorded from K_2P_2(80 kg K_2O ha^{-1} with 120 kg P_2O_5 ha^{-1}) treatments whereas the minimum were recorded from K_0P_0 (control). Based on the present results, it can be suggested that the combined use of 80 kg K_2O ha^{-1} with 120 kg P_2O_5 ha^{-1} increased plant growth and yield of okra in both the locations.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Full word	Abbreviation	Full word	Abbreviation
Percentage	%	Litre	L
Agro-Ecological Zone	AEZ	Least Significant	LSD
Bangladesh Bureau of	BBS	Difference	
Statistics		Master of Science	M.S
Bangladesh Council of	BCSRI	Meter squares	m^2
Scientific Research Institute		Milligram	mg
Calcium	Ca	Milliliters	ml
Centimeter	Cm	Sodium hydroxide	NaOH
Percent Coefficient of	%CV	Number	No.
Variation		Degree Celsius	^oc
Days After Sowing	DAS	Degree Celsius	^oF
Duncan's Multiple Range	DMRT	Phosphorus	P
Test		Quintal per hectare	q/ha
exempli gratia (L), for	e.g	Sher-e-Bangla	SAU
example		Agricultural	
and others	et. al.	University	
Etcetera	etc	United Nations	UNDP
Food and Agricultural	FAO	Development	
Organization		Program	
Gram (s)	g	United States of	USA
id est (L), that is	i.e.	America	
Geometric Mean	GM	Variety	Var.
Hectare	Ha	World Health	WHO
Potassium	K	Organization	
Kilogram	Kg	Microgram	µg

CHAPTER 1

INTRODUCTION

Vegetables play an important role in human nutrition. It provides carbohydrates, fat, minerals, vitamins, and roughages, which constitute the essentials of a balanced diet. In Bangladesh, out of 260.32 thousand hectares of vegetables growing area, Okra [*Abelmoschus esculentus* (L.) Moench] is an annual vegetable crop in tropical and subtropical parts of the world (Thakur and Arora, 1986). It is one of the important nutritious vegetable crops grown round the year in Bangladesh. is a popular vegetable belonging to the family Malvaceae and locally known as “Dherosh " or “Bhindi ".

It is well distributed throughout the Indian subcontinent and East Asia (Rashid, 1999). Its tender green fruits are popular as vegetables among all classes of people in Bangladesh and elsewhere in the world. Okra is specially valued for its tender and delicious edible pods which are a rich source of vitamins and minerals. Tender green pods of Okra contain approximately 2.2% protein, 0.2% fat, 9.7% carbohydrate, 1.0% fiber and 0.8% ash (Purseglove, 1987).Its every 100 g green pod contains among others, protein 1.8g, carbohydrate 6.4g, fiber 1.2g, vitamin C 18 mg and Ca 90 mg (Rashid, 1999). Okra is a vegetable which is still infamous in most of the countries owing to all the medicinal benefits it holds. It is an excellent source of nutrition and comes with a bundle of goodness (Muneerappa, 2018).

Okra as a summer/ rainy season vegetable can play a vital role to ameliorate the lower availability of vegetables in the rainy season to a certain extent.

The total production of okra was about 22,000 metric tons during 2019-20 and the average yield was 6.0 t/ha which was very low (BBS, 2020) compared to that of other neighboring country like India (6.12 t/ha) and other developing countries (7.12 t/ha) of the world (Yamaguchi, 1998). So, the yield and total production of okra should be increased. Okra is a multipurpose crop. Its tender pods are cooked as vegetables, stewed with meat, cooked into soup and also canned and dried. Okra seeds are roasted and used as a substitute for coffee in Turkey. Mature pods and stems containing crude fiber are used in the paper industry. Okra is a nutritious and delicious vegetable, fairly rich in vitamins and minerals.

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 enhances the biological activities. Deficiency of soil nutrient is considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 2011). To attain considerable production and quality yield for any crop it is necessary to proper management ensuring the availability of essential nutrients in proper doses. Generally, a large amount of fertilizer is required for the growth and development of okra (Opena *et al.*, 1988). So, the management of fertilizer, especially potassium and phosphorus, is the important factor that greatly affects the growth, development and yield of okra. So, to meet up our vegetable requirements as well as the shortage of vegetable production, okra can partially improve the vegetable production in the country. Use of proper doses of fertilizer is one of the most important ways of quality green pod yield production of okra and phosphorus and potassium fertilizer have a great role in this respect.

Ahmed and Tullok-Reid (1968) observed 75 percent yield increase due to phosphorus application at 56 kg/ha. Moreover, okra is a fruit vegetable. So, phosphorus fertilization can influence fruiting and development of fruits. Phosphorus has been called “the key to life” because it is directly involved in most physiological processes. Potassium also has an important role in balancing physiological activities. Different levels of potassium influence the growth and yield of okra.

To increase the production of okra, it can be cultivated on the rooftop of many urban areas. Nowadays in this urban planet, 54 percent of the world’s population are living in urban areas and the share is expected to increase to 76 percent by 2050 (United Nations, 2019). Farming on the rooftop of the buildings in urban areas is usually done by using green roof, hydroponics, organic, aeroponics or container gardens (Asad and Roy, 2014). In Dhaka, one of the world’s fastest growing megacities, open and cultivable land has been converted to built-up area indiscriminately and thus agricultural land has been decreased at an alarming rate (Islam and Ahmed, 2011). Due to the practice of okra production on rooftop gardens, okra production will be increased which will meet the demand of urban people and also reduce the costs of transport as well as encourage the varieties of vegetables production in the urban area than field (Rhodes *et al.*, 2000).

Under the above circumstances, the present research was undertaken to study the effect of potassium and phosphorus on the growth and yield of okra on rooftop and field with the following objectives:

- To determine the optimum levels of potassium and phosphorus on the growth and yield of okra
- To find out the suitable combination of potassium and phosphorus for ensuring the optimum growth and higher yield of okra and
- To compare the effect of potassium and phosphorus on growth and yield on rooftop and field.

CHAPTER 2

REVIEW OF LITERATURE

Okra is an important vegetable crop in Bangladesh. Management of fertilizer especially Potassium and Phosphorus are the important factors that greatly affect the growth, development and yield of Okra. So it is important to assess the effect of nitrogen for the best growth and yield of okra. However, limited research reports on the performance of okra in response to potassium and phosphorus have been done in various parts of the world including Bangladesh and the work so far done in Bangladesh is not adequate and conclusive. Different levels of potassium and phosphorus application influence the growth and yield of okra. Optimum doses of potassium and phosphorus application are related to best growth, yield of okra. The present investigation was carried out to study the performance of potassium and phosphorus on okra cultivated to rooftop and field conditions. The pertinent literature in relation to the proposed work is reviewed in this chapter.

2.1 Effect of potassium on growth and yield of okra

Potassium is absorbed by plants in the form of the potassium ion (K+). Soil Potassium exists in solution and in exchangeable and non-exchangeable forms, which are in dynamic equilibrium with each other (Cox *et al*., 1999). Solution Potassium and exchangeable Potassium are replenished by non-exchangeable Potassium when they are depleted by plant removal or leaching (Gardiner and Miller, 2004).

In two years trials on okra the response was assayed to N, P and K applied at 60, 30 and 30 kg/ha, respectively (Bid *et al*., 1971). The best growth was obtained when all three elements were applied. Of the two-nutrient combinations NK was the most effective, followed by NP and PK. In trials with okra cv. Pusa Sawani, N and K_20 were each applied at 0-120 kg/ha (Mishra and Pandey, 1987). N at 80 kg/ha and K at 40 kg/ha significantly increased the number of fruits/plants, 1000 seed weight and seed yield. Application of N above 80 kg/ha and K above 40 kg/ha adversely affected seed yield. Interaction effect was significant with 80 kg N, 40 kg K/ha giving the highest seed yield of 15.47 q/ha.

Potassium is essential in photosynthesis, sugar translocation, nitrogen metabolism, enzyme activation, stomatal functioning, water relations and growth of meristematic tissues (Mitchell, 1970). Mitchell (1970) describes Potassium as a major osmotic ion for the regulation of water flow in the plant. Potassium is also found in the leaves, where it acts as a catalyst for reactions involved in the activation of enzymes, synthesis of proteins, synthesis and translocation of starch and translocation of NO_3^- (Archer, 1988). Plants well supplied with Potassium have strong stems that are resistant to lodging. Potassium makes plants more winter-hardy, less likely to be injured by spring or autumn frosts and it helps them to resist diseases (Mengel and Kirby, 1982). Potassium also encourages root development, but not to the same extent as P (Plaster, 2003).

In many plants, K deficiency does not immediately result in visible hunger symptoms. At first there is only a reduction in the growth rate (hidden hunger), and only later chlorosis and necrosis may occur (Mengel and Kirby, 1982). Generally, these symptoms first occur in the older leaves, because Potassium is translocated from old to young foliage. In most plant species 16 necrosis and chlorosis first occur along the margins and tips of the leaves (Plaster, 2003)

Excess K can cause plants to first become deficient in Mg, and then in Ca, due to induced nutrient imbalances, which upset the K: Mg and K: Ca ratios, especially when Mg and Ca availability are at the low end of their sufficiency ranges. The negative response of plants to high applications of K may also be the result of an excessive salt concentration in the soil solution, which causes various types of chemical and physical stress in plants (Kuiper, 1984).

Adelana (1985) reported that significant responses were obtained from 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. In a study with the cultivars Pusasawni and Punjab Padmini, the highest pod glycoprotein content was obtained with plants receiving N: P2O5 at 90:60 kg/ha (Arora *et al.*, 1985).

Lenka *et al.* (1989) investigated a field trial 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 level of 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 P20s/ha gave a satisfactory seed yield (7.60 q/ha). The influence of method of placement on the utilization of fertilizer phosphorus by okra was studied in a field experiment on a clay loam soil at Bangalore, using 32 P leveled single super phosphate. Deeper placement at 10 or 15 cm depth below the seed resulted in maximum utilization of applied P fertilizer which was significantly higher than placement at 5 cm depth and in two bands of either side of the seed furrow.

Hossain *et al*. (2011) conducted an experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during October 2006 to May 2007 to study the response of cabbage to fertilizer application in Salina Silty clay loam soil. The experiment was carried out to study the response of cabbage variety Autumn Queen to added N, P, K and S nutrients in respect of growth, dry matter production and yield, nutrient contents in loose and heading leaves of the crop. Treatment receiving 240 kg N, 45 P, 180 kg K and 45 S/ ha performed the best recording plant height, root length, number of loose and heading leaves, leaf length and breadth, thickness and diameter of head and yield.

Bishop *et al*. (2007) conducted an experiment on fertilizer treatments for cabbage, grown on sphagnum peat, consisting of an N, a P and a K series. Each nutrient was applied at four rates in combination with constant rates of the other two. Results indicated that 270 kg N/ha, the highest rate used, may not have been adequate whereas P and K at 80 and 150 kg/ha respectively were. In the N, the P, and the K series, highest head weights coincided with midribs containing 2.06% N, 0.48% P and 4.18% K respectively.

An experiment was conducted by Chauhan and Gupta (1973) to find out the effect of NPK on the growth and yield of okra (*Abelmoschus esculentus*). They found that plant height and girth, number of leaves and yield of green pod increased by increasing the application of N (22.5, 45.0 or 67.5 kg/ha). P at 22.5 or 45.o kg/ha and K at 22.5 kg/ha had no effect on growth and yield. NPK applications, however, generally increased yields. In a 2 year trials with okra the effects were assessed of N(as urea) at 40-120 kg/ha, P2O5 (as superphosphate) at 17.44-52.32 kg/ha and K (as murite) at 24.9-74.7 kg/ha (Sharma and Shukla, 1973). The highest yields were obtained with N at 120, P2O5 at 34.88 and K at 49.8 kg/ha.

Bhandari *et al.*, (2019) conducted an experiment to demonstrate the effects of different fertilizers on the yield and yield parameters of okra (var. Arka Anamika). Among all the fertilizers, synthetic fertilizer (NPK) responded well to the numbers of fruits.

Halim *et al*. (1994) conducted an experiment on the effect of different doses of NPK on growth and yield of cabbage at Jamalpur in Bangladesh. Nitrogen was applied at 0, 100, 150 or 200 kg/ha, P at 0, 50, 100 or 150 kg P2O5 and K at 0, 75, 150 or 225 kg K_2O/ha in 12 combinations to cabbage cv. K-K cross. Gross yield and marketable head weight per plant were found the highest with 150 kg N+ 100 kg P_2O_5 + 150 kg K_2O or 200 kg N + 100 kg P_2O_5 +150 kg K_2O.

In a two year trial, Samant *et. al.* (1981) studied the effects of different levels of N, P and K on the yield of cabbage in the Eastern Ghat Island zone of Orissa. N, P_2O_5 and/or K_2O were applied at 75-150: 40-80: 75-150 kg/ha in 27 different combinations. They reported that the best fertilizer combination was 75:80:150 kg/ha.

2.2 Effect of phosphorus on growth and yield of okra

Manga *et al*. (1999) reported that the growth and yield of French beans were influenced by phosphorus and molybdenum fertilization. In their trail, the crop received 0, 13 or 26 kg P and 0, 0.5 or 1.0 kg ammonium molybdate/ha. Phosphorus application significantly increased the number of pods per plant, number of seeds per pod and shelling percentage. The seed yield was increased by 43.2 and 73.32% (averaged over years) when 13 and 26 kg P/ha were applied, respectively.

The chemical fertilizer supplies sufficient available nutrients readily for proper growth and yield of plants. Among the macro nutrients, NPK are used largely by the plants. Physio-morphological and biological development of plants depends on the judicious application of NPK. An excess or deficiency of NPK causes a remarkable effect on growth and yield of plants.

Mohan and Rao (1997) observed that seed yield and number of pods/plants generally increased with increasing rate of P (90 kg P2O5/ha) and Mo (0.50 kg Mo/ha) respectively.

Mohanta (1998) reported that okra yield increased with increasing rate of phosphorus application up to 60 kg P_20_5/ha. The yield decreased with further increase of phosphorus application. Phosphorus application up to 60 kg/ha significantly increased green pod yield per plant and per hectare, pod length and diameter, number of pods per plant and individual pod weight. The optimum level of phosphorus fertilizer was found to be 60 kg P_2 0 t/ha yielding 34.79 t/ha of marketable pods. The highest pod yield 39.95 t/ha obtained from BARI Dherosh 1 by applying P2O5 at the rate of 60 kg/ha was considered the best combination of genotype and phosphorus, which was 17.4% higher over the second highest yield (34.04 t/ha) obtained from IPSA okra with 60 kg P2O>5/ha followed by BARI Dherosh 1 with 40 kg P20s/ha (32.52 /ha).The study suggested that 60 kg P2O5 /ha to be optimum for okra in red brown terrace soil.

Yogesh and Arora (2001) conducted an experiment in Nagina, Uttar Pradesh, India, during the kharif season of 1988 and 1990 to study the effect of N (80,100 and 120 kg/ha), P(60 and 80 kg/ha) and sowing date (25 june and 15 july) on okra (cv. Parbhani Kranti) seed yield. One-third of N and 100% P were applied during sowing; the remaining N was applied as a top dressing at 30 days after sowing and at flowering stage. Seed yield, which increased with the increase N rate was not significantly affected by P rate. The highest number of seed per pod (57.0) and yield per plot(2.94 kg) was obtained with the application of 120 kg/ ha and 80 kg P/ha, along with sowing time on 25 June.

Rathi *et al*. (1993) carried out an experiment with the effect of irrigation and phosphorus levels on protein content and uptake of nutrients in field pea at Jabalpur, Madhya Pradesh in the rabi seasons of 1988-90. Peas, cv. JP-885 were grown in sandy loam soil and given no irrigation, 1 irrigation at branching (B) or flowering (F) or pod development (P), 2 Irrigation at B + F, B + P or F + P, or 3 Irrigation at B+ F + P and given 0, 20, 40 or 60 kg P_2O_5/ha. N and P content in the seed were highest with irrigation at B in both years and protein content was highest with irrigation at B or F in 1989 and at B in 1990. N content in the seeds was highest with 40 and 60 kg P_2O_5/ha in 1989 and 1990, respectively. P content was highest at 40 kg P_2O_5/ha and protein content at 60 kg P_2O_5/ha.

Naik *et al*. (1992) studied the response of okra to different levels of nitrogen and Phosphorus fertilizer. Sources used in the trial were SSP powder and granular forms, Mussoorie rock phosphate (MRP) alone or MRP + seed inoculation with Pseudomonas strain. SSP in powder and granular forms produced similar D and seed yields, which were greater than applying MRP with or without seed inoculation. Seed yields with SSP were 30% higher than that with MRP. There was no impact of different rates of P application on yield of okra.

Arora *et al*. (1991) compared the growth and yield of a new okra cultivar, Punjab Padmini, with that of cv. Pusa Sawni grown under variable N (0, 30, 60 and 90 kg/ha) fertilizer application. They stated that plant height, number of pods, pod size and total green pod yield were significantly improved by the application of 90 kg N/ha and 60 kg P/ha. A significant increase in mean marketable yield for both cultivars was obtained with an increase in N application from 0 to 90 kg/ha (100.9 to 156.0 q/ha) and increase in P application from 0 to 60 kg/ha (116.0 to 136.5 q/ha). Optimum treatment was 90 kg N + 60 kg P/ha for giving a yield of 192.1 q/ha.

Bieleski (1973) conducted research and found that phosphorus is recognized as an important mineral element limiting crop growth and production. It is generally considered as the second most limiting nutrient after nitrogen (N) for plant growth.

Firoz (2009) conducted an experiment to study the effect of nitrogen and phosphorus on growth and yield of okra on hill slope conditions during the rainy season. The highest yield was obtained from 100 kg N/ha which was identical to 120 kg N/ha. In case of phosphorus the highest yield was obtained from 100 kg P2O5/ha. Considering the treatment combinations, the highest yield was obtained from 100 kg N plus 120 kg P2O5 per hectare.

In an experiment of okra cultivars White Velvet and NHAE 47-4 to fertilization in Northern Nigeria was examined using 0, 25, 50 and 100 kg N/ha and 0, 13, and 26 kg P/ha (Majanbu *et al*., 1985). Nitrogen application significantly increased green pod yield, pod number and diameter of pod per plant, number of seeds/pod and pod weight. Application of phosphorus also significantly increased green pod yield, pod number and number of seeds/pod. For optimum green pod yield of White Velvet 35 kg N/ha was suggested while for NHAE 47-4, N fertilization could be increased to 70 kg/ha. There was no differential response of cultivars to phosphorus fertilization for green pod yield; However, the application of 13 kg P/ha enhanced the performance of cultivars.

Heuvelink (2005) found that Phosphorus is essential to crops, in much smaller quantities than N. It is associated with early root development and architecture especially when P levels are low.

Singh *et al*. (2007) to study the nitrogen, copper and iron on growth and yield of okra cv. Pusa Sawani. The maximum yield was recorded with the application of 100 kg N/ha and 1000 ppm iron and copper as compared to over the controls during both years.

Singh *et al.* (2018) conducted an experiment to study the influence of integrated nutrient management on growth, yield and quality of okra (*Abelmoschus esculentus* L.). Application of 10 t FYM, 120kg each N and P2O5 were found significantly superior in enhancing the growth, yield and quality of okra.

Sharma and Mann (1972) in an experiment working with different phosphorus levels (30, 60 or 90 kg P_20_s/ha) in vegetables reported that increasing levels of phosphorus increased the number of branches per plant and number of leaves per branch of okra.

Mohsen *et al.,* (2015) studied the effect of different levels of nitrogen and phosphorus fertilizer in combination with botanical compost on growth and yield of okra and found that application of 100 kg N +75 kg P with or without compost to okra gave the highest values of plant growth, yield and quality in the two seasons.

Uddin *et al.,* (2014) conducted an experiment to evaluate the different doses of phosphorus on growth and yield of okra (BARI Dherosh 1) and found 90 kg P2O5/ha showed the best results regarding growth and yield. On the other hand, Po (0kg P2O5/ha) gave the minimum results.

Achebe *et al.,* (2013) conducted a study to investigate the effect of different levels of N.P.K. fertilizer on six okra cultivars and found that applying 250 kg/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 results.

2.3 Literature review on rooftop gardening

Rooftop gardening can be a positive approach in ensuring meals furnish and enjoyable dietary desires of the inhabitants (Helen Keller International and Institute of Public Health Nutrition 1985). Rooftop gardening, though is being practiced in the town in many structures for years in the past, there have been infrequently any concerted effort on section of the Government, neighborhood groups and as properly the ordinary residents to combine it to city agriculture. Proper appreciation of the troubles and potentialities related with the adoption of insurance policies will contribute, to a fantastic extent, to elevated meals furnished in the city.

Tokyo is the first city to mandate building vegetation that must constitute 20% of all new construction. Recently, urban agriculture and food security have attracted considerable interest in many cities of Canada. The green roof by law passed in 2009 states that all new buildings over six stories tall and with more than 2000 m2 of floor space must have minimum 20 percent rooftop greenery (Torstar News Service, 2015).

Orsini *et al*. (2014) carried out a study addressing the quantification of the potential of rooftop vegetable production in the city of Bologna (Italy) as related to its citizens‟s needs. The potential benefits to urban biodiversity and ecosystem service provision were estimated. RTGs could provide more than 12,000 t /yr vegetables to Bologna, satisfying 77 % of the inhabitants‟ requirements.

Fioretti *et al*. (2010) has discovered that thermal reduction ratio (TRR) is positively related to the coverage ratio (CR) of plants and the total leaf thickness (TLT) of plants on the rooftop. The area of shadow increases with CR and reduces the transmission of solar radiation. Higher TLT will provide greater thermal resistance and increase the thermal reduction effect.

Rashid et al. (2010) mention that the green roof design concept is to reduce the heat gain and minimize the cooling load for the mechanical air conditioning, it is one of the primary focuses in the building policy nowadays.

Moustier (2007) provides an extensive summary of the importance of urban agriculture in 14 African and Asian cities. Among the results they found that 90 % of all vegetables consumed in Dar es Salaam (Jacob *et al*., 2000) and 60 % of vegetables consumed in Dakar originate from urban agriculture.

McDonough (2005) engages with the overall construction of urban landscapes, inclusive of rooftop gardens, the various types, techniques and loading capacities associated with them. This proved useful when realizing the numerous constraints attached to rooftop gardens. Furthermore, the introduction of sustainable techniques can help reduce problems arising from global warming and opportunity costs when constructing buildings in different habitats and climates.

Shaw *et al*. (2004) addressed that People generally want wildlife in urban areas and suburban areas, even if they are unsure about some of the potential conflicts. “Having nature around us in urban environments is an indication that nature still prospers in the places where we dwell. It is a sign that our habitat still retains some of its ecological integrity”.

Bennett (2003) reported that RoofTop Gardens, while being aesthetically appealing, can contribute to biodiversity in the urban environment, achieve more sustainable conditions, including those necessary for the production of food and improve the overall quality of urban life.

High winds and high temperatures are often a problem; windbreaks and heat-tolerant crops have to be deployed in the rooftop environment. Pesticide use in densely populated areas can be a problem and many rooftop gardeners go with organic farming for this reason (Tiller, 2008).

Sometimes, maintenance may be costly. Many of the city residents do not have training in agriculture. Starting gardening without proper training may lead to frustrating outcomes, which might result in unwillingness of the people in initiating new projects (Islam, 2004).

CHAPTER 3

MATERIALS AND METHODS

This experiment was conducted at roof of Biotechnology Department and Agroforestry research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from April 2021 to September 2021 to study the effect of Potassium and Phosphorus on the growth and yield of okra on rooftop and field condition. The materials and methods that were used for conducting the experiment are described under the following headings:

3.1 Experimental Site

The experiment was arranged at the roof of the Department of Biotechnology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh (**Figure 3.1**). The duration of the experiment was April to September 2021. The site is 90.2°N and 23.5°E Latitude and at an altitude of 8.25 m from the sea level. Location of the experimental site is presented in Figure 3.1.The entire experimental site was divided into two parts. The first part of the experiment was conducted on the roof of the biotechnology department. Here three concrete blocks were prepared using sand, brick, cement etc. Each block was 9 m x 5m x 0.5 m in size. Okra was produced in three blocks, maintaining three replications. Each block was divided into 1m x 1 m plots leaving 0.3 m area between plots. So, total experimental plots were nine where selected vegetables were cultivated. The 2nd part of the experiment was conducted on the agroforestry farm maintaining the same measurable areas. Okra was produced on the farm maintaining the same treatments and replications. All management practices were the same for both rooftop and field conditions.

3.2 Climatic condition

The experimental area was under the sub-tropical monsoon climate, which is characterized by heavy rainfall during Kharif season and scanty in the Rabi season. There was little rainfall during the months of October, November, December and January. The average maximum temperature during the period of experiment was 29.35˚C and the average minimum temperature was 15.10˚C. Rabi season is characterized by plenty of sunshine. The maximum and minimum temperature, humidity, rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department (Climate Division) and have been presented in Appendix.

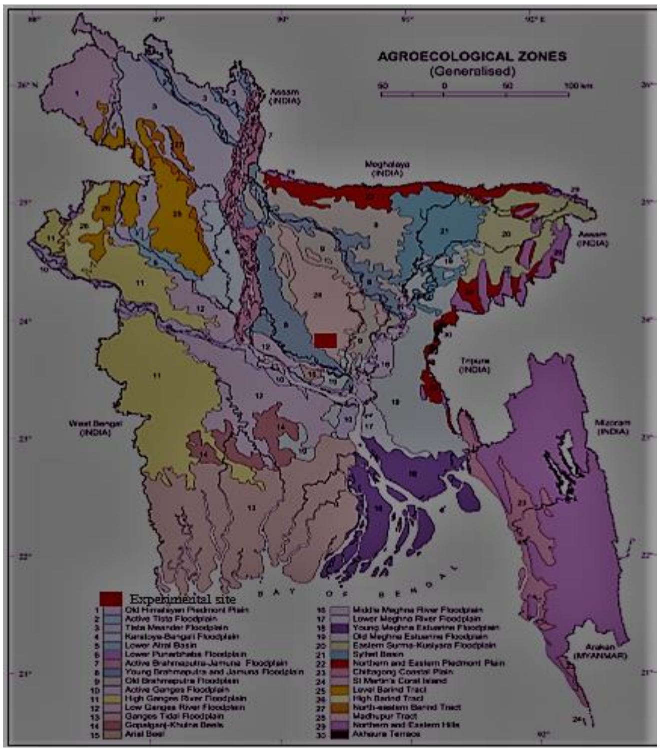

Figure 3.1 Experimental site

3.3 Soil characteristics of the experimental site

The soil of the experimental site was collected from outside of Dhaka city which was sandy clay. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resource Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and were presented in Appendix I.

3.4 Collection of plant materials

The seeds of BARI Dherosh-2 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Treatment of the experiment

The experiment conducted in two locations i.e.

1. **Rooftop condition**

On the rooftop following doses of Potassium and Phosphorus was used-

Factor A: Three Level of Potassium

- K_0 = 0 kg K_2O ha^{-1} (Control)
- K_1 = 50 kg K_2O ha^{-1}
- K_2 = 80 kg K_2O ha^{-1}

Factor B: Three Level of Phosphorus

- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}

- P_2 = 120 kg P_2O_5 ha^{-1}

There were in total 9 (3×3) treatment combinations such as: K_0P_0, K_0P_1, K_0P_2, K_1P_0, K_1P_1, K_1P_2, K_2P_0, K_2P_1, K_2P_2

2. Field condition

In the field, the same doses of potassium and phosphorus were used for production of okra. i.e.

Factor A: Three Level of Potassium

- K_0 = 0 kg K ha^{-1} (Control)
- K_1 = 50 kg K ha^{-1}
- K_2 = 80 kg K ha^{-1}

Factor B: Three Level of Phosphorus

- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}
- P_2 = 120 kg P_2O_5 ha^{-1}

There were in total 9 (3×3) treatment combinations such as: K_0P_0, K_0P_1, K_0P_2, K_1P_0, K_1P_1, K_1P_2, K_2P_0, K_2P_1, K_2P_2.

3.6 Application of manure and fertilizers

Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) were used as sources of nitrogen, phosphorus, and potassium, respectively. Cow Dung was also applied to the field before final plowing. Total amount of TSP and 50% of urea were applied as basal doses during final land preparation. The remaining 50% urea was applied as top dressing at 25 DAT, 50 DAT and 75 DAT during flowering and fruiting start stage. The doses and application method of fertilizers were given below:

Manure and fertilizers	Doses/plot
Cowdung	**As per requirement**
Nitrogen (as urea)	**195 g**
TSP	**130 kg ha-1**
MoP	200 ha-1

3.6 Seed sowing:

The okra seeds were sown in the experimental plot on 13 April in 2021. Seeds were treated with Bavistin @ 2 ml/L of water before sowing the seeds to control the seed borne diseases.

Figure 3.2 Sowing of seed in the main field

3.8 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors with three replications. The entire experimental site was divided into two parts. The first part of the experiment was conducted on the roof of the biotechnology department. Here three concrete blocks were prepared using sand, brick, cement etc. Each block was 9m x 5m x 0.5 m in size. Okra was produced in three blocks, maintaining three replications. Each block was divided into 1m x 1 m plots leaving 0.3 m area between plots. The design and layout of the experiment was shown in figure 3.2.

3.9 Preparation of the main field and block of roof top

The selected experimental plot was opened on the 5th April 2021 with a power tiller and was exposed to the sun for a week. After 3 days the land was plowed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil for sowing of okra seeds. The experimental plots and blocks were partitioned into the unit plots according to the experimental design and organic and inorganic fertilizers were applied as per treatments of each unit plot.

R1	R2	R3
K_0P_0	**K_1P_0**	**K_1P_1**
K_2P_0	**K_0P_1**	**K_0P_0**
K_0P_2	**K_2P_0**	**K_2P_0**
K_1P_0	**K_1P_1**	**K_0P_1**
K_1P_2	**K_2P_1**	**K_2P_2**
K_2P_2	**K_1P_2**	**K_0P_2**
K_0P_1	**K_0P_2**	**K_2P_1**
K_1P_1	**K_0P_0**	**K_1P_0**
K_2P_1	**K_2P_2**	**K_1P_2**

Replication

R_1, R_2, R_3

Unit plot size:

1 m x1m

Unit block size:

9m x 5m x 0.5m

Block to plot

0.3m x 0.3m

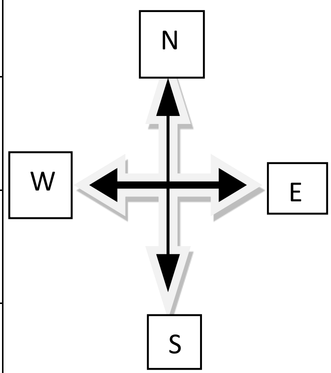

Figure 3.3 Layout of the experimental design for both rooftop and field

The experimental blocks were first filled on 5th April 2021. Block soil was brought into desirable fine tilth by hand mixing. The stubble and weeds were removed from the soil. The final block preparation was done on 11th April 2021. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final block preparation to protect young plants from the attack of soil inhabiting insects such as cutworm and mole cricket.

3.10 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.

Figure 3.4 Preparation of blocks on rooftop

3.10.1 Gap filling

The seedlings in the experimental plot were kept under careful observation.Some seedlings were damaged after germination and such seedlings were replaced by new seedlings. Replacement was done with healthy seedlings in the afternoon. The seedlings were given watering for 7 days starting from germination for their proper establishment.

3.10.2 Wedding

The wedding was done by nirani with roots to keep the plots free from weeds. This process was the same for both rooftop and field.

3.10.3 Irrigation

Irrigation was given lightly by a watering pipe every morning and afternoon and it was continued for a week for rapid and well establishment of the germinated seedlings.

3.10.4 Pest and disease control

Insect infestation was a serious problem during the period of establishment of seedlings in the field. Cut worms were controlled both mechanically and spraying Bavistin 50 WP, Furadan 5G, Ripcord 10EC as and when necessary. Some discolored and yellowish diseased leaves were also collected from the plant and removed from the field.

3.11 Harvesting

Fruits were harvested at a 1 day interval based on eating quality at soft and green conditions. Harvesting was started from 25 July, 2021 and was continued up to September 2021.

Figure 3.5 Irrigation in the main field

Figure 3.6 Harvesting of Okra

3.12 Data collection

The following parameters were collected from rooftop and field during the present study

- Plant height (cm)
- Number of leaves plant^{-1}
- Number of branches plant^{-1}
- Number of fruits /plant
- Fruit length (cm)
- Fruit diameter (cm)
- Fruit weight (g)
- Yield plot^{-1} (kg)
- Yield ha^{-1} (t)

3.13 Procedure of collecting data

3.13.1 Plant height (cm)

Plant height was measured from sample plants in centimeters from the ground level to the tip of the longest stem of five plants and mean value was calculated.

3.13.2 Number of leaves plant^{-1}

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.

3.13.3 Number of branches plant $^{-1}$

The total number of branches 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.

3.13.4 Number of fruits plant^{-1}: The number of fruits per plant was counted from the sample plants for the whole growing period and the average number of fruits produced per plant was recorded and expressed in fruits per plant.

3.13.5 Fruit length (cm): The length of fruit was measured with a meter scale from the neck of the fruit to the bottom of 10 selected marketable fruits from each plot and there an average was taken and expressed in cm.

3.13.6 Fruit diameter (cm)

Breath of fruit was measured at the middle portion of fruit from each plot with a digital Calipers and average was taken and expressed in cm.

3.13.7 Fruit weight (g)

The weight of a single fruit was measured with a digital weighing machine from 10 selected marketable fruits from each selected plot and their average was taken and expressed in grams.

3.13.8 Yield per plot (kg)

Yield of okra per plot was recorded as the whole fruit per plot by a digital weighing machine for the whole growing period and was expressed in kilograms.

3.13.9 Yield per hectare (t)

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

3.14 Statistical analysis

The recorded data on different parameters were statistically analyzed by using MSTAT-C software to find out the significance of variation resulting from the experimental treatments. The mean values for all the treatments were accomplished by DMRT test. The significance of difference between pairs of means was tested at 5% and 1% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, results of the study entitled “Effect of potassium and phosphorus on growth and yield of okra on rooftop and field" conducted during April 2021 to September 2021, have been presented. Data recorded on various observations during investigation are tabulated and statistically analyzed to find out the effects of different treatments on growth and yield of okra on the rooftop and field. The results are furnished in this chapter in the form of tables and illustrated through the graphs wherever necessary under appropriate headings.

4.1. Plant height (cm)

4.1.1 Effect of Potassium on plant height

The plant height varied significantly due to different doses of potassium on okra on the rooftop and field (Table 1). Results showed that plant height increased with increasing potassium rate up to 80 kg K2O ha-1. The tallest plant (91.88cm) was recorded in K2 (80 the highest plant height was 37.70 cm.

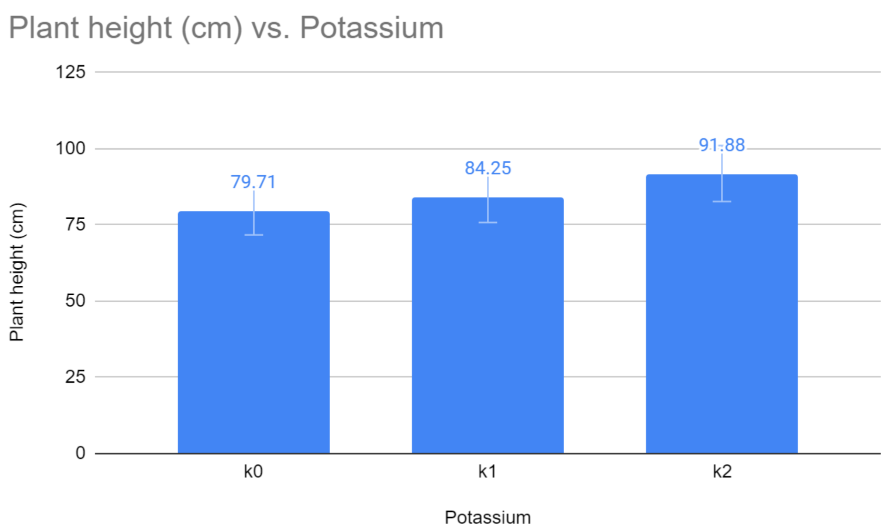

Figure 4.1 Effect of potassium on plant height (cm) on the rooftop

kg K_2O ha-1) on the rooftop (Figure.4.1). On the other hand, the shortest plant (79.71 cm) was recorded in control (0 kg K_2O ha-1) on the rooftop. On Field plants, the tallest plant (86.82) was recorded in K_2 (80 kg K_2O ha-1) and shortest plant (77.19 cm) was recorded in K_0 (0 kg K_2O ha-1).The tallest plant was found due to K_2 (80 kg K_2O ha-1) and shortest plant height was found in (0 kg K_2O ha-1) . Khatun (2012) revealed that.

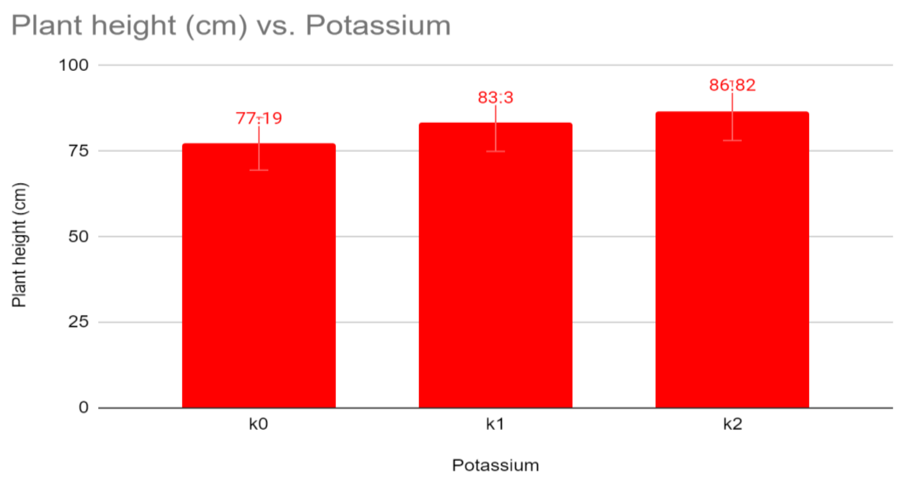

Figure 4.2 Effect of Potassium on Plant height in the field

4.1.2 Effect of phosphorus on plant height

The plant height of okra was statistically significant with various levels of phosphorus (Table 1 and figure 4.3). The result revealed that the tallest plant (87.69 cm) was recorded from P_2 (120 kg P_2O_5 ha^{-1}) on the rooftop, whereas the shortest plant (83.67 cm) height was found from P0 (0 kg P_2O_5 ha^{-1}).On field plants, the tallest plant *al.*

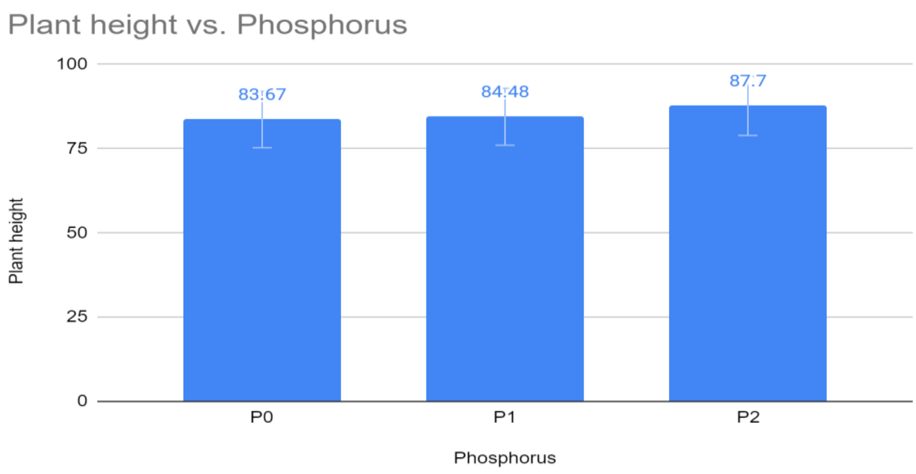

Figure 4.3 Effect of phosphorus on plant height on rooftop

(2011) also agreed with this result. (83.87cm) was recorded in P_2 and shortest plant (81.11) was found in P0. Similar results were found by Murugan *et al.*, (2001) they reported that plant height increased with the increasing levels of nitrogen and also same for phosphorus application. Roy *et al.*

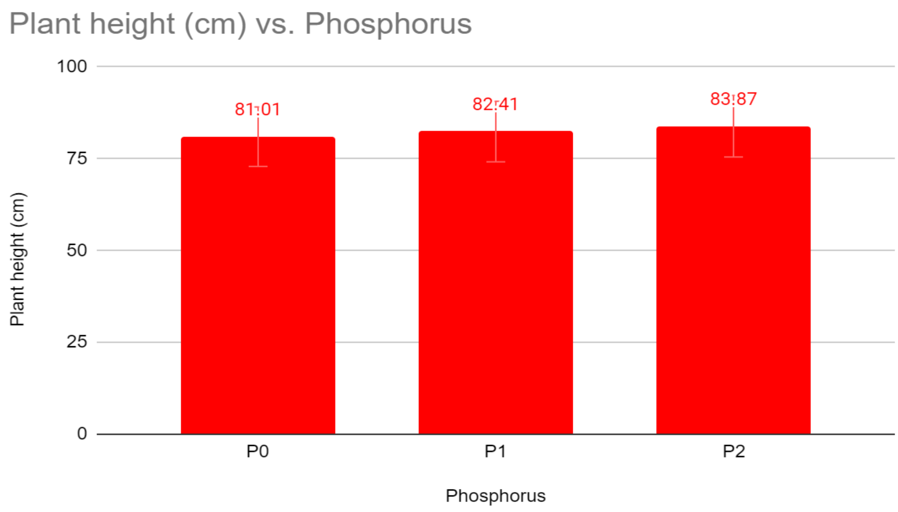

Figure 4.4 Effect of Phosphorus on plant height in field

Combined effect of potassium and phosphorus on plant height:

The interaction effect of potassium and phosphorus levels had a significant effect on plant height in okra. The highest plant height (94.53 cm) was recorded in the treatment combination of K_2P_2 **(**80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}) on the rooftop and lowest plant height (79.08 cm) was recorded in P0 (Table 4**.**1). In field plants, the lowest plant height (75.30 cm) was recorded in KoPo where the highest plant height was found in the treatment combination of K_2P_2 at all growth stages of okra. In comparison to the field plants, the lower value was obtained than on the rooftop. Khan *et al.* (2000) found similar results.

Table 1. Combined effect of Potassium and Phosphorus on Plant height of Okra in rooftop

Treatments	Plant Height(cm)	
	Rooftop	Field
K_0P_0	79.08 g	75.30 g
K_0P_1	77.96 h	77.25 f
K_0P_2	82.08 f	79.01 e
K_1P_0	82.60 f	82.03 d
K_1P_1	83.70 e	83.55 c
K_1P_2	86.47 d	84.25 c
K_2P_0	89.34 c	85.71 b
K_2P_1	91.78 b	86.41 b
K_2P_2	94.53a	88.35 a
Mean	85.28	82.43
$LSD_{0.05}$	0.328	1.358
CV (%)	0.32	0.58

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Coefficient of variation in percentage

Here,

- K_0 = 0 kg K_2O ha^{-1} (Control)
- K_1 = 50 kg K_2O ha^{-1}
- K_2 = 80 kg K_2O ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}
- P_2 = 120 kg P_2O_5 ha^{-1}

4.2 Number of leaves per plant

4.2.1 Effect of Potassium on number of leaves

In potassium rates, leaf production varied significantly on the rooftop and field. The highest leaf production (43.01) was recorded on the rooftop from K_2 (80 kg K_2O ha^{-1}). In contrast, the control plant produced the lowest number of leaves $plant^{-1}$ (38.53) (Figure 4.5). This result is consistent with Singh *et al.* (2007) who reported that leaf production was higher in potassium applied plants than control plants. In field plants, the highest leaf production (37.10) was found in K2 than K1 and Ko (Figure 4.6).

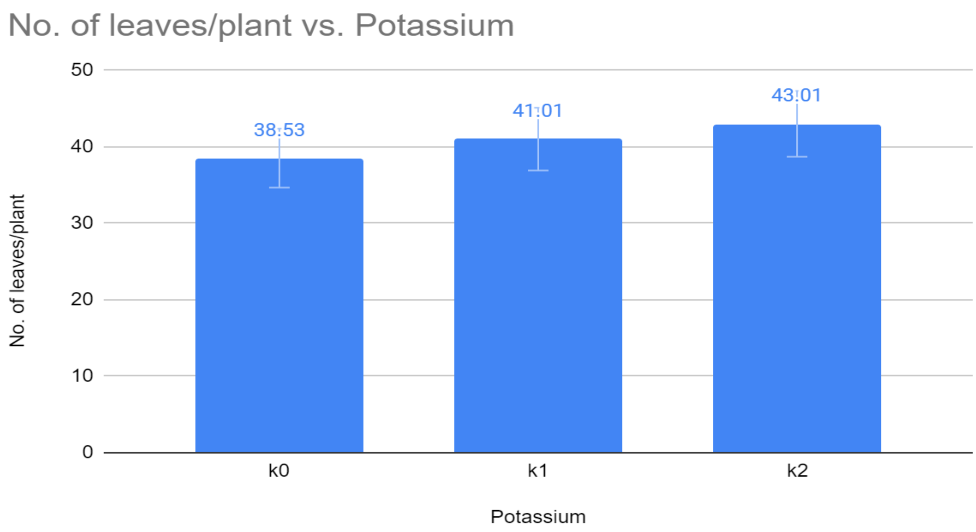

Figure 4.5 Effect of Potassium on No. of Leaves per plant on the rooftop

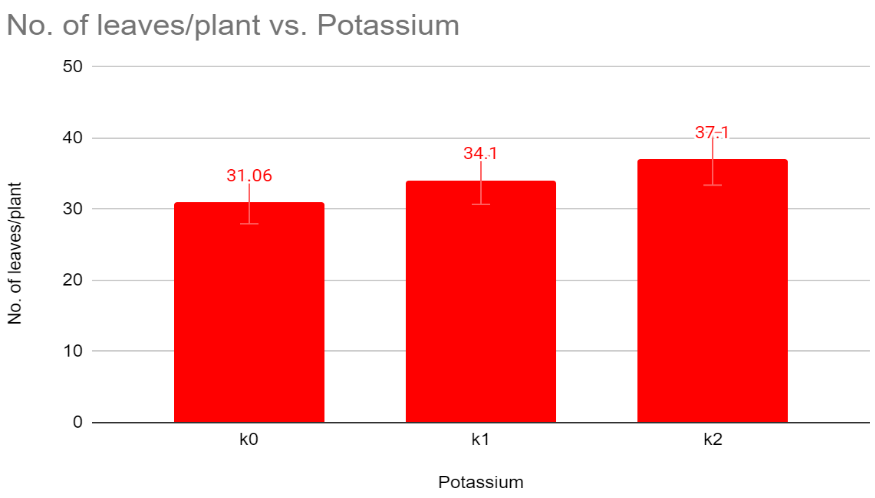

Figure 4.6 Effect of potassium on No. of leaves per plant in the field

4.2.2 Effect of phosphorus on No. of leaves per plant:

Significant variation was observed in case of number of leaf plant^{-1} affected by phosphorus. However, the highest number of leaves plant^{-1} (41.33) was found from the treatment P_2 (120 kg P_2O_5 ha^{-1}). Whereas the lowest number of leaves plant^{-1} (40.38) was recorded from the control treatment P_0 (0 kg P_2O_5 ha^{-1}) on rooftop plants (Figure 4.4).In field plants, higher numbers of leaves (35.25) were found in P_2 (120 kg P_2O_5 ha^{-1}) and lower numbers of leaves (32.9) were found in P_0 (0 kg P_2O_5 ha^{-1}). Similar results were found by Uddin *et al.,* (2014).

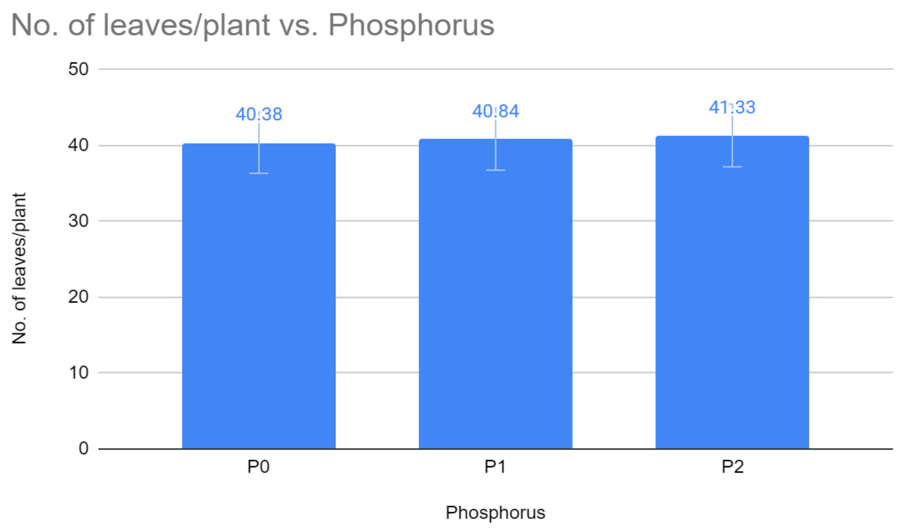

Figure 4.7 Effect of Phosphorus on No. of Leaves of okra in rooftop

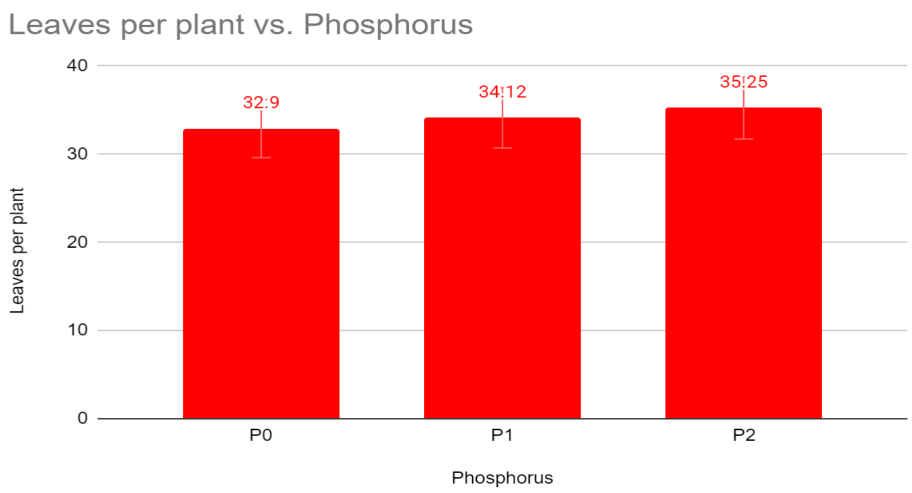

Figure 4.8 Effect of phosphorus on No. Of leaves in field

Combined effect of Potassium and Phosphorus on No. of leaves:

The interaction effect of potassium and phosphorus levels had a significant effect on the number of leaf production in okra. The maximum number of leaf production (45.50) was recorded in the treatment combination of K_2P_2 (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}) at all growth stages (Table 4.2). In contrast, the lowest number of leaves (35.36) was recorded in the treatment combination of K0P0 at all growth stages of okra. Similar result was by Ali Z (2018).

Table 2. Combined Effect of Potassium and Phosphorus on No. of Leaves of Okra in rooftop and field

Treatments	No. of Leaves	
	Rooftop	Field
K_0P_0	38.47 e	29.87 g
K_0P_1	38.56 e	31.18 fg
K_0P_2	38.47 e	32.12 ef
K_1P_0	40.14 d	33.10 de
K_1P_1	41.13 cd	34.25 cd
K_1P_2	41.76 bc	34.95 c
K_2P_0	42.44 b	35.71 bc
K_2P_1	42.83 ab	36.92 ab
K_2P_2	43.76 a	38.66 a
Mean	40.85	34.09
$LSD_{0.05}$	1.254	0.764
CV(%)	1.07	1.86

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%)= Coefficient of variation in percentage

Here,

- K_0 = 0 kg K_2O ha^{-1} (Control)
- K_1 = 50 kg K_2O ha^{-1}
- K_2 = 80 kg K_2O ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}
- P_2 = 120 kg P_2O_5 ha^{-1}

4.3 Number of branches per plant

4.3.1 Effect of Potassium

Significant variation was recorded at different growth stages of okra due to different potassium doses on the number of branches/plants. At harvest, the highest number of branches $plant^{-1}$ (4.29) was found from the treatment K_2 (80 kg K_2O ha-1) on the rooftop. The lowest number of branches plant-1 (3.95) was recorded from the control

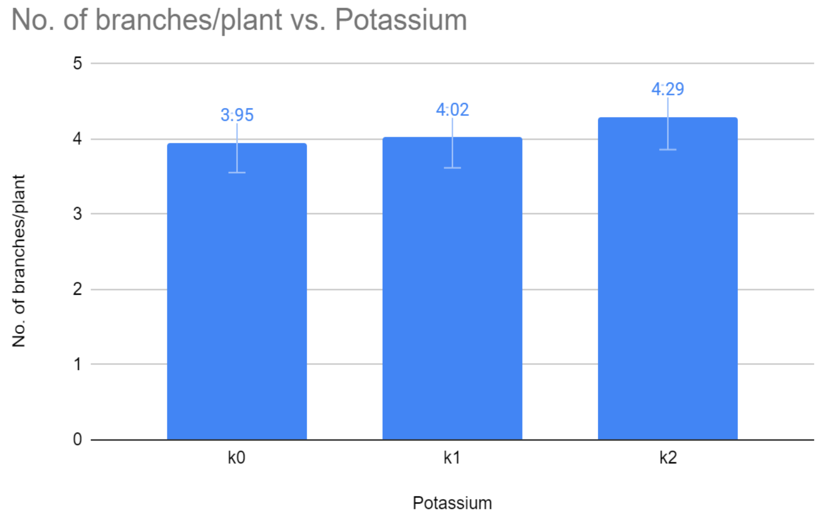

Figure 4.9 Effect of Potassium on number of branches/plant of okra in rooftop

treatment K_0 (0 kg K2O ha-1) (Figure 4.9). In field plants, the higher number of branches (3.7) was found from K2 than K1 and Ko. Medeiros *et al*. (2018) also found similar results with the present study and found the highest number of branches plant-1 from 80 kg K_2O ha-1.

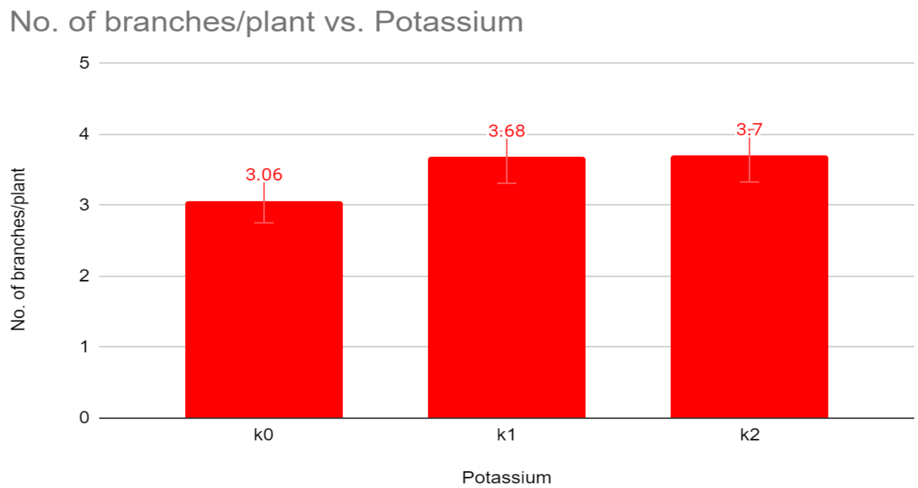

Figure 4.10 Effect of Potassium on number of branches in field

4.3.2 Effect of Phosphorus

There was a significant difference in the number of branches plant^{-1} due to different levels of phosphorus application in okra. Results showed that the number of branches plant-1 increased with age till harvest followed by a decline due to some branches dying at later growth stages. Results further showed that the number of branches plant-1 increased with increasing phosphorus levels. The highest numbers of branches per plant

(4.2) was recorded in P_2 (120 kg P_2O_5 ha^{-1}) followed by P_1 (80 kg P_2O_5 ha^{-1}) at all growth stages on the rooftop. In field plants, the P0 produced the lowest number of

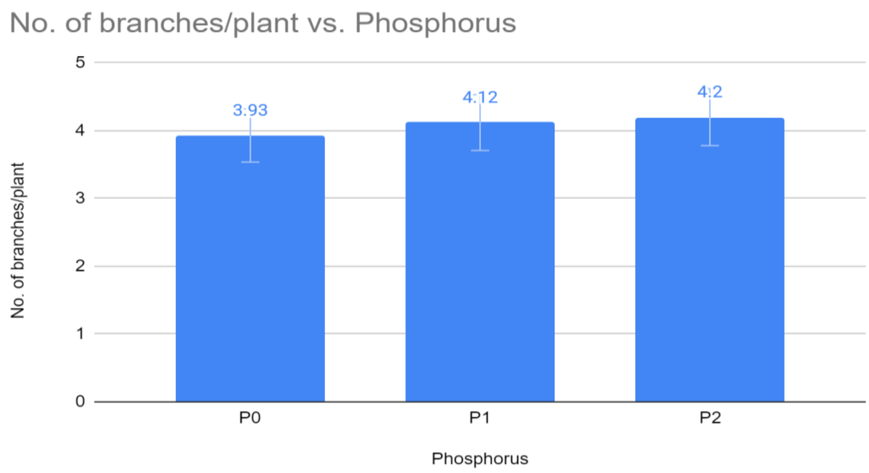

Figure 4.11 Effect of Phosphorus on No of branches/plant of okra on rooftop

branches per plant (3.07) at all growth stages where no significant difference was in P1 and P2 (Figure 4.12). The lesser amount of phosphorus application may not be available for uptake by the plants in control plots and probably was not sufficient for normal plant growth and development and resulted in reduction of the number of branches $plant^{-1}$. Uddin *et al*., (2014) found similar results on numbers of branches.

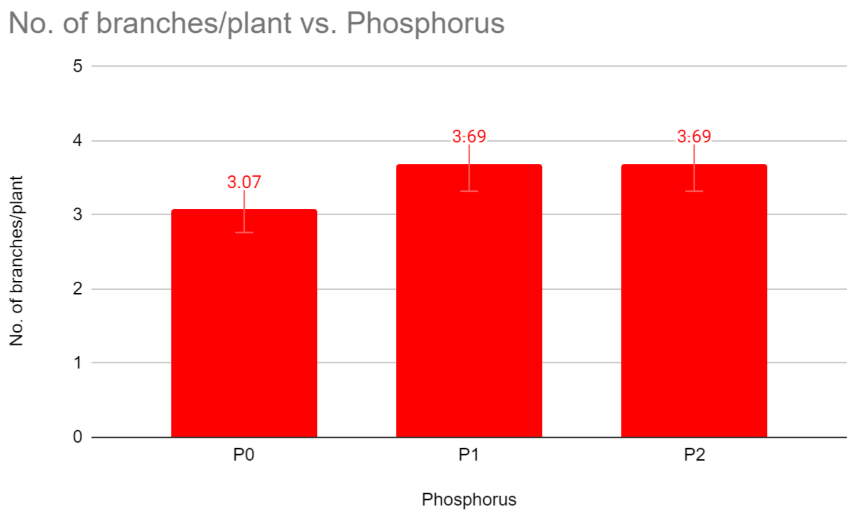

Figure 4.12 Effect of phosphorus on number of branches in field

Combined effect of Potassium and phosphorus on No. of branches:

The interaction effect of phosphorus and potassium level had a significant effect 0n number of branches per plant. The highest number of branches per plant was recorded

(4.34) in the treatment combination of K_2P_2 (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}) on the rooftop (Table 3). In contrast, the lowest number of branches plant-1 (3.71) was recorded in the treatment combination of K_1P_0 of okra on rooftop. In field plants, highest (3.97) and lowest (2.86) numbers of branches were found in K_1P_2 And KoPo respectively. Khan and Hossain (2006) revealed that nitrogen and potassium influenced the growth and yield of okra. The Number of branches increases with increasing levels of fertilizers.

Table 3. Combined Effect of Potassium and Phosphorus on No of branches/plant of Okra in rooftop and field

Treatments	No of branches/plant	
	Rooftop	Field
K_0P_0	3.83 de	2.86 d
K_0P_1	3.97 cd	3.10 cd
K_0P_2	4.03 c	3.27 bcd
K_1P_0	3.71 e	3.38 abcd
K_1P_1	4.10 bc	3 .72 ab
K_1P_2	4.23 ab	3.97 a
K_2P_0	4.25 ab	3.67 abc
K_2P_1	4.30 a	3.69 abc
K_2P_2	4.34 a	3.69 abc
Mean	4.09	3.48
$LSD_{0.05}$	0.168	0.62
CV (%)	1.44	6.30

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Coefficient of variation in percentage

Here,

- K_0 = 0 kg K_2O ha^{-1} (Control)
- K_1 = 50 kg K_2O ha^{-1}
- K_2 = 80 kg K_2O ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}
- P_2 = 120 kg P_2O_5 ha^{-1}

4.4 Number of fruits plant^{-1}

4.4.1 Effect of potassium on number of fruits:

Significant variation was found for the number of fruits plant-1 among the treatment due to different potassium doses (Figure 4.13 and 4.14). Results indicated that the highest number of fruits plant-1 (24.67) was found from the treatment K_2 (80 kg K_2O ha^{-1}) on the rooftop which was significantly different from other treatments i.e.K_1

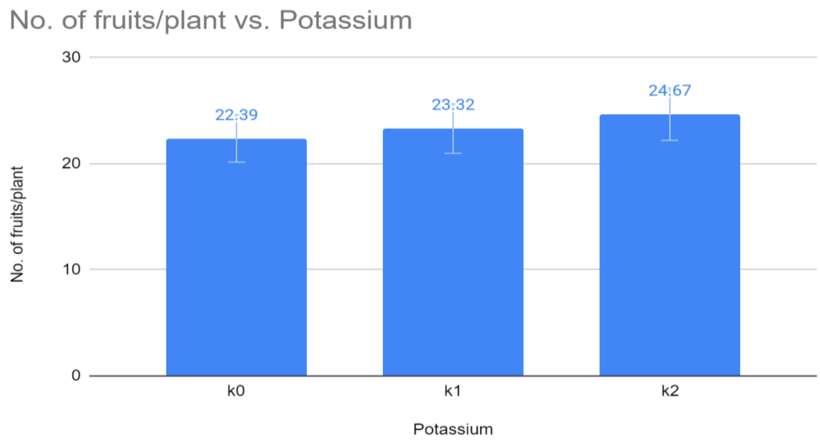

Figure 4.13 Effect of Potassium on Number of fruits/ plant of okra on rooftop

and K_0 whereas the lowest number of fruits plant^{-1} (22.39) was recorded from the control treatment K0 (0 kg K_2O ha-1). In field plants, the highest number of fruits (24.45) was found K_2 (80 kg K_2O ha^{-1}) and lowest (20.13) was found from K0 (0 kg

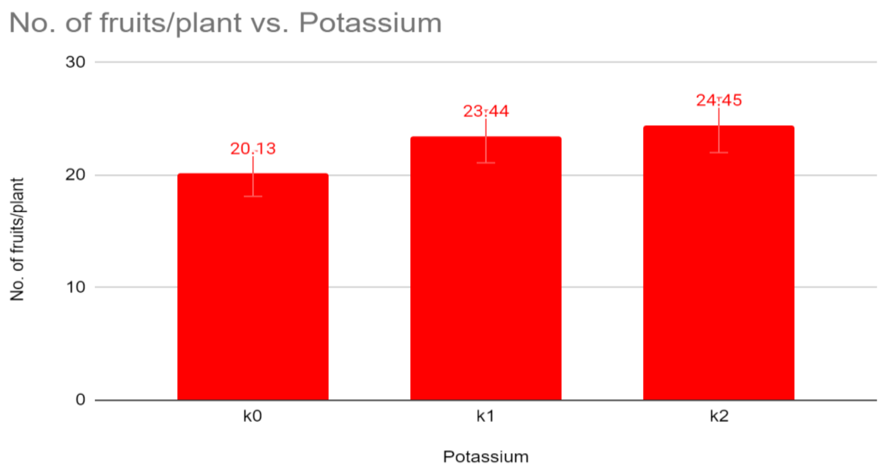

Figure 4.14 Effect of potassium on number of fruits/plant in field

K_2O ha-1). Jana *et* al. (2010) reported that 150 kg K/ ha produced the highest number of fruits per plant (13.7). Medeiros et al. (2018) also found similar results with the present study.

4.4.2 Effect of Phosphorus on numbers of fruits/plant

Due to varying phosphorus dosages a significant difference in the quantity of fruits plant^{-1} was discovered between treatments (Figure 4.15 and 4.16). The treatment P_2 (120 kg P_2O_5 ha^{-1}) on the rooftop produced the maximum number of fruits plant^{-1}

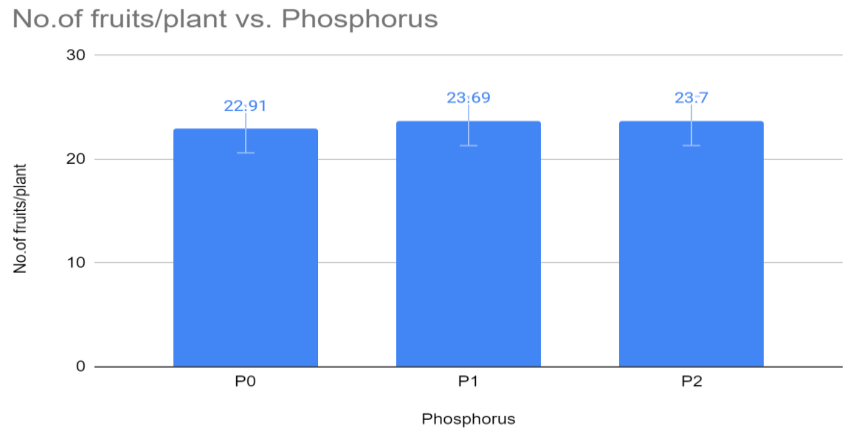

Figure 4.15 Effect of Phosphorus on number of fruits plant-1 of okra on rooftop

(23.7), which was similar to the treatment of P_1 (23.69).No significant difference was found between these two treatments on rooftop plants. In field plants, a significant

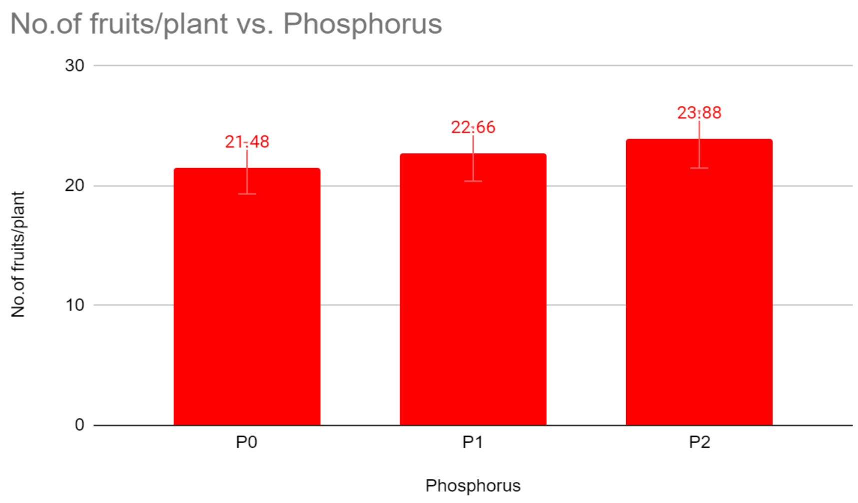

Figure 4.16 Effect of Phosphorus on number of fruits

difference was found among the three treatments (Figure 16). Uddin et al. (2014) also found similar results.

Combined effect of Potassium and Phosphorus on No. of fruits:

The amount of phosphorus and potassium exhibited a significant interaction effect on the number of fruits per plant (Table 4). The highest number of fruits per plant (25.17) was produced by the treatment combination K_2P_2 (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}) on rooftop (Table 4). Okra grown in the field with the K_0P_0 (control) treatment

Table 4. Combined effect of Potassium and Phosphorus on No of fruits /plant of okra in rooftop and field

Treatments	Number of fruits /plant	
	Rooftop	Field
K_0P_0	22.16 e	17.58 d
K_0P_1	22.92 de	19.68 c
K_0P_2	22.16 e	23.13 b
K_1P_0	22.69 de	22.76 b
K_1P_1	23.47 cd	23.80 ab
K_1P_2	23.80 c	23.76 ab
K_2P_0	24.14 bc	24.10 ab
K_2P_1	24.71 ab	24.51 a
K_2P_2	25.17 a	24.73 a
Mean	23.46	22.67
$LSD_{0.05}$	0.842	1.363
CV (%)	1.25	2.10

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Coefficient of variation in percentage

Here,

- K_0 = 0 kg K_2O ha^{-1} (Control)
- K_1 = 50 kg K_2O ha^{-1}
- K_2 = 80 kg K_2O ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}
- P_2 = 120 kg P_2O_5 ha^{-1}

combination had the smallest number of fruits (17.58) in field plants. In both rooftop and field, the K_2P_2 treatment (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}) generated the best outcomes in this experiment. Bhende *et al.*, (2015) found that cultivars ×phosphorus, cultivars × potassium and potassium × phosphorus significantly increased most of the studied characters including number of fruits.

4.5 Fruit length (cm)

4.5.1 Effect of Potassium on fruit length

Fruit length is an important parameter for measuring yield performance of okra. Significant variation was recorded for fruit length among the treatment due to different potassium doses. However, the highest fruit length (14.79 cm) was found from the treatment K_2 (80 kg K_2O ha-^{1}) which was significantly different from other treatments whereas the lowest fruit length (12.83 cm) was recorded from the control treatment K_0 (0 kg K_2O ha-1) (Figure 4.17).In field plants, the highest fruit length (11.5cm) was

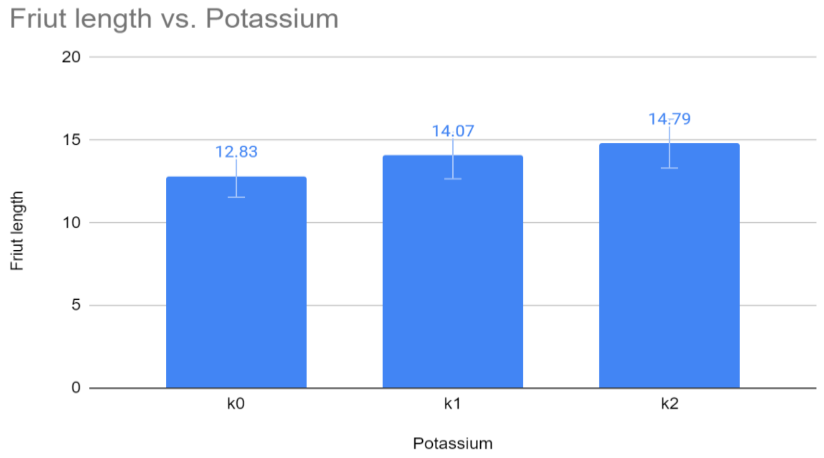

Figure 4.17 Effect of Potassium on Fruit length (cm) of okra in rooftop

found from K_2 (80 kg K_2O ha^{-1}) and lowest (9.8) was found from K_0 (0 kg K_2O ha^{-1}) (Figure 4.18).Singh *et al*., (2007) reported that fruit length was higher in potassium applied plants than control plants that supported the present experimental result.

4.5.2 Effect of Phosphorus on fruit length:

Significant variation was found among the different treatments due to different doses of phosphorus in respect of fruit length on the rooftop and field (Figure 4.19, 4.20). Average fruit length was recorded 13.42 cm, 14.1cm, and 14.17 cm in P0, P1 and P2 treatments on the roof top and 10.14 cm, 10.38 cm and 10.62 cm in P0, P1 and P2

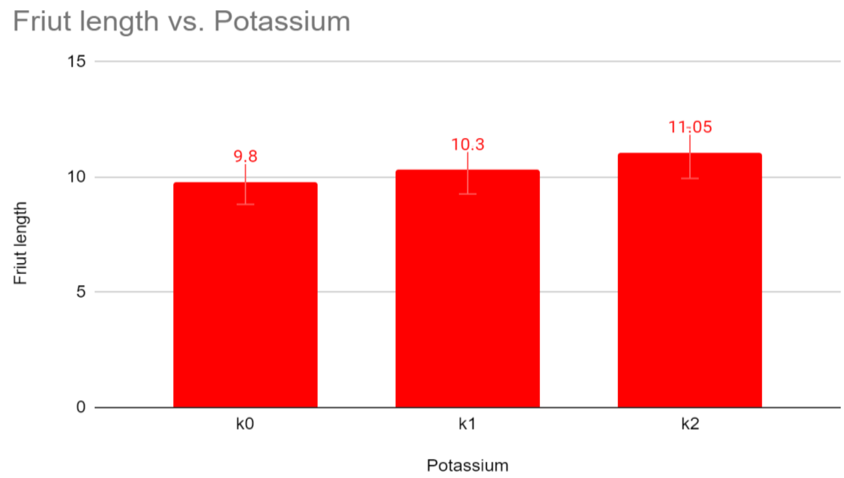

Figure 4.18 Effect of potassium on fruit length in field

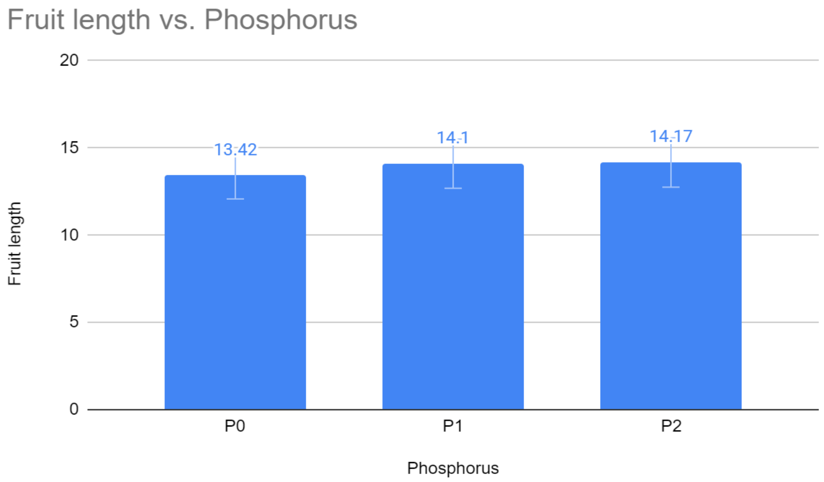

Figure 4.19 Effect of Phosphorus on Fruit length (cm) of okra on the rooftop

treatments in the field respectively. However, maximum (14.17 cm) fruit length was found in P_2 treatment on the rooftop whereas minimum fruit length was recorded in P_0

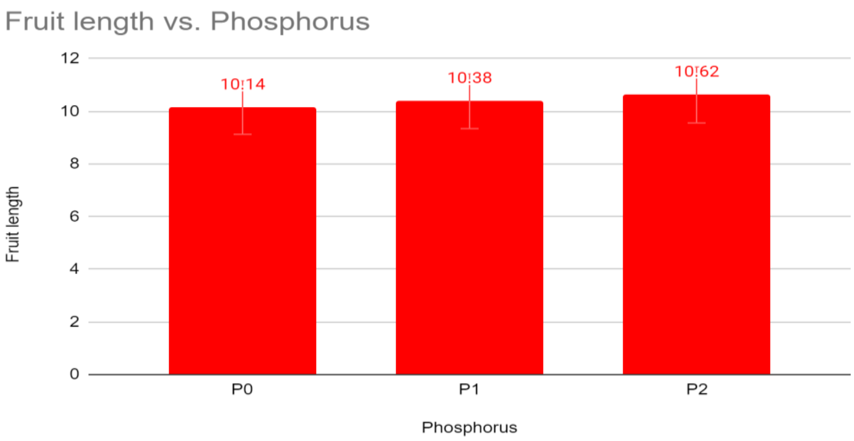

Figure 4.20 Effect phosphorus on fruit length in the field

Combined effect of Potassium and Phosphorus on fruit length:

Combined effect of potassium and phosphorus doses showed significant variation on fruit length of okra (Table 5). Maximum (15.28 cm) fruit length was recorded in K_2P_2 (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}) treatment and minimum (12.16 cm) fruit length was recorded in K_0P_0 or control treatment on the rooftop. In field plants, K_2P_2 (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}) treatment gave the higher fruit length than any other combinations in the field. But in general comparison between rooftop and field, rooftop gave the highest result in this present study. Khan *et al.*, (2000) found similar results with this present study.

Table 5. Combined Effect of Potassium and Phosphorus on Fruit length (cm) of okra in rooftop and field

Treatments	Fruit length (cm)	
	Rooftop	Field
K_0P_0	12.16 e	9.63 h
K_0P_1	13.87 cd	9.8 gh
K_0P_2	12.47 e	9.96 fg
K_1P_0	13.62 d	10.12 ef
K_1P_1	14.02 c	10.30 df
K_1P_2	14.56 b	10.47 cd
K_2P_0	14.49 b	10.68 c
K_2P_1	14.60 b	11.04 b
K_2P_2	15.28 a	11.43 a
Mean	13.90	10.38
$LSD_{0.05}$	0.335	0.291
CV (%)	0.84	0.98

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Coefficient of variation in percentage

Here,

- K_0 = 0 kg K_2O ha^{-1} (Control)
- K_1 = 50 kg K_2O ha^{-1}
- K_2 = 80 kg K_2O ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}
- P_2 = 120 kg P_2O_5 ha^{-1}

4.6 Fruit diameter (cm)

4.6.1 Effect of Potassium on fruit diameter

Fruit diameter of okra was significantly influenced due to different potassium and phosphorus doses (Figure 4.21, 4.22). However, the highest fruit diameter (5.82 cm) was found from the treatment K_2 (80 kg K_2O ha-1) on the rooftop whereas the lowest

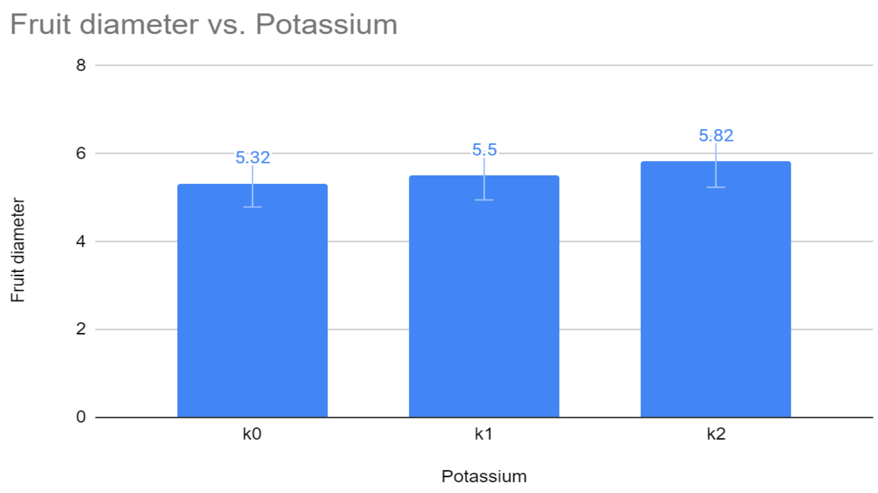

Figure 4.21 Effect of Potassium on fruit diameter (cm) of okra on rooftop

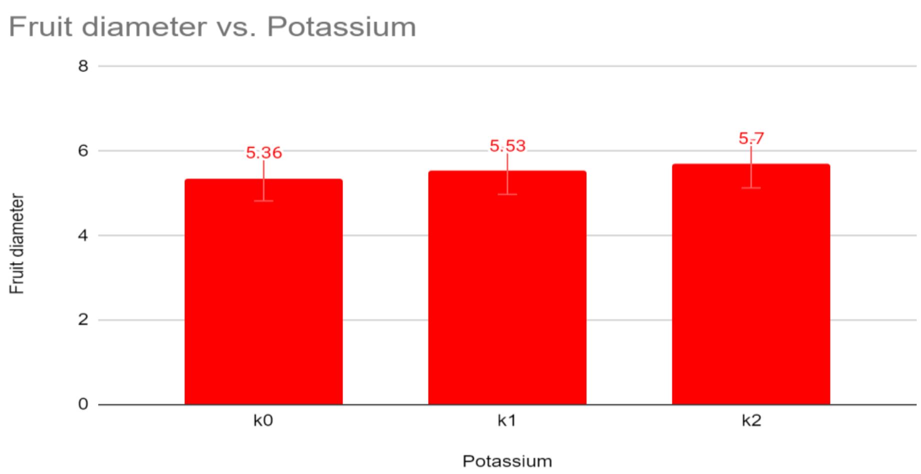

Figure 4.22 Effect of Phosphorus on fruit diameter (cm) of okra in field

fruit diameter (5.5 cm) was recorded from the control treatment K_0 (0 kg K_2O ha-1) which was significantly different from other treatments. In field plants, the diameter (5.7cm) which was found from the treatment K2 and lowest (5.36 cm) was found from K0. Similar result was found by Khan and Hossain (2006).

4.6.1 Effect of Phosphorus on fruit diameter:

Significant variation was found on fruit diameter due to the effect of different levels of phosphorus in okra (Figure 4.23, 4.24). Fruit diameter was recorded 5.51, 5.52 and 5.63 cm in P_0, P_1, and P_2 treatments on the rooftop where Po and P1 are identical, P2 showed

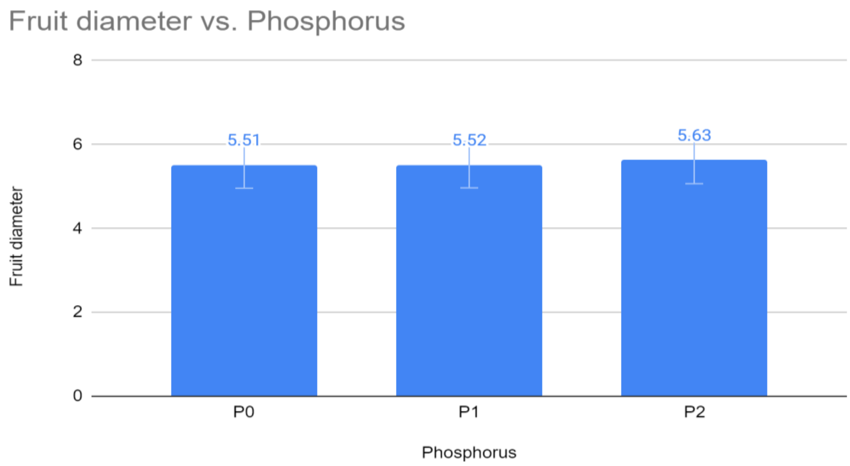

Figure 4.23 Effect of Phosphorus on fruit diameter of okra on the rooftop

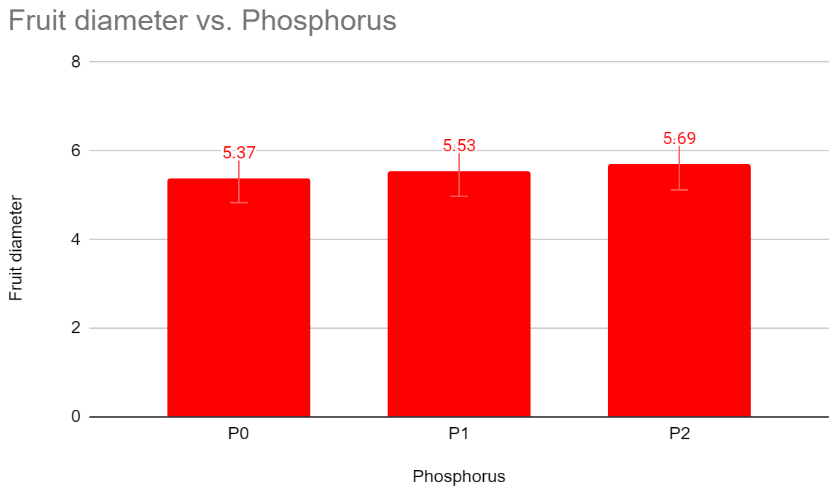

Figure 4.24 Effect of phosphorus on fruit diameter in the field

higher diameter. In field plants, 5.37, 5.53 and 5.69 in P_0, P_1, and P_2 treatments respectively. These results indicated that increasing levels of phosphorus increased the diameter of fruit of okra after a certain level and then decreased. Similar result was found by Mohanta (1998).

Combined effect of Potassium and Phosphorus on fruit diameter:

Diameter of fruit is a measurement of the size of actual okra fruit which indicates yield amount and market value. The interaction effect of potassium and phosphorus rate on fruit diameter was significant on the rooftop and field (Table 6). The highest fruit diameter (5.95 cm) was recorded in the treatment combination of K_2P_2 (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}) (Table 6). On the other hand, the lowest fruit diameter (5.23 cm) was obtained from K_0P_0 (control). In field plants, highest diameter(5.53 cm) and lowest diameter(5.24) was In both cases i.e. on the rooftop and field conditions K_2P_2 (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}) gave the best result in terms of fruit diameter than other treatment condition.

Table 6. Combined Effect of Potassium and Phosphorus on Diameter of fruit (cm) of okra in rooftop and field

Treatments	Diameter of fruit (cm)	
	Rooftop	Field
K_0P_0	5.23 e	5.24 e
K_0P_1	5.37 d	5.40 cd
K_0P_2	5.38 d	5.43 cd
K_1P_0	5.52 c	5.53 bc
K_1P_1	5.45 cd	5.51 c
K_1P_2	5.54 c	5.54 bc
K_2P_0	5.79 b	5.33 de
K_2P_1	5.73 b	5.68 b
K_2P_2	5.95 a	6.10 a
Mean	5.55	5.53
$LSD_{0.05}$	0.122	0.152
CV (%)	0.77	0.96

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Coefficient of variation in percentage

Here,

- K_0 = 0 kg K_2O ha^{-1} (Control)
- K_1 = 50 kg K_2O ha^{-1}
- K_2 = 80 kg K_2O ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}
- P_2 = 120 kg P_2O_5 ha^{-1}

4.7 Fruit weight (g)

4.7.1 Effect of Potassium on fruit weight:

Different levels of potassium showed a significant variation on fruit weight on the rooftop and field. The maximum fruit weight (13.63 g) was recorded from K_2 (80 kg $K_2$0/ha) and the minimum (12.41 g) was recorded from control conditions of potassium

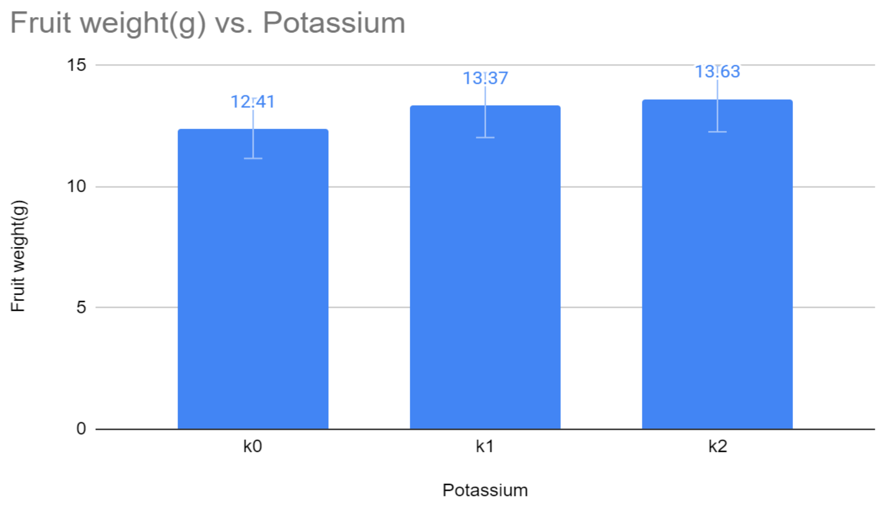

Figure 4.25 Effect of Potassium on Fruit weight (g) of okra on rooftop

(Figure 4.25). In field plants, K_2 (80 kg $K_2$0/ha) also gave a satisfactory result in case of fruit weight. Potassium influenced vegetative growth as well as increased individual fruit weight with increasing levels. El-Shaikh (2005) revealed that weight of green pods increased with the increasing levels of potassium.

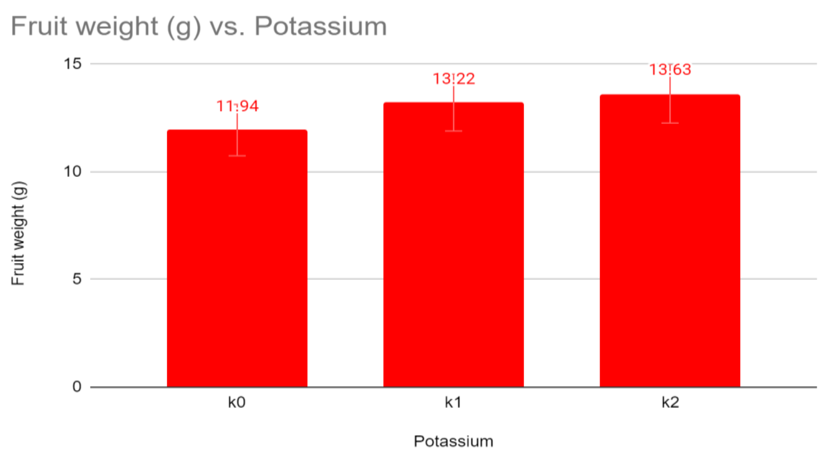

Figure 4.26 Effect of potassium on fruit weight in field

4.7.2 Effect of Phosphorus on fruit weight

The effect of different levels of phosphorus showed significant variation for fruit weight under the present trial in rooftop and field. In both cases the maximum fruit weight was recorded from P_2 (120 kg K_2O/ha) and the minimum was recorded from field condition.

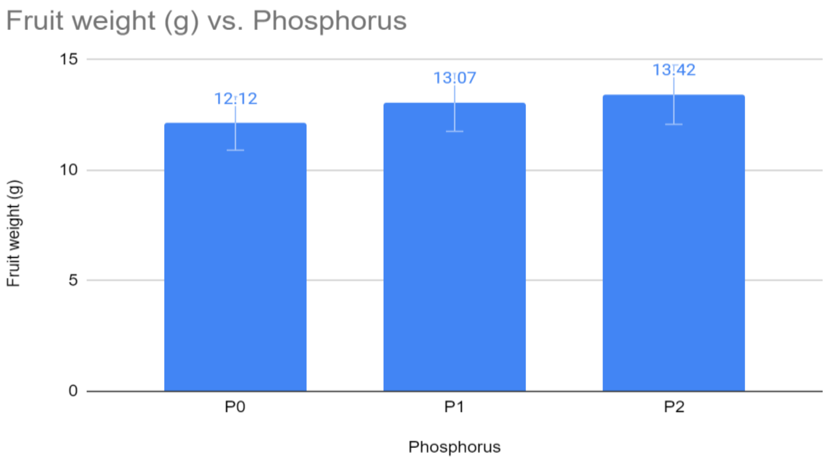

Figure 4.27 Effect of Phosphorus on Fruit weight (g) of okra on rooftop

However, the highest weight (13.75 g) was recorded from P_2 (120 kg K_2O/ha) and the minimum (13.46 g) was recorded from control condition (Figure 4.27). These results indicated that increasing levels of phosphorus increased fruit weight after a certain level and then decreased with increasing phosphorus. Similar result was found by Monhanta (1998).

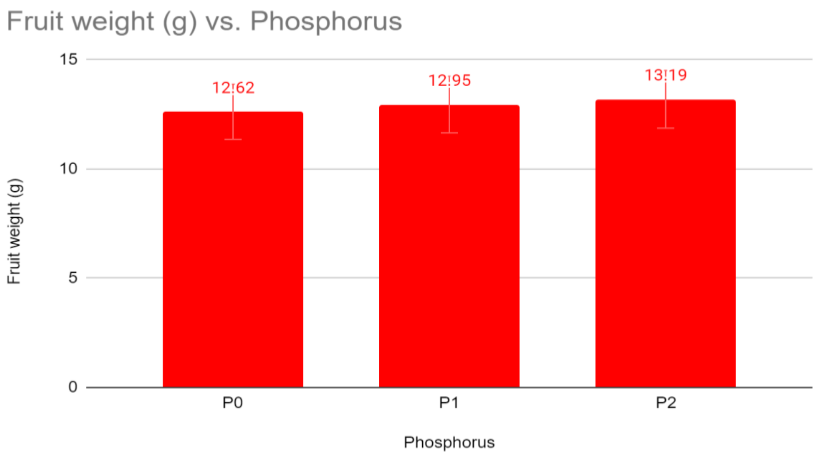

Figure 4.28 Effect of Phosphorus on fruit weight (g) of okra in field

Combined effect of Potassium and Phosphorus on fruit weight:

Determination of weight of fruit is an important measurement for comparing yield performance of okra under the present study. Interaction of potassium and phosphorus showed a significant difference for fruit weight. The maximum (13.76 g) individual fruit weight was recorded from K_2P_2, while K_0P_0 gave the minimum (11.98 g) fruit weight of okra on the rooftop (Table 4.9). In the field, the maximum fruit weight was recorded from K_2P_2 (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}) and the minimum was recorded from control conditions. The combination of potassium and phosphorus significantly improved the growth related parameters. The weight of green pods increased by combined application of potassium and phosphorus (El-Shaikh, 2005). Bhende et al., (2015) revealed that 75 kg P/ha plus 75 kg K/ha was the optimum dose for enhancing qualities of okra like fruit weight. Mishra et al. (1987) also found similar type results.

Table 7. Combined Effect of Potassium and Phosphorus on Fruit weight (g)

Treatments	Fruit weight (g)	
	Rooftop	Field
K_0P_0	11.98 e	11.35 g
K_0P_1	12.23 e	12.03 f
K_0P_2	13.02 d	12.45 e
K_1P_0	13.26 cd	13.03 d
K_1P_1	13.37 bc	13.22 cd
K_1P_2	13.47 abc	13.40 bc
K_2P_0	13.51 abc	13.50 abc
K_2P_1	13.61 ab	13.58 ab
K_2P_2	13.76 a	13.72 a
Mean	13.13	12.92
$LSD_{0.05}$	0.322	0.299
CV (%)	0.86	0.81

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Coefficient of variation in percentage

Here,

- K_0 = 0 kg K_2O ha^{-1} (Control)
- K_1 = 50 kg K_2O ha^{-1}
- K_2 = 80 kg K_2O ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}
- P_2 = 120 kg P_2O_5 ha^{-1}

4.8 Yield per plot

4.8.1 Effect of Potassium on yield per plot

Potassium showed a significant variation for different levels on yield per plot on rooftop and field (Figure 4.29, 4.30). The maximum yield (15.69 kg/plot) was recorded from K_2 (80 kg K2O/ha) on the rooftop while the minimum (13.05 kg/plot) was recorded

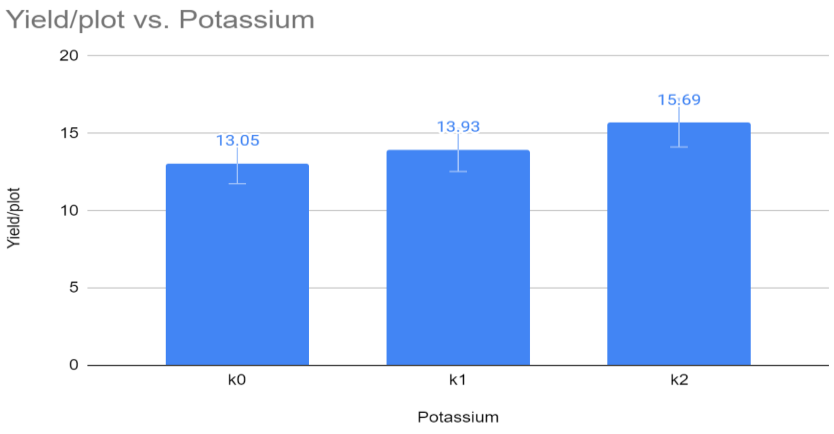

Figure 4.29 Effect of Potassium on Yield (kg/plot) of okra on rooftop

from control conditions (Figure 4.29).In field, the maximum yield/plot (14.72 kg) and minimum yield/plot (12.04kg) was found from K2 and Ko respectively. Potassium influenced vegetative growth as well as increased the yield per plot with increasing levels. The green pod yield significantly affected by the application of 80kg K2O/ha (Khan, 2006).

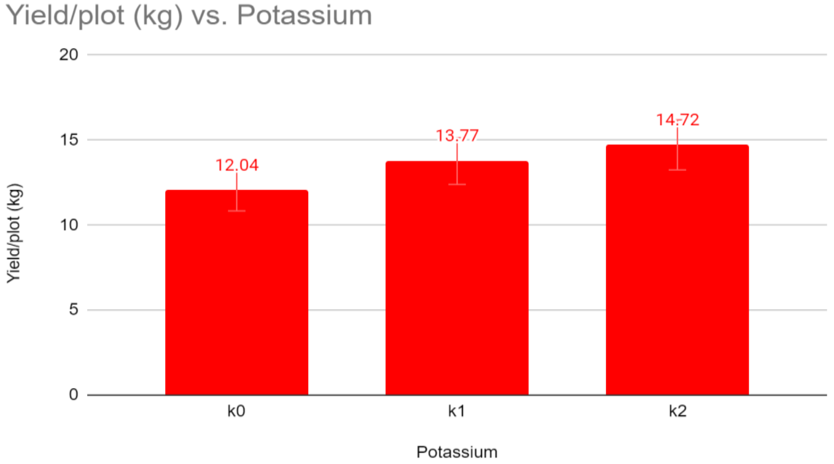

Figure 4.30 Effect of Phosphorus on yield per plot in field

4.8.2 Effect of phosphorus on yield per plot:

Yield per plot varied significantly for the effect of different levels of phosphorus under the present trial in rooftop and field. The maximum yield (14.68 kg/plot) was recorded from P2 (120 kg P_2O_5/ha) and the minimum (13.7 kg/plot) was recorded from control yield.

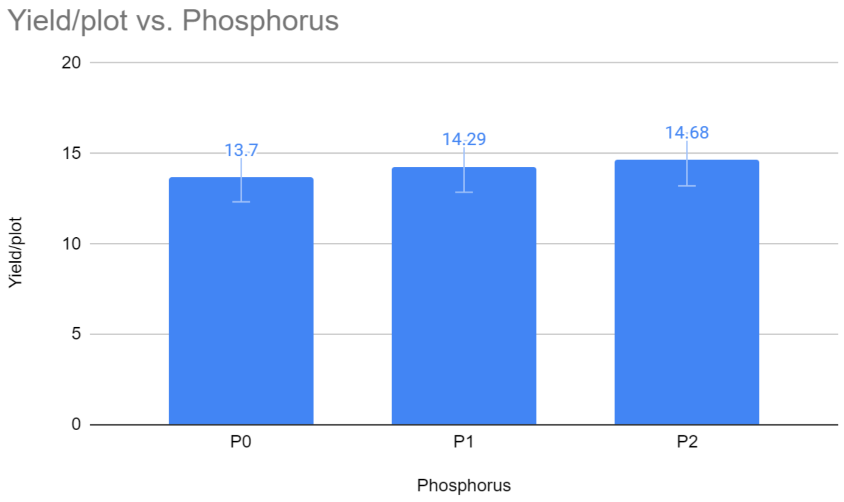

Figure 4.31 Effect of phosphorus on yield (kg/plot) of okra on rooftop

conditions (Figure 4.31). In the field, the maximum yield was found in P2 and minimum was found from P0 (Figure 4.32). In both cases P_2 (120 kg P_2O_5/ha) gave the maximum yield. These results indicated that increasing levels of phosphorus increased vegetative

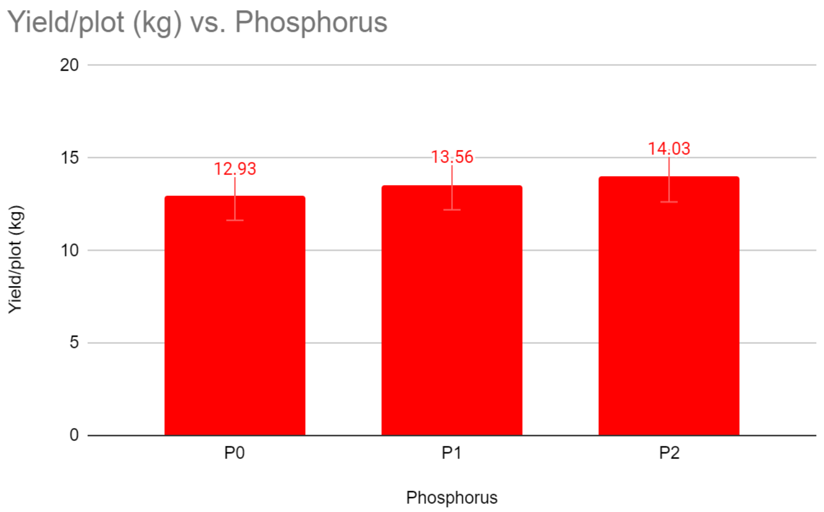

Figure 4.32 Effect of Phosphorus on yield (kg/plot) of okra in field

growth as well as yield per plot after a certain level. Gupta *et al.*, (1981) stated that phosphorus fertilization increased pod size which finally contributed towards increasing the pod yield. Application of 60 kg phosphorus per hectare gave the highest yield as compared to other levels. The result related with the findings of Majanbu et al. (1985). They reported that application of phosphorus significantly increased green pod.

The combined effect of Potassium and Phosphorus on yield per plot:

Interaction of potassium and phosphorus showed a significant difference for yield per plot in rooftop and field. The maximum yield (16.15kg/plot) was recorded from K_2P_2 (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}), while K_0P_0 gave the minimum (12.27 kg/plot)

Table 8. Combined effect of Potassium and Phosphorus on Yield (kg/plot) of Okra

Treatments	Yield (kg/plot)	
	Rooftop	Field
K_0P_0	12.27 h	11.00 h
K_0P_1	13.25 g	12.12 g
K_0P_2	13.63 f	13.00 f
K_1P_0	13.63 f	13.51 e
K_1P_1	13.90 e	13.80 f
K_1P_2	14.24 d	14.00 cd
K_2P_0	15.19 c	14.29 c
K_2P_1	15.73 b	14.77 b
K_2P_2	16.15 a	15.10 a
Mean	14.22	13.51
$LSD_{0.05}$	0.199	0.327
CV (%)	0.49	0.85

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Coefficient of variation in percentage

Here,

- K_0 = 0 kg K_2O ha^{-1} (Control)
- K_1 = 50 kg K_2O ha^{-1}
- K_2 = 80 kg K_2O ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}
- P_2 = 120 kg P_2O_5 ha^{-1}

yield per plot on the rooftop (Table 8).The field gave maximum yield (15.10kg/plot) and minimum yield (11.00kg/plot) from K2P2 and KoPo respectively. Combination of P and K, improved the yield of green pods significantly. The highest yield/ha was recorded in plots filled with 120-90-60 kg NPK per hectare (Ahmed, 1999).

4.9 Yield per hectare

4.9.1 Effect of Potassium on yield per hectare:

Potassium showed a significant variation for different levels of yield per hectare in rooftop and field. The maximum (4.72t/ha) yield was recorded from K_2 (80 kg K_2O/ha), while the minimum (2.98 t/ha) was recorded from the control condition of potassium

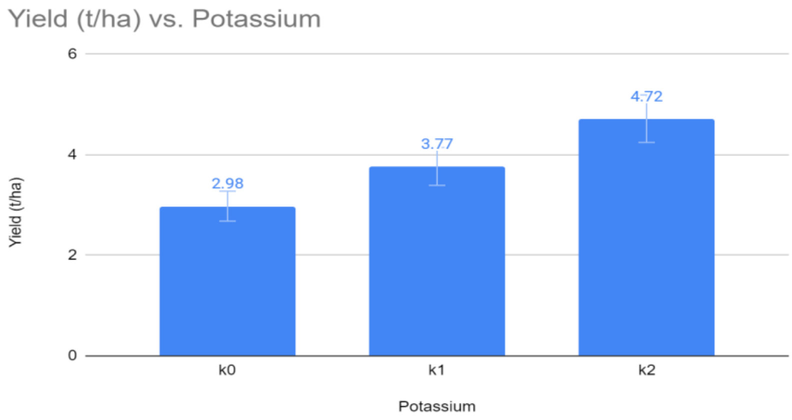

Figure 4.33 Effect of Potassium on Yield (t/ha) of okra on rooftop

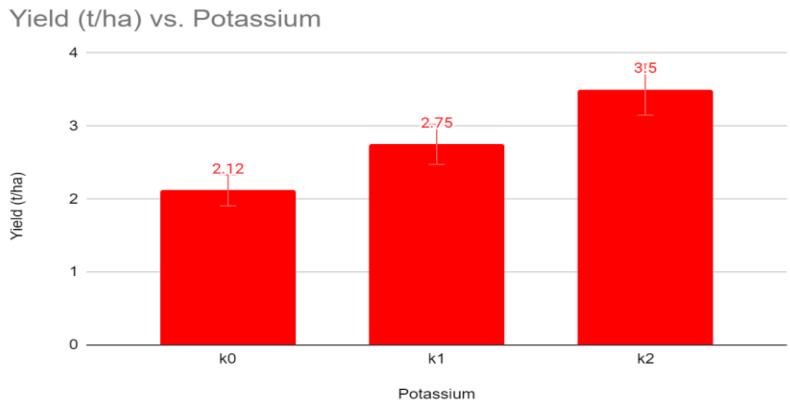

Figure 4.34 Effect of Potassium on yield (t/ha) of okra in field

(Figure 4.33). The maximum (3.5t/ha) yield and minimum (2.12t/ha) yield was found from K2 and Ko respectively. Potassium influenced vegetative growth as well as increased the yield per plot with increasing levels. Ahmed and Tullock (1968) studied the response of okra to nitrogen, phosphorus, potassium and magnesium fertilization at Trinidad on loam soil and best yields were obtained with 280 kg K per hectare.

4.9.2 Effect of Phosphorus on yield per hectare:

Yield per hectare varied significantly due to the effect of different levels of phosphorus under the present trial in rooftop and field. The maximum (4.22 t/ha) yield was recorded from P_2 (120 kg P_2O_5/ha) and the minimum (3.34 t/ha) was recorded from control condition (Figure 4.35). Again, in the field the maximum yield (2.99t/ha) was found

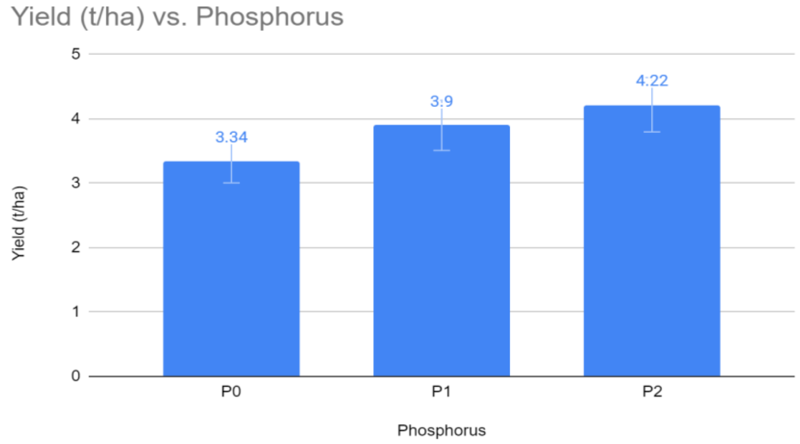

Figure 4.35 Effect of phosphorus on Yield (t/ha) on rooftop

from P2 and minimum was found from P0. These results indicated that increasing levels of phosphorus increased vegetative growth as well as yield per hectare after a certain level. Majanbu *et al*., (1985) reported that the increase of phosphorus yield per hectare increased with a certain level. Arora *et al.*, (1991) stated that total green pod yield was significantly improved by the application of 60 kg P/ha.

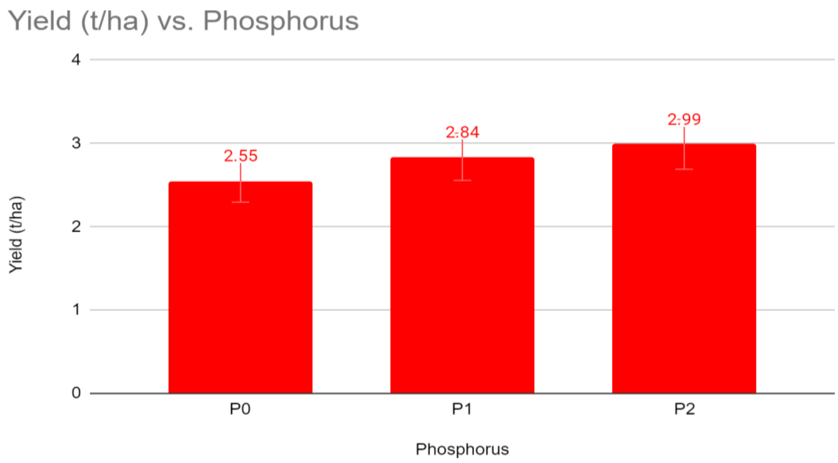

Figure 4.36 Effect of Phosphorus on yield (t/ha) of okra in field

Combined effect of Potassium and Phosphorus on yield per hectare:

Interaction of phosphorus and potassium showed a significant difference for yield (Table 9). The maximum (5.18 t/ha) yield was recorded from K_2P_2 (80 kg K_2O ha^{-1} with 120 kg of P_2O_5 ha^{-1}), while K_0P_0 i.e. control gave the minimum (2.27 t/ha) yield per hectare on rooftop. The field gave maximum results from k2p2 and minimum from

KoPo. K_2P_2 gave maximum value in both the locations. In combinations, K and P affect the yield. Ahmed (1999) also found similar results.

Table 9. Combined effect of Potassium and Phosphorus on Yield (t/ha) of Okra

Treatments	Yield (t/ha)	
	Rooftop	Field
K_0P_0	2.27 g	2.05 h
K_0P_1	3.25 f	2.08 h
K_0P_2	3.42 f	2.22 g
K_1P_0	3.39 f	2.39 f
K_1P_1	3.85 e	2.84 e
K_1P_2	4.07 d	3.01 d
K_2P_0	4.37 c	3.22 c
K_2P_1	4.60 b	3.53 b
K_2P_2	5.18 a	3.75 a
Mean	3.82	2.79
$LSD_{0.05}$	0.203	0.071
CV (%)	1.86	0.89

$LSD_{0.05}$ = Least significant difference at 0.05 % level

CV (%) = Coefficient of variation in percentage

Here,

- K_0 = 0 kg K_2O ha^{-1} (Control)
- K_1 = 50 kg K_2O ha^{-1}
- K_2 = 80 kg K_2O ha^{-1}
- P_0 = 0 kg P_2O_5 ha^{-1} (control)
- P_1 = 80 kg P_2O_5 ha^{-1}
- P_2 = 120 kg P_2O_5 ha^{-1}

CHAPTER 5

SUMMARY AND CONCLUSION

SUMMARY

An experiment was conducted during Kharif-II season 2021 in completely Randomized design (RCBD) with three replications at two locations i.e., roof of Biotechnology Department and Agroforestry research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. This experiment was studied to know the effect of potassium and phosphorus on growth and yield of okra on rooftop and field. In the present investigation, seeds of BARI- Dherosh-2 were used. Plants were grown in both the locations. The experiment was two factorials. One was Factor A: Three potassium levels such as K_0: 0 kg K_2O ha^{-1} (Control), K_1: 50 kg K_2O ha^{-1} and K_2: 80 kg K_2O ha^{-1} and another was Factor: B which was designed by three levels of phosphorous P_0:0 kg P_2O_5 ha^{-1} (control) P_1 : 80 kg P_2O_5 ha^{-1}, and P_2 : 120 kg P_2O_5 ha^{-1} . Data on plant height, number of leaves per plant, number of branches per plant, number of fruits per plant, fruit length, fruit diameter, fruit weight, yield per plot and yield (t/ha) of okra collected. MSTAT-C was used for processing and analysis of data. The mean differences were adjusted by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

In okra, yield parameters value were increased with increasing dose of potassium and phosphorus for all of the parameters studied like plant height, number of leaf, number of branches per plant, number of fruits per plant, fruit length, fruit diameter, fruit weight, yield per plot and yield (t/ha) of okra.

On the rooftop and in the field, the highest values were obtained from increased doses of potassium and phosphorus. From the present study it was found that for all growth and yield parameters the highest alues were found from the rooftop, otherwise the lowest data were found from the field.

The effect of potassium was considered significant under the present study. On the growth parameters; plant height, number of leaves, number of branches per plant, number of fruits per plant,fruit length, fruit diameter, fruit weight, yield per plot and yield of okra in the rooftop garden. All the parameters were higher with the higher doses of potassium on the rooftop than the field. In case of plant height (91.88), number of leaf (), number of branches per plant (4.29), number of fruits per plant (24.67), fruit length (14.79 cm), fruit diameter (5.82 cm), fruit weight (g), yield per plot (15.69

kg/plot) and yield (4.72 t/ha) of okra were found highest in the K_2(80 kg K_2O ha^{-1}) treatment. On the other hand, lowest value obtained from the control treatment.

Results revealed the influence of phosphorus on growth and yield of okra on rooftop and field. In case of plant height (87.7cm), number of leaf (), number of branches per plant (4.2) , number of fruits per plant (23.7),fruit length (14.79 cm), fruit diameter (5.82 cm), fruit weight (13.72 g), yield per plot (14.68 kg/plot) and yield (4.22 t/ha) of okra were found highest in the P_2(120 kg P_2O_5 ha^{-1}). On the other hand, lowest value obtained from the control treatment.

There also had a significant effect in case of combined treatment of potassium and phosphorus on rooftop and field. In case of plant height (85.28 cm), number of leaf (40.85), number of branches per plant (4.09), number of fruits per plant (23.46), fruit length (13.90cm), fruit diameter (5.55 cm), fruit weight (13.13 g), yield per plot (14.22 kg/plot) and yield (3.82 t/ha) of okra were found highest in the K_2P_2 (80 kg K_2O $ha^{-1}$with 120 kg P_2O_5 ha^{-1}). On the other hand, lowest values were obtained from the control treatment.

In both the locations, i.e., rooftop and field the maximum mean values were recorded from K_2P_2 (80 kg K_2O/ha with 120 kg P_2O_5 ha^{-1}) treatments whereas the minimum was recorded from K_0P_0 (control). On roof top condition, the highest means were recorded in terms of plant height (85.28 cm), number of leaf (40.85), number of branches per plant (4.09), number of fruits per plant (23.46),fruit length (13.90 cm), fruit diameter (5.55cm), fruit weight (13.13g), yield per plot (14.22 kg/plot) and yield (3.82 t/ha) of okra. On the other hand, plant height (82.43cm), number of leaf (34.09), number of branches per plant (3.48), number of fruits per plant (22.67), fruit length (10.38 cm), fruit diameter (5.53 m), fruit weight (12.92 g), yield per plot (13.51kg/plot) and yield (2.79 t/ha) of okra were found lowest from the field. No significant difference was found in fruit diameter in field plants.

CONCLUSION

Considering the above results of this experiment the following conclusions can be drawn:

1. The single optimum dose of potassium, 80 kg/ha and phosphorus, 120 kg/ha provides the higher yield in the locations.
2. Potassium and phosphorus had a significant effect on growth and yield of okra on the rooftop and field. The maximum yield was recorded from increased levels of potassium and phosphorus. That's why K_2P_2 (80 kg K_2O ha^{-1} with 120 kg P_2O_5 ha^{-1}) can be used as an optimum dose for okra cultivation.
3. On the rooftop, the okra's growth and yield components were favorably observed. In contrast to the field, the largest yield was achieved from rooftops. On the other hand, the yield from the field was found low.

Further research works at different regions of the country are needed to be conducted for the confirmation of the present findings.

REFERENCES

Achebe U. A., Obidiebule E. A., Akparobi S.O. Nwachukwu E.F. (2013). Effect of different levels of N.P.K (20:10:10) fertilizer on the growth and yield of six okra cultivars in Asaba soils. *Inn. J. Agri. Sci.* **3**(9): 689-698.

Adelana, B.O. (1985). Effect of N, P, and K fertilizers on the yield of okra in South-Western Nigeria. *Samaru J. Agril*. Res. **3**(1-2): 67-72.

Ahmed and Tullok-Reid (1968). The response of okra to nitrogen, phosphorus, Potassium and magnesium fertilization at the rate of 112 kg N, 168 kg P, 280 kg K and 112 kg Mg per hectare at trinidad on loam soil for best yield of okra. *Haryana J. Hort. Sci.,* **10**(1-20**):** 136-140.

Ahmed F., Ishtiaq M. and Muhammad S. (1999). Effect of different levels of nitrogen alone and in combination with constant doses of phosphorus and potassium on growth and yield of okra cv. T-13. *Sarhad J. Agri*. *Pakistan*.

Ali Z (2018). Response of okra to various levels of applied nitrogen and phosphorus fertilizers. *Open Acc*. *J. Agri. Res*: OAJAR -100012.

Archer, O. (1988). Effect of. NPK at the rate of 60, 50 30 kg per hectare, respectively, were recommended for getting the best yield of okra. (*Abelmoschus esculentus* L.) *Gujarat Agril. Univ. Res. J.,* **13**(2): 8-11.

Arora, S.K., Narinder, K., Sharma, B.R. and Kumar, N. (1991). Effect of nitrogen and phosphorus and fertilizer on growth and yield components in okra (*Abelmoschus esculentus L.*Moench). *Haryana J. Hort. Sci*., **13**(2): 8-11.

Asad, K.M. and Roy, M.R. (2014). Urban Greening and Roof Top Gardening: Scope and Opportunities in Bangladesh. Retrieved from gobeshona.net: 〈 http:// gobeshona.net/wp-content/uploads/2015/01/Urban-Greening-and-Roof-TopGardening-Scope-and-Opportunities-in-Bangladesh.pdf〉.

BBS. (2020). Yearbook of Agricultural Statistics. Dhaka: Bangladesh Bureau of Statistics, Ministry of Planning, Government of Bangladesh. Govt. of the People’s Republic of Bangladesh. pp. 150-157.

Bennett, (2003). Linkages in the landscape: The role of corridors and connectivity in wildlife conservation. Gland: International Union for Conservation of Nature and Natural Resources.

Bhandari S., Pandey S. R. Giri K., Wagle P., Bhattarai S. and Neupare R. B. (2019). Effect of different fertilizers on the growth and yield of okra *(Abelmoschus esculentus)* in the summer season in Chitwan, Nepal. *Arc. Agri. Env. Sci.* **4**(4): 396-403.

Bhende S. K., Deshmukh H. K., Nimbolkar P. K., Dewangan R.K. and Nagone A.H. (2015). Effect of phosphorus and Potassium on quality attributes of okra cv. 'Arka Anamika'. *Inn. J. Env. Sci.* **6**(2): 225- 231.

Bid, N.N.; P.K. Days and S.P. Dhua. (1971). Efficacy of nitrogenous and phosphatic fertilizers on growth and yield of Bhindi. Technology India. **8(**2): 145-148.

Bieleski RL. (1973). Phosphate pools, phosphate transport, and phosphate availability. Annual review of plant physiology. **24**: 225-252.

Chauhan, D.S. and M.L. Gupta. (1973). Effect of nitrogen, phosphorus and potash on growth and development of okra (*Abelmoschus esculentus* L. Moench). *Indian J. Hort.* SW. **30** (l2**)**:401-406.

Cox, K.L. and A.K. Singh. 1999. Effect of different levels of phosphorus, GA3 and pickings on seed production of okra. Environ, and Ecol. **16**(2): 350-352.

El-Shaikh (2005). Effect Phosphorus and Potassium fertilizer on green yield, seed production and quality of two okra cultivars in reclaimed soils. *Assuit. J. Agric. Sci*. **36**: 51-68.

Fioretti, R.Palla, A., Lanza, L. G. and Principi, P. (2010). Green roof energy and water related performance in the Mediterranean climate. Building Environ. **45 (**8): 1890-1904.

Firoz Z. A. (2009). Impact of nitrogen and phosphorus on the growth and yield of okra (*Abelmoschus esculentus* (L.) Moench) in hill slope condition. *Bangladesh J. Agri. Res*. **34**(4): 713-722.

Gardiner, D. T., & Miller, R. W. (2004). *Soils in our environment*. 126-165.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research (2nd edn.). Int. Rice Res. Inst. A Willey Int. Sci., pp. 680.

Gupta A., Srinivas K. and shukla V. (1981). Response of okra (Abelmoschus esculentus L.) to plant spacing and nitrogen, phosphorus fertilization. *Indian J. Hort*. **38**(3 - 4): 218-222.

Halim M., I.A. Siddique and S.S. and Shaukat.(1994). Improvement of *Pseudomonas fluorescens* CHA0 biocontrol activity against root-knot nematodes by the addition of ammonium molybdate. Letters in Applied Microbiology **36:** 239–244.

Helen Keller International and Institute of Public Health Nutrition. (1985) Bangladesh NutritionalBlindness Study 1982-83, Dhaka.

Heuvelink, E. (2005). Tomatoes. Crop Production Science in Horticulture 13. CABI Publishing. Massachusetts, USA. Pp. 339

Hossain, D, Haque, M.A, Abuyusuf, M, Riad, M.M. and Hussain, A.S.M. (2011). Response of cabbage to different levels of fertilizer application in salinity clay loam soil. *Bangladesh Res. Pub. J.* **6**(2): 155-166.

Islam, K.M. (2004). Rooftop Gardening as a Strategy of Urban Agriculture for Food Security: The Case of Dhaka City, Bangladesh. Retrieved from teiep.gr: (http://wwwlib.teiep.gr/images/stories/acta/Acta%20643/643_31.pdf).

Islam, M.S. and Ahmed, R. (2011). Land Use Change Prediction in Dhaka City Using GIS Aided. **6**: 81-89. Retrieved August 28, 2015.

Islam, M.S. and Noor, R. (2011). Land Use Change Prediction in Dhaka City Using GIS Aided. **6**: 81-89. Retrieved August 28, 2015.

Khan H.,Khan M., Rasul K.,Majeed A., and Safi F.A. (2000) Effect of nitrogen and in combination with constant doses of phosphorus and potassium on growth and yield of okra (*Abelmoschus esculentus* L.) Cv.vT-13 under the agro climatic conditions Mingora swat. *Pak. J. Bio. Sci*., **3**(12): 2101-2104.

Khan M. and Hossain M. (2006). Effect of different levels of nitrogen and potassium on growth and yield of okra (*Abelmoschus esculentus*). http://archive.saulibrary.edu.bd:8080/xmlui/handle/123456789/1073

Khatun, K., Hossain, F. and Saha, S. R. (2012) Effect of different transplanting dates on the growth and yield of okra *J. Exp. Bio. Sci.*, **3**: 13-18.

Kuiper M.L. (1984). Effect of 4 (four) fertilizer levels on the growth and development of okra cultivars (Parbhani Kranti, ArkaAnamika and PusaSawani). *Haryana J. Hort. Sci*., **9:** 3-14.

Lenka, P.C., D.K. Das and H.N. Mishra. (1989). Effect of nitrogen and phosphorus on seed yield of bhindi CV. *Parbhani Kranti. Orissa J. Agril. Res*., **2**(2): 125-127.

Lisiewska, Z. and W.Kmiecik.(1969). Effects of level of potassium fertilizers, processing conditions and period of storage of frozen broccoli and cauliflower on vitamin C retention. Food Chemistry **57**(2): 267-270.

Majanbu I.S., Ogunlela V. B., Ahmed M. K. and Olarewaju J. D. (1985). Response of two okra varieties to fertilizers: yield and yield components as influenced by nitrogen and phosphorus application. Fertilizer Research. **6**(3): 257-267.

Manga, A. A.; Chiezey, U. F. and Yusuf, Y. (1999). Effect of phosphorus, molybdenum and staking on yield and yield components of winged bean (*Psophocarpus tetragonolobus* (L.) D.C.). National Horticultural Research Institute, Bagauda Sub-station, P. M. B. 3390, Kano, Nigeria.

McDonough, W. (2005) Green Roofs, Ecological Design and Construction. Earth Pledge, Schiffer Publishing Ltd.

Medeiros, A.S., Queiroz, M.M.F. and Renato A. (2018). Yield of the Okra Submitted to Nitrogen Rates and Wastewater in Northeast Brazilian Semiarid Region. *J. Agric. Sci.*, **10**(4): 409-416.

Mellgren R. (2008) Effect of irrigation and nitrogen treatments on yield, quality, plant nitrogen uptake and soil nitrogen status and the evaluation of sap test, SPAD chlorophyll meter and dualex to monitor nitrogen status in broccoli.Thesis, Horticultural Science Programme Department of Horticulture, SLU, Alnarp.

Miller, R. C. 2004. Effect of phosphorus and potassium on yield and nutrients uptake and oil contents of groundnut. *Indian J. Agril. Sci*., **60**: 559-566.

Mishra, H.P. and Pandey, R.G. (1987). Effect of N and K on the seed production of okra (*Abelmoschus esculentus* L. Mill J in calcareous soil. *Indian J. Agron*., **32**(4): 425-427.

Mitchell, J. D. D. (1970). Potassium uptake by potatoes. *J. Agri. Sci*., ***74***(3): 495-500.

Mohan, K. K. and Rao, L. M. (1997). Effect of phosphorus and molybdenum on growth, nitrogen fixation and yield of soybean *Res. J. Aung Rau* .**25(4)**: 77-80.

Mohanta, H.C. (1998). Effect of phosphorus and genotype on the yield and yield contributing characters of okra (*Abelmoschus esculentus* L. Moench). Fert. Res. **6**(3): 257-267.

Mohsen A. A. M. and Abdel-fattah M. K. (2015) Effect of different levels of nitrogen and phosphorus fertilizer in combination with botanical compost on growth and yield of okra (*Abelmoschus esculentus* L.) under sandy soil conditions in Egypt. **9**(5): 249-258.

Muneerappa S. (2018). A review on okra as an antidiabetic, antioxidant and excellent energy source. *Organic and medicinal Chemistry International Journal,* **6**(1) : 18-27.

Murugan, M. (2001). Quality of chili (*Capsicum annuum* L.) variety Co-3 as influenced by levels and sources of phosphorus and levels of nitrogen. *J. Spices and Aromatic crops*, **10**(1**):** 1-5.

Naik L. B. and Srinivas K.(1992).Influence of nitrogen and phosphorus fertilizer on seed crop of okra. *Indian J. Agro.* **37**(4): 769-771.

Opena, K.J.; P. Naurijal and A. Singh (1988). Response of okra (*Abelmoschus esculentus* L. Moench,) to various levels of nitrogen, phosphorus and potassium, pp. 501-508. InterSubtropical and tropical Horticulture.

Orsini, F., Gasperi, D., Marchetti, L., Piovene, C., Draghetti, S., Ramazzotti, S. and Gianquinto, G. (2014). Exploring the production capacity of rooftop gardens (RTGs) in urban agriculture: the potential impact on food and nutrition security, biodiversity and other ecosystem services in the city of Bologna. *Food Security*, **6**(6): 781-792.

Plaster B. M. (2003). Influence of some soil amendments on insect pest infestation and damage to okra (*Abelmoschus esculentus* (L.) Moench) in Umudike, *Abia State. Res. J. Biol. Sci.,* **2**(1): 108-111

Purseglove, J. W. (1987). Tropical Crops: Dicotyledons Longman Group Ltd. *Burnt Hill*.

Rahman, H. U., Hadley, P. and Pearson, S. (2007). Relationship between temperature and cauliflower (*Brassica oleracea* L. var. botrytis) growth and development after curd initiation. Plant Growth Regulation. **52**: 61-72.

Rain, K.M. and Lal, M.L. (1999). Effect of 4 (four) fertilizer levels on the growth and development of okra cultivars (Parbhani Kranti, Arka Anamika and Pusa Sawani). *Haryana J. Hort. Sci*., **9:** 3-14.

Rashid R., M.H.B. Ahmed, M.S. Khan. (2010). Green Roof and Its Impact on Urban Environmental Sustainability: The Case in Bangladesh. *World J. Manag*. **2**(2): 59 – 69.

Rashid M. (1999). Sabjibiggan. Bangla Academy, Dhaka, p.468.

Rathi G. S., Sharma R. S. and Sachidanand B. (1993). Effect of irrigation and phosphorus levels on protein content and uptake of nutrients in field pea (*Pisum Sativum* L). J. of Soils and Crops. Jabalpur, Madhya Pradesh, India. **3**(2): 80-83.

Rhodes, C.C., G.E. Eckert, and D.C. Coleman. (2000). Soil carbon differences among forest, agriculture and secondary vegetation in lower montane Ecuador. Ecological Applications **10**(2): 497-505.

Roy, S. S., Khan, M. S. I. and Pall, K. K. (2011). Nitrogen and phosphorus efficiency on the fruit size and yield of capsicum. *J. Exp. Sci.*,**2**(1): 32-37.

Samant, B. M. and J. P. S. Yadav. 1976. Availability of phosphorus to grain as influenced by phosphatic fertilization and irrigation. *Indian J. of Agric. Sci*. **46**: 205-210

Sharma, C.B. and V. Shukla. (1973). Nature of response in okra {Abelmoschus esculentus L. Moench). To nitrogen, phosphorus and potassium applications and their economic optima. *Indian J. Agril. Sci.*, **43**(10): 930-933.

Sharma C. B. and Mann H. S. (1972) Effect of phosphate and nitrogen nutrition and seasonal variation on growth of tomato. *Indian J. Hort*. **29**(3-4): 322-329.

Shaw, W.W. Harris, L.K. and VanDruff, L. (2004) Proceedings of the 4th International Symposium on Urban Wildlife Conservation. May 1-5, 1999.

Singh K.V., Singh M.K. and Singh B. (2007). Response of macro and micronutrients on growth and yield of okra [*Abelmoschus Esculentus* (L.) Moench] cv. Pusa*Sawani. Prog. Agric.,* **7**(1-2): 63-65.

Singh H., Yadav R. R., Singh R. P.B. Reliva P. K. and Kumar A. (2018) Influence of integrated nutrient management on growth, yield and quality of okra (Abelmoschus esculentus (L.) Moench). *Plt. Arc*. **18**(1) 1144-1146.

Thakur, D.S., and Verma, K.D. (2001). Vegetable marketing in Himachal Pradesh: constraints and opportunities. *The Bihar J. Agril. Mktg*.**4**: 406-15.

Thakur M.R. and S.K. Arora. (1986). Okra. In: Vegetable Crops in India, ed. Bose T.K. and Som M.G. NayaProkash, Calcutta. P. 606.

Tiller, A. (2008). June 30. Rooftop Farms Could Feed City Slickers. Retrieved February,9,2016,fromblog.alextiller.com⟨http://blog.alextiller.com/_blog/Alex_Tiller‟s_Blog_on_Agriculture_and_Farming/post/Rooftop_Farms_Could_Feed_CitySlickers/⟩.

Torstar News Service (2015). June 8. Rooftop farming could be the next step in Toronto architecture. Retrieved February 7, 2016.

Uddin M. J., Akand M. H., Islam S., Mehraj H. and Uddin A. F. M. J. (2014). Phosphorus levels on growth and yield of Okra (Abelmoschus esculentus). *Bangladesh Res. Pub. J.* **10**(2): 120-124.

UNDP. (1998). Land Resource Appraisal of Bangladesh for Agricultural Development. Report 2: Agro-ecological Regions of Bangladesh. FAO, Rome, Italy, pp 212 and 577.

United Nations (2014). World Urbanization Prospects: The 2014 Revision. Retrieved fromesa.un.org:⟨http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf⟩.

Yadav, P., Singh, P., Yadav, R.L. and Lal, R. (2004). Ameliorative potential of organic manures and nitrogen levels on okra cv. Varsha Uphar. *Haryana J. Hort. Sci*., **33**(1-2): 124-126.

Yamaguchi, (1998). Effect of nitrogen, phosphorus and potassium on bhindi (*Abelmoschus esculentus L*. Moench/ Prog Hort.; **10**(4): 21-30 [Cited from Hort. Abstr., **50**(6): 360, 1980].

Yogesh M.D., and Arora S. K. (2001). Effect of N, P and sowing date on okra (cv. Parbhani Kranti) yield. *Indian J. Agron*., **36**(9): 81-86.

APPENDICES

Appendix I. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Madhupur Tract
Soil type	Deep red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent (%)**
Sand	45
Silt	27
Clay	28
Textural class	Sandy clay
Chemical characteristics	
Properties	**Value**
pH	5.85
Organic carbon (%)	0.46
Organic matter (%	0.75
Total nitrogen (%)	0.03
Available P (ppm)	20.88
Exchangeable K (me/100 g soil)	0.12

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix II. Monthly meteorological information during the period from October, 2020 to March, 2021

Year	Month	Air Temperature (0 c)		Relative Humidity (%)	Total Rainfall (mm)
		Maximum	Minimum		
2021	April	34.45	24.25	61	28
	May	33.65	23.21	62	36
	June	31.23	22.23	65	54
	July	30.25	18.21	64	69
	August	29.78	17.63	63	66
	September	28.56	14.43	62	52

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)