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Effect of Different Levels of Controlled Release Fertilizers on Growth, Yield and Quality of Red Okra (*Abelmoschus esculentus*) Var Kashi Lalima under Prayagraj Agro-climatic Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

About 40-70% of conventional fertilizer is wasted due to leaching causing environmental issues. Controlled release fertilizers provide a promising solution as they gradually release nutrients to match the crop's nutrient requirements, improving nutrient uptake efficiency and reducing nutrient

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losses. The Experiment was carried out During March To June 2021-22, using a randomized block design with three replications and eight treatments, including a control using the recommended dose of fertilizer (RDF). The statistical analysis of the variance showed that the use of CRF had a significant effect on the growth, yield, and quality of red okra. Among the different levels of CRF used, treatment T_7 (11g CRF/plant) performed the best in terms of growth parameters such as plant height and number of leaves. Treatment T_2 (7g CRF/plant) was found to perform the best in terms of earliness parameters. Treatment T_5 (9g CRF/plant) had the highest yield with 14.30 t/ha. Treatment T_6 (10g CRF/plant) was found to be the best for quality parameters. The highest benefit-cost ratio was recorded in treatment T_5 (9g CRF/plant) which is 4.7. From the present investigation, it is concluded that, CRF can be used efficiently for higher crop production.

Keywords: Control release fertilizer; recommended dose of fertilizer red okra; analysis of variance.

1. INTRODUCTION

Okra (*Abelmoschus esculentus L. Moench*) is an economically important vegetable crop that is widely grown in tropical and subtropical regions of the world. It is a member of the Malvaceae family and in local language referred to as bhindi, or ladies' fingers. Okra is a rich source of nutrients, including vitamins, minerals, and fiber, and has been shown to have several health benefits, such as reducing cholesterol levels, improving digestion, and boosting immunity [1,2].

However, the productivity of okra is often limited by various biotic and abiotic factors, including poor soil fertility. Fertilizer application is a common practice for enhancing soil fertility and improving crop yield. Conventionally, farmers use soluble fertilizers that are applied in one or two doses during the growing season. However, this method often results in high nutrient losses due to leaching, volatilization, and runoff, leading to reduced fertilizer use efficiency and environmental pollution [3].

Controlled release fertilizers (CRFs) are a type of fertilizer that are designed to slowly release plant nutrients over an extended period of time. They consist of a blend of nutrients and a polymer coating, which controls the rate of nutrient release. The polymer coating can be designed to break down at different rates, depending on the specific needs of the plant and the growing conditions.

CRFs have several advantages over traditional fertilizers. They can reduce the frequency of fertilizer applications, which can save time and labor costs. They can also reduce the risk of over-fertilization, which can lead to environmental pollution and plant damage. Additionally, CRFs can improve nutrient uptake efficiency, leading to higher yields and improved crop quality. The use of CRFs has been studied in a variety of crops, including rice [4], tomato [5], maize [6]. Control release fertilizers (CRFs) have gained popularity as an alternative to conventional fertilizers due to their ability to supply nutrients gradually over an extended period of time. CRFs are coated with a semi-permeable membrane that controls the rate of nutrient release, leading to better nutrient use efficiency and reduced environmental pollution [7]. The use of CRFs has been shown to improve crop yield and quality in several crops, including maize, rice, and tomato [4-6].

Red okra is a popular variety of okra that is known for its deep red color and high nutritional value. It is rich in antioxidants, including anthocyanin, which have been shown to have several health benefits, such as reducing inflammation and improving cognitive function [8]. The effect of CRF application on the growth, yield, and quality of red okra has not been well studied, especially under different agro-climatic conditions.

Therefore, the present study aimed to investigate the effect of different levels of CRF on the growth, yield, and quality of red okra under Prayagraj agro-climatic conditions. The results of this study could provide valuable information for red okra growers and contribute to the development of more sustainable and efficient fertilizer management practices

2. MATERIALS AND METHODS

The experiment was conducted at the Vegetable Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj (UP), in the year 2022-23. The

experiment was conducted on Red Okra *(Abelmoschus esculentus*) Var. Kashi Lalima with seven treatments including a control and three replications in a Randomized Block Design. The result of the investigation concerning the effect of control release fertilizers on 7 treatments, i.e., T_0 Control (RDF, 100:50:50, N:P:K) T_1 Control Release Fertilizer (5grams/plant), T_2 (Control Release Fertilizer (6grams/plant),T_3(Control Release Fertilizer (7grams/plant) T_4(Control Release Fertilizer (8grams/plant) T_5 (Control Release Fertilizer (9grams/plant) T_6 (Control Release Fertilizer (10grams/plant) T_7 (Control Release Fertilizer(11grams/plant) per plant. Composition of Control Release Fertilizer was (21:4:8 N:P:K) To find out the best performance in terms of growth, yield and quality.

2.1 Statistical Analysis

The Data recorded throughout the course of investigation was subjected to Statistical analysis by using analysis of variance (ANOVA) for randomized block design (RBD) by Fischer and Yates (1963). Whenever 'F' test was found significant for comparing the means of two treatments, a critical difference (C. D. at 5%) was worked out.

3. RESULTS AND DISCUSSION

Growth parameters: Data pertaining to growth parameters which are Plant height,(30 and 60 days) Number of Leaves(30 and 60 Days) and Days taken for 50% flowering.

3.1 Plant Height at 30 Days

There was a significant difference observed with the application of control release fertilizers on plant height at 30 days. The mean performance was recorded statistically analyzed in Table 1 and represented. The maximum plant height was recorded in treatment T_7 CRF (11 grams/plant) was used i.e. 21.50cm at 30 days, followed by 19.42cm in treatment T5 CRF (9Grams/plant) and minimum in treatment T0 (RDF) i.e. 18.33cm.

3.2 Plant Height at 60 Days

There was a significant difference observed with the application of control release fertilizers on plant height at 60 days. The mean performance was recorded and statistically analyzed in Table 1 and represented. The plant height maximum was recorded in treatment T_7 CRF(11grams/plant) i.e. 73.92cm followed by 66.83cm in T_5 CRF (9grams/plant) and Minimum plant height was recorded in T_0(RDF) i.e. 42.42cm. This is similar to the findings of Ali et al. [9].

3.3 Number of Leaves at 30 days

There was a significant difference observed with the application of control release fertilizers on number of leaves at 30 days. The mean performance was recorded and statistically analyzed in Table 1 and represented. The maximum number of leaves was recorded in treatment T_7 CRF (11grams/plant) i.e. 8.20, followed by T_5 CRF (9grams/plant) i.e. 8.01. The minimum number of leaves was recorded at 30 days was in T_0 (RDF) i.e. 6.37.

3.4 Number of Leaves at 60 Days

There was a significant difference observed with the application of control release fertilizers on number of leaves at 60 days. The mean performance was recorded and statistically analyzed represented in Table 1. The maximum number of leaves was recorded in treatment T_7 CRF (11grams/plant) i.e. 25.50, followed by T_0 (RDF) 23.33. The minimum number of leaves was recorded at 60 days was in T_5 CRF (9grams/plant) i.e. 16.92.

Study found that the application of CRF had a positive effect on the number of leaves of okra, which is similar to the findings of Jia et al. [10] and Chakraborty et al. [11] who reported an increase in the number of leaves per plant with the increase in the application rate of CRFs in sweet pepper and cucumber, respectively.

3.5 Days Taken For 50% Flowering

There was a significant difference observed with the application of control release fertilizers on Days taken for 50% flowering. The mean performance was recorded and statistically analyzed in Table 1 and also graphically represented.. The minimum of 43.50 days taken for 50% flowering in Treatment T_1 and Maximum 46.00 days taken for 50% flowering treatment T_3 followed by T_5 i.e. 45,75 days.

It can be concluded that the days taken for 50% flowering in okra can be reduced by using controlled-release fertilizers. The exact number of days taken for 50% flowering may vary depending on factors such as the type and level of controlled-release fertilizer used, environmental conditions, and other factors.

Study is similar to the results of Sharma et al. (2018) and Khan et al. [12], as both studies investigated the effect of controlled-release fertilizers on the days taken for 50% flowering in okra. The findings of study, which showed that the days taken for 50% flowering ranged from 45.50 to 46.00 days, are consistent with the findings of these studies.

Yield Parameter: Data pertaining to Yield parameters which are Number of fruits per plant, Fruit Yield Per plant, Fruit Yield Per plot, Fruit Yield Per Ha, Fruit Weight, Length, Diameter respectively.

Table 1. Effect of controlled release fertilizer on growth of Red Okra

Treatment	Plant Height at 30 days	Plant Height at 60 days	No. of Leaves at 30 days	No. of Leaves t at 60 days	Days at 50% flowering
TO RDF (100:50:50) N:P:K	18.5	50.5	6.37	23.33	43.75
T1 5g. of Control Release Fertilizer/plant (24:4:8) NPK	18.25	54	6.83	22.33	43.25
T2 6g of Control Release Fertilizer/plant (24:4:8) NPK	18.25	64	6.84	20.92	43.75
T3 7g of Control Release Fertilizer/plant (24:4:8) NPK	16.5	59.25	7.11	23.08	46
T4 8g of Control Release Fertilizer/plant (24:4:8) NPK	15.25	41.75	7.35	19.08	43.5
T5 9g of Control Release Fertilizer/Plant (24:4:8) NPK	18.75	67.25	8.01	16.92	45.75
T6 10g of Control Release Fertilizer/plant (24:4:8) NPK	17.25	61.5	7.27	21.83	43.5
T7 11g of Control Release Fertilizer/plant (24:4:8) NPK	20.75	74	8.20	25.50	44.25
F-Test	S	S	S	S	S
SE.d (+)	0.75	1.77	0.33	0.60	0.34
C.D at 5%	1.62	3.81	0.71	1.28	0.72
C.V	5.02	3.69	5.61	3.38	0.94

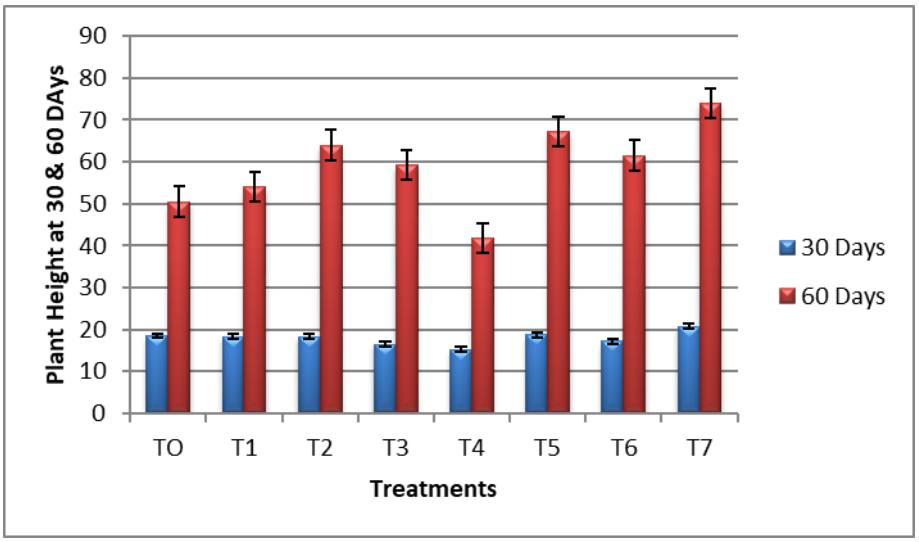

Fig. 1. Effect of controlled release fertilizer on plant height at 30 & 60 days in Red Okra

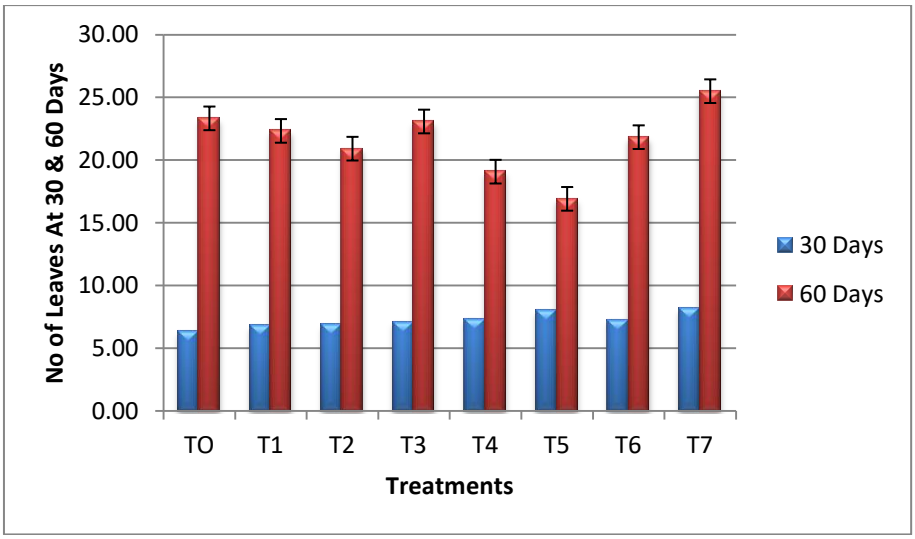

Fig. 2. Effect of controlled release fertilizer on number of leaves at 30 & 60 days Red Okra

3.6 Number of fruits per Plant

There was a significant difference observed with the application of control release fertilizers on Number of fruits per plant. The mean performance was recorded and statistically analyzed in Table 2 and also graphically represented. The maximum numbers of fruits was recorded in T_5 i.e. 18.50 fruits, Followed by T_2 i.e. 16.50 fruits and the minimum numbers of fruits was recorded in T_0 i.e. 12.75 per plant.

This increase in fruit yield due to the gradual release of nutrients from the CRF, which sustained plant growth and development over a longer period of time. Similar result was found by Singh et al. [13] found that the use of controlled-release fertilizers (CRF) significantly increased the number of fruits per plant in okra. Specifically, the treatment with the highest CRF rate resulted in a significantly higher number of fruits per plant compared to the control treatment.

3.7 Fruit Yield per Plant (g)

There was a significant difference observed with the application of control release fertilizers on

Fruit Yield per Plant. The mean performance was recorded and statistically analyzed in Table 2 and also graphically represented. The maximum fruit yield per plot was recorded in treatment T_5 i.e. 178.74 g, followed by in Treatment T_7 154.39g, and the minimum fruit yield per plot was recorded in T_0 i.e. 104.40g.

3.8 Fruits Yield per Plot (kg)

There was a significant difference observed with the application of control release fertilizers on Fruit Yield per Plot. The mean performance was recorded and statistically analyzed in Table 2 and also graphically represented. The maximum fruit yield per plot was recorded in treatment T_5 i.e. 2.11 kg, followed by T_7 1.87 kg, and the minimum fruit yield per plot was recorded in T_0 i.e. 1.21kg.

3.9 Fruit Yield per Hectare (t/ha)

There was a significant difference observed with the application of control release fertilizers on Fruit Yield Per Hectare. The mean performance was recorded and statistically analyzed in Table 2 and also graphically represented. The maximum fruit yield per hectare was recorded in treatment T_5 i.e. 14.30t/ha, followed by T_7 12.35 t/ha, and the minimum fruit yield per plot was recorded in T_0 i.e. 8.35 t/ha.

Controlled-release fertilizers release nutrients slowly and steadily over a longer period of time, which provides a continuous supply of nutrients to the plants. This ensures that the plants have access to the required nutrients throughout their growth cycle, which leads to better growth and higher yields Similar findings was observed by Singh et al. [14] & Zahoor et al. [15].

3.10 Fruit Weight (g)

There was a significant difference observed with the application of control release fertilizers on Fruit Weight (g). The mean performance was recorded and statistically analyzed in Table 3 and also graphically represented. The maximum Fruit weight was recorded in treatment T_7 i.e. 9.88g followed by T_3 9.75 g and the minimum fruit weight was recorded in treatment T_0 7.85g.

CRF could have resulted in better root development and improved nutrient uptake efficiency, which can lead to increased plant growth and yield. Moreover, the slow-release nature of CRF may also reduce nutrient losses due to leaching, volatilization or runoff, which can enhance nutrient use efficiency and ultimately lead to improved plant performance.

3.11 Fruit Length (cm)

There was a significant difference observed with the application of control release fertilizers on Fruit Length (cm). The mean performance was recorded and statistically analyzed in Table 3 and also graphically represented. The maximum Fruit length was recorded in treatment T_7 i.e. 10.47cm followed by T_6 10.23cm and the minimum fruit weight was recorded in treatment T_0 8.62cm. This result is similar to the study conducted by Chen et al. [16] on cucumber found that the use of controlled release fertilizers increased fruit length compared to conventional fertilization. The difference in fruit length between the treatments could be attributed to the variations in nutrient uptake and translocation, as well as changes in plant hormonal balance induced by the different fertilization regimes.

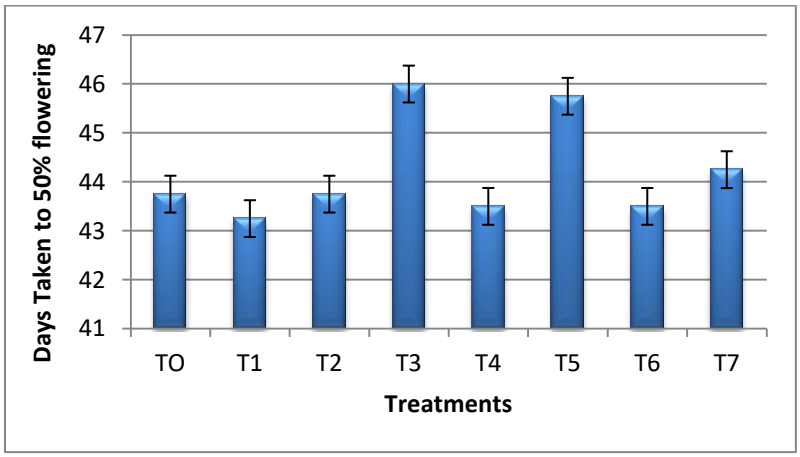

Fig. 3. Effect of controlled release fertilizer for days taken to 50% flowering in Red Okra

3.12 Fruit Diameter (cm)

There was a significant difference observed with the application of control release fertilizers on Fruit Length (cm). The mean performance was recorded and statistically analyzed in Table 3 and also graphically represented. The maximum Fruit diameter was recorded in treatment T_6 i.e. 2.17 cm followed by T_4 2.17cm and the minimum fruit diameter was recorded in treatment T_0 1.53cm.

Quality parameter: Data pertaining to quality parameter which are total soluble solids, Vitamin C, and Crude fiber content

TSS (°B): There was a significant difference observed with the application of control release fertilizers on TSS (**Brix**). The mean performance was recorded and statistically analyzed in Table 4 and also graphically represented. The maximum TSS was recorded in treatment T_6 i.e. 4.24 followed by T_3 4.20 and the minimum TSS was recorded in treatment T_0 3.80. This suggests that the use of CRF at a

Specific level can positively affect the TSS content of okra, which can impact its growth, yield, and quality.

Vitamin C (mg/100g): There was a significant difference observed with the application of control release fertilizers on Vitamin C (mg/100g). The mean performance was recorded and statistically analyzed in Table 4 and also graphically represented. The maximum Vitamin C content was recorded in treatment T_6 i.e. 13.62 (mg/100g) followed by T_5 13.48 (mg/100g) and the minimum Vitamin C content was recorded in treatment T_0 12.80(mg/100g). It is possible that the slow-release nature of the CRF provided a sustained supply of nutrients to the plants, resulting in better growth and higher Vitamin C content.

Table 2. Effect of controlled release fertilizer on yield parameter

Treatment	Number of fruits per plant	Fruit yield per plant (g)	Fruit yield per plot (kg)	Fruit yield per hectare (t/ha)
TO RDF (100:50:50) N:P:K	12.75	104.40	1.208	8.35
T1 5g. of Controlled Release Fertilizer/plant (24:4:8) NPK	13	112.71	1.365	9.01
T2 6g of Controlled Release Fertilizer/plant (24:4:8) NPK	16.5	143.40	1.663	11.20
T3 7g of Controlled Release Fertilizer/plant (24:4:8) NPK	15	142.35	1.755	11.38
T4 8g of Controlled Release Fertilizer/plant (24:4:8) NPK	13.5	128.20	1.511	10.25
T5 9g of Controlled Release Fertilizer/plant (24:4:8) NPK	18.5	178.74	2.109	14.30
T6 10g of Controlled Release Fertilizer/plant (24:4:8) NPK	15.75	152.98	1.748	12.80
T7 11g of Controlled Release Fertilizer/plant (24:4:8) NPK	15.75	154.39	1.867	13.10
F-Test	S	S	S	S
SE.d (+)	0.60	5.57	0.07	0.44
C.D at 5%	1.29	11.94	0.14	0.95
C.V	4.83	4.88	4.90	4.79

Table 3. Effect of controlled release fertilizers on Yield parameters

Treatment	Fruit Length (cm)	Fruit Weight (g)	Fruit Diameter (cm)
TO RDF (100:50:50) N:P:K	8.62	7.85	1.53
T1 5g. of Controlled Release Fertilizer/plant (24:4:8) NPK	8.97	8.75	1.63
T2 6g of Controlled Release Fertilizer/plant (24:4:8) NPK	8.65	8.4	1.72
T3 7g of Controlled Release Fertilizer/plant (24:4:8) NPK	9.42	9.75	1.94
T4 8g of Controlled Release Fertilizer/plant (24:4:8) NPK	8.98	9.33	2.17
T5 9g of Controlled Release Fertilizer/plant (24:4:8) NPK	9.11	9.5	1.91
T6 10g of Controlled Release Fertilizer/plant (24:4:8) NPK	10.23	9.25	2.20
T7 11g of Controlled Release Fertilizer/plant (24:4:8) NPK	10.47	9.88	1.96
F-Test	S	S	S
SE.d (+)	0.19	0.18	0.02
C.D at 5%	0.41	0.39	0.03
C.V	2.54	2.46	0.27

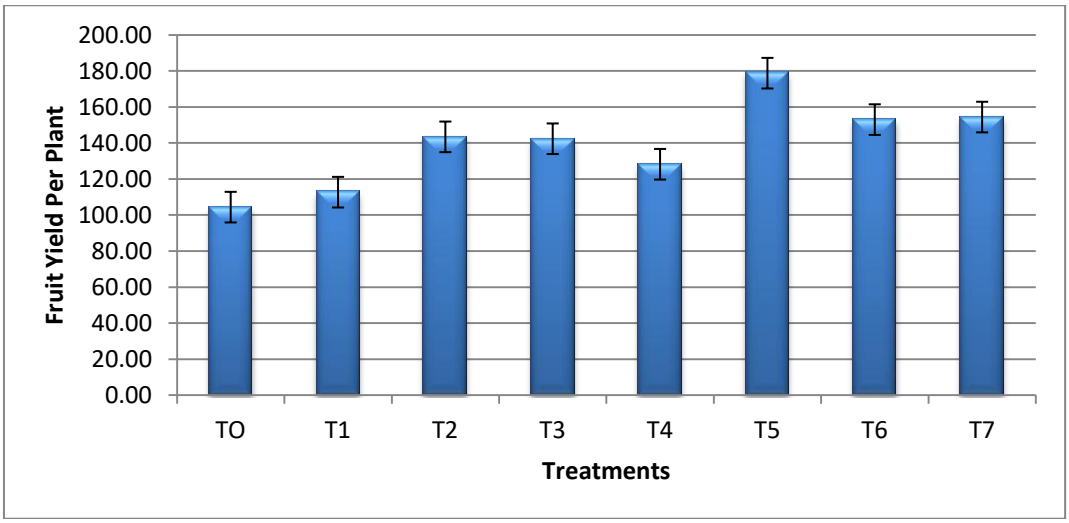

Fig. 4. Effect of controlled release fertilizer on no. of fruits per plant (g) in Red Okra

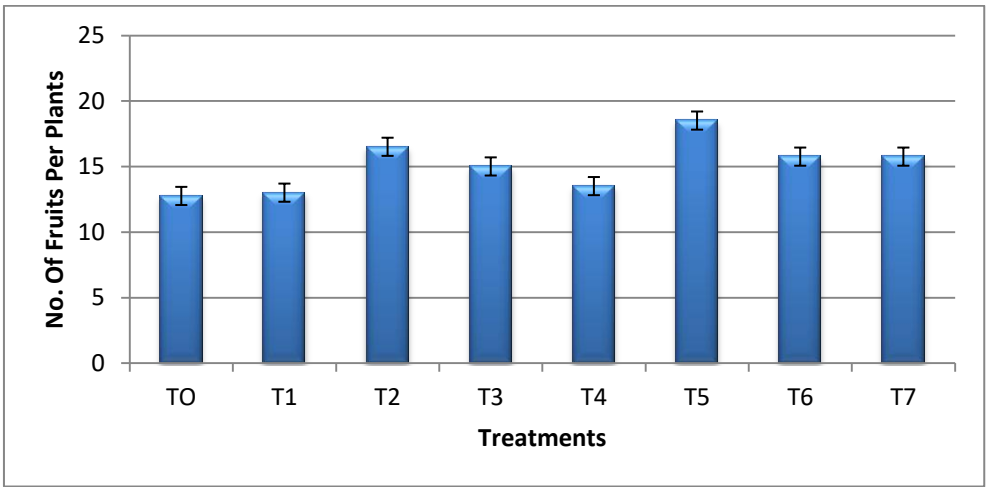

Fig. 5. Effect of controlled release fertilizer on fruit yield per plant in Red Okra

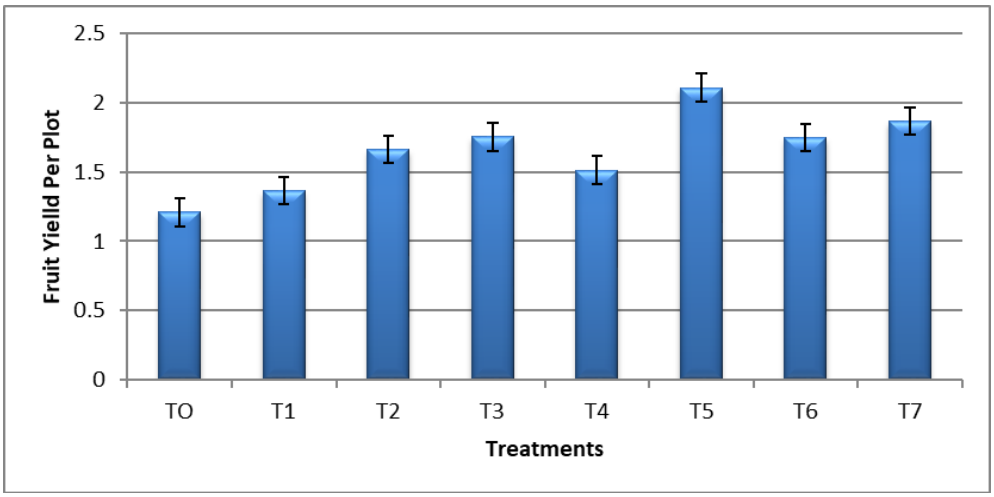

Fig. 6. Effect of controlled release fertilizer on fruit yield per plot in Red Okra

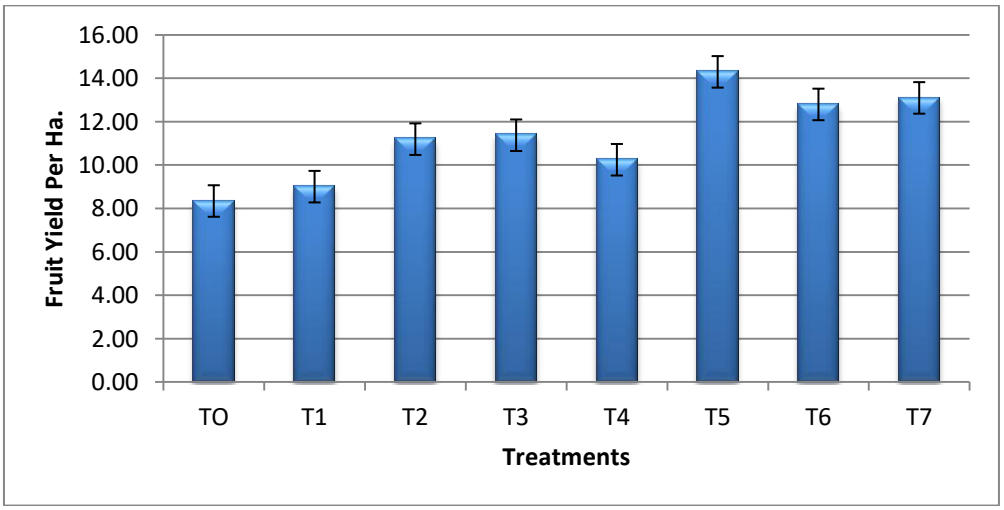

Fig. 7. Effect of controlled release fertilizer on fruit yield per (t/ha) of Red Okra

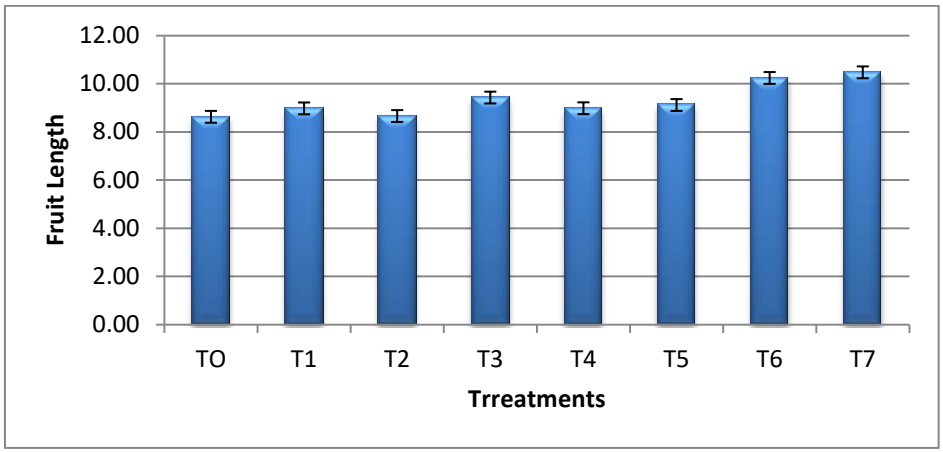

Fig. 8. Effect of controlled release fertilizer on fruit length (cm) of Red Okra

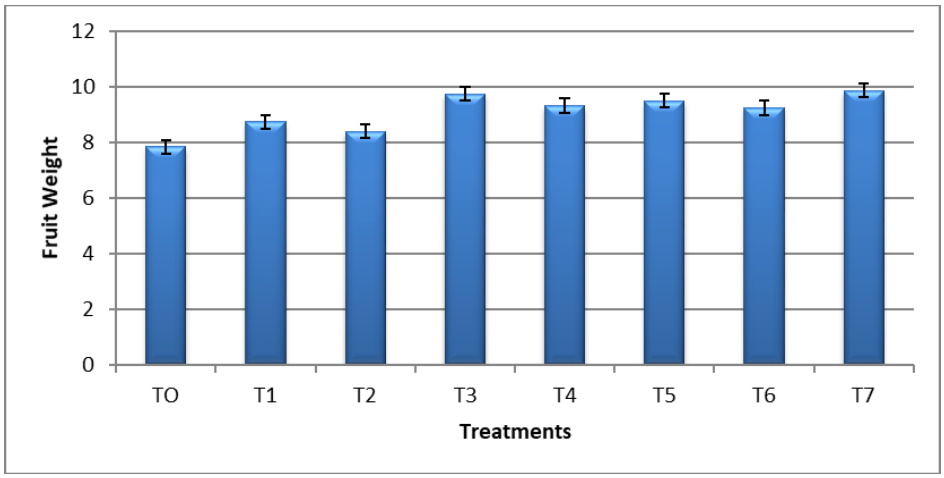

Fig. 9. Effect of controlled release fertilizer on fruit weight (g) of Red Okra

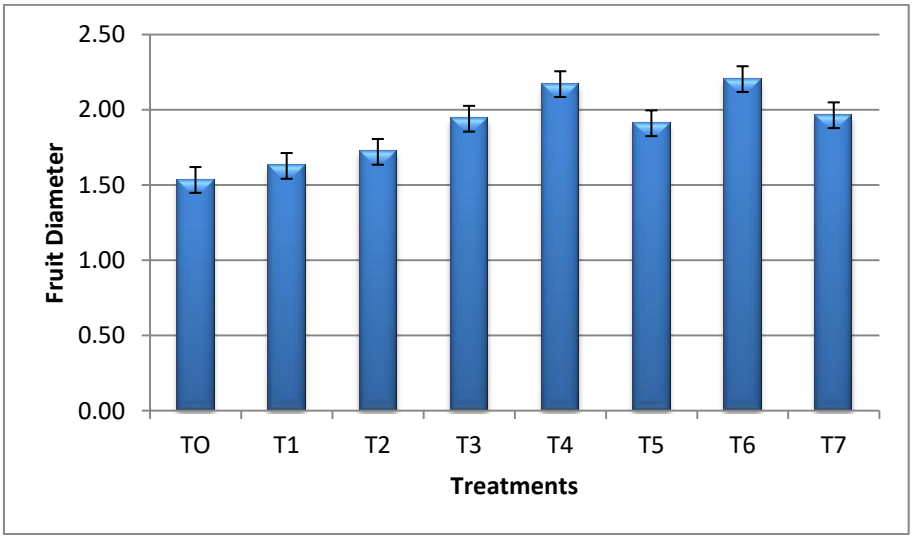

Fig. 10. Effect of controlled release fertilizer on fruit diameter of Red Okra

Crude Fiber (mg/100g): There was a significant difference observed with the application of control release fertilizers on Vitamin C (mg/100g). The mean performance was recorded and statistically analyzed in Table 4 and also graphically represented. The maximum Crude Fiber content was recorded in treatment T_6 i.e. 7.25 (mg/100g) followed by T_7 7.23 (mg/100g) and the minimum Crude fiber content was recorded in treatment T_0 7.18(mg/100g).

Table 4. Effect of controlled release fertilizers on quality parameters

Treatment	TSS	Vitamin C (mg)	Crude Fibre (mg)
TO RDF (100:50:50) N:P:K	3.80	12.80	7.18
T1 5g. of Controlled Release Fertilizer/plant (24:4:8) NPK	3.92	12.92	7.19
T2 6g of Controlled Release Fertilizer/plant (24:4:8) NPK	4.03	12.81	7.21
T3 7g of Controlled Release Fertilizer/plant (24:4:8) NPK	4.20	13.15	7.22
T4 8g of Controlled Release Fertilizer/plant (24:4:8) NPK	4.02	12.93	7.22
T5 9g of Controlled Release Fertilizer/plant (24:4:8) NPK	3.98	13.48	7.19
T6 10g of Controlled Release Fertilizer/plant (24:4:8) NPK	4.24	13.62	7.25
T7 11g of Controlled Release Fertilizer/plant (24:4:8) NPK	4.12	13.33	7.23
F-Test	S	S	S
SE.d (+)	0.03	0.18	0.02
C.D at 5%	0.07	0.39	0.03
C.V	0.99	1.70	0.27

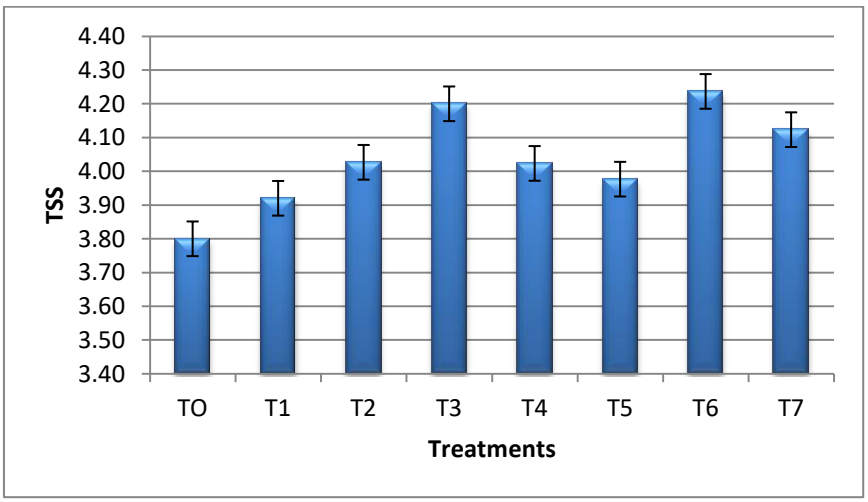

Fig. 11. Effect of controlled release fertilizers on TSS of Red Okra

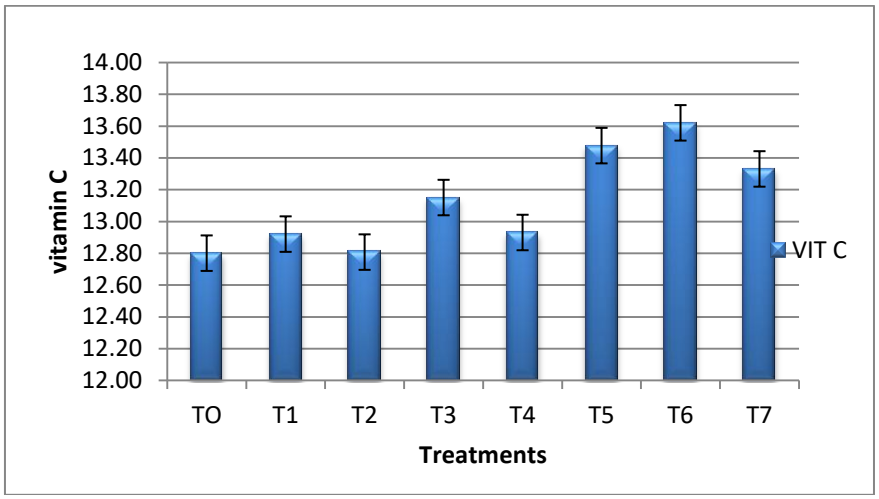

Fig. 12. Effect of controlled release fertilizer on vitamin c of Red Okra

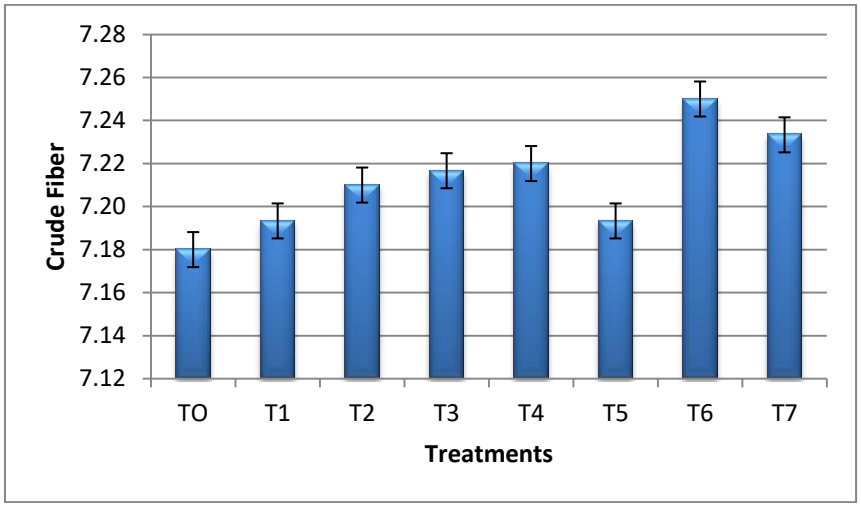

Fig. 13. Effect of controlled release fertilizer on crude fiber of Red Okra

4. CONCLUSION

From the present investigation, it is concluded that treatment T_7 performed best in terms of plant growth, however, treatment T5 gave higher yield and on the other hand treatment T6 was best in terms of quality of okra fruit. The highest benefit-cost ratio was 4.7 in treatment T5

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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