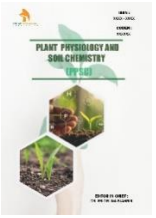
ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2805-5063 (Online)
CODEN: PPSCCU

Plant Physiology and Soil Chemistry (PPSC)

DOI: http://doi.org/10.26480/ppsc.02.2024.91.99



RESEARCH ARTICLE

EFFECT OF DIFFERENT SPACING AND SEED/STAND ON GROWTH AND YIELD OF OKRA IN KHAIRAHANI, CHITWAN, NEPAL

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ARTICLE DETAILS

Article History:

Received 15 April 2024
Revised 23 May 2024
Accepted 28 June 2024
Available online 02 July 2024

ABSTRACT

A field experiment was carried out at research farm of Rampur Campus, Khairahani, Chitwan, Nepal to investigate the combined effect of different spacing and seed/stand on the growth and yield of okra (*Abelmoschus esculentus*).The experiment was laid in randomized complete block design (RCBD) with five treatment combinations, including Broadcasting, 50*30 cm spacing + single seed/stand, 50*30 cm spacing + double seed/stand, 40*20 cm spacing + single seed/stand and 40*20 cm spacing + double seed/stand. Phenological parameters, biometrical parameters, and yield attributes were assessed, revealing noteworthy findings. The finding revealed that treatment 2 (50*30 cm spacing + single seed/stand) consistently outperformed other treatments across multiple parameters, resulting in early (38.25 DAS) flowering, highest number of branches (3) and leaves (21.12) per plant, the highest (197.6 cm^2) leaf canopy, a wider (12.22mm) stem diameter, highest (17.3) number of fruits per plant, and the highest (282.9gm) fruit yield per plant. In contrast, treatment 1 (Broadcasting) consistently exhibited the poorest performance across all parameters. Treatment 5 (40*20 cm spacing double seed/stand) demonstrated the highest (25.54 tons/hectare) total yield per hectare. While plant height, fruit length, and fruit diameter showed nonsignificant differences during statistical analysis. This finding suggests that a combination of 50*30cm spacing and a single seed /stand can be used to substantially boost okra yields and growth performance.

KEYWORDS

Okra, Spacing, Seed/stand, Growth, Yield

1. INTRODUCTION

Okra (Abelmoschus esculentus (L.) Moench) is an annual fruit bearing vegetable that is widely cultivated in tropical and warmer temperate zones around the globe (Patil et al., 2015). This species belongs to the Malvaceae family and is popular for its widespread familiarity and significant utilization (Naveed et al., 2009). The tropical African region is the native home of this crop and was first cultivated in the 12th century by Egyptians (Ibitoye and Kolawole, 2022). Okra is considered a versatile crop with multiple purposes due to its diverse applications involving fresh leaves, buds, flowers, pods, stems, and seeds(Gemede, 2015). The young and undeveloped fruits of okra, recognized as green seed pods, are commonly consumed as vegetables and can also be used as salads, soups, and stews (Ndunguru and Rajabu, 2004). In addition to their culinary applications, extracts derived from okra fruit have found diverse uses in the food and pharmaceutical sectors(Arlai et al., 2012). Okra's fruits are rich in important nutrients such as vitamins A, B, and C, as well as carbohydrates, fats, and proteins, which play key role in meeting the nutritional needs of people(Owolarafe and Shotonde, 2004). However, one of the most important problems limiting the nutritional properties of food is the presence of an anti-nutritional factor that can negatively affect the bioavailability of certain minerals such as zinc, calcium and iron(Gemede et al., 2016; Kathirvel and Kumudha, 2011).

Global production of okra is estimated at 11.2 million tons. The leading country in okra production is India with 6.8 million tones followed by Nigeria with 1.92 million tones (FAOSTAT, 2022). Okra occupies a prominent position among vegetable crops in Nepal and is widely cultivated in Jhapa, Morang, Saptari, Bara, Chitwan, Rautahat, Kailali, and Dhanusa districts of Nepal (Jha et al., 2018). In Nepal, the total production of okra in the year 2021/22 was found to be 112,260 metric tons with area of 9397 hectare (MoALD, 2022). Similarly the cultivated area of okra in Chitwan district was found to be 353 hectare with total production of 4730 metric tons and an average yield of 13.40 metric tons/hectare (MoALD, 2022).

The productivity of okra is commonly influenced by various factors, including seeding rate and the appropriate plant spacing. Achieving the right spacing is crucial to prevent intense competition among plants for essential growth elements like sunlight, water, space, and nutrients. As the number of plants per area increases, the yield per unit area rises up to a certain threshold. However, once this limit is surpassed, the available resources for each plant become insufficient, leading to a decline in yield (Khanal et al., 2020). Appropriate plant spacing varies from one situation to another situation and plant population for okra differs from 30,000 to 120,000 plants per hectare depending on variety and other practices (Paththinige et al., 2008). Furthermore, it has been documented that achieving an optimal plant population holds the pivotal role in attaining increased yields. This is due to the fact that both the growth of plants and their overall yield are influenced by the inter and intra row spacing (Muhammad et al., 1999). Similarly, adequate number of plants/stands is required for better growth and yield of okra. The number of seeds sown per unit area directly affects the density of plants and subsequently affects their development and productivity(Yohanna and Muhammad, 2018).

Quick Response Code	Access this article online	
	Website: www.ppsc.org.my	**DOI:** 10.26480/ppsc.02.2024.91.99

Cite The Article: Sadikshya Khanal and Shankar Subedi (2024). Effect of Different Spacing and Seed/Stand on Growth and Yield of Okra in Khairahani, Chitwan, Nepal. *Plant Physiology and Soil Chemistry, 4(2): 91-99.*

This experiment therefore aims to investigate the effects of spacing and seed/stand on growth and yield of okra, providing insights that can inform agronomic practices and improve production efficiency.

2. METHODOLOGY (MATERIALS AND METHODS)

The detail explanation of materials and methods used during research are described below in following headings:

2.1 Description of experimental site:

2.1.1 Geographical location

The experiment was conducted at the Rampur Campus Research Farm in Chitwan, a district of Bagmati province, Nepal. The research was conducted on a specially irrigated lowland known as "khet land", where the soil is mostly sandy loam. The field area is located in central Nepal at 27.6198 'N and 84.5746 ' E at an altitude of 199masl.

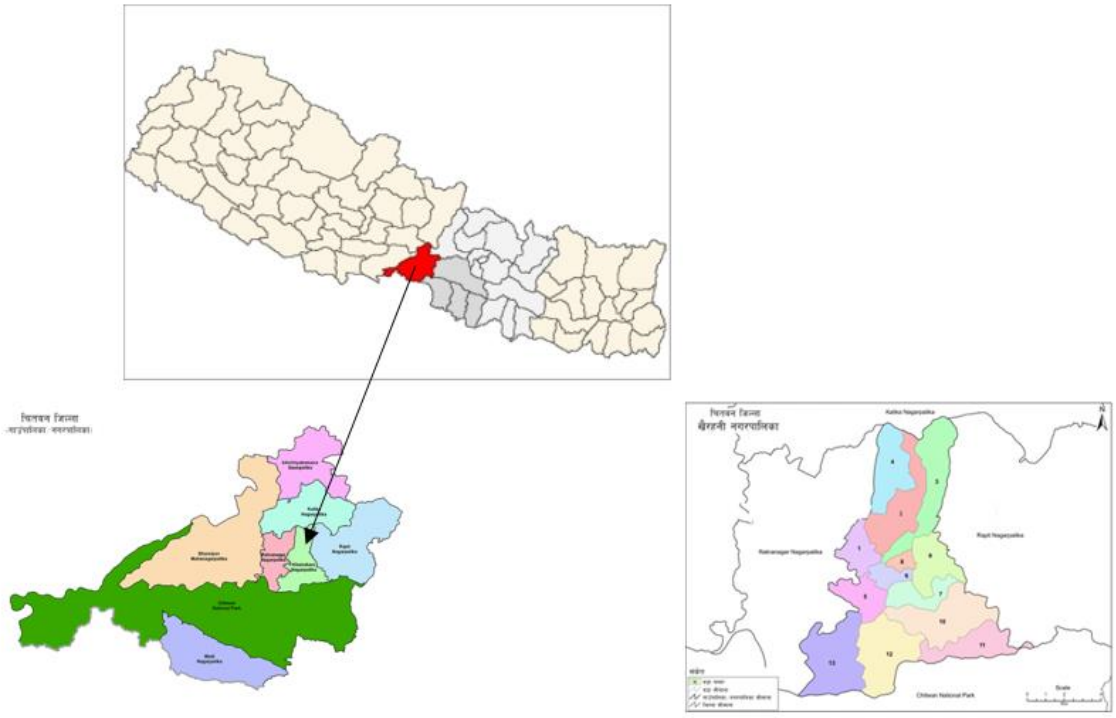

Figure 1: Map of Experimental site

2.1.2 Climatic condition during experimentation

The experimental site is located in the subtropical humid region of Nepal, which has three clearly defined seasons: the monsoon season (June to October), the winter season (November to February), and the spring season (March to May). The figure below illustrated weather data collected during the cropping season from March to June.

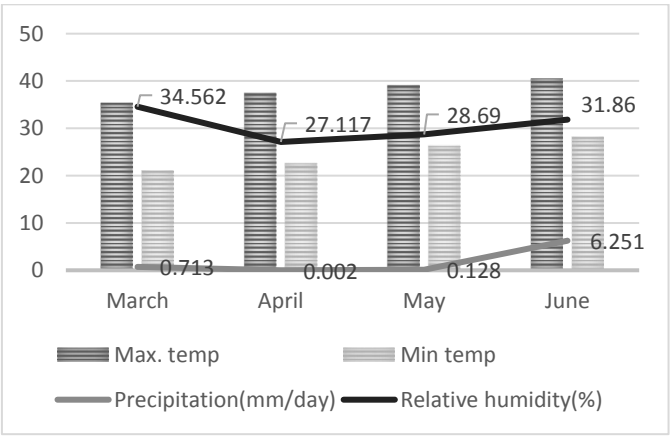

Figure 2: Climatic data during research period

(Source: NASA GISS,2023)

2.2 Cropping History

Research was conducted in low land condition with rice as a main crop. The experimental site was under cabbage cultivation prior to this experiment.

2.3 Experimental design

The experiment was conducted in randomized complete block design (RCBD) with 5 numbers of treatments and 4 replications. The entire field was divided into four blocks with 5 treatments in each. All together there were 20 individual plots. Individual plots were 2 m in length and 1.8m in breadth with net experimental plot area of 3.6m^2. The plot–plot spacing was 50 cm and block-block spacing was also 50 cm, thus total area for research was 104.4m^2.

2.4 Treatment details

Treatments consist of combination of spacing and seed/stand. The treatments are given in table below:

Table 1: Different treatments applied in the experiment

S. N	Treatments	Notation
1.	Broadcasting	T_1
2.	50*30cm spacing + single seed/stand	T_2
3.	50*30 cm spacing +double seed/stand	T_3
4.	40*20 cm spacing + single seed/stand	T_4
5.	40*20 cm spacing + double seed/stand	T_5

2.5 Crop Variety

Arka Anamika variety of okra was selected for research which is recognized as a promising okra variety recommended for cultivation in all three geographical regions of Nepal. This variety is selected due to its special character of resistant to Yellow Mosaic Virus (YMV) which was created at the Indian Institute of Horticulture Research in Banglore (Ram,1997).

2.6 Cultural operations

2.6.1 Seed priming

In order to improve the uniformity and speed of germination, increase seedling emergence, and promote early crop establishment, okra seeds were soaked in lukewarm distilled water (24 hours) which is followed by drying in the shade for 6 hours.

2.6.2 Field Preparation

The field was ploughed to fine tilth by giving two thorough ploughing within sufficient interval. For proper levelling, planking was done. The field was then separated into beds and waterways.

2.6.3 Manure and Fertilizer application

FYM was applied at the rate of 12 tons per hectare (4.32kg/plot) and chemical fertilizers Urea, DAP and MOP were applied at the rate of 6kg/ropani(42.46g/plot), 4kg/ropani (28.30g/plot) and 2kg/ropani (14.15g/plot) respectively. Half of the urea was applied in basal dose and remaining half was applied 30 and 45 days after sowing.

2.6.4 Seed sowing

The seeds were sown on March 16, 2023 with different row spacing and seed per stand as per the treatment.

2.6.5 Irrigation

Irrigation was done as per the requirement, usually every 10-12 days.

2.6.6 Weed management

For higher yields, the crop should be weed free up to the 25-30day crop stage. Weeding was done at 30 and 60 days after sowing.

2.6.7 Plant protection measures

In order to safeguard the plants from the seedling disease known as damping off, a fungicide containing Metalaxyl 8% and Mancozeb 64% in wettable powder (W.P.) form was applied. This fungicide was sprayed at a rate of 2.5 grams per liter of solution when the initial signs of the disease were observed in the experimental field. Additionally, to manage insect-related issues, an insecticide was also utilized.

2.6.8 Harvesting

The first harvesting was done 51 days after sowing on May 7, 2023, A total of 9 harvests were made at 4 days interval. Harvesting was done using simple picking method and various observations were taken.

2.7 Parameters under study

5 plants were selected from each plot as a sample plant and tagged. All the observations were recorded from these selected sample plants.

2.7.1 Phenological observations

2.7.1.1 Days to first flowering

The day when the first flower was noticed was considered as days to first flowering.

2.7.1.2 Days to 50% flowering

The day when 50% of total okra plants in a plot flowered was recorded as days to 50% flowering.

2.7.2 Biometrical observations

2.7.2.1 Plant height

Plant height was measured from ground surface to the top of the longest leaf at 30, 40 and 50 DAS through ordinary meter scale. Data was collected from selected sample plant.

2.7.2.2 No of leaves per plant

The number of leaves per plants were recorded by counting from the sample plants in a plot.

2.7.2.3 Number of primary branches per plant

The number of primary branches were recorded by counting from the sample plants in a plot from each plot at 40 and 50 DAS.

2.7.2.4 Leaf canopy(cm^2)

Data was collected with the help of measuring scale by measuring length and breadth of leaves from sample plants.

2.7.2.5 Stem Diameter

Stem diameter of sample plants were measured by verniar calipar at 30,40 and 50DAS.

2.7.3 Observations for yield and yield attributing characteristics

2.7.3.1 Number of fruits per plant

The number of fruits per plant was recorded by counting total number of fruits from the sample plants in a plot divided by 5 i.e. number of sample plant.

2.7.3.2 Number of marketable fruits per plant

The number of marketable fruits per plant was recorded by counting number of marketable fruits in a sample plants and taking average of it.

2.7.3.3 Number of non-marketable fruit per plant

The number of non-marketable fruits per plant was recorded by counting number of non-marketable fruits in a sample plants and taking average of it.

2.7.3.4 Average fruit weight (gm)

The average fruit weight was recorded by dividing total fruits weight of sample plant by number of fruits in 5 sample plants.

2.7.3.5 Fruit length (cm)

The length of 10 okra fruits from sample plants were recorded by ordinary meter scale at each harvest.

2.7.3.6 Fruit girth (mm)

Fruit girth of 10 randomly selected fruits from sample plants were measured by using Vernier Caliper.

2.7.3.7 Yield per plant

The total yield produced by sample plants was divided by number of sample plants i.e 5 to obtain yield per plant.

2.7.3.8 Total fruit yield (tons/ha)

The total yield was obtained by recording total weight of fruits in net plot excluding border plants and was converted into tons per hectare.

2.8 Statistical analysis

Data were systematically arranged on the basis of various observed parameters. Different statistical tools as MS-EXCEL and GENSTAT 18 EDITION were used for the ANOVA test and DMRT analysis of variance and other data analysis. Analysis was done at 5% level of significance.

3. Result and Discussion

This chapter encompasses the analysis and presentation of the experimental findings, supplemented with relevant figures and tables when seems essential. An effort has been undertaken to assess the outcomes obtained and provide explanations, supported by available evidence, wherever feasible, to evaluate the observed variations in the mentioned parameters.

3.1 Phenological parameter

3.1.1 Days to 1st flowering

There was significant difference between days to 1st flowering of the different spacing and seed/stand used. The result shows that T_2 i.e. 50*30 cm spacing + single seed /stand flowered early i.e just within 38.25 days which is followed by T_4 i.e 40*20cm spacing + single seed /stand (39.25 days).The treatment 3 i.e 50*30cm spacing + double seed /stand (40.75 days) and treatment 5 i.e 40*20cm spacing + double seed /stand (41 days) are statistically at par.

Days to first flowering were at last observed for T_1 i.e. broadcasting (42.5 days). The difference in days to first flowering may be due to resource availability (eg. light, nutrients, water), competition between plants and overall growing conditions. Wider spacing and seed/stand configurations generally allowed individual plants to access resources more efficiently, resulting in earlier flowering allowed individual plants to access resources more efficiently, resulting in earlier flowering. This result is in line with GHOSH & JANA (2022) who revealed that wider spacing results in earlier days to first flowering and vice versa.

3.1.2 Days to 50% flowering

Table below shows that the days to 50% flowering was significantly influenced by different spacing and seed/stand with T_2(50*30 cm spacing

+ single seed/stand) first attaining 50% flowering just within 40.25 days which is followed by T_4 (40*20 cm spacing + single seed /stand) i.e. 41.75days.The treatment 3 (50*30cm spacing + double seed /stand) and treatment 5 (40*20cm spacing + double seed /stand) are statistically at par. The longest days to 50% flowering (46 days) was observed in treatment 1 (Broadcasting). Similar result was obtained in the report of (J, A. & A, M., 2018) which reported the significant influence of seed/stand on days to 50% flowering of okra plant. The result has shown that okra planted at one seed/stand attain 50% flowering earlier(36DAS) while okra planted at two seed/stand attain 50% flowering later (38DAS). This result also contradicts with the report of Kochar (1986).

Table 2: Phenological parameters of okra in response to different spacing and seed/stand

Treatments	Days to 1st flowering	Days to 50% flowering
T_1 (Broadcasting)	42.5[d]	46[d]
T_2 (50*30cm spacing + single seed /stand)	38.25[a]	40.25[a]
T_3 (50*30cm spacing + double seed /stand)	40.75[c]	44.25[c]
T_4 (40*20cm spacing + single seed /stand)	39.25[b]	41.75[b]
T_5 (40*20cm spacing + double seed /stand)	41[c]	44.25[c]
Grand Mean	40.35	43.3
F value	***	***
LSD (0.05)	0.878	0.796
CV (%)	1.4	1.2
Sem (±)	0.285	0.258

Note: CV=Coefficient of variance, SEM=Standard Error of Means, LSD= Least Significant Difference, Means separated by DMRT and column represented with same letters are not significant at 5% level of significance

3.2 Biometrical parameters

3.2.1 Plant Height

The findings indicate that none of the various combinations of spacing and seed/stand demonstrated a significant impact on plant height at 30, 40, and 50 days after sowing (DAS). Nevertheless, there were observable differences in plant height. At 30 DAS, tallest plant(18.72cm) was observed in treatment 1 (Broadcasting) while smallest plant height (17.12cm) was observed in treatment 3 (50*30cm spacing + double seed /stand). All the treatments were statistically at par with each other. At 40 DAS, tallest plant (31.12cm) was observed in treatment 3(50*30cm spacing + double seed /stand) which was statistically at par with all the treatments except broadcasting. The smallest plant (26.33cm) was observed in treatment 1 (Broadcasting). At 50DAS tallest plant (53.11cm) and smallest plant (47.30cm) was observed in treatment 3 (50*30cm spacing + double seed /stand) and treatment 1 (broadcasting) respectively. However, all the treatments were found to be statistically at par at 5% level of significance.

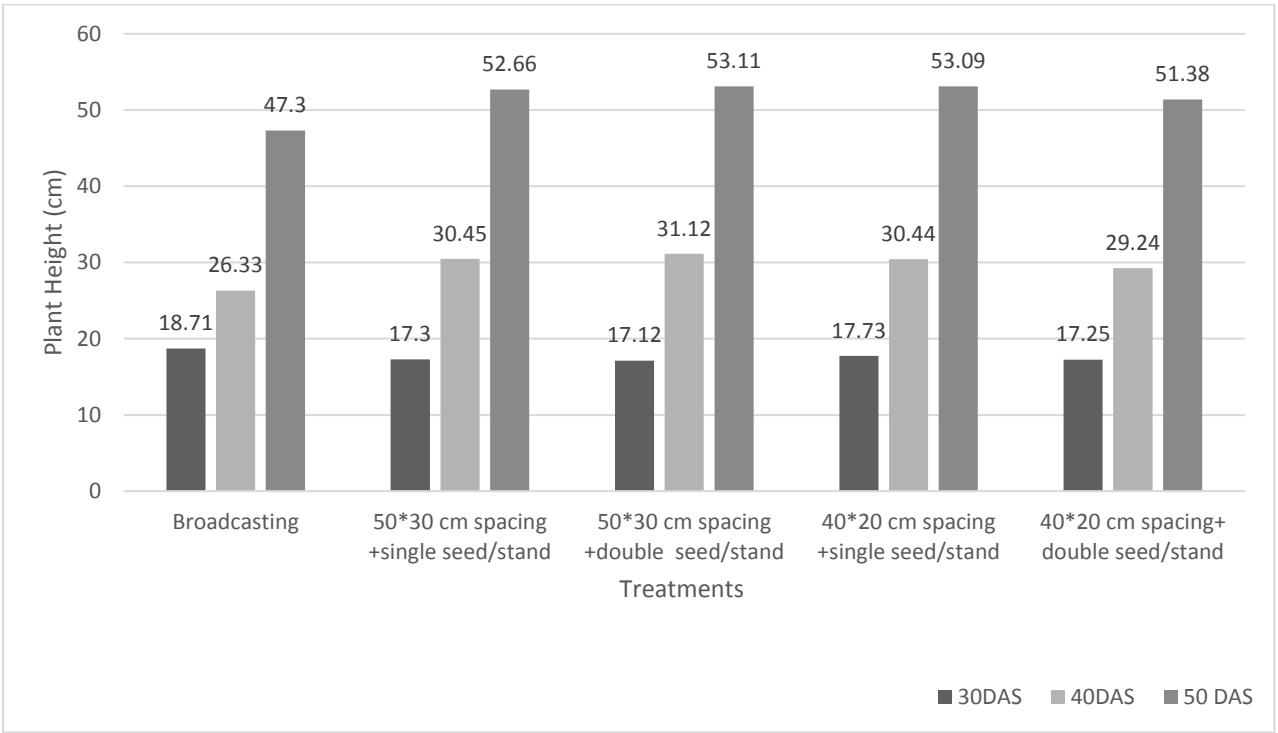

Figure 3: Plant height of okra in response to different spacing and seed/stand

This non-significant result might be due to availability of ample amount of light during research period which result in no competition among okra plant of different combinations of spacing and seed/stand. The finding of this research is in agreement with the finding of (Lamichhane et al., 2021). A researcher in 2013 who observed non-significant impact on plant height while working on Arka Anamika variety (Shrestha, 2013). Similar finding was obtained in (Jha et al., 2018). This result is in contrast with the finding of researchers in 2020 which showed that maximum plant height obtained in lower spacing and vice versa (Khanal et al., 2020).

3.2.2 No. of branches per plant

The different combination of spacing and seed/stand had significant influence on number of branches per plant at 40DAS and 50DAS. At 40DAS the highest number of branches per plant (2.85,) was recorded in combination of 50*30 cm spacing and single seed/stand followed by 40*20 cm spacing +single seed/stand having branch number of 2.2. The smallest number of branches per plant (1.3) was observed in treatment 1 i.e. broadcasting.

Table 3: Effect of different spacing and seed/stand on no. of branches per plant of Okra		
Treatments	**No. of branches per plant**	
	40 DAS	50DAS
Broadcasting	1.3[a]	2[a]
50*30cm spacing + single seed /stand	2.85[d]	3[b]
50*30cm spacing + double seed /stand	1.55[ab]	2.55[ab]
40*20cm spacing + single seed /stand	2.2[c]	2.85[b]
40*20cm spacing + double seed /stand	1.8[bc]	1.95[a]
Grand Mean	1.94	2.47
F value	***	*
LSD $_{(0.05)}$	0.42	0.6369
CV (%)	14.1	16.8
Sem (±)	0.1363	0.2076

Note: CV=Coefficient of variance, SEM=Standard Error of Means, LSD= Least Significant Difference, Means separated by DMRT and column represented with same letters are not significant at 5% level of significance

At 50DAS, the highest number of branches (3) was found in T_2 (50*30cm spacing + single seed /stand) which is followed by T_4 (40*20cm spacing + single seed /stand) having branch number of 2.85. The lowest number of branch (1.95) was found in T_5 (40*20cm spacing + double seed /stand) which is statistically at par with T_1 (Broadcasting). Okra at the wider space have maximum exposure to sunlight for the process of photosynthesis ,increased photosynthesis lead to increasing the plant growth, biomass and the number of branches per plant(Idoko et al., 2018). This result was in agreement with the finding of (Maurya, 2013) who reported that number of branches per plant increases with wider spacing and vice versa and also agreement with (J, A. & A, M., 2018) and (Agba et al., 2011) .

3.2.3 Leaf Canopy

The table below shows that there was significant difference among different combinations of spacing and seed/stand on leaf canopy of okra at 30,40 and 50 DAS. The highest leaf canopy was found in 50*30 cm spacing +single seed/stand i.e 38.18cm^2, 75.41cm^2 and 197.6cm^2 respectively at 30,40 and 50DAS which was followed by 40*20cm spacing +single seed /stand (30.05cm^2, 71.53cm^2 and 189.2cm^2). The shortest leaf canopy was measured in broadcasting (22.57cm^2 ,49.27cm^2 and 125.4 cm^2) at 30,40 and 50 DAS. This result might be due to as row spacing increases plants are more exposed to sunlight and competition for nutrient is reduced resulting in higher leaf canopy (López-Bellido et al,2003). This is also concluded by Maurya (2013), Caliskan et al. (2004), Levy et al. (1985) and Osei Bonsu (1975).

Table 4: Effect of different spacing and seed/stand on leaf canopy of Okra			
Treatments		**Leaf Canopy (cm^2)**	
	30DAS	40DAS	50DAS
T_1 (Broadcasting)	22.57[a]	49.27[a]	125.4[a]
T_2 (50*30cm spacing +single seed /stand)	38.18[b]	75.41[b]	197.6[c]
T_3 (50*30cm spacing +double seed /stand)	29.64[a]	65.32[b]	180.6[bc]
T_4 (40*20cm spacing +single seed /stand)	30.05[a]	71.53[b]	189.2[c]
T_5 (40*20cm spacing +double seed /stand)	27.55a	61.34[ab]	149.2[ab]
Grand Mean	29.6	64.6	168.4
F test	*	*	*
LSD $_{(0.05)}$	7.9	14.58	34.43
CV (%)	17.3	14.7	13.3
Sem (±)	2.56	4.73	11.17

Note: CV=Coefficient of variance, SEM=Standard Error of Means, LSD= Least Significant Difference, Means separated by DMRT and column represented with same letters are not significant at 5% level of significance

3.2.4 Number of leaves per plant

The table below indicates that the different combinations of spacing and seed/stand had statistically significant difference on number of leaves per plant at different growth stages (30, 40 and 50 DAS). The results show that Treatment 2 (50x30cm spacing with a single seed per stand) consistently produced the highest number of leaves across all growth stages (6.350, 12.650 and 21.12 at 30, 40 and 50 DAS respectively) which is followed by 40*20cm spacing +single seed /stand (5.925, 10.5 and 17.05). The lowest leaf number was observed in 40*20cm spacing +double seed /stand at all growth stages (5.3,9.05 and 13.80). This might be due to as the plant population decreased and as the row spacing increased vegetative growth and development of branches per plant increased as a result more number of leaves per plant(Lakew et al., 2018).

Reduced competition for light, nutrients, and space between neighbouring okra plants allowed each plant to devote more energy to extensive branching, resulting in a greater number of leaves Maurya, (2013). These findings are also in line with the findings of (Jha et al., 2018).

Table 5: Effect of different spacing and seed/stand on number of leaves per plant.			
Treatments		**Leaf Number**	
	30DAS	40DAS	50DAS
T1 (Broadcasting)	4.750[a]	8.250[a]	13.47[a]
T_2 (50*30 cm spacing + single seed/stand)	6.350[c]	12.650[c]	21.12[c]
T_3 (50*30 cm spacing + double seed/stand)	5.600[b]	9.450[ab]	14.95[ab]
T_4 (40*20 cm spacing + single seed/stand)	5.925[bc]	10.500[b]	17.05[b]
T_5 (40*20 cm spacing + double seed/stand)	5.300[ab]	9.050[a]	13.80[a]
Grand Mean	5.585	9.98	16.08
F test	**	***	***
LSD $_{(0.05)}$	0.6539	1.355	2.867
CV (%)	7.6	8.8	11.6
Sem (±)	0.2122	0.440	0.930

Note: CV=Coefficient of variance, SEM=Standard Error of Means, LSD= Least Significant Difference, Means separated by DMRT and column represented with same letters are not significant at 5% level of significance

3.2.5 Stem diameter

This table shows the results of an experiment examining the stem diameter of okra plants at three different growth stages (30, 40 and 50 DAS) with five different spacing and seed/stand treatment combinations. A different combination of spacing and seed/stand had a very significant effect on stem diameter at an early stage (30DAS and 40DAS), while a relatively less significant difference was observed at a later stage (50DAS).

Treatment 2(50*30cm spacing +single seed /stand) consistently produced the widest stem diameters across all three growth stages, with values of 4.583mm, 8.408mm, and 12.22mm at 30DAS, 40DAS, and 50DAS, respectively. In contrast, Treatment 1(Broadcasting) consistently had the narrowest stem diameters (4.750 mm,8.250 mm and 13.47mm respectively). The wider spacing and single-seed approach of treatment 2 probably promoted better resource availability, reduced competition and promoted healthier root and stem diameter compared to the other treatments. This result is in line with the observation of Maurya, (2013) which resulted in a wider stem diameter of okra plants planted with greater inter-row spacing, while this result contradicts the observation of Jha et al., (2018) which showed a non-significant effect on stem diameter due to different spacing.

Table 6: Effect of different spacing and seed/stand on stem diameter of okra

Treatments	Stem Diameter (mm)		
	30DAS	40DAS	50DAS
T_1 (Broadcasting)	3.458^{a}	5.295^{a}	8.37^{a}
T_2 (50*30cm spacing +single seed /stand)	4.583^{c}	8.408^{c}	12.22^{c}
T_3 (50*30cm spacing +double seed /stand)	3.950^{b}	6.405^{ab}	10.34^{b}
T_4 (40*20cm spacing +single seed /stand)	4.460^{c}	7.288^{bc}	12.21^{c}
T_5 (40*20cm spacing +double seed /stand)	3.528^{ab}	6.250^{ab}	9.42^{ab}
Grand Mean	3.99	6.73	10.51
F value	***	***	***
LSD $_{(0.05)}$	0.456	1.150	1.221
CV (%)	7.4	11.1	7.5
Sem (±)	0.148	0.528	0.396

Note: CV=Coefficient of variance, SEM=Standard Error of Means, LSD= Least Significant Difference, Means separated by DMRT and column represented with same letters are not significant at 5% level of significance

3.3 Yield and yield attributing parameters

3.3.1 Number of fruits per plant

The results of an experiment that examined the number of fruits per plant across different treatment combinations of spacing and seed/stand is given in table below. Statistical analysis revealed highly significant differences in fruit yield among the treatments. The highest number of fruits per plant (17.3) was observed in treatment 2(50*30cm spacing +single seed /stand) which is followed by 40*20cm spacing +single seed /stand (16.52). The treatment 2 is statistically similar with treatment 3 (50*30cm spacing +double seed /stand) and 4 (40*20cm spacing +single seed /stand). The lowest number of fruits per plant (9.75) was observed in treatment 1 (broadcasting). Plants subjected to wider spacing had the advantage of encountering less competition for water and sunlight in comparison to those planted closely together.

This favorable condition encouraged lateral growth of the plants, resulting in formation of many lateral branches. Consequently, these wider spacing increases the number of fruits produced per plant(Paththinige et al., 2008). These results were in close agreement with the finding of previous researchers (Muhammad et al., 1999). They documented that as plant spacing increased, the number of green pods per individual plant increased accordingly.

3.3.2 Marketable fruits per plant

The data indicates that different combinations of spacing and seed/stand had highly significant difference on marketable fruits per plant. Treatment 2 (50*30cm spacing + single seed/stand) resulted in the highest number of marketable fruits per plant compared to the other treatments. With an average of 12.85 marketable fruits per plant, Treatment 2 significantly outperformed all other treatments. This suggests that the specific spacing and planting method used in Treatment 2 were particularly effective in promoting the production of fruits that met marketable standards. Treatment 3 (50*30cm spacing + double seed/stand) also showed a respectable number of marketable fruits per plant, with an average of 11.95, although it was slightly lower than Treatment 2. On the other hand, Treatment 1 (Broadcasting) had the lowest number of marketable fruits per plant at 7.55, indicating that this particular planting method was less conducive to producing fruits meeting market standards.

3.3.3 Non-marketable fruits per plant

The table below shows that different combinations of spacing and seed/stand had significant difference on non-marketable fruits per plant. The treatment 2(50*30cm spacing +single seed /stand) had highest number of non-marketable fruits per plant (4.525) which is statistically at par with all other treatments except broadcasting. The lowest number of non-marketable fruits per plant was observed in broadcasting.

3.3.4 Yield/plant (gm)

The data on yield per plant are presented in below table, which indicated the highly significance difference in yield per plant due to various combinations of spacing and seed/stand. Among the various treatments tested, Treatment 2, characterized by a planting arrangement of 50 *30cm spacing and single seed per stand, emerged as the most effective in terms of yield per plant. With an impressive average yield of 282.9 grams per plant, Treatment 2 significantly outperformed all other treatments. This finding highlights the importance of proper spacing and single seeding, which appear to be conducive to maximizing crop productivity. In contrast, Treatment 5, involving 40 *20cm spacing and double seed per stand, resulted in the lowest yield per plant at 227.4 grams. Similar finding was resulted by Panthinige et al. (2008) who reported highest yield per plant of okra on wider row spacing. Other supporting evidences were reported by Muhammad et al. (1999); Singh (1990); Mondal, G &Mallik, S.C (1990) and Klassen (2005).

Table 7: Effect of different spacing and seed/stand on yield and yield attributing characters of okra

Treatments	Number of fresh fruits/plant	M/plant	NM/Plant	Yield/plant(gm)
T_1 (Broadcasting)	9.75^{a}	7.55^{a}	2.20^{a}	149.2^{a}
T_2 (50*30cm spacing +single seed /stand)	17.3^{c}	12.85^{c}	4.525^{b}	282.9^{c}
T_3 (50*30cm spacing +double seed /stand)	15.70^{c}	11.95^{c}	4.20^{b}	279.7^{c}
T_4 (40*20cm spacing +single seed /stand)	16.52^{c}	12.73^{c}	3.875^{b}	270.5^{bc}
T_5(40*20cmspacing +double seed /stand)	13.65^{b}	9.80^{b}	3.850^{b}	227.4^{b}
Grand Mean	14.60	10.98	3.73	241.9
F test	***	***	*	***
LSD $_{(0.05)}$	1.603	1.504	1.517	43.46
CV (%)	7.1	8.9	26.4	11.7
Sem (±)	0.520	0.488	0.492	14.10

Note: M= Marketable fruit, NM= Non-marketable fruit, CV=Coefficient of variance, SEM=Standard Error of Means, LSD= Least Significant Difference, Means separated by DMRT and column represented with same letters are not significant at 5% level of significance

3.3.5 Fruit length (cm)

The data on fruit length (up to 9 picking) is presented in table below which indicated statistically non-significant difference in the fruit length among different combinations of spacing and seed/stand at 5% level of significance with LSD of 0.979. Inspite of non-significance difference Treatment 2, characterized by 50*30cm spacing and single seed per stand, resulted in the longest average fruit length, measuring 13.96 cm. Conversely, Treatment 1 (Broadcasting) produced fruits with the shortest average length at 12.70 cm. The grand mean for fruit length across all treatments was calculated at 13.46 cm. The observed differences in fruit length among treatments likely result from variations in planting density, nutrient availability, or other cultivation practices unique to each treatment.

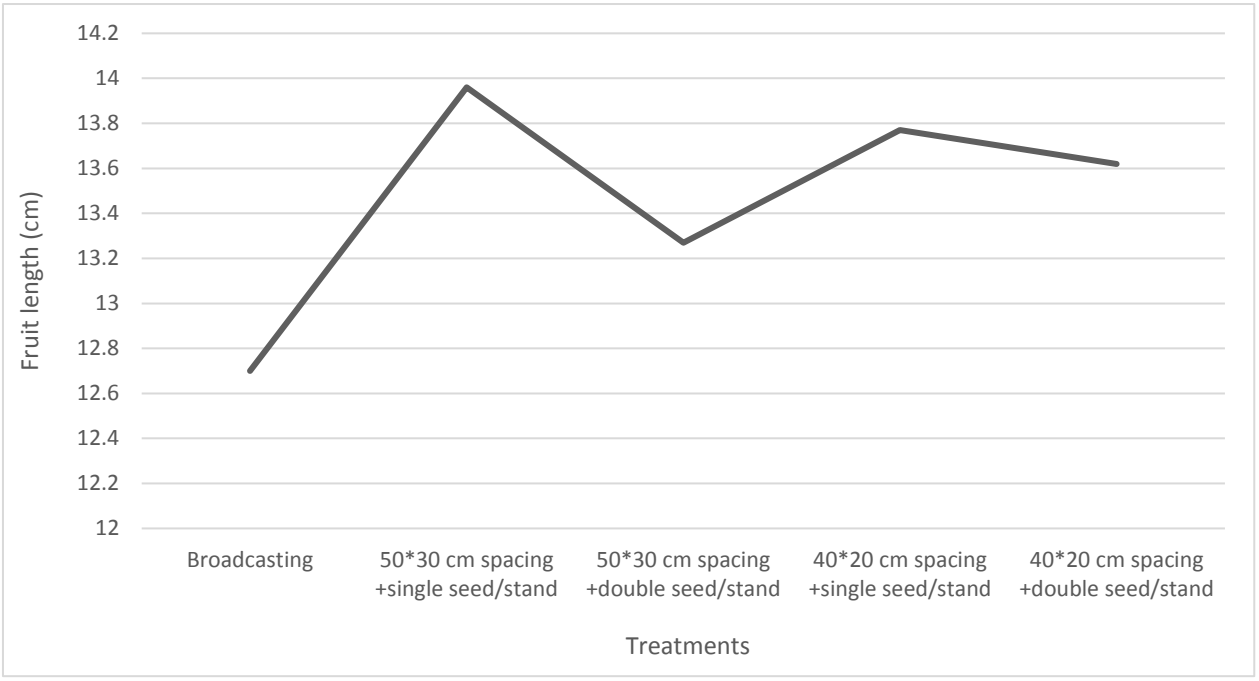

Figure 4: Fruit length of okra in response to different spacing and seed/stand

This result is in line with the result of researchers in 2018 who reported non-significant difference in fruit length due to different spacing (Jha et al., 2018). This result is in contrast with the finding of multiple researchers who reported that fruit length were higher in plant at higher spacing and vice versa (Bishnoi et al., 2019; Maurya, 2013; Panthinige et al., 2008; and Muhammad et al.,1999).

3.3.6 Fruit girth (mm)

The data on fruit girth (up to 9 picking) is presented in table below which indicated statistically non-significant difference in the fruit girth among different combinations of spacing and seed/stand at 5% level of significance with LSD of 0.746. The highest fruit girth (13.48mm) was observed in treatment 2 (50*30cm spacing +single seed /stand) while the least value for fruit girth (12.82mm) was observed in treatment 1 (broadcasting). All the treatments were statistically similar with each other. This result is also in lined with studies in 2018 where non-significant effect in fruit girth due to different spacing (Jha et al., 2018).

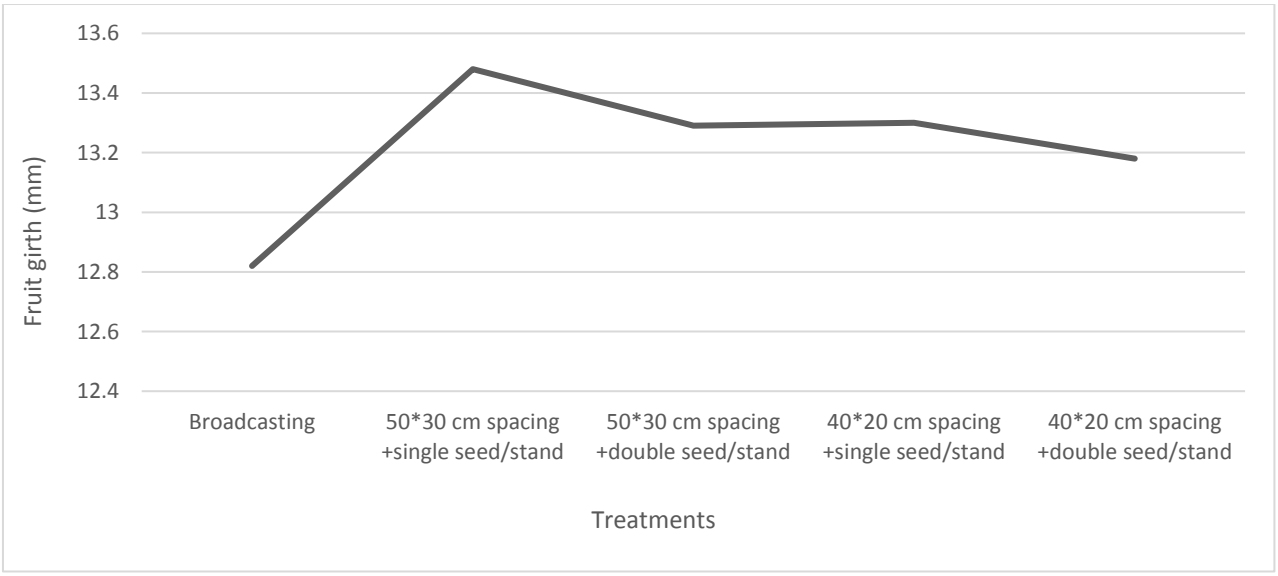

Figure 5: Fruit girth of okra in response to different spacing and seed/stand

3.3.7 Average fruit weight(gm)

The table below shows that different combinations of spacing and seed/stand had significant difference on average fruit weight. Treatment 2(50*30cm spacing +single seed /stand) stands out prominently, with an average fruit weight of 17.53 grams. This result demonstrates that Treatment 2 yielded significantly heavier fruits compared to the other treatments. Conversely, Treatment 1(Broadcasting) produced fruits with an average weight of 14.80 grams, which was the lowest among the treatments. The grand mean for average fruit weight across all treatments was calculated at 16.29 grams. This finding is in line with previous studies where researchers reported highest average fruit weight in wider spacing (Panthinige et al., 2008). Other supporting evidence for this result was reported (Muhammad et al., 1999; Singh, 1990; Mondal and Mallik, 1990; Klassen, 2005).

3.3.8 Average fruit yield per harvesting (ton/ha)

A crucial examination of data presented in table below shows that the use of different combinations of spacing and seed/stand had highly significant difference on average fruit yield per harvesting. The highest average yield per harvesting (2.837 tons/ha) was observed in treatment 5 (40*20cm spacing +double seed /stand) which was followed by treatment 3 (50*30cm spacing +double seed /stand) with average fruit yield per harvesting of 2.478 tons/ha. The lowest yield (1.756 tons/ha) was observed in treatment 1 (Broadcasting).

3.3.9 Total yield (tons/ha)

The table presented below revealed that the different combination of spacing and seed/stand had highly significant difference on total yield of okra (tons/ha). Treatment T5 (40*20cm spacing + double seed/stand) stood out with the highest total yield, reaching 25.54 tons per hectare which is followed by treatment 3 (50*30cm spacing +double seed /stand) having total yield of 22.30 tons/hectare. Conversely, treatment T1 (Broadcasting) yielded the lowest total, with 15.81 tons per hectare. Total yield is primarily influenced by two key factors: the yield per individual plant and the overall plant population. When plants are spaced closer together, up to a certain threshold, it results in higher total yields because there are more plants within a hectare. Conversely, wider spacing reduces the number of plants per hectare, ultimately leading to lower total yields (Paththinige et al., 2008). Similar finding was observed in Singh (1990).

Table 8: Effect of different spacing and seed/stand on yield and yield attributing characters of okra

Treatments	Avg fruit weight	Average yield /harvesting(ton/ha)	Total yield(ton/ha)
T_1 (Broadcasting)	14.80^{a}	1.756^{a}	15.81^{a}
T_2 (50*30cm spacing +single seed /stand)	17.53^{b}	2.034^{ab}	18.30^{ab}
T_3 (50*30cm spacing +double seed /stand)	16.52^{ab}	2.478 ^{cd}	22.30^{cd}
T_4 (40*20cm spacing + single seed /stand)	16.69^{b}	2.310^{bc}	20.79^{bc}
T_5 (40*20cm spacing +double seed /stand)	15.89^{ab}	2.837^{d}	25.54^{d}
Grand Mean	16.29	2.28	20.55
F test	*	***	***
LSD $_{(0.05)}$	1.710	0.367	3.306
CV (%)	6.8	10.4	10.4
Sem (±)	0.555	0.119	1.07

Note: CV=Coefficient of variance, SEM=Standard Error of Means, LSD= Least Significant Difference, Means separated by DMRT and column represented with same letters are not significant at 5% level of significance

3.4 Correlation analysis

Estimation of Pearson's correlations between total yield and other related traits are shown in the table. Total pod yield per hectare had positive correlation with plant height, number of branches per plant, leaf canopy, stem diameter, number of fruits per plant, yield per plant, average fruit weight, fruit length and fruit girth whereas number of leaves per plant, days to 1st flowering and days to 50% flowering had negative and non-significant correlation with total yield. Plant height, yield per plant, average fruit weight, fruit length and fruit girth had positive and significant correlation with total yield per hectare. The positive correlation of various traits with total yield suggest that they play a major role in okra yield performance and viceversa.This result contradicts with the report of Malik and Mondal (1996) that indicate plant height at different stages are vegetative traits that are important for yield determination in okra. There existed a linear relationship between green pod yield per plant and plant spacing.

Table 9: Correlation between different growth and yield parameters and total yield

	PH	LN	BN	LC	S	FF	50%F	No/P	AvgFW	FL	FG	TY
PH	1											
LN	0.268	1										
BN	0.196	0.647**	1									
LC	0.740**	0.304	0.066	1								
SD	0.600**	0.583**	0.452*	0.714**	1							
FF	-0.560*	-0.695**	-0.582**	-0.617**	-0.849**	1						
50%F	-0.347	-0.756**	-0.605**	-0.515*	-0.813**	0.939**	1					
No/P	0.456*	0.592**	0.560*	0.614**	0.762**	-0.819**	-0.789**	1				
AvgFW	0.651**	0.604**	0.416	0.493*	0.508*	-0.632**	-0.505*	0.620**	1			
FL	0.523*	0.615**	0.514*	0.309	0.453*	-0.671**	-0.630**	0.581**	0.711**	1		
FG	0.113	0.548*	0.529*	-0.132	0.151	-0.372	-0.392	0.395	0.626**	0.730**	1	
TY	0.451*	-0.01	0.140	0.131	0.089	-0.212	-0.092	0.313	0.600**	0.548*	0.517*	1

Note: PH=Plant height, LN = Number of leaves per plant, BN = Number of branches per plant, LC = Leaf canopy, SD = Stem diameter, FF = Days to first flowering, 50%F = Days to 50%flowering, No/P = Number of fruits per plant, Avg FW =Average fruit weight, FL = Fruit length, FG = Fruit girth, TY = Total yield

4. Conclusion

In research done to find out the effect of various combinations of spacing and seed/stand arrangements on growth and yield of okra in Khairahani, Chitwan, Arka Anamika variety of okra was used as planting material with 5 different treatment combinations, including varying spacing and seed/stand arrangements. The treatments included broadcasting, 50*30 cm spacing + single seed/stand, 50*30 cm spacing + double seed/stand, 40*20 cm spacing + single seed/stand, and 40*20 cm spacing + double seed/stand. The study found that treatment 2, characterized by 50*30 cm spacing and one seed per stand, was superior in early flowering, higher number of leaves and branches per plant, a larger leaf canopy, wider stem diameter, increased fruit production per plant, highest average fruit weight, and the highest marketable fruit yield. In Khairahani, Chitwan treatment 5, 40*20 cm spacing, and double seed per stand were found to increase the total yield per hectare. These results will have significant implications for farmers in Chitwan district and beyond. By adopting scientifically informed spacing and seed/stand, farmers can substantially improve their okra yield.

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