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Evaluation of Different Okra *(Abelmoschus esculentus L.)* Cultivars for Yield and Biomass Production

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Authors' contributions

This work was carried out in collaboration among all authors. The individual contributions of authors to the manuscript should be specified in this section. All authors read and approved the final manuscript.

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ABSTRACT

In a field experiment conducted at Girija Prasad Koirala College of Agriculture and Research Center, Morang, Nepal, spanning from April to August 2022, the study aimed to assess the yield and biomass production of various okra (*Abelmoschus esculentus L*.) varieties, including Arka Anamika, Chandani, Chiranjeevi F1, F1 Glory, Gunjan, JK1666, OH-940, Punjab Selection, R35 Selection, and Swastik-2. Results unveiled significant variability among the varieties, with F1 Glory (0.91 Kg/m2) and Punjab Selection (0.96 Kg/m2) emerging as top performers in average yield per m2. Conversely, Arka Anamika, Gunjan, and JK1666 exhibited the lowest yields. Notably, Punjab Selection (4.17 Kg/m2), OH-940 (4.28 Kg/m2), and Swastik-2 (3.86 Kg/m2) showed the highest fresh biomass, while Gunjan had the lowest biomass. F1 Glory demonstrated the highest harvest index (1.14), followed by Chandani and Punjab Selection (both 0.88). These findings underscore

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the significant impact of varietal selection on okra productivity, highlighting the potential of Punjab Selection and F1 Glory for further exploration in vegetable cultivation and biomass production. The study underscores the importance of varietal selection in enhancing okra productivity and biomass production. Farmers should consider planting high-yielding varieties such as Punjab Selection and F1 Glory to maximize their yields and biomass. Additionally, further research is needed to explore optimal cultivation practices and management techniques tailored to these high-performing varieties. This study provides actionable recommendations for farmers to improve okra cultivation practices, ultimately enhancing agricultural productivity in Nepal and comparable agro-ecological conditions.

Keywords: Abelmoschus esculentus; okra biomass; fresh plant weight; okra performance; okra varieties.

1. INTRODUCTION

The fibrous pods of okra (*Abelmoschus esculentus* L.), commonly referred to as "lady's finger," make it one of the most significant and nutrient-dense vegetables widely cultivated in tropical and warm temperate areas of the world [1]. Biomass is the leftover residue of agricultural plants like roots, shoots, and stems [2,3]. Biomass is classified into four types; they are woody biomass (it consists of wood plants and trees), non-woody biomass (plants parts like stems, roots, and leaves), process waste biomass (waste from various typed of agroindustry), and processed fuel biomass (producer gas, charcoal, etc.) [4]. The biomass of the plant is determined by weighing the overall part of the plant individually and the root and shoot separately of an individual plant on the same day [5,6]. The maximum Bbiomass can be highlybe obtained from the area where the leguminous crop wais planted in the last planting season [7]. A measure of energy produced from Ggreen biomass technology is the most effective way to decrease the emission of greenhouse gasses to meet the increasing energy demand and to reduce the problem of global warming [8].

Okra, known for its rich nutritional content including vitamins, carbohydrates, minerals, proteins, and unsaturated fats [9,10], is influenced by soil constituents affecting biomass production directly. The application of fertilizers during cultivation significantly impacts okra biomass production, with higher nitrogen integration resulting in increased dry matter composition and vice versa. Optimal biomass and pod yield are achieved through fertilizer application exceeding standard recommendations [1].

The biomass of okra has diverse applications, including the synthesis of biodegradable and eco-friendly fibers compared to synthetic alternatives [4,11,12]. These lignocellulosic fibers, primarily derived from the stem through a process known as retting, contain about 70% α-cellulose, comparable in quality to jute and suitable for various fabric and textile productions [11].

Furthermore, second-generation fuels derived from okra offer a promising avenue for reducing reliance on nonrenewable sources. Additionally, okra can serve as a valuable component in animal feed formulations, further enhancing its utility and potential impact [3,13]. Additionally, okra cellulose holds promise as an adsorbent for wastewater treatment, capable of removing various ions and metals from aqueous solutions due to its composition of hemicellulose, cellulose, and lignin [12]. The dried biomass, converted into powder form, is used for bioenergy production after complete drying for improved quality [4]. Moreover, bio-flocculants derived from okra biomass present an eco-friendly alternative to chemical flocculants [3].

Biomass production emerges as a versatile solution to tackle energy-related challenges, facilitating the generation of various types of energy. Despite its inherent benefits after production, the cultivation phase introduces challenges affecting arable land usage, competition with food and fiber crops, uneven soil distribution, nutrient depletion, weed proliferation, environmental impacts, and farmers' predominant focus on marketable pods. Unfortunately, the potential utilization of leftover plant biomass is often overlooked. This study uniquely centers on the exclusive assessment of biomass production and yield in different okra varieties. Given the limited existing research on okra varieties that simultaneously yield the highest biomass and yield, there exists a notable gap in knowledge on this topic. To bridge this gap and address challenges encountered during cultivation, including those related to environmental factors and farmers' practices, the research places a specific emphasis on evaluating ten okra varieties sourced from both domestic and foreign origins. This research aims to contribute valuable knowledge to an underexplored area, shedding light on okra varieties that can potentially maximize both yield and biomass production.

2. MATERIALS AND METHODS

2.1 Site Description

The experiment was conducted in the research field at G. P. Koirala College of Agriculture and Research Center located at Sundarharaicha, Morang, Nepal, to evaluate the yield and biomass of different okra varieties from April to August 2022. The geographical coordinates of this location are approximately 26º 40' 49.3" North latitude and 87º 21' 16.1" East longitude, and it sits at an elevation of 150 meters above sea level. The climate in this region is classified as tropical, characterized by an average annual temperature ranging from 25°C to 35°C. The soil characteristics of the experimental site were analyzed in qualitative measures with the help of a soil test kit (Table 1).

2.2 Meteorological Data

The average maximum temperature recorded was 33.46°C, while the minimum temperature averaged at 22.86°C. Throughout the experimental period, total precipitation reached 1254.20 mm. The maximum relative humidity observed was 86%, contrasting with a minimum of 48%. Fig. 1 illustrates the meteorological data encompassing the entire experimental period.

2.3 Cultural Practices

The field experiment followed a Randomized Complete Block Design (RCBD) and involved ten okra varieties i.e., Arka Anamika, Chandani, Chiranjeevi F1, F1 Glory, Gunjan, JK 1666, OH-940, Punjab Selection, R35 Selection, and Swastik-2 with three replications. Each plot covered an area of nine square meters (3m x 3m), resulting in a total experimental area of 270 m^2. In each plot, there were 40 plants with a spacing of 0.6 m between rows and 0.35 m between individual plants. Fertilizer was applied at a rate of 120:60:60 kg NPK per hectare, and FYM was applied at a rate of 25 t/ha. The total amount of phosphorus (P) and potassium (K), as well as half of the nitrogen (N) fertilizer, were applied at the time of sowing. The remaining nitrogen doses were split into two applications at 22 and 40 days after sowing (DAS). Weeding was performed manually two times at 20 and 42 DAS. Irrigation was carried out in every two days in response to the soil moisture content.

Table 1. Soil characteristics of the experimental site

S. N.	Soil constituents	Properties
1	Soil pH	6.5
2	Soil texture	Silty loam
3	Nitrogen	Medium
4	Potassium	Medium
5	Phosphorus	Low
6	Surface soil wetness	0.648
7	Profile soil moisture	0.606
8	Root zone soil moisture	0.628

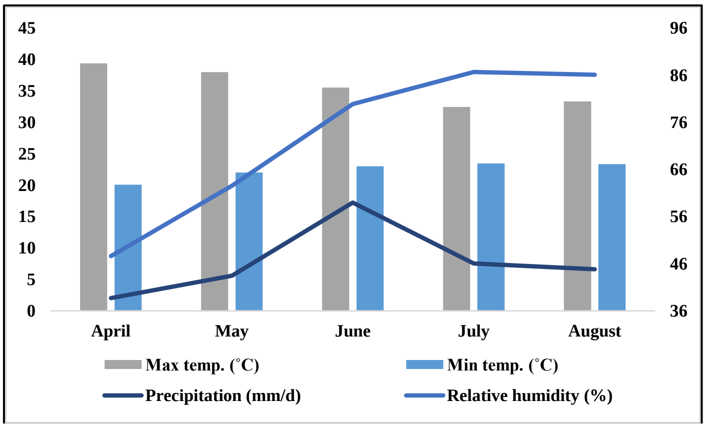

Fig. 1. Observational meteorological data throughout the growing period of okra in Gothgaun, Morang

2.4 Data Collection

The data collection involved randomly selecting 12 plants from each plot, and data were collected from the first harvest to the last harvest. Harvesting was conducted based on maturity criteria, where okra pods were harvested when they reached a specific size of 12 cm or exhibited a bright green, fleshy appearance according to standard agricultural practices [14,15]. Yield (kg/m^2) was recorded at weekly intervals throughout the growth period. Fresh biomass, encompassing stem, shoots, roots, and leaves, were recorded at the end of the plant's growth period in August. The yield per m^2 was calculated by aggregating individual plant yields within each plot and then normalizing it to the plot area.

2.5 Statistical Analysis

The obtained data on various parameters was subjected to statistical analysis using Rstudio (4.2.2 version) using datasets and agricolae data packages. The significance of the results was assessed through an analysis of variance (ANOVA). Data entry was performed using MS Excel (2019), and the same software was utilized to create graphs and bar charts for the parameters under investigation. To compare the means of various parameters, Duncan's Multiple Range Test (DMRT) was employed, with a significance level of 5% [16].

3. RESULTS

3.1 Yield of Different Okra Varieties

The experimental findings underscored the substantial variability in okra yield per m^2 across diverse varieties at distinct days after sowing (DAS), as detailed in Table 2. Statistically, the observed variations in each DAS were significant. These findings accentuate the temporal dynamics and significant varietal influences on okra yield, providing valuable insights for agronomic optimization and varietal selection. These findings indicate the dynamic growth patterns in okra crop output over time. Notably, the overall mean at 45 DAS stood at 0.09 kg/m^2, exhibiting a subsequent progressive increase, peaking at 1.19 kg/m^2 by 75 DAS before exhibiting a decline. Chandani (1.13 Kg), Punjab selection (1.13 Kg), and Swastik-2 (1.11 Kg) manifested the highest yields per m^2, succeeded by F1 Glory (0.84 Kg) and OH-940 (0.82 Kg). In contrast, Gunjan and JK 1666 displayed the lowest yields (0.20 Kg/m^2).

3.2 Fresh Biomass and Harvest Index of Different Okra Varieties

Table 3 presents a comparative analysis of fresh biomass measurements across different okra varieties. Among the varieties studied, OH-940 and Punjab Selection demonstrated the highest average fresh biomass values, registering at 4.28 and 4.17 Kg/m^2, respectively. These Figures were found to be statistically similar to the fresh biomass values of Swastik-2 at 3.86 Kg and Chiranjeevi F1 at 3.50 Kg per square meter. On the other end of the spectrum, Gunjan exhibited the lowest fresh biomass value at 1.63 Kg/m^2. The calculated mean fresh biomass per square meter across all varieties was determined to be 3.07 Kg. This analysis yielded highly significant results at a confidence level of 0.1%, indicating substantial differences in fresh biomass production among the okra varieties under study. Furthermore, the investigation revealed noteworthy variability in the harvest index across various varieties, as illustrated in Table 3. Variety F1 Glory exhibited the highest harvest index (1.14), followed by Chandani and Punjab Selection with indices of 0.88. Conversely, the lowest harvest index (0.47) was noted in variety Chiranjeevi F1. The statistical significance of these results was established at a 5% level of significance.

Table 2. Yield per m^2 of different varieties of okra on various days after sowing

Varieties	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	Average
Arka Anamika	0.04^{de}	0.36^{d}	0.82^{c}	0.58^{cde}	0.45^{bcd}	0.45^{d}
Chandani	0.09^{bcd}	0.53^{cd}	1.17^{bc}	1.12^{ab}	1.13^{a}	0.80^{ab}
Chiranjeevi F1	0.01^{e}	0.56^{bcd}	0.97^{bc}	0.72^{bcde}	0.33^{cd}	0.52^{cd}
F1 Glory	0.12^{b}	0.92^{ab}	1.66^{a}	1.03^{ab}	0.84^{ab}	0.91^{a}
Gunjan	0.20^{a}	0.64^{abcd}	1.00^{bc}	0.39^{e}	0.20^{d}	0.49^{cd}
JK 1666	0.09^{bcd}	0.76^{abc}	1.15^{bc}	0.55^{de}	0.20^{d}	0.55^{bcd}
OH-940	0.11^{bc}	0.69^{abcd}	1.32^{ab}	0.96^{abcd}	0.82^{ab}	0.78^{ab}
Punjab Selection	0.05^{cde}	0.97^{a}	1.32^{ab}	1.31^{a}	1.13^{a}	0.96^{a}
R35 Selection	0.11^{bc}	0.57^{bcd}	1.24^{abc}	0.99^{abc}	0.72^{abc}	0.73^{abc}
Swastik-2	0.09^{bcd}	0.57^{bcd}	1.30^{ab}	1.11^{ab}	1.11^{a}	0.84^{a}

Varieties	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	Average
Mean	0.09	0.66	1.19	0.88	0.69	0.70
SEM±	0.010	0.047	0.055	0.064	0.076	0.039
CV (%)	32.54	30.00	20.18	25.83	35.46	19.66
LSD	0.05	0.34	0.41	0.39	0.42	0.23
F-Test	***	*	*	**	***	**

**Significant at 5% level of significance, **Significant at 1% level of significance, ***Significant at 0.1% level of significance, CV: Coefficient of variance, LSD: Least Significant Difference, SEM: Standard Error of Mean*

Table 3. Fresh biomass and harvest index of different varieties of Okra

Variety	Fresh biomass (Kg/m^2)	Harvest index (HI)
Arka Anamika	2.01^{e}	0.55^{bc}
Chandani	3.27^{cd}	0.88^{ab}
Chiranjeevi F1	3.50^{bc}	0.47^{c}
F1 Glory	2.84^{d}	1.14^{a}
Gunjan	1.63^{e}	0.72^{bc}
JK 1666	1.93^{e}	0.79^{abc}
OH-940	4.28^{a}	0.68^{bc}
Punjab Selection	4.17^{a}	0.88^{ab}
R35 Selection	3.17^{cd}	0.78^{abc}
Swastik-2	3.86^{ab}	0.81^{abc}
Mean	3.07	0.77
SEM	0.173	0.043
CV (%)	10.26	24.24
LSD	0.54	0.32
F-Test	***	*

**Significant at 5% level of significance, **Significant at 1% level of significance, ***Significant at 0.1% level of significance, CV: Coefficient of variance, LSD: Least Significant Difference, SEM: Standard Error of Mean*

4. DISCUSSION

The results revealed significant variations in yield and biomass production among distinct okra varieties used in the research. Notable disparities were observed in yield, ranging from 0.45 to 0.91 Kg/m², which is within a narrower range compared to Biswas et al. [17] who reported a wider range of 0.57 to 1.4 Kg/m² in fruit yield, surpassing our findings. Possible factors contributing to this variation include differences in cultivation practices, environmental conditions, or genetic factors, highlighting the multifaceted nature of yield outcomes in agricultural studies. Similarly, Bulo et al. [18] reported the highest fruit yield per plant as 0.212 Kg and 0.202 Kg, aligning closely with the yield of Punjab Selection (0.217 kg) and F1 Glory. Sibsankar et al. [19] reported a wider range of fruit yield per plant from 0.2562 to 0.2744 kg, which differs significantly from our results, possibly due to differences in genotype, management practices, or climatic factors. Zareen et al. [20] reported a pod yield value of 0.99 Kg/m², similar to our findings of Punjab Selection at 0.96 Kg/m². However, Imoloame & Usman [21] reported lower okra yields ranging from 0.185 to 1.812 Kg/m², which contrasts sharply with our study. Disparities in agricultural yield might result from variances in soil quality, agronomic practices, or regional weather variables. Sharma & Singh [22] found that the greatest biomass yield occurred in treatment T1 Arka Anamika, yielding 7.2 tons/ha (0.72 Kg/m²), notably lower than OH-940, which reported the highest yield of 4.28 Kg/m². This suggests potential factors such as robust growth conditions or genetic influences contributing to OH-940's superior fresh plant weight. The disparity underscores the complex interplay of environmental and genetic factors influencing biomass production, warranting further investigation into optimizing growth conditions and understanding genetic contributors to enhance yields. Statistically, Punjab Selection (4.17 Kg) and OH-940 (4.28 Kg) showed similar performance, while Gunjan exhibited lower weight (1.63 Kg/m²), possibly due to environmental stress or genetic traits influencing reduced growth. Statistically, Gunjan, Arka Anamika, and JK1666 exhibited comparable weights, implying similar genetic potential or adaptation to common growing conditions. Attarde et al. [23] reported a fresh biomass ranging from 51.5 to 72.4g, significantly lower than our research results, potentially attributed to variations in fertilizer doses or differences in methodology procedures. Additionally, discrepancies may arise from environmental factors such as soil quality, climate, and cultivation practices, influencing plant growth and overall productivity. Moreover, genetic variations among okra varieties utilized in the studies could contribute to the observed differences in fresh plant weights.

5. CONCLUSION

In conclusion, Punjab selection displayed superior performance among the ten examined okra varieties, boasting the highest average fresh biomass and overall yield. Conversely, Arka Anamika, Gunjan, and JK1666 exhibited lower biomass, with Arka Anamika producing the least yield. This highlights the substantial impact of varietal selection on okra productivity. Future research should investigate specific traits contributing to high yields, guiding farmers toward optimal cultivar choices. Exploring agronomic practices and environmental factors affecting yield variations could further enhance overall okra production. These findings offer crucial insights for sustainable agriculture, emphasizing the importance of tailored variety selection. Consequently, based on these parameters, Punjab selection and F1 Glory emerge as promising varieties, recommended for further evaluation and utilization in vegetable cultivation and biomass production.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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