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Screening of okra (*Abelmoschus esculentus* Moench) genotypes for yield and other morphological components under the agro-climatic conditions of Khyber Pakhtunkhwa

Syed Tariq Shah[1*], Roshan Zamir[1] and Iqbal Saeed[1]

[1]Nuclear Institute for Food & Agriculture (NIFA), Peshawar, Khyber Pakhtunkhwa-Pakistan

Abstract
Okra (*Abelmoschus esculentus*) is an important vegetable grown throughout Pakistan and many other countries. Due to its diverse genetic background it is possible to screen and develop approved varieties for yield and quality, using existing germplasm pool. The current study aimed to assess the morphological and yield parameters of 18 okra genotypes including two check varieties (Green Finger and Arka Anamika). The initial study was carried out in 2021 to evaluate performance of the selected genotypes for 50% flowering, internode length, number of nodes, capsule yield, 1000 seed weight, leaf color, leaf shape, and capsule color. Mean yield results showed that NIFA Bhindi Line-1 (NBL-1) and NIFA Bhindi Line-2 (NBL-2) performed well for the traits under study compared to the other genotypes. NBL-1 took 44 days to 50% flowering, and its minimum plant height was 130 cm with shorter internode length (4.35 cm), highest number of nodes (57), maximum fruit yield (18062 kg ha^{-1}) and maximum 1000 seed weight (67.5 g). Preliminary Yield Trial (PYT) conducted during 2022 at NIFA showed that NBL-1 displayed early fruiting (54 days), minimum plant height (124 cm), maximum fruit yields (13107 kg ha^{-1}) and maximum 1000 seed weight (67 g) over the other genotypes. Based on superior performance over the other genotypes, NBL-1 possesses the potential to become new commercially viable okra variety in the near future.

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Introduction

Okra (*Abelmoschus esculentus* Moench) is considered as an important consumable vegetable crop grown in tropical regions and temperate parts of the world (Temam et al., 2020; Faisal et al., 2021). In Pakistan, okra is a popular summer vegetable and is particularly valued for its tender and flavorful fruit, which contributes for calcium, potassium, vitamins and additional minerals availability (Petropoulos et al., 2018; Rajesh et al., 2018; Zeb et al., 2021). The presence of antioxidants such as polyphenols and flavonoids which have anti-fatigue properties and also other medicinal uses are used for reducing blood cholesterol, diabetes, ulcers and neurodegenerative diseases (Xia et al., 2015; Elkhalifa et al., 2021; Mohammed et al., 2022). Similarly, okra is known for curing gastrointestinal ulcer by neutralizing gastric acids (Swany, 2023).

***CONTACT** Syed Tariq Shah, stariq81@yahoo.com, Nuclear Institute for Food & Agriculture (NIFA), Peshawar, Khyber Pakhtunkhwa-Pakistan

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Okra is known as an important cash crop with good economic value, and is grown across Pakistan in two cropping seasons as spring and summer crops. The okra fruit yield is acknowledged as one of the intricate traits controlled by a number of consistent components (Koli et al., 2020). Therefore, fruit yield depends on capsule number per plant, emergence of flowers and weight of fruit (Chaudhary et al., 2006; Rahman et al., 2012; Sheferie et al., 2023). Though climatic conditions are relatively favorable for okra cultivation, minimum average yield of okra is attributed to availability of space among the plants, genetic factors, and soil mineral deficiency (Amjad et al., 2001; Sheferie et al., 2023). Similarly, the susceptibility of the okra crop toward certain pathogens also needs proper attention. Hence, screening for development of new varieties with maximum fruit yield and resistance are essentially needed (Amjad et al., 2001; Bandyopadhyay et al., 2001; Comas et al., 2010). Thus, the current study conducted at NIFA Peshawar focused with the aim to evaluate based on initial screening of different okra genotypes to develop high yielding and better quality okra cultivars to be grown effectively under the agro-climatic conditions of KP.

Materials and Methods

The current study was conducted in the fields of Nuclear Institute of Food and Agriculture, Peshawar during March, 2021 using 18 genotypes of okra from local sources. The experiment was carried out according to a Randomized Complete Block Design (RCBD) with three replicates, having the plot size 2 m x 5 m (10 m^2) long. The genotypes were grown and screened for different parameters under standard cultural practices. Distance among rows was kept at 2 m, row length at 5 m and sowing was done on ridges. The two registered varieties Green Finger and Arka Anamika were used as checks. Data for selection and evaluation of the genotypes were recorded on 50% flowering, plant height, internode length, number of nodes, fruit yield, 1000 seed weight, leaf color, leaf shape, and fruit color. Likewise, Preliminary Yield Trial (9 genotypes) was performed in March, 2022 at NIFA for assessing days to fruiting, plant height, fruit yield, 1000 seed weight, and leaf and fruit color of nine genotypes.

Results and Discussion

Initial screening was conducted during 2021, which showed that among 18 genotypes, NBL-1 out-performed when compared to the other okra genotypes including the checks. NBL-1 showed 50% flowering after 44 days as compared to the check varieties Green Finger and Arka Anamika that produced 50% flowering after 47 days and 48 days, respectively, while genotype NBL-15 produced 50% flowers after 49 days (**Figure 1A**). To develop new varieties, the concept of prompt flowering in okra, its duration and net flower numbering are of prime importance. A number of research studies had highlighted the importance of flowering in okra (Rani et al., 1999) and reported that different okra genotypes have different flowering duration (Ramanjinappa et al., 2011). Moreover, Preliminary Yield Trial (PYT) performed during 2022 showed that among nine genotypes, NBL-1 displayed early fruiting (54 days), while NBL-11 displayed fruiting after 61 days as compared to the check varieties (**Table 1**). Other researchers also highlighted the importance of early fruiting that leads to early picking of the fruit and extension of the crop duration that directly benefits the farmers (Rambabu et al., 2021; Ragheb and Helmy 2022).

In okra crop, plant height with compact internodes is preferred by the farmers for maximum fruit yield. Mean results of 18 genotypes showed that minimum plant height was depicted by okra genotype NBL-1 (130 cm) as compared to the check varieties Green Finger (167 cm) and Arka Anamika (159 cm), whereas maximum plant height was shown by NBL-14 (202 cm). Likewise, okra genotypes NBL-9 (135 cm) and NBL-10 (139 cm) also displayed minimum plant height, respectively (**Figure 1B**). The present study findings have analogy with Faisal et al. (2021) in which lowest plant height of okra genotypes with high yield was reported. Likewise, Ogwu et al. (2018) reported that okra genotypes showed significant variation in plant height. Different responses of okra genotypes in plant height were also recorded in another research report (Bangulzai., 2005). Similarly, in PYT minimum plant height (124 cm) was also reported by NBL-1 as compared to that of the check varieties Green Finger (153 cm) and Arka Anamika (156 cm). A substantial difference was reported in internode length in different okra genotypes. Internode length of various okra genotypes showed that the highest internode length (6.65 cm) was accompanied by okra genotype NBL-14 followed by NBL-7 and NBL-11(6.4 cm), whereas NBL-1 displayed the lowest internode length (4.35 cm). Other okra genotypes NBL-2 (4.7 cm) and NBL-9 (4.65 cm) also displayed minimum internode length (**Figure 1C**). The observed difference in internode length may be attributed to the genetic characteristics of diverse okra genotypes as reported by other researchers (Baghel et al., 2022; Mohammed et al., 2022; Khan et al., 2023). Data regarding number of nodes revealed that the maximum nodes were recorded in okra genotype NBL-1 (57) followed by NBL-2 (49.5).

The minimum number of nodes was noted for okra genotype NBL-6 (32). Similarly, other genotypes NBL-8 (46) and NBL-15 (44) also showed a significant increase in number of nodes, respectively, as has already been reported elsewhere (Abdelkader et al., 2024).

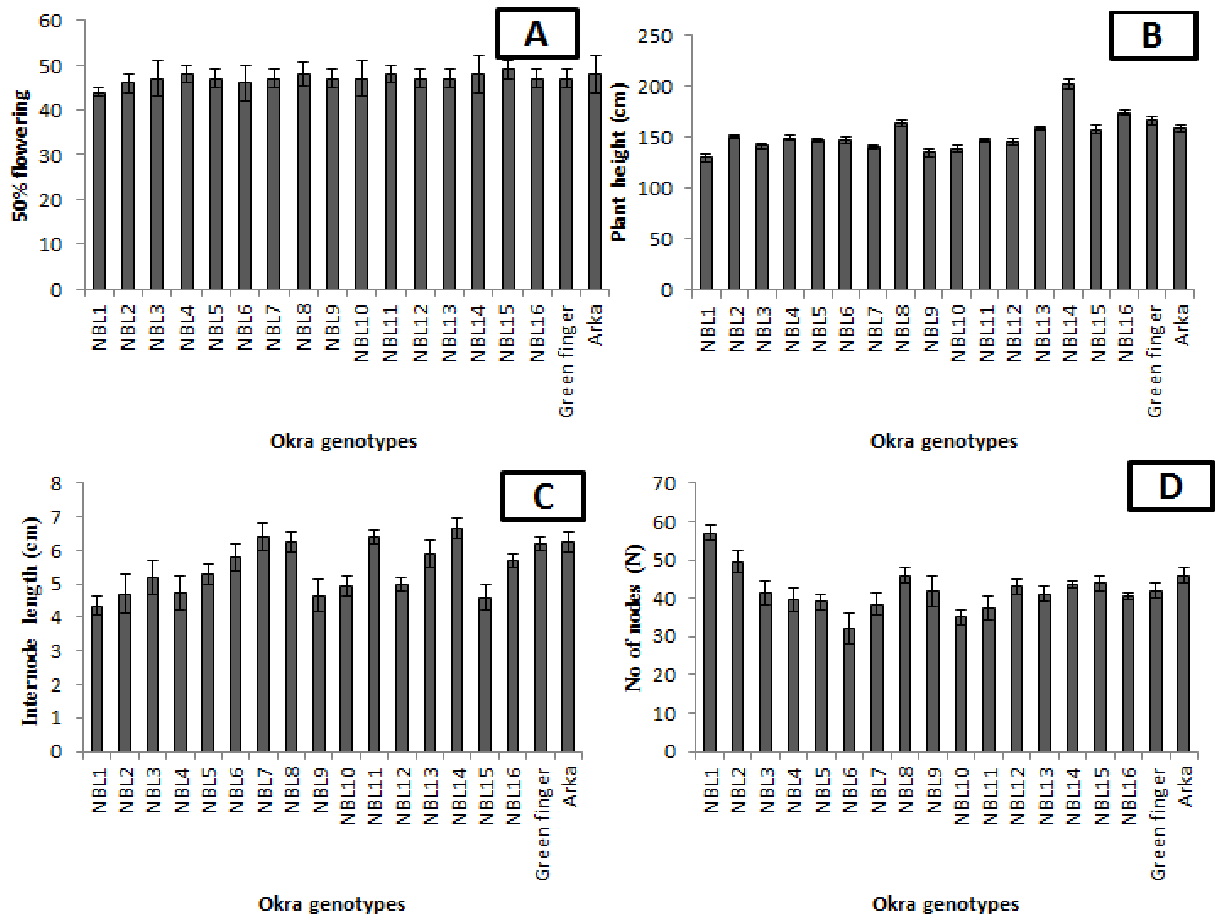

Figure 1: Variation in yield components of okra genotypes.

(A) 50% flowering; (B) Plant height (cm); (C) Internode length (cm); (D) No of nodes (N) Values are mean ± SE.

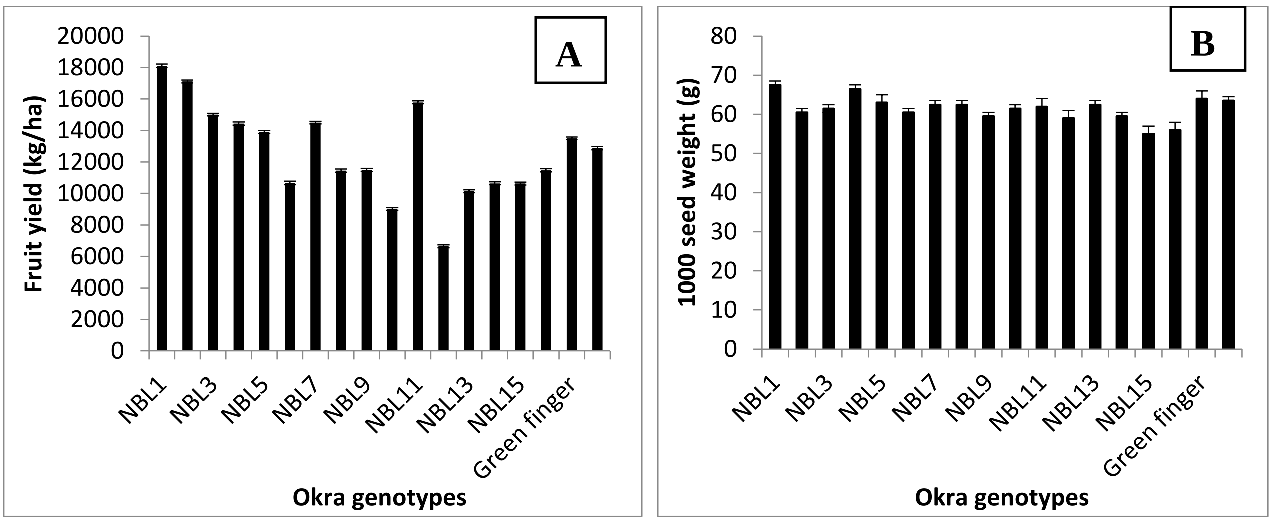

Figure 2. Fruit yield (A) and 1000 seed weight (B) of okra genotypes

Table1. Morphological characteristics of okra genotypes

Genotype code	Leaf color	Leaf shape	Fruit color
NBL-1	Dark green	Medium	Dark green
NBL-2	Green	Medium	Dark green
NBL-3	Dark green	Medium	Dark green
NBL-4	Green	Deep	Green
NBL-5	Dark green	Shallow	Light green
NBL-6	Light green	Deep	Green
NBL-7	Green	Deep	Green
NBL-8	Green	Deep	Green
NBL-9	Green	Deep	Light green
NBL-10	Green	Deep	Green
NBL-11	Green	Medium	Green
NBL-12	Green	Medium	Green
NBL-13	Dark green	Shallow	Green
NBL-14	Green	Medium	Green
NBL-15	Green	Deep	Green
NBL-16	Green	Deep	Dark green
Green finger	Green	Deep	Green
Arka Anamika	Green	Medium	Green

The current study highlighted the development of potential advance lines for achieving the current demand of fruit yield in the okra crop (**Table 2**). A significant increase in fruit yield was recorded by various okra genotypes. Maximum fruit yield was noted by okra genotype NBL-1 (18,063 kg ha^{-1}) followed by NBL-2 (15,693 kg ha^{-1}), whereas the minimum fruit yield was observed in okra genotype NBL-12 (6,576 kg ha^{-1}) with respect to that of the check varieties Green Finger (13,415 kg ha^{-1}) and Arka Anamika (12,872 kg ha^{-1}) (**Figure 2A**). Likewise, okra genotypes NBL-3 (14,933 kg ha^{-1}) and NBL-4 (14,342 kg ha^{-1}) also displayed a considerable increase in fruit yield correspondingly as compared to that in the checks (**Figure 2A**). Our results are similar to those reported elsewhere (Faisal et al., 2021) in which maximum fruit yield was recorded in cv. Sabz Pari than that in cv. Anamika. Similarly, Bandyopadhyay et al. (2001) stated that okra cv. Parbhani Kranti out-yielded the rest of the okra varieties in terms of fruit yield. Similarly, in PYT the maximum fruit yield (13,107 kg ha^{-1}) was observed in NBL-1 as compared to that in the check varieties Green Finger (11,070 kg ha^{-1}) and Arka Anamika (10,712 kg ha^{-1}) correspondingly. Genotype NBL-2 also obtained a significant fruit yield (12,123 kg ha^{-1}) as compared with that of the checks (Table 2). Our results show that NBL-1 and NBL-2 surpassed the other tested okra genotypes by giving maximum fruit yield that is the desired goal of all growers (Ibrahim et al., 2018). The difference in the results might have been due to climatic conditions and genetic make-up of the genotypes. Okra genotype NBL-1 produced highest 1000 seed weight (67.5 g) as compared to the check varieties Green Finger (64 g) and Arka Anamika (63.5 g). NBL-4 (66.5 g) also showed a significant increase in 1000 seed weight, whereas okra genotype NBL-15 contributed to the minimum 1000 seed weight having a mean value of 55 g. NBL-5 exhibited an increase of 63 g in 1000 seed weight, and NBL-7 and NBL-8 displayed similar results having mean value 62.5 g (**Figure 2B**). In PYT, the maximum 1000 seed weight (67 g) was also recorded in NBL-1 compared with the check varieties Green Finger (62 g) and Arka Anamika (61 g). Our results are in agreement with other researchers (Rajesh et al., 2018; Nana et al., 2019) and variation in 1000 seed weight in the current study might have been the selection of extensive diversity of genotypes for precise screening.

Table 2. Yield performance of okra genotypes in Preliminary Yield Trial (PYT) at NIFA-2023

Genotype Code	Days to fruiting (DF)	Plant height (cm)	Fruit yield (kg ha^{-1})	1000-seed weight (g)	Leaf color	Fruit color
NBL-1	54	124	13107	67	Dark Green	Dark Green
NBL-2	56	130	12123	65	Dark Green	Dark Green
NBL-3	58	146	11017	64	Green	Dark Green
NBL-4	60	145	11570	63	Green	Green
NBL-5	56	148	12028	64	Green	Green
NBL-7	59	147	10720	62	Green	Green
NBL-11	61	144	11230	60	Green	Green
Green Finger	60	153	11070	62	Green	Green
Arka Anamika	59	156	10712	61	Green	Green
CV	2.07	0.54	1.80	1.06	-	-
LSD (0.05)	2.08	1.33	359.62	1.15	-	-

Morphological characters are important indicators of screening in diverse genotypes (Alvi et al., 2024). Traits like leaf color, leaf shape and fruit color are desirable for screening of elite okra genotypes from seedling to maturity. Among 18 okra genotypes, 13 displayed green leaf color, four genotypes (NBL-1, NBL-3, NBL-5, NBL-13) had dark green leaf color with the exception of only one genotype that exhibited light green leaf color (Table 1). The PYT results showed that among nine okra genotypes, seven genotypes had green leaf color while dark green leaf color was observed in two genotypes (NBL-1 and NBL-2) (Table 2). Genotype NBL-1 showed dark leaf and fruit color from the seedling stage to maturity. The results agreed with another research findings in which dark green leaf color was recorded in eight okra genotypes, green leaf color in four genotypes, while light green was recorded in two okra genotypes (Pallakki et al., 2022). In the current study, deep, medium and shallow shapes in okra genotypes were recorded. Of 18 okra genotypes, seven genotypes showed medium leaf shape, nine genotypes (NBL-4, NBL-6, NBL-7, NBL-8, NBL-9, NBL-10, NBL-15, NBL-16) showed deep leaf shape, two genotypes had shallow shape (Table 1). Other reports have also reported variation in leaf shape in okra genotypes (Suma et al., 2023; Swamy, 2023). Variation was also recorded in fruit color of different okra genotypes that ranged from light green, green and dark green. Four genotypes had dark green fruit color (NBL-1, NBL-2, NBL-3, and NBL-16), twelve genotypes displayed green fruit color, whereas two genotypes revealed light green fruit color (Table 1). Similarly, the PYT findings revealed dark green color of fruit in three genotypes (NBL-1, NBL-2, and NBL-3), whereas six genotypes had green fruit color (Table 2). Our results are similar to previous research findings reported elsewhere (Oppong-Sekyere et al., 2011) in which 14 okra genotypes were screened and found light green color of fruit in four genotypes and light to dark green fruit color in two genotypes, whereas dark fruit color was recorded in two other genotypes.

Conclusion

In the present study, 18 okra genotypes were evaluated for morphological and fruit yield parameters during 2021, and 9 genotypes in 2022. Of 18 genotypes, NBL-1 and NBL-2 showed better performance in initial screening and Preliminary Yield Trial (PYT). These two lines were better in yield and other morphological characters compared with the check varieties. These two genotypes are semi-dwarf, having dark fruit and dark leaf color which are desirable characters for end-users and farmers. Thus, the two genotypes screened in this study can be used for varietal development in future.

Author(s), Editor(s) and Publisher's declarations

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Contribution of authors
Conceptualized and designed the study: STH. Research supervised: STH. Conduction of experiment: STH, RZ. Data collection, visualization and interpretation: STH, RZ. Preparation of initial draft and review of initial draft: STH, IS, RZ. Revision of the manuscript and final proof reading: STH, IS, RZ.

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No supplementary material is included with this manuscript.

Ethical approval
This study does not involve human/animal subjects, and thus no ethical approval is needed.

Handling of bio-hazardous materials
The authors certify that all experimental materials were handled with care during collection and experimental procedures. After completion of the experiment, all materials were properly discarded to minimize/eliminate any types of bio-contamination(s).

Availability of primary data and materials
As per editorial policy, experimental materials, primary data, or software codes are not submitted to the publisher. These are available with the corresponding author and/or with other author(s) as declared by the corresponding author of this manuscript.

Authors' consent
All authors have critically read this manuscript and agreed to publish in IJAaEB.

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