Selection of Promising Pure Lines of Okra (*Abelmoschus esculentus* l. Moench) for Developing of New Hybrid Cultivars in Egypt

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ABSTRACT

This study was carried out to select and evaluate the best okra pure lines with high yield and appropriate agronomical characteristics, which were produced from selfing with selection in S_3 up to S_6 generations. The program started with 18 improved families of Balady cultivar, and eight pure lines were developed during the period from 2017-2019. The selectorial program relied on estimating both correlation coefficient and selection indices as two important tools for contributing to the selection program. During the summer season of 2020, the resulting eight pure lines were evaluated compared with Balady cultivar; in a randomized complete block design. Means and coefficients of variation were estimated for the three generations S_0, S_3, and S_6. The results showed that

- **Eleven families from of the 18 families were selected based on estimates of the correlation coefficient and selection indices.**
- **Eight pure lines were selected from the 11 compositions during the three cycles of the individual plant selection program.**
- **The behavior of the three previously mentioned generations, i.e. S_0, S_3, and S_6 in general, reflected a noticeable improvement in the values of both means and coefficients of variation for all the traits under study. This improvement represented a decrease in the values of the coefficient of variation, while mean of the different traits increased during the three generations, except for the vegetative growth traits.**
- **Evaluation of the eight pure lines showed that there is a marked distinction in all the studied traits, which was represented in reaching pure lines of short to medium length with the least number of branches, shortest internode length, and productivity.**

Accordingly, all the selected pure lines outperformed the original population, as well as the families selected from it. Therefore, those new pure lines can be used in okra improvement breeding program in Egypt.

Keywords: *Abelmoschus esculentus* L., Correlation, Okra, Selection, Selection indices.

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench, 2n = 130) is a member of the Malvaceae family. It is one of Egypt's most popular vegetables and a good source of calcium, iron, and vitamins. It is a versatile vegetable grown primarily for its edible green pods, which can be eaten fresh, canned, frozen, or dried.

Currently, due to crop rivalry and the ongoing propensity to vertical expansion, as well as working not to abuse irrigation water, increasing the cultivated area of okra and other crops has become challenging. Accordingly, cultivation cultivars with higher yield potential are critical for increasing the productivity of okra or any other crop. High-yielding okra cultivars has always been a primary goal of any breeding program. Balady cultivar is Egypt's most popular okra cultivar. Typically, this cultivar is produced from local open-pollinated seeds propagated by farmers without the assistance of seed specialists. Therefore, such cultivars exhibit a high degree of variability (Abo El-Khar, 2003; Masoud *et al*. 2007; Ibrahim et al., 2013 and 2018); thought Balady cultivar consisted of mix of heterogeneous genotypes kept by farmers for self-consumption and sold in the local market. As a result, these cultivars have several undesirable characteristics in addition to being potentially poor-growing and low-yielding.

The improvement of any crop depends on the amount of the genetic variability in the available genotypes. The presence of this variation gives a great opportunity to select the superior families within the population. Therefore, selfing with selection was very sufficient in reaching a group of families with desirable traits of okra. In, this respect (Hussein, 1994; Moualla *et al*. 2005; Masoud *et al*. 2007) studied the biological and economic features of some okra families. In this regard, also, Helmy and Ragheb, 2019, selected some families of okra from Balady cultivar, using the individual plant selection program for three cycles. The authors recorded significant variation in vegetative growth, productivity, and pod quality in selected okra families, and reported that improving these traits can be effective and rewarding with the completion of the selection program and access to more distinct genotypes that can be used in releasing new cultivars.

The current okra breeding program aims to develop pure lines with high yield and other desirable agronomic characteristics. Multiple-character selection is often more challenging than single-character selection. As a

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result, while selecting superior genotypes, multiple features should be considered at the same time, and the ideal technique for selecting characters at the same time is to use selection indices. Selection indices function as additional characters because of the combination of various characteristics from which selection responses are desired Santos *et al*. (2007), allowing the improvement of various characters simultaneously, independently of the existence or not of a correlation between them (Smith, 1936; Hazel, 1943; Williams, 1962; Cruz and Regazzi, 2001; Vilarinho *et al*. 2003). Accordingly, selection indices can be considered as a distinct tool that can assist the plant breeder during the selection process, saving time and effort while enhancing selection efficiency (Entringer *et al*. 2016 and Coutinho *et al*. 2019).

As a result, this study was carried out to complete the selection program that began in 2014 on Balady cultivar of okra crop by (Helmy and Ragheb, 2019) to obtain new superior pure lines with desirable yielding characteristics of the local okra for using as parents used in producing commercial hybrid cultivars.

MATERIAL AND METHODS

Developmental of genetic materials

The experimental material consisted of 18 advanced families derived from individual plant selection program in okra over three cycles carried out during 2014 to 2017. Helmy and Ragheb, 2019 conducted the first part of this study on Balady okra cultivar, and the results revealed significant differences in plant growth, productivity, and pod characteristics were appeared after three cycles of individual plant selection and selected 18 families by the end. So, the present study used these 18 families; to complete the selectorial program to reach promising pure lines with high productivity. The selectorial program was carried out in three as follows:

1- **The first stage:** began by measuring the correlation coefficient among the major production characteristics and the corresponding vegetative growth parameters to evaluate the degree of the association between those traits. According to the correlation coefficient obtained; the 18 families were liquidated into 11 families.

2- **The second stage:** involved performing multi-characteristic indirect selection utilizing the selection indices (Robinson *et al*. 1951) among the 11 families that were selected in the first stage, 8 distinct families were chosen, in which the third stage of the selection would commence. It's worth noting that the first and second phases of the study started and ended during the 2017 summer season.

3- **The third stage:** started with 8 families, that were selected before and selection with selfing was carried out for three cycles to reach high productivity promising pure lines. This stage carried out during three seasons from 2017-2019 to complete the cycles of individual plant selection program.

Selection procedures of the third stage:

The current breeding program was carried out at the experimental station farm, Faculty of Agriculture, Alexandria University in Abies, Alex, A.R.E. from 2017 to 2020. During this period, the best eight families out of 18 were selected to complete the individual plant selection program and achieve genetic purity in the pure lines created for the current study.

On March 10, 2017, the seeds of 18 families were sown separately to represent the original populations and complete the individual plant selection program. All agricultural practices were carried out in the manner typically recommended for commercial okra production. The various studied measurements were recorded on individual plants, and during the flowering stage, all plants in all cultivated families were selfed, as per the individual plant selection program. The selection was primarily based on a set of desirable characteristics, namely: plant height (cm), internode length (cm), branches number per plant, pod length (cm), pod diameter (cm), average pod weight (g), pods number per main stem, pods number per branches, total pods number per plant, and total yield per plant (g). Selfed seeds of the eight genotypes were collected separately, extracted, and stored for use in the next cycle. This season's selfed seeds represent the fourth generation of selfing with selection. Seeds of the fourth-generation genotypes (S_4) were sown separately on March 10, 2018. The selection was carried out as the same manner of the previous season. Similarly, work was done in the most recent selection season, which began on March 15, 2019, and ended with eight promising pure lines. The pure lines obtained from the individual plant selection program were cultivated at the following season for evaluation.

Assessment of selected pure lines:

The seeds of the populations of Balady cultivar, eight selected families ($S_{3\text{-}1}$ to $S_{3\text{-}8}$), and the eight selected pure lines up to the sixth generation ($S_{6\text{-}1}$ to $S_{6\text{-}8}$) were planted on March 15, 2020. A complete randomized block design with three replicates was used in this experiment. The experimental unit consisted of three rows that were 4.00 m long and 0.70 m wide, with a 0.30 m spacing between plants. When necessary, all commercial agricultural practices for okra were carried out. The ten studied characters were measured on five randomly chosen plants from each genotype in each replication. Statistical measurements such as mean (X), and coefficient of variation (C.V.%) were calculated in the three generations S_0, S_3, and S_6 for some important traits.

Statistical analyses

Statistical analyses of all data collected from the above-mentioned traits were performed by the standard method of randomized complete block design, as explained by Al- Rawi and Khalf-Alla (1980), using Co-Stat (2004), a computer program for statistics of differences between means.

RESULTS AND DISCUSSION

Initial selection in the eighteen families:

During this study, genotypes with medium plant height, the fewest number of branches per plant, and shortest internode length with high productivity were selected. The selection took place in three steps to attain these intended aims during the program.

The first selection stage: Correlation estimate

The first stage started by estimating the correlation between the important traits of productivity and the associated traits of vegetative growth. The results in Table (1) revealed the presence of several significant correlations that contributed to the initial stage of selection. A positive and highly significant association was found between the attribute of plant height and internode length, implying that plants of shorter height should be selected to achieve a short internode length. No significant relationships were found between plant height and any of pods number per branches, pods number per stem, and total pods number per plant, as well as an insignificant and negative correlation were found between pods number per branches and total yield per plant. This means that the selection of plants of short plant height will be associated with plants of lower internode length, and total yield per plant will not be affected by plant height.

It was also shown from the estimated correlation values that there was a negative correlation between the internode length and both of pods number per stem (insignificantly) and total pods number per plant (significantly). This correlation direction means that selected for the short internode means an increase in both pods number per main stem as well as the total pods number per plant (Singh *et al*., 2006; Reddy *et al*. 2013; Rambabu *et al*. 2019; Raval, *et al*. 2019). Also, a strong positive highly significant correlation was found between pods number per main stem and total pods number per plant, and total yield per plant. While the correlation was highly significant between pods number per branches and total pods number per plant, and the relationship was very weak and not significant with total yield per plant. This result in Table (1) supports selection against high branches number, as the total yield per plant was more affected by pods number per main stem. Based on the obtained results from estimating the correlation between these traits, eleven families were selected out of the 18 families; by excluding families with a high number of branches and tall plants.

The second selection stage: selection indices estimate

The second stage is based on selecting the best families (within the 11 families) based on length of internode, pods number per main stem, and total pods number per plant, which is done through indirect multi-characteristic selection by estimating the selection indices Table (2 and 3), which leads to select the best families in terms of overall plant productivity.

Table 1. Correlation coefficients among seven traits in okra

Traits	IL	BNP	PNS	PNB	TPNP	TYP
PH	0.641**	0.134	0.173	-0.093	0.128	-0.102
IL		0.142	-0.252	0.389*	-0.341*	0.178
BNP			-0.489*	0.495*	-0.264	-0.514*
PNS				0.296	0.941**	0.621**
PNB					0.578**	0.036
TPNP						0.738**

PH: Plant height (cm), **IL:** Internode length (cm), **BNP:** Branches number per plant, **PNS:** pods number per stem, **PNB:** pods number per branches, **TPNP:** total pods number per plant, **TYP:** total yield per plant (g)

Table 2. Means of internode length (IL cm), pods number per main stem (PNS), total pods number per plant (TPNP), and their selection indices (SI) for 11 improved families of okra

Family	IL	PNS	TPNP	SI
S3-1	4.69	24.63	43.64	-249.845
S3-2	5.55	19.08	29.08	-183.954
S3-3	6.81	22.04	42.09	-243.102
S3-4	5.34	19.00	46.94	-244.406
S3-5	4.60	25.02	30.08	-204.22
S3-6	6.98	20.03	40.05	-229.847
S3-7	6.99	19.01	41.07	-229.944
S3-8	4.50	20.08	40.21	-221.998
S3-9	4.27	28.05	43.09	-258.116
S3-10	5.59	25.69	40.72	-246.541
S3-11	6.52	20.00	52 03	-269.365
Mean	5.62	22.05	40.81	234.667

Table (3) shows the families that were selected based on the four trait criteria i.e. shortest internode length, the highest pods number per main stem, highest total pods number per plant, and higher selection indices values. For each of the four criteria, an average is also calculated. For criterion 1 (selection for lower IL) 7 families were included (S_{3-1}, S_{3-2}, S_{3-4}, S_{3-5}, S_{3-8}, s_{3-9}, S_{3-15}), while for criterion 2 (selection for higher PNS) 6 families were included (S_{3-1}, S_{3-3}, S_{3-5}, S_{3-8}, S_{3-9}, S_{3-10}), as for criterion 3 (TPNP selection highest) includes 9 families (S_{3-1}, S_{3-3}, S_{3-4}, S_{3-8}, S_{3-9}, S_{3-8}, S_{3-9}, S_{3-10}, S_{3-11}), and criterion 4 (highest SI) It included 6 families (S_{3-1}, S_{3-3}, S_{3-4}, S_{3-9}, S_{3-10}, S_{3-11}). As can be seen from the Table (3) the extent of congruence among the different criteria, the results indicated that combination occurred among the four criteria of only three families (S_{3-1}, S_{3-9}, S_{3-10}), while combination occurred among three criteria in three families (S_{3-3}, S_{3-4}, S_{3-8}), and a combination also occurred between two criteria only in two families (S_{3-5}, S_{3-11}), as for the three families S_{3-2}, S_{3-6}, S_{3-7}, they only appeared with one criterion. Also, it is noticeable from Table (2) that the two families S_{3-6} and S_{3-7} had the highest mean values of internode length (6.98 and 6.99 cm), respectively, and the lowest mean for pods number per the main stem (20.03 and 19.01), respectively, as well as low values of selection indices when compared to the other families. The obtained results cleared that these two families should be excluded because their characteristics are incompatible with the selectorial program's goals. Likewise, for family S_{3-2}, that had the lowest values of pods number per main stem, total pods number per plant, and selection indices.

So, it can be summarized what was done in the previous step, the use of indirect selection with multiple traits aided to select families that have more than a favorable trait. That stage began with 11 families, three of them were excluded by estimating the selection indices and combining more than one desirable trait in the same family, resulting in the selection of 8 distinct families that had more than one of the traits understudy. There are several research results of the efficiency of the use of selection indices in relation to the indirect selection in different crops such as okra (Monpara and Chhatrola, 2010); baby corn (Dovale *et al*., 2011); soybean (Andrade *et al*., 2016); carrot (Carvalho *et al*., 2017); Sweet corn (Silva, 2020). By the end of this stage, the best eight families had been selected, to complete the breeding program by selection.

Table 3. Selected okra families and their means for four selection criteria

Selection criterion	Selected families (S_3)	Mean
<Internode length (IL)	S_{3-1}, S_{3-2}, S_{3-4}, S_{3-5}, S_{3-8}, S_{3-9}, S_{3-10}	4.93 cm
>Pods number per main stem (PNS)	S_{3-1}, S_{3-3}, S_{3-5}, S_{3-8}, S_{3-9}, S_{3-10}	24.25 pods per stem
>Total pods number per plant (TPNP)	S_{3-1}, S_{3-3}, S_{3-4}, S_{3-6}, S_{3-7}, S_{3-8}, S_{3-9}, S_{3-10}, S_{3-11}	43.31 pods per plant
>Selection indices (SI)	S_{3-1}, S_{3-3}, S_{3-4}, S_{3-9}, S_{3-10}, S_{3-11}	251.89

The third stage: individual plant selection program

Performance of different generations

Means and coefficients of variation; for the traits understudy for all the studied populations, Balady cultivar, the third-generation families (S_{3-1}: S_{3-8}), and the pure lines resulting from selfing with selection for six generations (S_{6-1}: S_{6-8}); are shown in Tables (4 and 5). In general, the means performance of the selected genotypes showed considerable changes in all the studied traits throughout the different generations, beginning with S_0, gradually, to S_3, and finally down to S_6, for all traits. Across the three generations of the diverse genotypes, mean values for vegetative growth characteristics decreased, while productive features increased gradually. The same result was given by Metwally *et al.* (2011), who found a remarkable changes in all studied traits of okra in S_2 compared in S_0 generations, as well as decrease in mean values of all studied traits were observed. In addition, the data showed that the coefficient of variation values decreased clearly across generations for all genotypes

Table 4. Means and coefficients of variation of vegetative growth characters for the three generations of okra (S_0, S_3, and S_6) genotypes

Generations		Plant height (cm) $\bar{X}$	Plant height (cm) C.V.%	Internode length (cm) $\bar{X}$	Internode length (cm) C.V.%	Branches number per plant $\bar{X}$	Branches number per plant C.V.%
1	S_0	190.15	26.55	7.00	28.41	5.51	32.00
	S_3	125.6	10.30	4.69	8.11	1.10	12.51
	S_6	130.17	2.70	2.00	2.00	1.00	0.00
2	S_0	190.15	26.55	7.00	28.41	5.51	32.00
	S_3	150.32	10.00	6.81	6.14	2.01	12.00
	S_6	140.13	2.30	2.21	2.21	2.00	0.00
3	S_0	190.15	26.55	7.00	28.41	5.51	32.00
	S_3	116.89	8.14	4.60	6.55	1.03	14.11
	S_6	110.21	2.50	2.07	2.04	1.00	0.00
4	S_0	190.15	26.55	7.00	28.41	5.51	32.00
	S_3	102.68	7.23	5.34	7.03	2.81	11.21
	S_6	120.00	2.30	2.00	2.00	2.00	0.00
5	S_0	190.15	26.55	7.00	28.41	5.51	32.00
	S_3	130.18	7.41	6.52	8.00	1.99	11.00
	S_6	135.22	2.70	2.31	2.31	2.00	0.00
6	S_0	190.15	26.55	7.00	28.41	5.51	32.00
	S_3	125.14	9.11	4.50	6.11	1.01	12.09
	S_6	115.32	2.10	1.91	1.91	1.00	0.00
7	S_0	190.15	26.55	7.00	28.41	5.51	32.00
	S_3	120.00	9.22	4.27	6.08	1.03	11.71
	S_6	120.41	2.40	2.00	2.00	1.00	0.00
8	S_0	190.15	26.55	7.00	28.41	5.51	32.00
	S_3	130.31	8.00	5.59	7.00	2.00	11.31
	S_6	123.78	2.40	2.50	2.13	2.00	0.00

S_0: Original population (Balady cultivar). **S_3:** The third generation of selfing with selection.
S_6: The sixth generation of selfing with selection.

In terms of vegetative growth characteristics (Table 4), comparisons among the means of different generations in each genotype demonstrated a noticeably drop in the mean values of the three traits (desired effect). Where, all genotypes of S_6 are distinguished by a shorter plant height, shorter internode length, and fewer branches per plant as compared to S_3 and S_0. This result was accompanied by a high decrease in the coefficient of variation values, indicating a positive response to the selection program for these traits. The mean value of plant height was 190.15 cm in the S_0 population and ranged from 150.32 – 102.68 cm in the families of the third generation, up to it reached 140.13 – 110.21 cm in the pure lines of the sixth generation. In regard of internode length, it was 7.00 cm in S_0, and ranged from 6.81 to 4.27 cm in the third generation and reaching 2.31-1.91 cm in the sixth. In addition, branches number per plant had a mean value of 5.51 in S_0, then ranged from 2.81 – 1.01 in the third generation to 2.00-1.00 in the sixth. The results showed a considerable graded homogeneity in such traits, according to the coefficient of variation values (Falconer and Mackay, 1996). Where the coefficients of variation for plant height ranged from 26.55% in S_0 to 10.30% -7.23% in S_3 and reached 2.70% -2.10% in S_6. As for the internode length character, the variation coefficient in S_0 was estimated to be 28.41%, in S_3 it ranged from 8.11% to 6.08%, and in S_6 it was 2.31% to 1.91 %. The coefficient of variation values for the attribute of branches number per plant ranged from 32.00% in S_0 to 14.11%-11.00% in S_3 and 0.00% in S_6.

Referring to the features of pods number per main stem, pods number per branches, total pods number per plant, and total yield per plant (g), the results in Table 5 generally indicate advances for these four traits over different selection cycles for different generations compared to the original population. For the previously mentioned characters, the population S_0 reported mean values of 17.18, 28.01, 47.06, and 110.33 g, respectively. And after selection for three generations (S_3) for those traits; the means of most of them increased highly; which ranged between 28.05 - 19.00 for pods number per main stem, 28.16 - 15.08 for pods number per branches, 46.94 - 30.08 for pods number per plant, and 211.53 - 136.27 g for total yield per plant. As noted, the mean values of these traits increased after selection for three generations, except for the characteristic of fruits number per branches, where the mean values decreased. These can be attributed to a decrease in branches number per plant, which decreases from 5.51 in S_0 to 2 - 1 in S_6. Noting that the decrease in the number of pods is not equivalent to the decrease in branches number, which is a degree of improvement in and of itself. For the same prior traits, the mean values of the sixth generation ranged from 57.00 to 35.19, 28.18 to 16.42, 75.23 to 60.44, and 324.99 to 232.82 g, respectively.

The estimated coefficient of variation (C.V.%) values for the different populations (Table 5) also confirmed the degree of variation or the extent of homogeneity within the different genotypes. where the values of C.V.% in the original population (S_0) were 35.14% for pods number per main stem, 25.00% for pods number per branches, 37.33% for total pods number per plant, and 40.25% for total yield per plant. then it decreased by rates ranging from 9.50% - 6.21%, 6.41% - 4.16%, 12.12% - 8.00%, and 15.21% - 10.00% for the previous productivity traits, respectively, after the third selection cycle (S_3). C.V.% estimate reached the least value after the sixth selection cycle (S_6) for the different pure lines to range between 3.50% - 2.00%, 3.00% - 1.32%, 2.87% - 1.89%, 6.54% - 4.00% for the same previous traits, respectively. The extent of the ensuing improvement may be traced based on what was previously stated for each of the mean values, as well as the coefficient of variation for the preceding productivity qualities. The gradual decreasing in the coefficient of variation values reflects a high degree of variation in the Balady cultivar, which decreased with improvement by selection to a relatively high degree of homogeneity in the third generation until the degree of homogeneity increased in the sixth generation. As a result, it can be confirmed that selfing with selection resulted in the concentration of the desirable genes for these features, which contributed to the achieved outcomes.

Table 5. Means and coefficients of variation of yield and it's components for the three generations of okra (S_0, S_3, and S_6) genotypes

Generations	Traits	Pods number per stem		Pods number per branches		Pods number per plant		Total yield per plant (g)	
		$\bar{X}$	C.V.%	$\bar{X}$	C.V.%	$\bar{X}$	C.V.%	$\bar{X}$	C.V.%
1	S_0	17.18	35.14	28.01	25.00	47.06	37.33	110.33	40.25
	S_3	24.63	9.15	20.95	5.01	43.64	10.00	170.99	15.21
	S_6	50.08	2.20	22.22	1.50	72.30	2.00	289.20	4.41
2	S_0	17.18	35.14	28.01	25.00	47.06	37.33	110.33	40.25
	S_3	22.04	9.00	20.04	6.41	42.09	12.12	148.74	13.52
	S_6	45.95	2.91	28.18	1.91	73.13	2.14	271.31	6.15
3	S_0	17.18	35.14	28.01	25.00	47.06	37.33	110.33	40.25
	S_3	25.02	6.21	15.12	4.16	30.08	8.13	149.01	15.00
	S_6	55.09	3.11	20.14	2.00	75.23	2.22	324.99	6.00
4	S_0	17.18	35.14	28.01	25.00	47.06	37.33	110.33	40.25
	S_3	19.00	7.00	28.16	5.35	46.94	8.00	188.72	12.31
	S_6	45.41	2.41	20.74	1.32	66.15	1.91	264.60	4.00
5	S_0	17.18	35.14	28.01	25.00	47.06	37.33	110.33	40.25
	S_3	20.00	6.87	22.01	5.91	42.03	9.21	172.32	13.92
	S_6	35.19	3.50	25.25	2.41	60.44	2.00	247.80	6.54
6	S_0	17.18	35.14	28.01	25.00	47.06	37.33	110.33	40.25
	S_3	20.08	9.50	20.08	6.14	40.21	11.32	141.33	10.99
	S_6	50.11	2.52	16.42	3.00	66.52	2.87	232.82	4.92
7	S_0	17.18	35.14	28.01	25.00	47.06	37.33	110.33	40.25
	S_3	28.05	8.00	15.08	4.92	43.09	9.50	211.53	12.00
	S_6	57.00	3.44	17.00	2.50	74.00	2.50	318.94	5.00
8	S_0	17.18	35.14	28.01	25.00	47.06	37.33	110.33	40.25
	S_3	25.69	6.71	15.14	5.00	40.72	8.93	136.27	10.00
	S_6	45.23	2.00	23.13	2.00	68.36	1.89	247.26	4.25

S_0: Original population (Balady cultivar).
S_3: The third generation of selfing with selection.
S_6: The sixth generation of selfing with selection.

Mean performance and improvement percentages of selected pure lines

Comparison of the mean values of vegetative growth characteristics for the selected pure lines (S_6) versus the Balady cultivar recorded the results in Table (6). Data in that table clearly showed that all the selected pure lines outperformed the original population in terms of mean values and improvement percentage for the three criteria, namely plant height, internode length, and branches number per plant. Where the selected pure lines recorded mean values for these three traits ranging from 140.13 to 110.21 cm for plant height, 2.50 to 1.91 cm for internode length, and 1.00 to 2.00 for branches number per plant, while the original population means values were 190.15 cm, 7.00 cm, and 5.51. This apparent drop in the mean values of these attributes illustrates the magnitude of the improvement achieved during the six cycles of the individual plant selection program. Where the goal of improving vegetative growth specifications aim to achieve short-medium plant height with the fewest number of branches and the shortest internode length, resulting in increasing productivity, for both plant and unit area, by increasing the number of plants per unit area. This in relation with earlier reports of Metwally *et al*., 2011, who noticed that the selected strains had the lowest values of vegetative traits after six generations of inbreeding and selection. The improvement percentages for these features were determined to be between 42.04% and 26.30%, 72.71% and 64.28%, and 81.85% and 63.70%, respectively. These findings showed that the six consecutive cycles of selfing with selection used were able to achieve the requisite improvement in the three vegetative growth traits investigated. These outcomes are to be expected, given these qualities appear to be simple inherited. Therefore, the selection success of those traits could be related to the gene action involved in the inheritance of these traits, which seemed to be additive, as mentioned by Martin *et al*., 1981; Ariyo, 1990; Shusmita and Das, 2003, who reported that additive gene action was more important in the inheritance of internode length and plant height.

Table 6. Mean performance (x) and improvement percentages (I%) of eight selected pure lines of okra after six cycles of individual plant selection program for some important characters

Characters / Genotypes	Plant height (cm)		Internode length (cm)		Branches No. per plant		Pod length (cm)		Pod diameter (cm)	
	$\bar{X}$	I%	$\bar{X}$	I%	$\bar{X}$	I%	$\bar{X}$	I%	$\bar{X}$	I%
S6-1	130.17 d	-31.54	2.00 e	-71.42	1.00 c	-81.85	3.58 f	-17.12	1.40 bc	-25.13
S6-2	140.13 b	-26.30	2.21 cd	-68.42	2.00 b	-63.70	3.50 f	-18.98	1.30 bc	-30.48
S6-3	110.21 h	-42.04	2.07 de	-70.42	1.00 c	-81.85	5.00 a	15.74	1.50 b	-19.78
S6-4	120.00 f	-36.89	2.00 e	-71.42	2.00 b	-63.70	4.00 d	-7.40	1.12 c	-40.10
S6-5	135.22 c	-28.88	2.31 bc	-67.00	2.00 b	-63.70	3.80 e	-12.03	1.31 bc	-29.94
S6-6	115.32 g	-39.35	1.91 e	-72.71	1.00 c	-81.85	4.00 d	-7.40	1.31 bc	-29.94
S6-7	120.41 f	-36.67	2.00 e	-71.42	1.00 c	-81.85	4.76 b	10.18	1.30 bc	-30.48
S6-8	123.78 e	-34.90	2.50 b	-64.28	2.00 b	-63.70	4.50 c	4.16	1.40 bc	-25.13
Balady C.V.	190.15 a	-----	7.00 a	------	5.51 a	------	4.32 c	-------	1.87 a	-------

Values having the same alphabetical letter (s) within each column, don't significantly differ from one another, using Duncan's multiple range test at 0.05 level of probability.

I% = ($\bar{x}$ value of character – $\bar{x}$ value of original population) / $\bar{x}$ value of original population

Table 7. Mean performance (x) and improvement percentages (I%) of eight selected pure lines of okra after six cycles of individual plant selection program for some important characters

Characters / Genotypes	Pod weight (g)		Pods No. per stem		Pods No. per branches		Pods No. per plant		Pod yield per plant (g)	
	$\bar{X}$	I%	$\bar{X}$	I%	$\bar{X}$	I%	$\bar{X}$	I%	$\bar{X}$	I%
S6-1	4.00 c	-8.46	50.08 b	191.50	22.22 c	-20.67	72.30 d	53.82	289.20 c	162.12
S6-2	3.94 cd	-10.91	45.95 c	167.46	28.18 a	0.60	73.13 c	55.39	271.31 d	145.90
S6-3	4.42 a	1.14	55.09 a	220.66	20.14 d	-28.09	75.23 a	59.85	324.99 a	194.56
S6-4	4.00 c	-8.46	45.41 c	164.31	20.74 d	-25.95	66.15 g	40.56	264.60 e	139.82
S6-5	4.10 bc	-6.17	35.19 d	104.83	25.25 b	-9.85	60.44 h	28.43	247.80 f	124.59
S6-6	3.66 d	-16.24	50.11 b	191.67	16.42 e	-41.37	66.52 f	41.35	232.82 h	111.02
S6-7	4.41 a	0.91	57.00 a	231.78	17.00 e	-39.37	74.00 b	57.24	318.94 b	189.07
S6-8	3.82 cd	-12.58	45.23 c	163.27	23.13 c	-17.42	68.36 e	45.26	247.26 g	124.10
Balady C.V.	4.37 ab	-------	17.18 e	--------	28.01 a	-------	47.06 i	-------	110.33 i	--------

Values having the same alphabetical letter (s) within each column, don't significantly differ from one another, using Duncan's multiple range test at 0.05 level of probability.

I% = ($\bar{x}$ value of character – $\bar{x}$ value of original population) / $\bar{x}$ value of original population

Regarding the characteristics of pods, pod length, and pod diameter in Table (6) and average pod weight in Table (7); the results reflected the convergence of the mean values of the selected pure lines to each other, as well as with the original population, with some significant differences among those means. As for pod length, pure line S_{6-3} recorded the highest significant mean value of this trait (5.00 cm), followed by pure line S_{6-7} with a mean value of 4.76 cm, then the pure line S_{6-8} with a mean value of 4.50 cm. Accordingly, those three pure lines recorded a percentage of improvement of (15.74%, 10.18%, and 4.16%), respectively. In terms of pod diameter, the selected pure lines were not statistically different from one another, and the recorded mean values were significantly lower than the original population. The two pure lines S_{6-3} and S_{6-7}; recorded the heaviest pod weight values (4.42 and 4.41 g, respectively), which differed significantly from the means of all the selected pure lines but did not differ significantly from the original population (4.37 g). In addition, compared to the original population, those two pure lines showed a slight improvement rate, ranging from 1.14 % to 0.91 % for S_{6-3} and S_{6-7}, respectively, as shown in Table (7).

Referring to the productivity characteristics (Table 7), the results, in general, reflected a distinct degree of improvement in these four traits after six cycles of selfing with selection; Since the mean values of these traits recorded a significant increase in the mean of those pure lines compared to the original population (Metwally *et al*., 2011; Ibrahim *et al*., 2013; Ibrahim *et al*., 2018). Concerning pods number per the main stem, all pure lines significantly outperformed the original population. Pure lines S_{6-7} and S_{6-3} having the highest mean value of 57.00 and 55.04 and an improvement percentage of 231.78% and 20.66, respectively. Conversely, the pure line S_{6-5} had the lowest mean value of 35.19 with a considerable improvement percentage (104.83%), but it was still better than the original population, which had the lowest mean value of 17.18. This great superiority in pods number per main stem can be attributed to the noticeable decrease in internode length as presented in Table 4; that caused an increase in nodes number with the relative stability of plant height, as shown in Fig. 1. As this was the trend during the successive cycles of this program, which is to increase pods number per main stem by selecting the short internode and not in the towered of selecting the highest plant height.

As for pods number per branches, it is noticeable that only the pure line S_{6-2} made a slight and insignificant improvement compared to the original population, which recorded a mean value of 28.18 with an improvement percentage of 0.60%. While all the other selected pure lines (the seven pure lines) had a significant decline compared to the original population. The above result can be explained by referring to Fig 2, that show a decrease in the number of branches per plant in the pure lines selected. Where, as previously indicated, this was the trend in the selectorial program to be between one or two branches compared to the original population, which recorded more than 5 branches per plant. This could explain why the selected pure lines have a low number of pods per branches. In terms of total pods number per pant characteristic, the data revealed that the selected pure lines significantly outperformed the original population (Table 7). The pure line S_{6-3} had the highest mean value 75.23, followed by S_{6-7}, S_{6-2}, and S_{6-1}, which had mean values of 74.00, 73.13, and 72.30, respectively, while the original population had the lowest significant mean value of (47.06). Accordingly, those pure lines showed distinct improvement percentages; reported as 59.85%, 57.24%, 55.39%, and 53.82%, respectively, while the lowest improvement percentage was in pure line S_{6-5} with 28.43%. By studying the behavior of the different pure lines of the previous three traits; it is clear that total pods number per plant is the sum of pods number per main stem and pods number per branches. The most important factor here is pods number per main stem, as illustrated in Fig. 3, which was favorably influenced by the reduction in internode length. As a result of the shorter internode length, there will be more internodes per plant, which will lead to more pods per main stem, consequently total pods number per plant will increase. Based on the foregoing, the highest total yield per plant of the different selected pure lines ranged from 324.99 to 232.82 g per plant in pure lines S_{6-3} and S_{6-6}, respectively, indicating an improvement percentage compared to the original population of 194.56% - 111.02%; while the original population recorded 110.33 g per plant, which was the least significantly. Concerning branch internode length, selection had no significant effect on this attribute during many cycles of improvement. As a result, pods number per branches was relatively stable, as opposed to pods number per main stem. This explains why plants with fewer branches are preferred; on the other hand, increasing the number of branches increases the space occupied by the plant during its growth, as well as increasing the shadowing area. As a result, plants with a high number of branches can be replaced by those possessed fewer branches, increasing the number of plants per unit area. It's worth noting that the nature of the branch exit on the stem should takes acute angle, allowing the plant to take up less space.

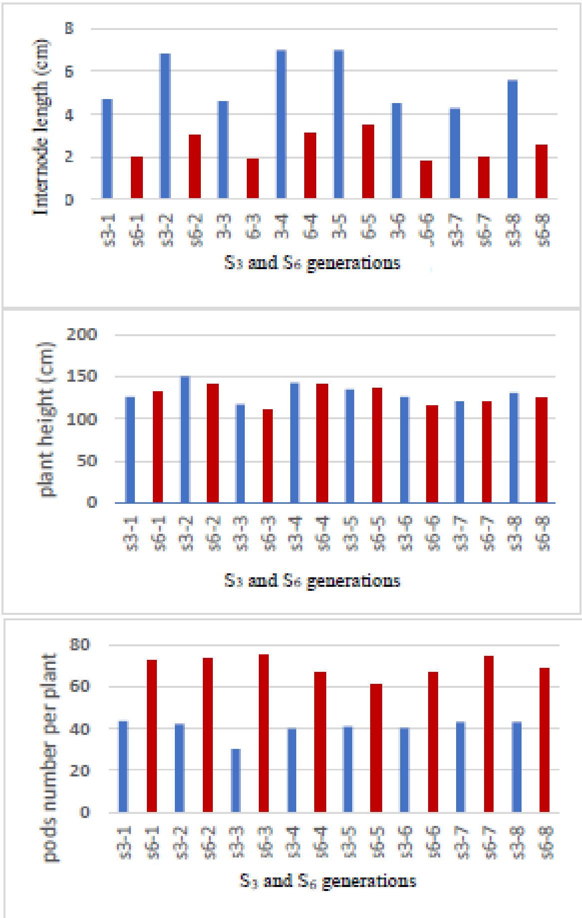

Fig. 1. Relationship between pods number per plant and both the two characters of vegetative growth

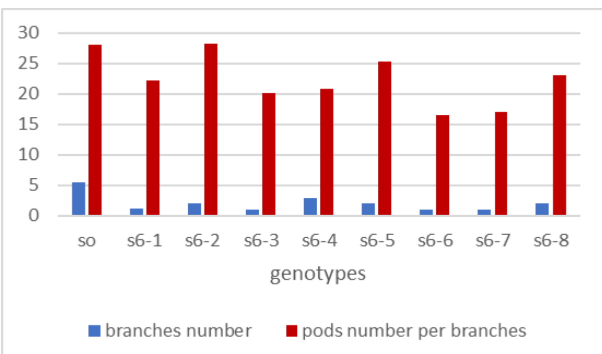

Fig. 2. Comparison the original population with the selected pure lines for the two characters branches number per plant and pods number per branches

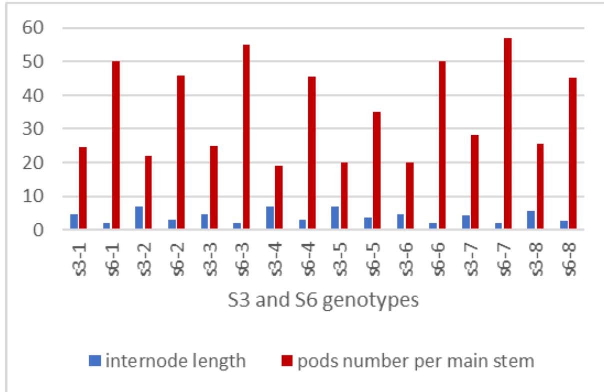

Fig. 3. Pods number per main stem as affected by internode length in different genotypes of the two generations

CONCLUSION

In conclusion, eight pure lines were selected and evaluated from 18 enhanced families of the okra local cultivar Balady. According to this study, improvement was defined as a decrease in the coefficients of variation for all studied qualities, while the mean values of yield traits increased across third to sixth generations, except for lower mean values of vegetative growth traits. For maximizing the production potential of okra, selection for yield components and yield related characteristics is an effective strategy. It is suggested that these eight promising pure lines can be used in another breeding program aimed at developing new Egyptian okra hybrids suitable for growing under local environmental conditions.

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الملخص العربي

انتخاب سلالات نقية واعدة من البامية لتطوير أصناف هجن جديدة في مصر

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أجريت هذه الدراسة لانتخاب وتقييم أفضل سلالات نقية من البامية ذات إنتاجية مرتفعة وخصائص زراعية جيدة، وذلك عن طريق التلقيح الذاتي مع الانتخاب بدءا من الجيل الثالث والملقح ذاتيا S3 إلى الجيل السادس من التلقيح الذاتى S6، لاستخدامها كآباء في انتاج أصناف هجن تجارية. بدأ البرنامج بـ ١٨ عائلة محسنة من الصنف البلدي وانتهى الى ثمانية سلالات نقية من الطرز الجينية المحلية (الصنف البلدى) خلال الفترة من ٢٠١٧-٢٠١٩. اعتمد البرنامج الانتخابى على تقدير كل من معامل الارتباط ومؤشرات الاختيار كأداتين مهمتين للمساهمة في البرنامج الانتخابى. اكتمل البرنامج بثلاث دورات من التلقيح الذاتى مع الانتخاب لتحسين الإنتاجية وبعض الصفات المهمة المرتبطة به. خلال موسم صيف ٢٠٢٠ تم تقييم السلالات الثمانية النقية الناتجة من الصنف البلدي. باستخدام تصميم القطاعات العشوائية الكاملة. كما تم تقدير كلا من المتوسط ومعامل الاختلاف للأجيال الثلاثة S0 و S3 و S6. وهى العشيرة الاصلية، الجيل الثلث من التلقيح الذاتى مع الانتخاب ، الجيل السادس من التلقيح الذاتى للانتخاب، على الترتيب. وقد أظهرت النتائج التي تم الحصول عليها ما يلي:

- تم انتخاب ١١عائلة من أصل ١٨ عائلة بناءً على تقديرات معامل الارتباط ومعامل الانتخاب.
- تم انتخاب ٨ سلالات نقية من الـ ١١ عائلة سالفة الذكر خلال الدورات الثلاث لبرنامج انتخاب النباتات الفردية.
- يعكس سلوك الأجيال الثلاثة المذكورة بشكل عام تحسنًا ملحوظًا في قيم كل من المتوسط ومعامل الاختلاف لجميع الصفات قيد الدراسة. وقد تمثل هذا التحسن فى انخفاض قيم معامل الاختلاف لجميع الصفات، بينما زادت قيم المتوسط للصفات المختلفة خلال الأجيال الثلاثة ، باستثناء صفات النمو الخضري التي انخفضت متوسطاتها.
- أظهر تقييم السلالات الثمانية النقية الناتجة عن تطبيق برنامج الانتخاب أن هناك تمييزا ملحوظا في جميع الصفات قيد الدراسة. والتي تمثلت في الوصول إلى سلالات نقية قصيرة إلى متوسطة الطول ذات عدد قليل من الافرع وسلاميات قصيرة. بالإضافة إلى ذلك ، عكست هذه السلالات النقية تمييزًا واضحًا في خصائص المحصول ، والتي ظهرت من خلال تقدير قيم المتوسط لصفة عدد القرون على الساق الرئيسي، وعدد القرون لكل فرع، عدد القرون الكلى للنبات، والمحصول الكلي للنبات.

وفقًا لذلك، تفوقت جميع السلالات النقية المنتخبة على العشيرة الأصلية، وكذلك العائلات المنتخبة منهم. لذلك، يمكن ادراج هذه السلالات النقية الجديدة في برامج التربية لتحسين إنتاج البامية في مصر.