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Improving some Economical Traits of Local Okra (*Abelmoschus esculentus* L. Moench) Through Selection and Inbreeding

Ibrahim, E. A.[1]; M. Y. Abed[1] and A. M. Moghazy[2]
[1]Cross pollinated Vegetable crops Dept., Horticulture Research Institute, Giza
[2]Vegetable Seed Technology Dept., Horticulture Research Institute, Giza

ABSTRACT

This investigation aimed to genetic improvement of local okra (cv. Balady) plants and to develop superior inbreds through selection and inbreeding. Three cycles of selection were employed in three consecutive seasons of 2013, 2014, 2015 and the developed inbreds were evaluated in summer season of 2016 with the local variety. The analysis of variance parameters showed a great variation for all studied traits within the cv. Balady. Therefore, the selection and inbreeding procedure resulted in isolation of twelve inbreds characterized by different horticultural traits. These inbreds showed uniform plants within each genotype. Highly significant variations were obtained for all the studied traits. On the basis of mean performance, the results of evaluation trial showed that the inbreds L5 and L8 were the earliest in flowering time. The selected inbreds L3, L6 and and L10 significantly exhibited the largest means of plant height. The developed inbreds significantly exceeded the cv. Balady for yield/plant and total yield, except for L8, L9 and L11. The selected inbreds L5 and L8 exhibited the largest means of pod length and pod weight and they surpassed the Balady pod measurements. The magnitudes of genetic variation were close to the magnitudes of phenotypic variation for all traits, indicating that the predomination of genetic component in the expression of the studied traits. There are positive and significant correlations between yield/plant and plant height, number of pods/plant and total yield/fed which prove the relative importance of the foregoing traits for yield improvement through selection of these traits. It is recommended to use the L3, L10, L4 and L7 inbreds for maximizing yield production Therefore, the foregoing inbreds are considered as promising genotypes suitable for growing under local environmental conditions.

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is one of the important vegetable crops in Egypt and throughout warm temperature regions of the world. It is a versatile vegetable, grown principally for its green pods that are used cooked, boiled, frozen, canned or as dried food. Green pods are good dietary supplement which is free of fat and low in calories (Patel *et al.*, 2013). The fresh pods are high in fiber, and have several valuable nutrients such as 30% of the recommended levels of vitamin C (16-29 mg), 10-20% of foliate (46-88 mg) and about 5% of vitamin A (Singh *et al.*, 2014) . Both mesocarp and seeds are excellent sources of zinc (80 mg/g) as well as phenolic compounds. Seeds are utilized as a source of protein and vegetable oil (Salunkhe and Kadam, 1998). The seed oil is high at unsaturated fats such as oleic acid and linolleic acid. The seed oil content is about 40 % (Tripathi *et al*, 2011). Furthermore, it has a wide range of medicinal value and has been used to reduce blood glucose levels and lowers cholestrol level in blood (Kittana *et al.,* 2014; Dubey and Mishra, 2017; Anjani *et al.*, 2018). A mucilaginous preparation from the pod can be used as a plasma replacement or blood volume expander (Siemonsma and Kouame, 2004). Okra was reported to have alkaline pH which contributes to its relieving effect in gastrointestinal ulcer by neutralizing digestive acid (Wamanda, 2007). It has an anti-inflammatory and anti-diarrheal properties (Shammi *et al*, 2014). Its ripe seeds are roasted , ground and used as a non-caffein substitute for coffee in some countries (Calisir and Yildiz, 2005).

Egyptian local varieties are the result of a non-programmed selection process conducted by the horticulturalists in every crop cycle. They standout for their productive adaptation to local conditions, showing advantages related to growth cycle, disease resistance and yield stability.

Thus, the availability of genetic basis to develop genotypes adapted to local agro-ecological conditions becomes critical. The massive genetic resources scattered in several regions in Egypt (Damarany and Farag, 1994; Hussein, 1994; Masoud, *et al*., 2007; Shalan *et al.*, 2011) is a prerequisite to develop the existing varieties or landraces (Abo El-Khar, 2003; Masoud *et al.*, 2007; Ibrahim *et al*, 2013). The local cultivars are open pollinated, so that they are subjected to out-crossing. Therefore, the generated populations from these cultivars show an enormous magnitude of variability. The local variety cv. Balady plants considered as a mixture of heterozygous genotypes originated in the past from out-crossing occurred in grower's farms, where they produce their own seeds without adequate isolation. Thus, some of the characters are undesirable and the plants are probably weak in growth and low in yield, accordingly.

The primary aim of the breeder is to evolve superior genotypes from the available landraces or varieties. The variation existed in this crop offers a great scope for the genetic improvement through selection. Selection is an appropriate method when wide variation is presented, particularly when the additive gene action is involved in the inheritance of the quantitative characters. Inbreeding with selection has been practiced to develop new strains of okra (Masoud *et al.*, 2007; Metwally *et al.*, 2011). This method resulted in producing superior populations derived from local cultivars (Abo EL-Khar, 2003; Ibrahim *et al.*, 2013)

Inbreeding has been used in plant breeding programs to fix favorable genotypes of agricultural interest (Allard, 1999), to separate favorable genotypes (Singh, 2006), and to reduce the percentage of heterozygousity in the population (Falconer and Mackay, 1996). However, inbreeding reduces population fitness, particularly in allogamous species (Singh, 2006), increases the genetic variance between families, and reduces it within families (Falconer and Mackay, 1996).

Creative use of inbreeding can increase response to selection. Inbreeding redistributes the genetic variance in a population, reducing or removing it within an inbred line and increasing it between collections of lines. Inbreeding also, generally, increases the covariance between relatives; as relatives become increasingly more genetically similar under inbreeding (Lynch and Walash , 2000)

The purpose of this investigation was to measure the improvement of okra plants after three cycles of selection and to develop superior inbreds, with desirable traits, from the local okra (cv. Balady) through inbreeding and selection.

MATERIALS AND METHODS

The present trials were carried out at El-Baramon Experimental Farm. Horticulture Research Institute, Dakahlia Governorate during the four consecutive summer seasons of 2013, 2014, 2015 and 2016

Plant materials and selection procedure

The seeds were collected from different farms in Delta. Seeds were planted in the summer season of 2013. The initial population consisted of 800 plants of the local okra cv. Balady. These plants are a mixture of local cultivars with different phenotypes. The plants were subjected to severe selection in the first selection cycle, and as a result, the best ninety plants were visually selected, based on earliness, plant height, leaves morphology, branching, yield ability and pod characteristics. These selected plants were self-pollinated to increase homozygousity in the next offspring. The selfed seeds were sown in summer season of 2014 and the best twenty plants were selected and were subjected to inbreeding to produce more homozygous inbreds. The same selection and inbreeding process was practiced in summer 2015. The selfed seeds were planted and were subjected to more severe selection, with diminishing the selected inbreds to the best twelve. The selected inbreds were denoted L_1, L_2, L_3, …………., L_{12}.

Horticultural Evaluation trial

During summer season of 2016, a field trial was carried out in order to evaluate the selected inbreds with the local variety (Balady), and to estimate the improvement achieved after three cycles of selection and inbreeding over the original variety. The experiment was laid out in a randomized complete blocks design with three replications. Each replicate included the Balady cv. and the twelve selected inbreds. Each plot consisted of four rows, 5 m long and 0.75 m wide, with spacing of 0.35 m between plants. Other cultural practices were carried out as recommended for okra planting.

Recorded measurements

Number of days to the first opening flower, plant height (cm) was measured at 100 days after sowing, the average number of branches/plant, plant yield was estimated as number (No/plant) and weight (g /plant) of pods per plant, total yield per feddan (ton/fed.), average pod length (cm) and diameter (cm) and average pod weight (g); were measured 5 days after fruit set.

Data analysis

The obtained data of horticultural evaluation were subjected to statistical analysis using the analysis of variance method and the F-test according to Snedecor and Cochran (1982), and the means of the genotypes were compared by using Duncan multiple range test (Duncan, 1955) at the level of 5% of probability

Genetic and variability analyses

Estimation of variability in the original population was studied in terms of standard deviation (SD), coefficient of variation (CV) and standard error (SE).

The variance components, genotypic (σ^2 g) and phenotypic variances (σ^2 ph) were analyzed using the procedure given by Johnson *et al.* 1955. Correlation coefficient (r) analysis between pairs of agronomic traits was performed as outlined by Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

Estimation of variability in the original population

The estimations of the variability of the various studied traits in the Balady cv. were studied and the data are presented in Table 1.

The estimated values for standard deviation (SD), coefficient of variation (CV) and standard error (SE) for number of days to flowering were 10.11, 16.74 and 4.52, respectively, indicating a remarkable variation for number of days to flowering . The estimations of SD, CV and SE for plant height were 26.01, 15.72 and 11.63, respectively. These relatively high estimates revealed that there is a wide variation for plant height within the Balady cv. Otherwise, these parameters revealed low variation for number of branches.

The estimated values of SD (9.41), CV (15.17) and SE (4.21) for number of pods/plant reflect the presence of notable variation among plants of the Balady cv. The plants of the original population differed greatly in their productivity as the estimation of SD recorded a high value (84.02) with a relatively high CV (24.08). Furthermore, a considerable variation was detected for total yield/fed as shown by the great estimation of CV (44.48). Regarding pod characteristics, e.g., pod length, diameter and weight, the obtained data show relatively low estimations of SD and SE. However, relative high estimations of CV were obtained for pod length (31.79) and pod weight (30.31), indicating the low variation and wide range of these traits among the plants of the base population.

Table 1. Standard deviation (SD), coefficient of variation (CV) and standard error (SE) for the local variety Balady

Traits	SD	CV	SE
Flowering days	10.11	16.74	4.52
Plant height (cm)	26.01	15.72	11.63
No. branches	1.11	36.45	0.50
No. Pods/plant	9.41	15.17	4.21
Yield/plant (g.)	84.02	24.08	37.58
Total yield (ton/fed.)	0.67	44.48	0.30
Pod length (cm)	1.21	31.79	0.54
Pod diameter (cm)	0.25	6.29	0.11
Pod weight (g)	1.70	30.31	0.76

The variation in the local variety (Balady) in most of the studied traits might be ascribed to the fact that natural cross-pollination between plants resulted in exchange of different alleles within the population. Such variation in the local cultivars has been reported (Damarany and Farag, 1994; Shalan *et al*., 2011 and Ibrahim *et al*., 2013)

The simple measurements of the variability suggest that Balady cv. has enough variability for most traits to carry out further selection program to develop new superior genotypes with more uniformity.

Variation among the tested genotypes

The analysis of variance of Balady cv. and the developed inbred genotypes are shown in Table 2. The results of analysis of variance and mean squares for studied traits revealed high significant variation for all traits. Furthermore, the magnitudes of genotypic mean squares were larger than their corresponding error mean squares. The results of the F-test showed that the mean squares of the genotypes were highly significant for all examined traits. Such results were expected since the tested genotypes included variable genotypes. The present for such significant differences for genotypes made it possible to compare the means of the different genotypes. These findings are in agreement with those obtained by Bello *et al*. (2006) and El-Gendy (2012). The results of the F-test indicate highly significant differences among the tested genotypes for all studied traits.

Table 2. Analysis of variance for all studied traits of Balady cv. and the developed inbreds after three cycles of selection and inbreeding.

Source of variation	d.f.	Flowering days	Plant height (cm)	No. branches	No. Pods/plant	Yield / plant (g.)	Total yield (ton/fed.)	Pod length (cm)	Pod diameter (cm)	Pod weight (g)
Replicates	2	12.8	5.7	0.06	23.7	39.2	0.01	0.09	0.05	0.09
Genotype	12	99.8**	3862.7**	6.50**	341.1**	14996.1**	3.35**	4.43**	0.10**	2.76**
Error	24	20.4	15.8	0.03	28.2	20.7	0.01	0.02	0.01	0.05

Horticultural evaluation of genotypes after three cycles of selection and inbreeding

Means comparison of the evaluated populations and the results of F-test are presented in Table 3. The results show that the examined genotypes varied in their horticultural characteristics after three cycles of selection and inbreeding. Unlike the local variety cv. Balady, the inbreds showed uniform plants within each genotype. The results revealed that selected inbreds L5 and L8 were the earliest genotypes for flowering time (58.20, and 59.43 days, respectively). There is a wide variation for plant height among the tested genotypes. The tallest plants were the three genotypes L6, L10 and L3 with mean values of 203.57, 203.40, and 201.17 cm, respectively; whereas L8 significantly recorded the shortest plants (83.93 cm). As for number of branches/plant, the two inbreds L1 and L10 possessed the largest number of branches/plant (5.04 and 4.85, respectively); while L5 and L8 exhibited the lowest means (0.7 and 0.6, respectively). Regarding yield/plant, it is evident that most of the selected inbreds surpassed the local variety. The significantly largest yield production per plant was recorded by L10 and L3 with mean values 461.17 and 458.73 g, respectively. Similarly, the inbreds L10 and L3 significantly produced the largest yield/feddan with average yields of 6.89 and 6.85 ton/fed., whereas the inbred L8 showed the lowest mean yield (3.74 ton/fed.). It is notable that most of the selected inbreds exceeded the Balady cv. for total yield production. These results proved the efficiency of selection breeding for developing superior populations of okra after three cycles of selection and inbreeding. Similar results were obtained by Masoud *et al*.(2007), Reddy *et al*. (2012) and Ibrahim *et al*. (2013).

Concerning fruit characteristics, data revealed that inbreds L5 and L8 possessed the tallest pod lengths (7.41 and 7.06 cm, respectively), whereas the shortest pod lengths were recorded by the inbreds L9, L12 and L6 (3.55, 3.66 and 3.70 cm, respectively). With respect to pod diameter, the inbred lines L5 and L6 significantly exhibited the lowest mean values (1.40 and 1.57cm, respectively) among all the studied genotypes. The largest pod weight were obtained by L5 (7.63 cm) and L8 (7.17 cm).

Table 3. Mean performance of Balady cv. and the selected genotypes of okra after three cycles of selection

Genotypes	Flowering days	Plant height (cm)	No. branches	No. Pods/plant	Yield/ plant (g.)	Total yield (ton/fed.)	Pod length (cm)	Pod diameter (cm)	Pod weight (g)
Balady	71.65 abc	136.17 e	3.71 cd	67.47 bc	299.40 f	4.47 f	4.28 ef	1.77 cde	6.67 c
L1	73.36 ab	160.90 d	5.04 a	81.82 a	427.7 c	6.39 c	5.23 b	1.60 ef	5.90 d
L2	76.07 a	184.47 b	3.09 e	76.30 ab	386.2 d	5.77 d	4.29 ef	1.90 b	5.37 e
L3	68.96 bc	201.17 a	2.24 f	72.9 abc	458.73 a	6.85 a	4.08 f	1.67 def	6.40 c
L4	71.50 abc	137.67 e	1.90 g	80.90 a	433.20 bc	6.47 bc	4.82 d	1.70 ef	5.35 de
L5	58.20 d	125.13 f	0.70 h	53.23 d	389.90 d	5.82 d	7.41 a	1.40 g	7.63 a
L6	74.47 ab	203.57 a	3.51 d	68.77 bc	357.93 e	5.35 e	3.70 g	1.57 fg	5.30 e
L7	68.77 bc	169.53	4.47 b	70.57 bc	440.84 b	6.58 b	4.74 d	1.70 cdef	5.23 e
L8	59.43 d	83.93 g	0.60 h	42.57 e	250.37 g	3.74 g	7.06 a	1.80 bcd	7.17 a
L9	65.19 cd	134.40 e	3.97 c	65.63 c	292.90 f	4.37 f	3.55 g	1.87 bc	4.63 f
L10	73.17 ab	203.40 a	4.85 a	70.60 bc	461.17 a	6.89 a	4.40 e	2.10 a	6.57 c
L11	70.33 bc	183.67 b	2.36 f	67.43 bc	296.27 f	4.42 f	4.15 f	1.83 bcd	4.53 f
L12	73.21 ab	161.67 d	1.83 g	75.90 ab	390.33 d	5.83 d	3.66 g	1.60 ef	5.22 f

Generally, the obtained results reflected high or relatively high improvment, with different magnitudes, in vegetative growth parameters, yield and its components and pod characteristics through of selection and inbreeding for three cycles.

Genotypic, phenotypic variations and coefficient of variation

Coefficient of variation is defined as the measure of variation and is independent of unit of measurement which is used for comparing different populations. It is provided by the standard deviation expressed as percentage of mean (Panse and Sukhatme, 1985). Genotypic coefficient of variation is the genotypic standard deviation expressed as percentage of mean and phenotypic coefficient of variation is expressed as the phenotypic standard deviation expressed as the percentage of mean.

The results of the genotypic (σ^2 g) , phenotypic (σ^2 ph) variation and coefficient of variation (CV) for the original population (Balady) and the developed inbreds are presented in Table 4. The estimations of the phenotypic variances were larger than the genotypic variances for all studied traits. This suggests that there is an environmental effect in the expression of these traits. Nevertheless, the magnitudes of genotypic variances were very close to the phenotypic variances, which signify that the genetic factors contributed massively in the phenotypic variance which indicate the predomination of genetic components in the expression of the studied traits, whereas the environmental factors had a little effect. Similar findings were reported by Yadav *et al*. (2016), Chinatu *et al*. (2017) and Sravanthi (2017). The magnitudes of estimated coefficient of variation (CV) were relatively low for the evaluated traits. This could be ascribed to the relative stability of the various characteristics within each genotype and the relatively low variation within each genotype after three cycles of selection and inbreeding.

Table 4.Genotypic, phenotypic variation and coefficient of variation of Balady cv. and the selected genotypes of okra after three cycles of selection and inbreeding.

Traits	$\sigma^2 g$	$\sigma^2 ph$	CV
Flowering days	26.45	34.79	6.49
Plant height (cm)	1282.33	1298.10	2.48
No. branches	2.17	2.19	6.05
No. Pods/plant	104.31	132.46	7.73
Yield/plant (g.)	4992.03	5012.75	1.21
Total yield (ton/fed.)	1.11	1.12	1.91
Pod length (cm)	1.47	1.49	2.93
Pod diameter (cm)	0.03	0.95	6.29
Pod weight (g)	0.90	0.95	3.91

Correlation among studied traits

A positive correlation between favorable traits is useful for plant breeder while selecting for genetic improvement because it helps the breeder to select for quantitatively inherited traits and take into account for the various characters as indirect selection procedure.

Phenotypic correlations (r) among the studied traits are given in Table 5. The data illustrate that highly significant and positive correlation between days to flowering and pod length (r = 0.48) was obtained. A positive and significant correlation was noticed between plant height and number of branches (r = 0.50), number of pods/plant (r = 0.56), yield/plant (r = 0.56) and total yield/fed. (r = 0.55), revealing the important association between plant height and yield components traits. Significant or highly significant and positive correlation between number of pods/plant and days to flowering (r = 0.32), plant height (r = 0.56) number of branches (r= 0.50), yield/ plant (r = 0.57) and total yield/fed (r = 0.56) were detected.

In respect with yield components traits, a positive significant correlation were detected between yield/plant and plant height (r= 0.56), number of pods/plant (r= 0.57) and total yield/fed (r= 0.99) which prove the relative importance of the foregoing traits for yield improvement through selection of these traits. Indirect selection of these yield contributing traits in early generations will enhance genetic potential of newly bred okra genotypes.

On the other hand, pod characteristics showed a positive correlation between pod length and flowering time (r= 0.48) and pod weight (r= 0.74), whereas pod diameter had a positive and significant correlation with number of branches (r= 0.38).

Table 5. Correlation coefficient among studied traits of okra plants after three cycles of selection

	Plant height	No. branches	No. Pods/plant	Yield/plant	Total yield	Pod length	Pod diameter	Pod weight
Flowering days	0.41^{**}	0.16^{ns}	0.32^{*}	0.12^{ns}	0.12^{ns}	0.48^{**}	0.24^{ns}	-0.33^{*}
Plant height		0.50^{**}	0.56^{**}	0.56^{**}	0.55^{**}	-0.65^{**}	0.19^{ns}	-0.39^{*}
No. branches			0.50^{**}	0.31^{ns}	0.30^{ns}	-0.52^{**}	0.38^{*}	-0.35^{*}
No. Pods/plant				0.57^{**}	0.56^{**}	-0.63^{**}	-0.03^{ns}	-0.48^{**}
Yield/plant					0.99^{**}	-0.12^{ns}	-0.13^{ns}	0.06^{ns}
Total yield						-0.13^{ns}	-0.12^{ns}	0.06^{ns}
Pod length							-0.29^{ns}	0.74^{**}
Pod diameter								-0.17^{ns}

The results are in line with the findings of Magar and Madrap (2009), Ramya and Senthilkumar (2009), Rashwan (2011) and El-Gendy (2012) and Yadav *et al* (2017).

In conclusion the present investigation revealed the existence of genetic variation within the local variety (Balady) plants. The breeding of the Balady through selection and inbreeding resulted in the development of newly superior inbreds with more uniform characters.

The improvement of the genetically inherited characters was greatly successful through three cycles of selection and inbreeding, particularly for out-crossing okra population. Selection for yield components and the yield associated traits is an efficient method for maximizing the yield potential of okra. It is recommended to use the L3 and L10 inbreds for maximizing yield production. Furthermore, the yield production was remarkably increased in L4 and L7. Therefore, the foregoing inbreds are considered as promising genotypes suitable for growing under local environmental conditions.

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تحسين بعض الصفات الاقتصادية في الباميا المحلية باستخدام الانتخاب و التربية الداخلية

ايهاب ابراهيم عوض الله[1] ، محمد يوسف عابد[1] و علي محمد مغازي[2]

[1]بحوث الخضر خلطية التلقيح -معهد بحوث البساتين - مركز البحوث الزراعية - الجيزة

[2]بحوث تكنولوجيا تقاوي الخضر -معهد بحوث البساتين - مركز البحوث الزراعية - الجيزة

تهدف هذه الدراسة الي التحسين الوراثي لصنف الباميا البلدي و الي انتاج سلالات عالية الانتاج و متوافقة مع الظروف المحلية من خلال برنامج تربية بالانتخاب و التربية الداخلية. اجريت ثلاث دورات من الانتخاب و التربية الداخلية في ثلاث مواسم متتالية اعوام 2013, 2014, 2015 ثم اجريت تقييم العشائر المنتخبة مع الصنف البلدي في الموسم الصيفي 2016. اظهر تحليل التباين للصنف البلدي وجود تباين كبير لجميع الصفات المدروسة مما يمكن معه اجراء الانتخاب و الحصول علي تباين في الصفات المختلفة. اجري برنامج الانتخاب لثلاث دورات متتالية و كان الانتخاب لصفات الازهار و المحصول و مكوناته و صفات القرن و انتهت دورات الانتخاب الي انعزال اثني عشر سلالة مختلفة الصفات الاقتصادية و تتميز بالتماثل بداخل كل عشيرة. تم تقييم العشائر المنتخبة مع الصنف البلدي و اظهر تحليل التباين اختلافات عالية المعنوية بين التراكيب الوراثية . كانت السلالاتان L8 و L5 هما الاكثر تبكيرا في التزهير بينما كانت السلالات L3 , L6, L10 اطول التراكيب الوراثية المنتخبة. بصفة عامة تفوقت العشائر المنتخبة علي الصنف البلدي في انتاجية النبات و كمية المحصول الكلي باستثناء L8 , L9 , L11 . كانت قيم التباين الوراثي كبيرة و تشكل الجزء الاكبر من التباين الكلي بينما تقل اهمية التباين البيئي في تأثيرها علي اظهار الصفات. اظهرت دراسة الارتباط وجود ارتباط معنوي بين محصول النبات و صفات طول النبات وعدد القرون للنبات و المحصول الكلي ممايدل علي اهمية هذه الصفات اثناء عملية الانتخاب حيث يمكن الانتخاب الموجهه لهذه الصفات لانتاج اصناف عالية الانتاج. يمكم التوصية بزراعة السلالات المنتخبة L7, L10, L3, L4 حيث انها سلالات واعدة وتتفوق في انتاجها تحت الظروف المحلية.