Efficiency of Simple Recurrent Selection and Selfing with Selection on Improving Growth, Yield and Quality of Pumpkin (*Cucurbita Moschata*)

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ABSTRACT: It is important to give a good consideration towards the establishment of effective breeding programs for pumpkin purification and improvement. This study was carried out during three successive summer seasons of 2013 till 2015 to determine the effectiveness and efficiency of one cycle of simple recurrent selection and selfing with selection for two generations, as two breeding methods, to improve some important characters of pumpkin cultivar 'Balady'. Eight derived genetic populations; i. e, original population (C_0), one cycle of simple recurrent selection (C_1) and six selected progenies from selfing with selection for two generations (S_2-1, S_2-2, S_2-3, S_2-4, S_2-5 and S_2-6) were evaluated for vegetative, flowering, yield components and fruit quality characters. The results of the estimated values of coefficient of variation indicated that the original population (C_0) had an extensive range of variability which ranged from 13.55% for number of days to first female flower up to 71.83% for total yield/plant. The first cycle of recurrent selection enhanced the main stem length, number of branches/plant, average fruit weight and number of fruits/plant with about 122.60%, 157.50%, 338.30 % and 243.33% respectively. Also, selfing with selection method for two generations enhanced main stem length within the range of 17.00% to 132.10 %, and number of branches per plant by 7.20% to 71.60%, average fruit weight was noticed to be within the range of 65.10% to 285.46% and number of fruits/plant was within the range of 4.00% to 191.66 % for all selected selfed progenies over that of the original population. The selected selfed progeny S_2-1 and C_1 gave high improvement values of total yield/plant with about 189.91% and 148.69%, respectively. The first cycle of recurrent selection was found to be apparently efficient in increasing and enhancing the general performances more than selfing with selection for two generations for most studied characters, except for number of days to first female flower and carotene content. Therefore, it may be concluded that recurrent selection seemed to be effective and efficient for developing of improved commercial pumpkin cultivar 'Balady'; whereas, selfing with selection can be successfully used to develop inbred lines for the production of hybrid or synthetic cultivar, out of the common commercial ones.

INTRODUCTION

Pumpkin (*Cucurbita moschata* Duch ex Poir, 2n= 40) is one of the important vegetable crops belonging to family Cucurbitaceae. It is considered as one of the essential and popular food crops in many tropical and sub-tropical countries. It is paramount as a good source of minerals, fibers, vitamins, carotenoids, antinutrients, antioxidants and phytonutrients. (**Aruah *et al*. 2010**). The consumption of pumpkins and pumpkin-based foods has been shown to confer several beneficial effects on human health due to their antioxidant capacity and terpenoid content. (**Angel *et. al.* 2020 and Milorad *et al*. 2021**). Pumpkin seed products can be added to wheat flour up to a 17% protein level for raw, roasted and autoclaved pumpkin meal, as well as the addition of pumpkin seed proteins resulted in increasing protein, lysine and mineral contents (**El-Soukkary, 2001**). The area allocated for the cultivation of pumpkin in Egypt is not estimated accurately. The production is mostly done on a small scale and the productivity of the growing cultivar is low. This lower productivity could be due to growing old local cultivar which is characterized by relatively low productive capacity.

It might be stated that no serious attempts have been so far made to purify and upgrade the productivity and suitability of pumpkin crop. Accordingly, it is important to give a good consideration towards the establishment of

effective breeding programs for pumpkin purification and improvement. Genetic differences are the raw material of plant breeders where the success of breeding program is depending on the amount of variability present in the original population for the studied crop. Therefore, information on the variability existed in a group of pumpkin populations are essential. High variability as values of coefficient of variation was observed for most characters of pumpkin genotypes (**Alsadon *et al*. 1998, Pandey *et al*. 2002, Pandey *et al*. 2008, and Solieman 2009**).

Recurrent selection is one of the efficient selection methods that are usually used for improving open-pollinated crops and leading to the identification of superior genotypes. It is considered as an effective breeding method of achieving improvement of quantitative characters within a population through maintaining genetic variability. Consequently, natural vigor in cross pollinated crops allows for the concentration of desirable alleles and increases the frequency of superior recombination in successive populations. Breeders often practice inbreeding to confirm desirable characteristics within a population. In plant breeding, inbred lines are used as stocks for the creation of hybrid populations to make use of the heterosis effect. Inbreeding in plants occurs naturally in the form of self-pollination. In many cases, inbreeding with selection increases the effectiveness of selection and the amount of genetic improvement in a breeding program by increasing the frequency of the desirable alleles. The significant inbreeding depression for all the yield characters in pumpkin (Cucurbita moschata Duch. ex. Poir.), except number of fruits per vine, was observed (**Jansi *et al.* 2018**).

Yield and traits related to fruit quality were evaluated for six pumpkin introductions (*Cucurbita moschata* Duch.) from open-pollination and their respective inbreeding line (S_1 and S_2) by **Grisales *et al*. 2009.** They reported that the inbreeding that was accompanied with selection did not cause negative effects on yield, nor the agribusiness characters; fruit pulp weight and color, and fruit dry matter. The local Egyptian pumpkin cultivar was improved through the two practiced breeding methods; one cycle of simple recurrent selection and selfing with selection for two generations, but with different magnitudes among the characters and the used breeding methods (**Solieman 2009**). Several investigators used recurrent selection or/and selfing with selection methods to improve the various economical characters of pumpkin crop such as. **Alsadon *et al*. 1998, Hazara *et al*. 2007, Pandey *et al*. 2008 and Srikanth *et al*. 2017.**

This study is a part of comprehensive breeding program aimed to improve productivity and quality of Egyptian local cultivar 'Balady' of pumpkin (*Cucurbita moschata*). The purposes of the present investigation are comparing the efficiency of two breeding methods; one cycle of simple recurrent selection and selfing with selection for two generations in improving some important characters of "Balady" pumpkin cultivar. Percentage of heritability in broad sense and variance components for each of the growth and productivity traits were considered in this investigation. The main goal of this research aimed to improve some important characteristics of the pumpkin cultivar "Balady".

MATERIALS AND METHODS

This study was carried out during three successive summer seasons of 2013 till 2015, at the Experimental Station Farm, Faculty of Agriculture, Alexandria University, at Abies, Alexandria, Egypt. Simple recurrent selection for one cycle and selfing with selection for two generations, as two breeding methods, were used to improve some important characters of pumpkin (*Cucurbita moschata* Duch ex Poir, 2n=40). The original genetic material consisted of the commercial cultivar of pumpkin crop 'Balady'. This cultivar was chosen since it commonly grown and well adapted to local environmental conditions of Egypt.

Evaluation of the Original Population and First Season for the Breeding Methods:

Seeds of the original population of pumpkin cultivar 'Balady' were sown on April 20th of April, 2013.The experimental area consisted of 115 rows, 4.0 m long and 2.5 m wide. The spacing between plants within rows was 80 cm. The total number of plants for this population was 570. To determine the magnitude and importance of genetic variability for the original population of pumpkin, the statistical parameters, i.e., mean, range and coefficient of variation (C.V. %) were estimated. These parameters were estimated for twelve characters (main stem length, number of branches/plant, number of days to first female flower, sex ratio, flesh thickness, number of fruits/plant, average fruit weight, total yield/plant, dry matter percentage, total soluble solids, carotene content and total sugars) during different growth stages.

Initial visual selection was made in the growing original population of pumpkin 'Balady' Only 227 plants from the 570 plants were selected to begin the procedures of the two selection methods; simple recurrent selection and selfing with selection for two generations. The selection procedures were made according to the measurements of the different studied characters, individual plant basis, depending on the degree of the taller main stem length, a greater number of

branches/plant, fewer number of days to first female flower, close sex ration, thicker flesh thickness, more number of fruits/plant and high content of chemical constituents (dry matter, total soluble solids, total carotenoids and total sugars contents). Selfed seeds of the best 12 plants were selected from the original population (227 growing plants) according to the previously mentioned characters.

At the end of fruit maturity stage, selfed seeds from each selected families, twelve families, of pumpkin were separately harvested as well as seeds of the original population were separately collected and extracted. Selfed seeds of all selected plants were obtained by the end of September, 2013. The seeds of the twelve selected families were divided to equal parts for two groups: the first group represents the seeds of the first selfed progenies; while, the second group was bulked to start the second season of simple recurrent selection.

Second Season of Recurrent Selection and Selfing with Selection:
In the second season on April 23th of April, 2014, seeds of each of the two selection methods, first season of recurrent selection and the first selfed progenies of each selected plant (twelve families), were separately sown; then, selection on the same forgoing basis were made. For simple recurrent selection, bulked seeds of the first season of simple recurrent selection were sown at 40 rows to represent base of the second season of the first cycle of simple recurrent selection. At flowering stage the plants were left for open-pollination to produce the seeds of the first cycle of simple recurrent selection (C_1). For selfing with selection method, seeds of each selected plant, twelve families, were cultivated in the form of separated families (50 plants for each family). Then the practices of selection between and within the selfed progenies of each S_1 families on the same foregoing basis were conducted. At flowering stage, some flowers were selfed, to produce the seeds of the second selfed progenies (S_2). At the end of the growing season selfed seeds of six families, according to selection between families, were separately collected to get the final selected selfed progenies (S_2) which came out to be six progenies.

Evaluation of Genetic Populations:
In this experiment seeds of each of the eight derived genetic populations; i. e, original population (C_0), one cycle of simple recurrent selection (C_1) and the six selected progenies derived from selfing with selection for two generations (S_2-1, S_2-2, S_2-3, S_2-4, S_2-5 and S_2-6) were separately sown on April 26, 2015, in a randomized complete blocks design (R.C.B.D), with three replicates. Each plot was represented by two rows, 4m long and 2.50 m wide and 0.80 m between growing plants. The common cultural practices were carried out according to the recommended practices for commercial pumpkin production.

Data Recorded:
The vegetative and flowering characters were recorded on random samples of five plants from each plot. At the end of the growing season, the main stem length (m) was measured from the first node up to the terminal bud, and the total number of main branches of each sample from each plot was counted. Number of days to the first female flower was recorded as the number of elapsed days from sowing to opining of the first female flower. Sex ratio (%) was determined by dividing the number of staminate flowers by the number of pistillate flowers.

Sample of five random fruits at the mature stage of each experimental plot, were taken to determine flesh thickness (in cm using a rural) and average fruit weight (Kg) (determined by dividing total fruits weight by their total number). The number of fruits/plant and total yield/plant Kg) were recorded for all growing plants in each plot.

A random sample of 8 fruits from each experimental plot was taken to determine fruit dry matter (%), total soluble solids (%), total carotenoid content (according to the method described by **Davies 1976**, and expressed as mg.100g^{-1}f.w) and total sugars (%) (according to Nelson's method as illustrated by **Malik and Singh 1980.**

Statistical Analysis
The statistical analysis of the recorded data of all various pumpkin characters were carried out using the standard method of the analysis of variance of the randomized complete blocks design, as illustrated by **Al-Rawi and Khalaf-Allah (1980)**; using Co-stat software (2004), a computer program for statistics of the differences between means. Heritability in broad sense was estimated through variance components methods according to **Allard (1960).**

RESULTS
Variability Estimates for the Original Population of Pumpkin:
The magnitude and importance of genetic variability for the original population of pumpkin was determined by estimating the statistical more than double of the population mean. The results of the estimated values of coefficient of variation, obviously, indicated that the original population (C_0) had an extensive range of variability which ranged from 13.55% for number of days to first female flower up to 71.83% for total yield/plant. The coefficient of variation values were more than 50% for five characters; sex ratio, number of fruits/plant, total yield/plant,

parameters mean, range and coefficient of variation for all studied characters (Table 1). The results of the estimated values of mean and range for the different characters showed that the range value for each character was wide and reached

carotene content, and total sugars content. Moreover, it ranged between 25% and 50% for five characters; main stem length, number of branches/plant, average fruit weight, dry matter content and total soluble solid. However, it was less than 25% only for number of days to first female flower and flesh thickness.

Table 1. Mean, range and coefficient of variation (CV%) for the studied characters in the original population of pumpkin cultivar 'Balady'.

Characters	Mean	Range	C.V. %
Main stem length (m)	4.80	1.00 – 12.00	41.69
No. branches/plant	3.57	1.00 – 7.00	32.98
No. days to first female flower	50.82	37.00 – 80.00	13.55
Sex ratio (%)	13.28	1.42 – 46.10	55.80
Flesh thickness (cm)	3.58	1.30 – 6.50	24.62
Average fruit weight (kg)	4.42	0.60 – 12.50	48.38
No. fruits/plant	2.05	1.00 – 6.00	53.95
Total yield/plant (kg)	9.02	0.60 – 39.40	71.83
Dry matter (%)	7.02	0.56 – 13.04	35.13
Total soluble solids (T.S.S)%	6.48	2.00 – 13.30	30.22
Carotene content (mg/100gm.fw)	2.07	0.29 – 7.32	55.03
Total sugars (%)	6.32	1.15 – 24.96	69.96

General Performances and Variability Magnitude of the Studied Genetic Populations:
Vegetative growth and flowering characters
The results concerning vegetative growth and flowering characters means, range and coefficient of variation of the eight different genetic populations; original population of pumpkin

cultivar 'Balady' (C_0), population derived from the first cycle of simple recurrent selection (C_1) and the second selfed progenies of the six individual selections (S_2-1, S_2-2, S_2-3, S_2-4, S_2-5 and S_2-6); are presented in Table (2). Generally, the second selfed progeny S_2-3 was noticed to significantly have the highest mean value for main stem length

Table 2. Mean, range and coefficient of variation (C.V. %) for vegetative and flowering characters in the eight populations of pumpkin.

Genetic populations	Main stem length (m)			No. of branches/plant		
	Mean	Range	C.V. %	Mean	Range	C.V. %
C_0	4.10 e	2.80 – 11.80	37.64	2.33 d	1.00 – 6.00	40.46
C_1	9.13 ab	4.00 – 11.50	27.97	6.00 a	3.00 – 7.00	26.55
S_2-1	6.53 cd	6.00 – 9.70	14.88	4.00 b	3.00 – 5.00	18.17
S_2-2	4.80 e	3.10 – 10.20	25.67	2.20 d	2.00 – 5.00	24.88
S_2-3	9.52 a	4.15 – 11.50	21.90	3.75 bc	2.00 – 4.00	21.08
S_2-4	5.83 d	3.25 – 11.10	24.67	2.85 cd	2.00 – 4.00	19.83
S_2-5	8.45 b	3.30 – 9.70	22.41	2.50 d	1.00 – 4.00	22.39
S_2-6	6.73 c	4.20 – 11.50	26.18	3.73 bc	3.00 – 5.00	18.32
	No. of days to first female flower			Sex ratio (%)		
	Mean	Range	C.V. %	Mean	Range	C.V. %
C_0	53.33 a	45.00 – 57.00	6.11	12.00 a	5.00 – 15.00	32.11
C_1	45.23 e	45.00 – 52.00	5.55	5.63 e	3.30 – 12.30	30.78
S_2-1	50.00 bc	45.00 – 55.00	4.18	5.40 e	4.90 – 13.80	28.98
S_2-2	47.83 cd	45.00 – 50.00	5.52	7.50 cd	4.00 – 10.10	20.56
S_2-3	48.70 cd	45.00 – 55.00	5.54	12.60 a	7.70 – 14.30	18.10
S_2-4	47.73 d	47.00 – 55.00	5.00	7.90 c	6.10 – 18.80	31.97
S_2-5	51.00 b	47.00 – 50.00	5.90	6.50 de	5.90 – 12.50	20.60
S_2-6	44.00 e	42.00 – 55.00	6.25	9.20 b	7.60 – 12.10	13.94

Values having a similar alphabetical letter, within a comparable group of means, are not significantly differ; using Revised LSD test at 0.05 probability level.

character, followed by that of the C_1 population. However, C_1 population significantly had the highest mean value for number of branches/plant, followed by that of S_2-1, S_2-3 and S_2-6 populations without significant differences among the later three progenies. On the other hand, C_0 had the lowest mean value for both stem length and number of branches/plant characters. The comparisons among mean values of number of days to the first female flower and sex ratio of the different eight evaluated populations clarified that the C_1 population reflected desirable significant lowest value, followed by that of S_2-6 and S_2-1 for number of days and sex ratio, respectively. It was also noticed that all the other second selfed progenies significantly gave lower mean values than that of the C_0 population. Therefore, it is a positive result to improve earliness characters.

The data of variability magnitude, expressed as range and coefficient of variation, illustrated that a reduction in variability was detected in all selected populations relative to the original population (C_0), but with different degrees (Table 2). Generally, all populations relatively reflected extensive ranges. The widest range was reflected by C_0 population, while, close range was reflected by second selfed progenies (S_2). The estimated values of range and C.V.% for main stem length and number of branches/plant characters showed that the variability estimate was reduced in all selected populations, compared with the original population. However, it was noticed that C_1 population (recurrent selection method) tended to relatively maintain higher variability than all S_2 populations (selfing with selection method), as

appeared from the comparisons among the C.V. values of the various genetic populations. All of the six selected progenies derived from selfing with selection for two generations appeared to have lower estimates for the coefficient of variations than that shown by the C_1. The coefficient of variation for number of days to first female flower was found to be 6.11% in the original population (C_0). After the first cycle of recurrent selection, the variability magnitude was reduced to 5.55%. The second selfed progeny populations recorded very close C.V. values; except S_2-6 which gave the highest estimated CV% value (6.25%) among all tested genetic populations (Table 2). The variability of sex ratio was reduced after the two selection methods. The variability magnitude was slightly decreased to be 30.78% at C_1 and to 31.97% at S_2-4. However, the other second selfed progenies clearly showed decrease variability than the original population. Moreover, S_2-6 gave the lowest estimated value of C.V. % which was 13.94%.

The enhancement percentage for vegetative and flowering characters in the selected genetic populations as compared to the original population are presented in (Fig. 1.) Populations S_2-3, C_1 and S_2-5 were found to be highly efficient in increasing stem length character with about 132.10%, 122.60% and 106.00%, respectively, over the original population (Fig.1a). However, C_1 was apparently efficient in increasing number of branches/plant with about 157.50%. Also, S_2-1, S_2-3 and S_2-6 enhanced this character by 71.60%, 60.90% and
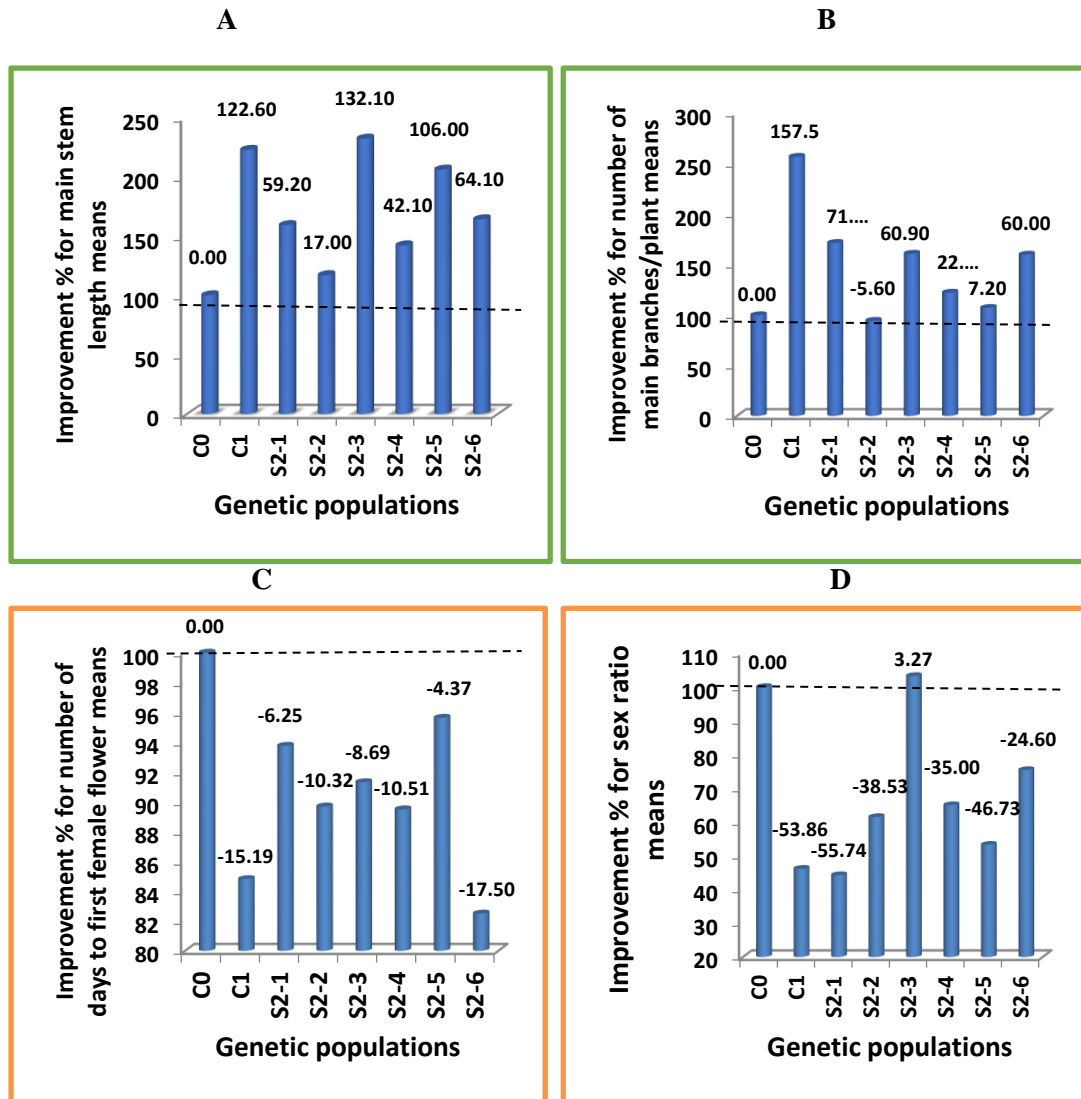
A

B

C

D

Fig. 1. The enhancement percentage for vegetative and flowering characters in the selected genetics populations as compared to the original population.

C_0 = The original population of pumpkin cultivar " Balady".

C_1 = The population derived from the first cycle of simple recurrent selection.

S_2-1: S_2-6 = The six selected progenies derived from selfing with selection for two generations.

60.00%, respectively. While, increasing rate was relatively low in the cases of S_2-4 and S_2-5 with about 22.30% and 7.20%. On the contrary, there is no improvement recorded in S_2-2, which reduced number of branches by 5.60% from the original population (Fig.1b). The data in (Fig.1c) showed that C_1 and S_2-6 reflected lower number of days to first female flower by 15.19% and 17.50%, respectively. It was, also, noticed that all the other selected selfed progenies enhanced this character compared with C_0 population by 10.51% in S_2-4, 10.32% in S_2-2, 8.69% in S_2-3, 6.25% in S_2-1 and 4.37% in S_2-5. The enhancement percentage of sex ratio trait; expressed in low value; are shown in Fig. (1d).

S_2-1 and C_1 gave high efficiency to improve this trait, which gave the highest percentage of improvement values with about 55.74% and 53.86%, respectively. The other selected selfed progenies, also, reflected some improvement for this character with different degrees.

Fruits, yield and its components characters
The results concerning fruits, yield and its components characters of the different studied populations of the pumpkin cultivar 'Balady' are listed in Table (3). The comparisons between the two selection methods; simple recurrent selection and selfing with

Table 3. Mean, range and coefficient of variation (C.V. %) for fruits and yield characters in the eight populations of pumpkin.

Genetic populations	Flesh thickness (cm)			Average fruit weight (kg)		
	Mean	Range	C.V. %	Mean	Range	C.V. %
C_0	2.13 f	2.00 – 6.00	30.78	1.72 h	1.50 – 9.60	45.71
C_1	6.43 a	3.00 – 7.00	27.22	7.54 a	1.10 – 8.30	37.54
S_2-1	5.10 b	2.50 – 5.50	25.43	4.66 d	1.20 – 6.65	31.82
S_2-2	2.83 e	2.00 – 4.50	20.08	3.36 f	2.15 – 6.40	33.68
S_2-3	3.63 d	2.00 – 5.50	23.61	2.84 g	2.25 – 7.00	31.13
S_2-4	4.30 c	2.50 – 6.00	21.37	5.75 c	1.10 – 7.10	31.25
S_2-5	3.05 e	2.00 – 5.00	22.60	6.63 b	1.45 – 7.50	33.01
S_2-6	3.86 d	2.50 – 5.00	18.76	3.83 e	2.76 – 5.65	18.86
	No. of fruits/plant			Total yield/plant (kg)		
	Mean	Range	C.V. %	Mean	Range	C.V. %
C_0	1.00 f	1.00 – 5.00	66.68	5.75 g	1.50 – 19.80	59.00
C_1	4.12 a	1.00 – 6.00	48.67	14.30 b	1.10 – 22.30	40.89
S_2-1	3.50 b	1.00 – 5.00	29.04	16. 67 a	1.20 – 24.40	42.39
S_2-2	2.00 d	1.00 – 5.00	40.45	12.53 c	2.40 – 15.70	39.20
S_2-3	1.62 de	1.00 – 4.00	35.60	8.06 e	2.70 – 16.00	40.04
S_2-4	2.58 c	1.00 – 5.00	50.00	12.66 c	3.80 – 21.70	41.07
S_2-5	1.25 ef	1.00 – 3.00	35.09	7. 06 f	2.90 – 21.00	48.31
S_2-6	3.11 bc	1.00 – 5.00	48.34	11.22 d	3.30 – 17.80	42.86

Values having a similar alphabetical letter, within a comparable group of means, are not significantly differ; using Revised LSD test at 0.05 probability level.

selection, reflected noticeable efficiency for increasing these characters in all selected populations, since the means of the derived populations appeared to be significantly higher than that of the original population. The highest mean value of each character of all evaluated populations was recorded by C_1, followed by those of the two selfed progenies S_2-1 and S_2-5. While, the lowest mean values were given by the original population (C_0). Flesh thickness, average fruit weight, number of fruits/plant and total yield/plant means significantly increased after the first cycle of recurrent selection (C_1) from 2.13 cm, 1.72 kg, 1.00 fruits/plant and 5.75 kg/plant in C_0 population to 6.43 cm, 7.54 kg, 4.12 fruits /plant and 14.3 kg/plant in C_1, respectively. These results indicated that the first cycle of simple recurrent selection and the second selfed progenies S_2-1 and S_2-5 were highly efficient in

increasing fruits, yield and its components characters.
Range and C.V. % values presented in Table (3) reflected that the eight studied populations had extensive range values for flesh thickness and average fruit weight characters and the original population reflected wide range of variability. Selfing with selection was effective in decreasing the variability of both traits. On the other hand, the first cycle of recurrent selection reflected the lowest reduction in variability compared to the original population. The data for number of fruits/plant relatively reflected lower variability in the second selfed progenies S_2-1, S_2-3 and S_2-5 populations (29.04%, 35.60% and 35.09%, respectively) than that of the original population (66.68%). Whereas, the C_1 and the other three selfed progenies (S_2-2, S_2-4 and S_2-6) relatively maintained higher variability than that of the later populations; but it is still lower than the

variability in the original population. However, for total yield character, the estimated values for the C.V.% and range values reflected wide range and pronounced variability magnitudes in all populations. The results clarified, also, that despite the apparent decrease in variability magnitude for the selected populations, it still had wide variability magnitude. The estimated coefficients of variation values were found to be 59.00% in C_0, 40.89% in C_1 and from 39.20% to 48.31% for the six selfed progenies.

The percentage of improvement for flesh thickness increased in all derived genetic populations (Fig. 2 a). Where, C_1 reflected increment with about 201.87%, followed by S_2-1, S_2-4 and S_2-6, which increased over that of C_0 by 139.43%, 101.87% and 81.22%, respectively. The percentage of increase in average fruit weight values presented in Fig. (2 b) extremely reflected increment of enhancement in C_1 population over that of C_0 with about 338.37%, followed by those of the S_2-5, S_2-4, S_2-1 and S_2-6 with about 285.46%, 234.30%, 170.93% and 122.60%, respectively. C_1 and S_2-1, S_2-6 were found to be efficient in increasing number of fruits/plant character with about 243.33%, 191.66%, and 159.16%, respectively, while the improvement rate was relatively low in the two selfed progenies S_2-3 and S_2-5 with about 35.00% and 4.00% (Fig. 2 c). Data on the percentage of improvement of total yield/plant illustrated that S_2-1 and C_1 gave high improvement percentage with about 189.91% and 148.69%, respectively. The

improvement rate was relatively low in S_2-3 and S_2-5 with about 40.17%, 22.78% over that of the original population.

Chemical constituents of fruits characters
The results concerning chemical constituents of fruits characters of the eight different genetic populations are presented in Table (4). Those comparisons illustrated that the first recurrent selection cycle produced the highest mean value of dry matter percentage that significantly differed from that of the original population as well as the six selfed progenies, followed by those of the second selfed progeny S_2-3 and S_2-1with significant differences. After the first cycle of recurrent selection, the total soluble solids value significantly increased relative to the original population. In the case of selfing with selection, the comparisons among the mean values clarified that all of the selected selfed progenies showed efficiency in increasing total soluble solids higher than C_0, where S_2-1 gave the highest significant mean value (9.26). Carotene content means for the selected populations compared to the original population reflected different responses. Where, it significantly increased in some populations and significantly decreased in the others. The second selfed progeny S_2-5 was noticed to significantly have the highest mean value (9.20) for carotene content, followed by S_2-6 (7.39) and C_1 (6.93). The mean value given by the original population was 5.33. Concerning total sugar character, the results illustrated that

Table 4. Mean, range and coefficient of variation (C.V. %) for chemical constituents of fruits characters in the eight populations of pumpkin.

Genetic populations	Dry matter (%)			Total soluble solids (%)		
	Mean	Range	C.V. %	Mean	Range	C.V. %
C_0	3.61 g	2.29 – 9.70	36.47	4.07 g	3.00 – 10.30	26.86
C_1	10.81 a	6.00 – 13.75	22.68	7.36 d	5.00 – 11.00	20.42
S_2-1	7.74 c	6.00 – 15.20	22.18	9.26 a	6.40 – 10.00	13.40
S_2-2	6.39 de	3.10 – 8.91	18.53	6.48 e	3.20 – 8.00	18.29
S_2-3	9.30 b	4.30 – 12.00	24.29	7.92 c	6.00 – 8.50	11.14
S_2-4	5.08 f	3.40 – 9.90	24.29	8.81 b	4.20 – 10.50	19.25
S_2-5	5.35 ef	4.43 – 10.00	21.85	5.32 f	3.80 – 8.90	18. 49
S_2-6	7.07 cd	5.00 – 11.50	23.39	5.43 f	4.50 – 7.30	15.09
	Carotene content (mg/100gm.fw)			Total sugars (%)		
	Mean	Range	C.V. %	Mean	Range	C.V. %
C_0	5.33 e	3.60 – 13.00	37.18	3.90 f	2.86 – 24.6	64.85
C_1	6.93 c	4.36 – 8.89	20.08	7.31 a	4.90 – 8.12	12. 91
S_2-1	5.64 e	4.90 – 12.00	25.25	6.03 cd	4.53 – 8.10	15.44
S_2-2	4.73 f	4.01 – 7.45	16.54	6.42 bc	3.90 – 7.06	12.43
S_2-3	3.72 g	3.00 – 7.65	22.02	5.56 d	5.09 - 7.81	13.36
S_2-4	6.20 d	5.00 – 7.60	11.94	6.64 abc	4.95 – 7.49	12.41
S_2-5	9.20 a	4.50 – 10.50	28.66	4.68 e	4.40 – 7.80	16.84
S_2-6						

Values having a similar alphabetical letter, within a comparable group of means, are not significantly differ; using Revised LSD test at 0.05 probability level.
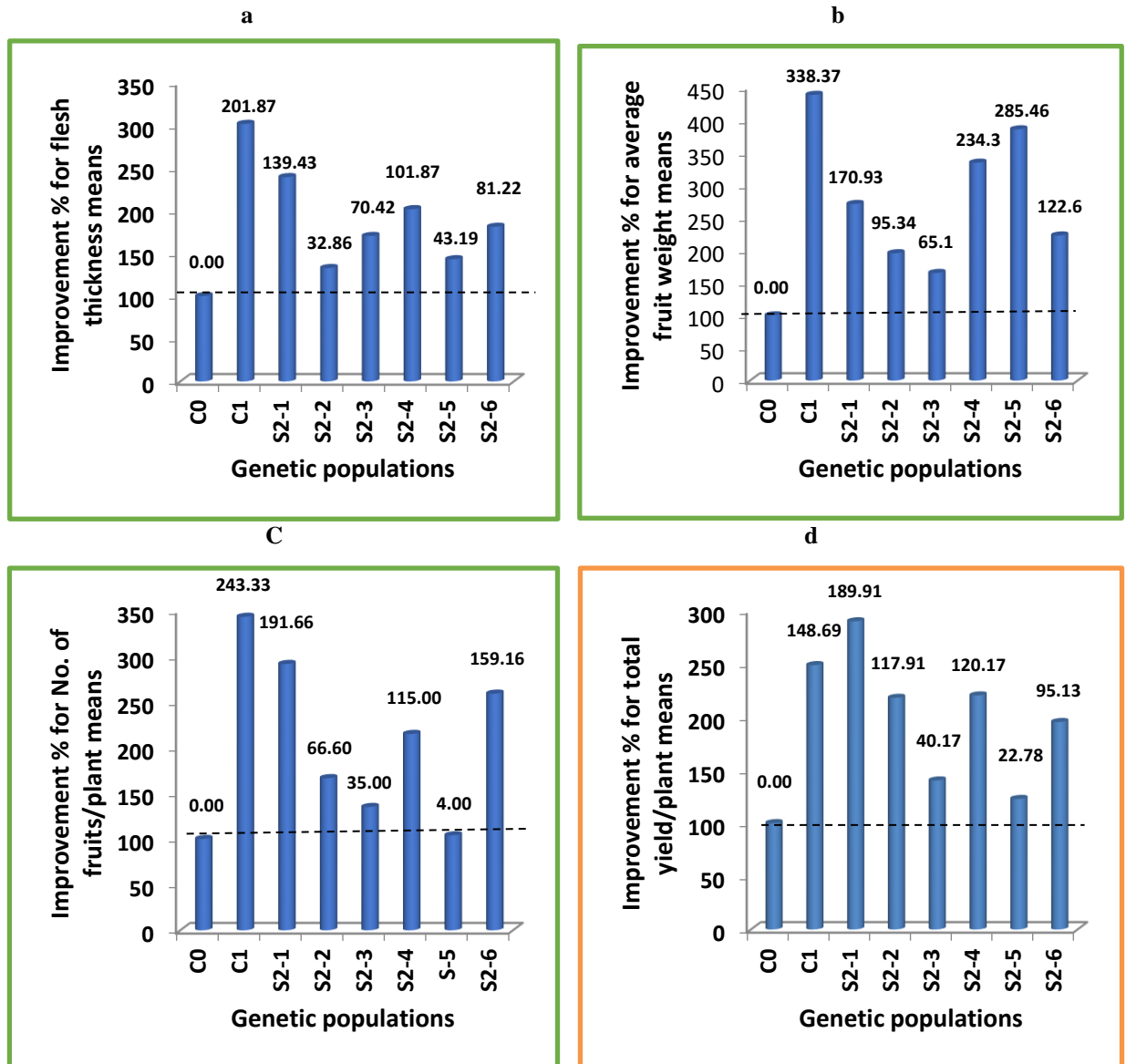
Fig. 2. The enhancement percentage for fruits and yield characters in the selected genetics populations as compared to the original population.

C_0 = The original population of pumpkin cultivar " Balady".

C_1 = The population derived from the first cycle of simple recurrent selection.

S_2-1: S_2-6   =   The   six   selected   progenies   derived from selfing with selection for two generations.

all selected populations showed significant superiority in total sugars over their original population. The total sugars of C_1, S_2-6 and S_2-4 populations significantly possessed the highest values of 7.31%, 6.84%, and 6.64%, respectively. Variability magnitude for chemical constituents of fruits characters indicated that the variability of these characters was reduced, but with different relative magnitudes, in all selected populations; in comparison with the original population (Table 4). The estimated C.V. % value for dry matter percentage was reduced from 36.47% in C_0 to 22.68% in C_1 population. In the case of selfing with selection, the reduction in variability was more severe in progeny S_2-2 (18.53%) than the other five selfed progenies populations. While, for the total soluble solids, C.V.% values were 26.86% in C_0 population and 20.42% in C_1. In the case of selfing with selection for two generations, the variability was noticed to reflect more reducing effect, since the C.V. % values of the six selfed progenies were estimated with lower values from 19.25% to 11.14% than that of the original population. For carotene content character, the results illustrated that the reduction in variability after one cycle of recurrent selection relatively seemed to be reasonable, from 37.18% in C_0 to 20.08% in C_1; whereas, in the case of selfing with selection populations, such reduction was noticed to be moderate for three progenies (S_2-1, S_2-3 and S_2-5) and was severe for the other three progenies (S_2-6, S_2-4, S_2-2). Where, the coefficient of variations ranged from 11.94% to 28.66%. Moreover, the variability in total sugar character, in general, was reduced in all derived populations

with different magnitudes from that of the original population. The coefficient of variation values reflected clear reduction in variability magnitude in C_1 population as well as the progenies of

selfing with selection. Where, the C.V. % value was estimated by 64.85% in C_0 and by a severe lower value of 12.91% in C_1. Moreover, selfing with selection reduced the variability in all selfed progenies, which gave C.V. % values ranged from 12.41% to 17.83%.

The percentages of improvement in mean values of chemical constituents of fruits characters for all selected populations over that of the original population are presented in Fig. 3. The highest increase in dry matter percentage was reflected by C_1 population with about 199.44%, followed by S_2-3 and S_2-1with about 157.61% and 114.40%, respectively (Fig. 3 a). The percentage of improvement in total soluble solids for the selected populations (Fig. 3 b) reflected that the second selfed progenies S_2-1, S_2-4 and S_2-3 recorded high efficiency to increase total soluble solids with about 127.51%, 116.46% and 94.59%, respectively. In the case of the first recurrent selection cycle, the improvement was around 80.83% relative to the original population. For carotene content character, S_2-5, S_2-6 and C_1 reflected increment with about 72.60%, 38.64% and 30.01%, respectively, over that of C_0 population. The increase rate was relatively small in S_2-4 and S_2-1 with about 16.32% and 5.81%. On the other hand, the two selfed progenies S_2-2 and S_2-3 reflected reduction percentage by 11.26% and 30.21%, respectively, compared with C_0 (Fig. 3 c). The results reflected high improvement for total sugars means in all derived genetic populations (Fig. 3 d). Where, C_1, S_2- 6, S_2-4, S_2-2, and S_2-1 recorded highly efficient increase in total sugars character with about 87.43%, 75.38% , 70.25%, 64.61% and 54.61% ; respectively, over that of the original population. The other progenies S_2-3 and S_2-5 increased this character by only 42.56% and 20.00%, respectively.
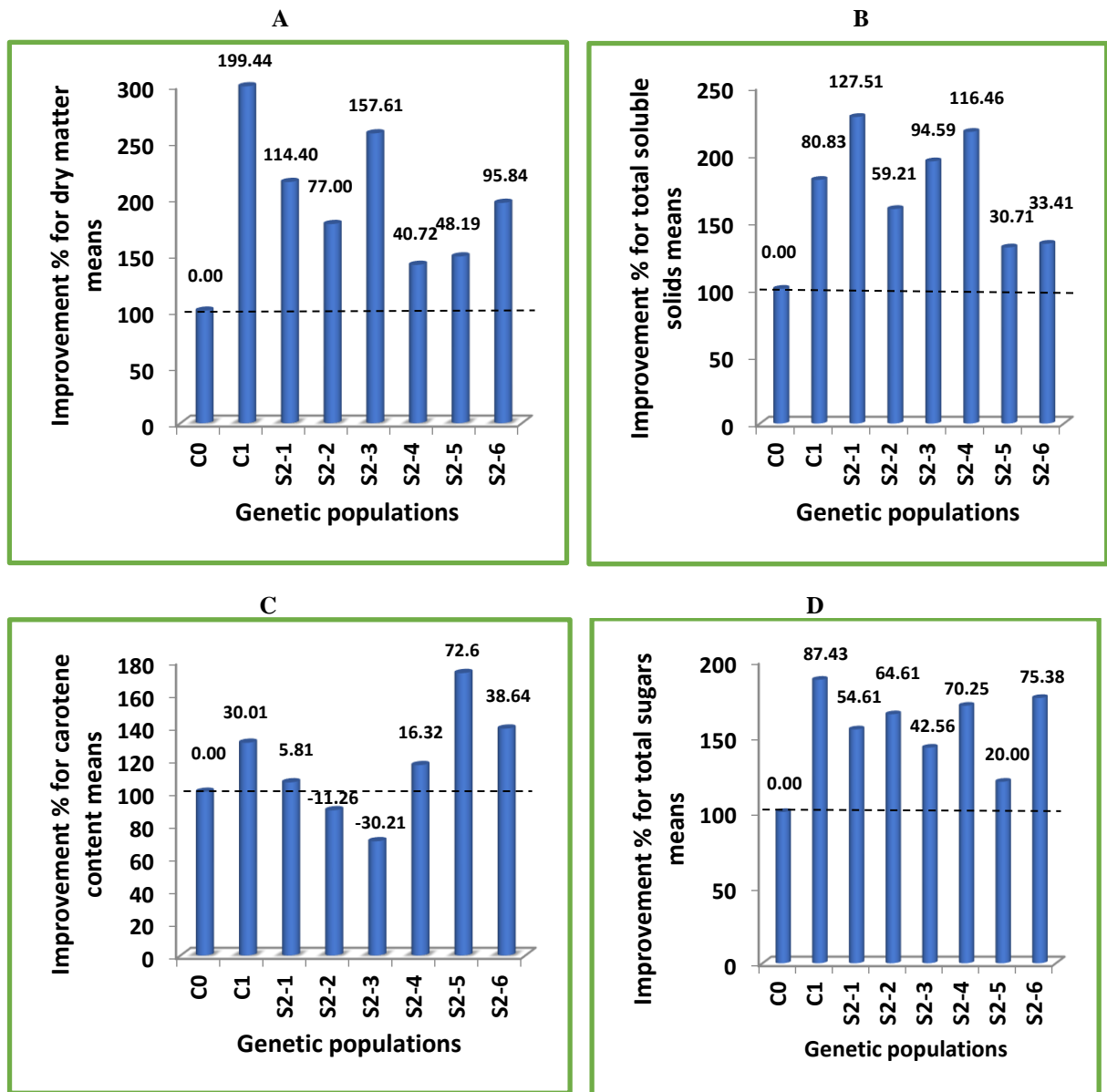
Fig. 3. The enhancement percentage for chemical constituents of fruits characters in the selected genetics populations as compared to the original population.

C_0 = The original population of pumpkin cultivar " Balady".

C_1 = The population derived from the first cycle of simple recurrent selection.

S_2-1: S_2-6 = The six selected progenies derived from selfing with selection for two generations.

Total Variance Components and Heritability Percentages

The estimated values of total variance components and broad sense heritability percentages of the various studied characters are presented in Table (5). The comparison between total variance components showed that the estimates of genetic variance (σ^2_g) obviously reflected obviously higher values than that of environmental variance (σ^2_e) in all studied characters, suggesting that the differences in plant characteristics for the studied populations are due to genetic variance. High broad sense heritability values were recorded for all studied characters. It was found to be in the range of 83.61% for number of branches/plant up to 99.49% for average fruit weight.

Table 5. Estimates of total variance components and heritability percentages for the studied characters on different genetic populations.

Characters	σ^2_e	σ^2_g	σ^2_p	h^2_{bs} %
Main stem length (m) Main	0.23	3.89	4.13	94.18
No. of branches /plant	0.29	1.48	1.77	83.61
No. of days to first female flower	1.61	8.58	10.19	84.20
Sex ratio (%)	0.50	7.63	8.13	93.74
Flesh thickness (cm)	0.01	1.86	1.87	99.46
Average fruit weight (kg)	0.01	3.93	3.95	99.49
No. of fruits/plant	0.11	1.21	1.32	91.66
Total yield/plant (kg)	0.29	13.54	13.83	97.90
Dry matter (%)	0.53	5.32	5.86	90.78
Total soluble solids (T.S.S) %	0.20	3.25	3.46	93.93
Carotene content (mg/100gm.fw)	0.04	2.88	2.92	98.63
Total sugars (%)	0.16	1.27	1.43	88.81

σ^2_p = Phenotypic variance.
σ^2_g = Genotypic variance.
σ^2_e = Environmental variance (error mean square).
h^2_{bs} % = Heritability in broad sense.

DISCUSSION

Variability Estimates for the Original Population of Pumpkin:

The studied characters reflected high variability within the original population of pumpkin cultivar Balady. This variability supported the high possibilities of conducting successful and efficient selection to improve the different characters in the original pumpkin population and to introduce new developed population, which means that superior cultivars and inbred lines can be derived through practicing selection methods. The detected high variability was reflected also on the observed wide ranges. Such results appeared to be due to that 'Balady' cv. is comparatively an old one that is commercially grown for a long period without any kind of improvement or purification. Accordingly, it was expected that most of the studied characters could be improved through selection methods; but with varying degrees, depending on the amount of variation present in the population and heritability of the concerned characters. On the other hand, the efficiency of selection for number of days to first female flower was expected to be low, since these characters showed the lowest variability estimates in the original population of pumpkin crop. Similar results were reported by **Solieman (2009)** and **Akter et al. (2013).** Selection can be done simply for the characters that reflected high variations, but the selection efficiency on their performance would depend on the selection pressure and the type of gene action involved in their inheritance. Therefore, the studied characters appeared to have high chance to be improved through selection since they maintained high variability, in the original populations. These finding agreed with those reported by **Alsadon et al. (1998),** and **Pandey et al. (2002).**

General Performances and Variability Magnitude of the Studied Genetic Populations:

Concerning the variability magnitudes that were maintained within the evaluated populations after the first cycle of recurrent selection or the selfing with selection for two successive generations, the foregoing results indicated that these magnitudes were generally reduced in all populations. However, the degree of such reduction in variability differed noticeably from one character to another, according to the type of the genetic structure involved in the inheritance of a

particular character. The differences between characters in the amount of variability maintained in the evaluated populations might be related to the degree of complication involved in their inheritance, the simply inherited characters are expected to show more reduction in variability than the quantitative ones in the early generations of selfing. The characters governed by small number of genes are expected to show more reduced variability than the characters governed by a large number of genes. However, it should be mentioned that the reduction in variability will continue for more and more generations in the case of the quantitative characters than that expected in case of qualitative or simply inherited characters.

Vegetative growth and flowering characters

The variability estimate for main stem length and number of branches per plant in the original population was relatively higher; however, it was reduced in all selected populations. It was noticed that recurrent selection method tended to maintain relatively higher variability than selfing with selection method. Therefore, the first cycle of recurrent selection was apparently efficient in increasing the main stem length and number of branches/plant with about 122.6% and 157.50%, respectively. Also, selfing with selection method for two generations enhanced main stem length within the range of 17.00% to 132.10 %, and number of branches per plant by 7.2% to 71.6% over that of the original population. The reduction in variability was detected in all selected populations relative to the original population, but with different degrees. These results agreed with the findings of **Solieman (2009)**. The successful selection for this trait occurred and also related to the high heritability of this character which was (94.18 %) and was in harmony with that reported by **Wang et al. (2012).** The low value of number of days to first female flower and low value for sex ratio is desirable to improve these characters; it is expressed and associated with the early flowering for pumpkin crop. Such achieved improvements might be due to the noticed relatively high amounts of variability present in the original population as well as to the high heritability of these characters which was 84.20% for number of days to first female flower and 93.74 % for sex ratio. These results are in harmony with those reported by **Tsivelikas and Koutsika (2010), Akter et al. (2013), Ragheb 2016** and **Srikanth et al. (2017)**.

Fruits, yield and its components characters

The great amount of variability for fruit flesh thickness that was present in the original population offered a good opportunity for realized improvements. The variability estimates were reduced in all selected populations compared to the original population. Moreover, such

improvement related to high heritability which was 99.46%. Results of heritability in the present study are in harmony with that reported by **Pandey et al. (2002)** and **Akter et al. (2013)** as well as **Srikanth et al. (2017).** They found that heritability for flesh thickness trait appeared to be high.

Generally, both of the first cycle of recurrent selection and selfing with selection for two generations methods resulted in obvious increments on both average fruit weight and number of fruits per plant. The percentages of increases reflected extremely increment of enhancement in the population of the first cycle of recurrent selection over that of the original population (increment reached 338.3 % and 243.33% for the two characters, respectively). However, in the case of selfing with selection method the increase in average fruit weight was noticed to be within the range of 65.10% to 285.46%, while in number of fruit/plant was noticed to be within the range of 4.00% to 191.66 % for all selected selfed progenies. These results are compatible with those of **Tsivelikas and Koutsika (2010)** and **Aruah et al. (2012).** The successful selection for these traits was related to the high heritability estimates of these characters. Total yield/plant increased after the first cycle of simple recurrent selection by 148.91 %. However, In case of selfing with selection for two generations, it was improved in most progenies by about 22.78% to 189.91%, such result was in harmony with those of **Solieman (2009),** and **Hazara et al. (2007)**. Moreover, this trait had a high heritability (97.90 %) which agreed with that reported by **Akter et al. (2013)**.

Chemical constituents of fruits characters

The obtained results indicated that after the first cycle of recurrent selection the four chemical constituents of fruit characters significantly increased relative to the original population. Also, in the case of selfing with selection, the comparisons among the mean values clarified that almost all of the selected selfed progenies showed efficiency in increasing these characters higher than original population. Similar results were obtained by **Hazara et al. (2007)** and **Solieman (2009)**. The great amount of variability that was present in the original population for these characters offered a good opportunity for realized improvements. Moreover, such improvement related to high heritability, where the heritability estimates for these characters appeared to be higher than 90.0% in all characters. Such result is compatible with **Wang et al. (2012)**. In contrast, **Akter et al. (2013)** found that heritability value of total soluble solid and total sugar appeared to be low. These results, clearly, indicated that the recurrent selection as well as selfing with selection breeding methods was effective in

raising the frequencies of the genotypes with increasing the general performances of these characters.

CONCLUSION

The results of the general performance of different studied characters for the various genetic populations of pumpkin, evidently, indicated that the two breeding methods one cycle of simple recurrent selection and selfing with selection for two generations were found to be efficient for improving the general performance and reducing the high variability of most of the studied characters relative to those of the original population. The first cycle of recurrent selection found to be apparently efficient in increasing and enhancement the general performances more than selfing with selection for two generations for most studied characters, except for number of days to first female flower and carotene content. Therefore, it may be concluded that recurrent selection seemed to be effective and efficient for development of improved commercial pumpkin cultivar 'Balady'; whereas, selfing with selection can be successfully used to develop inbred lines for the production of hybrid or synthetic cultivar, out of the common commercial one.

REFERENCES

Akter, S.; M. G. Rasul, A. K. Aminul Islam and M. M. Hossain. 2013. Genetic variability, correlation and path coefficient analysis of yield and quality traits in pumpkin (*Cucurbita moschata* Duch ex Poir). Bangladesh Journal of Plant Breeding Genetics. 26(1): 25-33.

Allard, R.W. 1960. Principles of Plant Breeding. Jon Wiley Sons. Ine. New York. London. Pp. 485. Al-Rawi, K. M. and A. M. Khalaf-Allah. 1980. Design and analysis of agricultural Experiments. Text Book. El-Mousil Univ. Press. Ninawa, Iraq. Pp. 487.

Al-Alsadon, H. H.; H. Hegazi and I. A. Almousa. 1998. Evaluation of local pumpkin genotypes in the central region of Saudi Arabia. American Society for Horticultural Research Service. Cucurbitaceae'98: 43-50.

Angel R. D.V., A. Campbell, T. J. K. Radovich, T. Silvasy, S. Moore, and M. B. Kantar. 2020. Quantitative Trait Loci (QTL) Analysis of Fruit and Agronomic Traits of Tropical Pumpkin (*Cucurbita moschata*) in an Organic Production System. Horticulturae , *6*(1), 14; **https://doi.org/10.3390/horticulturae6010014**.

Aruah, C. B.; M. I. Uguru and B. C. Oyiga 2010. Nutritional evaluation of some Nigerian pumpkins (*Cucurbita* spp.). Fruit, Vegetable and Cereal Science and Biotechnology. 5 (2): 64-71.

Aruah, C. B.; M. I. Uguru and B. C. Oyiga. 2012. Genetic variability and inter- relationship among some Nigerian pumpkin assessions (*Cucurbita sp*). International Journal of plant Breeding. Global Science Books. 6(1):34-41.

Davies, B. H. 1976. Analysis of carotenoid pigment. In: T. W. Goodwin (ed.).Chemistry and Biochemistry of Plant. Plant pigments. Academic Press. London New York.

El-Soukkary. F.A.H. 2001. Evaluation of pumpkin seed products for bread fortification. Plant Foods for Human Nutrition 56: 365–384.

Grisales, S. O.; D. B. Garcia and F. A. Cabrera. 2009. Effect of inbreeding on the quality traits of squash fruit. Acta Agronomica. 58(3):140-144.

Hazara, P.; A. K. Mandal; A. K. Dutta and H. H. Ram. 2007. Breeding pumpkin (*Cucurbita moschata* Duch. ex Poir.) for yield and carotene. Acta Horticulture. 752:431- 435.

Jansi, V., V. Rajasree, R. Kumar, S. Praneetha and S. Rajeswari. 2018. Heterosis and inbreeding depression studies in pumpkin (*Cucurbita moschata* Duch. ex Poir.). Electronic Journal of Plant Breeding, 9 (3): 1031 – 1037. DOI: 10.5958/0975-928X.2018.00128.X

Malik, C. P. and M. B. Singh. 1980. Plant Enzymology and Histo-Enzmology. A Text Manual. Kalyani Publishers New Delhi.

Milorad M., G. Rocchetti, S. Krstić, A. Mišan, M. Brdar-Jokanović, F. Marcheggiani, E. Martinelli, L. Lucini and E. Damiani. 2021. Comparative In Vitro Antioxidant Capacity and Terpenoid Profiling of Pumpkin Fruit Pulps from a Serbian *Cucurbita maxima* and *Cucurbita moschata* Breeding Collection Antioxidants, 10(10), 1580; **https://doi.org/10.3390/antiox10101580**.

Pandey, S.; J. Singh, A. K. Upadhyay and D. Ram. 2002. Genetic variability for antioxidant and yield component in pumpkin (*Cucurbita moschata* Duch. ex Poir). Indian Society of Vegetable Science. 29 (2):123-126.

Pandey, S.; S. Kumar; B. R. Choudahry; D. S. Yadav and M. Rai. 2008. Component analysis in pumpkin (*Cucurbita moschata* Duch ex. Poir). Vegetable Science. 35(1):35-37.

Ragheb, E. I. 2016. Recurrent selection and selfing with selection as a tool for improvement of sweet melon (*Cucumis melo* var. aegyptiacus). Egyptian Journal of Horticulture. 2(43):12-22.

Solieman, T. H. 2009. Simple recurrent selection and selfing with selection as two breeding methods for improving pumpkin [*Cucurbita moschata*, Duchesne ex (Poir)]. Plants. Journal of the Advances in Agriculture Researches (Faculty of Agriculture of Saba Basha).14 (2):409-428.

Srikanth, M.; S. G. Bharad; L. B. Thulasiram and N. R. Potdukhe. 2017. Studies on genetic variability, heritability and genetic advance in pumpkin (*Cucurbita moschata* Duch ex Poir.).

International Journal of Current Microbiology & Applied Sciences. 6 (6):1416-1422.

Tsivelikas, A.L. and M. S. Koutsika. 2010. Inbreeding effects on a winter squash landrace. Journal of Agricultural Science. 148(6):695-708.

Wang, L.; T. Liu; Z. Dai; W. Shi; M. Tan and X. Xu. 2012. Combining ability and heritability of 12 quantitative traits in *Cucurbita moschata*. Chinese journal of Cucurbits & Vegetables. 1:11-15.

الملخص العربى

كفاءة الانتخاب المتكرر البسيط والتلقيح الذاتي مع الانتخاب لتحسين نمو ومحصول وجودة القرع العسلي

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من المهم ان يؤخذ في الاعتبار العمل نحو تطبيق برامج التربية الفعالة لتنقية وتحسين القرع العسلي. أجريت هذه الدراسة خلال ثلاث مواسم زراعية صيفية للأعوام من 2013 إلى 2015 لتقييم فاعلية وكفاءة كل من طريقة التربية باستخدام الانتخاب المتكرر البسيط لدورة واحدة وطريقة التلقيح الذاتي مع الانتخاب لمدة جيلين وذلك لتحسين بعض الصفات الهامة في القرع العسلي صنف البلدي. تم الحصول على ثمانية عشائر وراثيه وهي العشيرة الأصلية (C_0) وعشيره الدورة الأولى من الانتخاب المتكرر البسيط (C_1) وسلالات الجيل الثاني من التلقيح الذاتي مع الانتخاب وعددها سته سلالات (S_2-1 و S_2-2 و S_2-3 و S_2-4 و S_2-5 وS_2-6). أوضحت نتائج تقديرات قيم معامل الاختلاف ان العشيرة الأصلية (C_0) احتوت على مدى واسع من الاختلافات الوراثية تراوحت بين 13.55% و71.83% لصفتي عدد الأيام حتى أول زهرة مؤنثة وصفة المحصول الكلي للنبات على الترتيب. الدورة الأولى من الانتخاب المتكرر البسيط أدت الى تحسين كل من صفات طول الساق الرئيسية وعدد الافرع للنبات ومتوسط وزن الثمرة وعدد الثمار للنبات بنسبه 122.6% و157.5% و 338.3% و243.3% على الترتيب. كذلك طريقة التلقيح الذاتي مع الانتخاب لمدة جيلين أدت الى تحسين صفة طول الساق الرئيسية بنسبه تراوحت بين 17.0% الى 132.1%، و صفة عدد الافرع للنبات بنسبه تراوحت بين 7.2% الى 71.6%، و صفة متوسط وزن الثمرة بنسبه تراوحت بين 65.1% الى 285.4%، وعدد الثمار للنبات بنسبه تراوحت بين 4.0% الى 191.6% وذلك مقارنه بالعشيرة الأصلية. وبالنسبة لصفه المحصول الكلي للنبات فقد أعطت السلالة (S_2-1) الناتجة من سلالات التلقيح الذاتي لجيلين (S_2-1) وكذلك عشيرة الدورة الأولى من الانتخاب المتكرر البسيط (C_1) أعلى نسب في التحسين بقيمه 189.9% و148.69% على الترتيب. عكست طريقة الانتخاب المتكرر البسيط لدورة واحدة فاعلية واضحة في زيادة وتحسين السلوك العام أكثر من طريقة التلقيح الذاتي مع الانتخاب لمدة جيلين، وذلك لمعظم الصفات موضع الدراسة باستثناء صفتي عدد الأيام حتى ظهور أول زهرة مؤنثة، ومحتوى الثمار من الكاروتين. ولذلك يمكن استنتاج أن الانتخاب المتكرر يستخدم بفاعلية وكفاءة في تطوير وتحسين الصنف البلدي التجاري للقرع العسلي، في حين يمكن استخدام طريقة التلقيح الذاتي مع الانتخاب بنجاح في حالة إنتاج السلالات المرباه داخليا والتي تستخدم لإنتاج الهجن أو الصنف التركيبي المتفوق عن الصنف التجاري.