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INDIVIDUAL SELECTION FOR EARLINESS AND SOLUBLE SOLIDS CONTENT IN TOMATILLO

Bushra A.A. Hassan[1*], A.Y.A.M. Elsayed[1*], A.A. Hassanin[2] and H.E.M. Ismail[3]

1. Veg. Breed. Dept., Hort. Res. Inst., ARC, Giza, Egypt

2. Genet. Dept., Fac. Agric., Zagazig Univ., Egypt

3. Hort. Dept., Fac. Agric., Zagazig Univ., Egypt

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ABSTRACT: This study carried out during two successive seasons 2019 and 2020 at Elbaramun experimental Farm, Horticulture Research Station, Dakahlia, Egypt to select superior genotypes with a good performance in traits of interest from a tomatillo heterogeneous population of the local variety "Balady". In addition, estimation the genetic gains with the simultaneous selection of yield component traits and soluble solids content. A population derived from "Balady" was used in current study as a basic material. The experimental design used was a randomized complete block design with three replicates. Different vegetative growth and fruit characters were estimated. Results showed that, moderate to high positive genetic gains (ΔG %) were obtained along the evaluated traits ranged from 0.086% to 32.33% for shape index and marketable fruit yield. Regarding earliness traits, genetic gain by selection estimated by 6.862% and 12.97% for early fruit number and early yield, respectively. In addition, the great genetic gain observed was for the marketable fruit yield that recorded 32.33%.Regarding the total soluble solids, a selection gain with 5.616% at 60 old days was obtained after first cycle of selection comparing with the original population. Twenty individuals for each studied trait represent about 8% of selection intensity, showed best values regarding each evaluated trait. The results revealed that the selection for TSS in tomatillo at 45 old days did not gave remarkable gain by selection, (1.538 %) indicating that the selection for this trait would be better at advanced stage of maturity.

Key words: *Physalis ixocarpa*, phenotypic selection, TSS, genetic parameters, path coefficient.

INTRODUCTION

Tomatillo (*Physalis ixocarpa Brot*.) is a solanaceous annual plant belongs to the genus *Physalis* (**Robledo-Torres *et al.*, 2011**). It widely cultivated in Mexico, Guatemala, tropical and subtropical regions all over the world, particularly in some countries of the American continent (**Zhang *et al.*, 2016**). Its fruits used in the traditional medicine for mitigation symptoms of fever, cough, and tonsillitis (**Maldonado *et al.*, 2011**). Tomatillo fruits varied in color as green, yellow-green, or purple, depending on the cultivated variety (**Barroso *et al.*, 2018**), and are used to make salads, soups, stews, and sauces (**Santiaguillo and Blas, 2009; Barroso *et al.*, 2017).**

Fruits and plants of tomatillo have a nutritional and commercial importance (Pretz and Deanna, 2020; Zhang *et al*., 2016) in several countries including Egypt. The fruits contain mineral, vitamins, phenolic compounds and secondary metabolites such as physicians and steroids (**Gonzalez-Chavira *et al.*, 2019; Maldonado *et al*., 2011**).

Tomatillo represents one of secondary crops grown in Egypt due to its limited cultivated land throughout the country Almost, the small areas being closed to big cities;Al-Bhera, Kalubia, Giza, Kalyubia, ChbeenAl-kanater and where the main regions for tomatillo production in Egypt. However, the "Balady" is a self-pollinated

*** Corresponding author: Tel. :**+201000843169
E-mail address: Ahmed.youssef@arc.sci.eg

tomatillo variety well-adapted of local conditions obtained from homogenous genotypes, but it become heterogeneous over time. This may be attributed to one or more of the following reasons; plants from a genotype could be subjected to mechanical mixing, cross-pollination, and/or mutation (**Ramalho *et al.*, 2012**). Also, extended use of the same variety by farmers over successive generations and reuse of the seeds caused natural variability derived from the aforementioned factors, which can be considered a magnificent opportunity for genetic improvement of this variety.

Thus, the aim of this study was to identify and select superior genotypes that possess a good performance in traits of interest from a heterogeneous population of the local tomatillo variety "Balady". In addition, estimation the genetic gains with the simultaneous selection of yield components and soluble solids content.

MATERIALS AND METHODS

An open-pollinated population derived from the local variety of tomatillo named "Balady" was used in the current study. Seeds of the basic population were sown in 20 February 2019 in 209-seedling trays. By the first week of April at 40-old days, the seedlings were transplanted to the field at experimental farm of Horticulture Research Station at Elbaramun station, Horticulture Research Institute, Agricultural Research Center, Egypt.

First Season

In the first week of April 2019, transplanting of the tomatillo seedlings was conducted. About 500 plants of tomatillo were grown in bulk in open field under clay soil conditions with surface irrigation system. At flowering stage, a visual identification of some vegetative characters as early vigor, plant height, number of clusters per plant, and other phenotypic characters were used to identify superior genotypes. Then, about 30 plants were selected and self-fertilized. At fruit yellow maturity stage, seeds of each selected plant, were individually collected and picked from each plant for seed extraction.

Second Season

The seeds of every selected plant at independent line in 209-seedling trays were sown. Tomatillo seedlings were transplanted in the field in 7th of April 2020.The experimental design used was a randomized complete block design (RCBD) with three replicates. Each entry (plot) contained 20 plants for each genotype. The plot area was 8.4 m^{2}included three rows, each row 0.7 cm apart and 4 m in length. The transplants were sown in hills on one side of ridge as one plant at 0.5 m. All the agricultural practices were applied whenever they were needed. Chemical fertilization as phosphorus and potassium fertilizers was added during soil preparation. While, nitrogen fertilizer was divided into three equal portions and added to the soil at 30, 55 and 80 days from transplanting. Growth characters; Plant height (cm), number of main branches per plant and number of leaves per plant were recorded. Yield components were estimated; number of flowers per plant, early fruit number (the sum of first five pickings of maturity fruits), early yield (the weight of the first five pickings were estimated for plant and recorded as grams/plant), total number of fruits (it was estimated by summing number of all picked fruits), total plant yield (it was determined by summing weight of all picked fruits (grams/plant)), total yield per feddan (it was estimated by multiplication the average yield of each plot in kg by the number of plants per feddan), average fruit weight :it was determined by dividing the weight of 10 fruits by their numbers (gram), fruit set %: it was estimated by the following formula:

$$\frac{\text{n of fruit set in the first five flower clusters}}{\text{total n of flowers anthesis in these clusters}} \times 100$$

Marketable yield : it was determined by summing weight of all picked fruits without damage (kg), fruit length (cm) and diameter (cm) :it was measured during harvest stage as the average of ten randomly selected fruits per replicate using a digital slide caliper, shape index: it was estimated by dividing the value of fruit length by value of fruit diameter and total soluble solids%:it was estimated two times at 45 and 60 old days using a hand refract meter.

Statistical Analysis

The statistical model was applied to obtain the analyses of variance of all traits according to Steel and Torrie 1960 using random model as follows:

Y_{ij}=μ+ G_i + R_j + E_{ij} where**:** Y_{ij}:the *i-th* genotype value in the *j-th* replication; μ: population means; Gi: the *i-th* genotype effect; Rj: the *j-th* replicate effect;E_{ij}:the experimental error effect.

Combined Analysis

In the combined analysis of several assays, the Z_{ijk} and Y_{ijk} values are admitted, which refer to the same variable, but are used to represent the values of the controls and the genotypes (families), being more enlightening, since the effects considered in the determination of each observation are differentiated (Bailey, 2008). In this analysis, it consider two sources of variance regarding the genotypes; the first is concerns the families in which each group occurs in a given trial, not being possible to quantify their interaction with the environments; the second refers to the controls, which are evaluated in a factorial system, quantifying the variation between them and the variation in the interaction with the environment. Contrast between controls and families were included along with the sources of variation inherent to the environments, characterized by blocks, assay and residual effects.

Where:

$Z_{ijk} = \mu + Te_i + B_{j(K)} + E_k + Te_{Eik} + \xi_{ijk}$

Since:

Z_{ijk}:value evaluated in the i-*th* common treatment, and j-*th* repetitions of the k trial.

μ: general mean of trial

Te_i : effect of i-*th* control (common treatment)

$Bj_{(K)}$: effect of the j-*th* block within the k-*th* trial

E_k : effect of k-*th* trail

Te_{Eik} : effect of interaction between the common treatment and the trial (season)

ξ_{ijk} : random error and $Y_{ij(k)} = \mu + F_i + B_j + \xi_{ij(k)}$ for each trial k

Where:

$Y_{ij(k)}$: value evaluated in i-*th* treatment (family) in j-*th* replication, for a particular trial k,

μ: General mean of the experiment

F_i : effect of i-*th* family in a k trial

B_j : effect of j-*th*block in a k trial and

$\xi_{ij(k)}$: random error in a k trial.

RESULTS AND DISCUSSION

Response to Selection

Actual and expected genetic gain for different vegetative growth, fruit and yield component traits were estimated and are presented in Table 1. Moderate to high positive genetic gains (ΔG %) were obtained along the evaluated traits ranged from 0.086% to 32.33% for shape index and marketable fruit yield per feddan, respectively. Among vegetative, growth traits, the number of leaves have the highest genetic gain in this group estimated by 20.78%. Regarding earliness traits, the amount of increasing in the improved population estimated by 6.862% and 12.97%for early fruit number and early yield, respectively. While selection gain for the total number of fruits estimated by 18.36%.

This gain could be attributed to genetic gain achieved by the average fruit weight, fruit set % and number of flowers per cluster and/or per plant. As amount, the total yield per plant and per feddan, their genetic gain ranged from 4.425% to 11.95%, respectively. On the other hand, the great response to selection, expressed by genetic gain, observed for the marketable fruit yield per feddan that recorded 32.33%.

For the total soluble solids, which are responsible for the acceptable fruit test and quality, it recorded an increase of 5.616% at 60 old days comparing with the original population. Whereas the shape index remain its same behavior as a round fruits during the selection and no significant differences in this trait was observed along both the basic population and selected individuals.

High genetic advance was obtained by **Haydar *et al*. (2007)** for fruit weight/plant. High heritability with moderate genetic gain observed for early fruit number is in accordance with findings previously reported by **Mohanty (2003)**. Based on heritability coefficient and genetic variability among the individuals of basic population, it's expected to achieve an increment in fruit weight, fruit set and consequently, total

Table 1. Actual and expected response to individual selection considering selection intensity of 8% in the basic population for vegetative growth, fruit and yield component traits in tomatillo during 2019/2020

Traits	X_0	X_s	S.D	h^2	X_m	ΔG	GS%
Plant height	133.0	134.6	1.600	0.176	134.4	0.282	0.212
No. of leaves	173.3	222.9	49.53	0.845	226.0	36.01	20.78
No. of branches	22.67	24.23	1.567	0.014	21.70	0.222	0.981
No. of flowers	21.67	26.40	4.733	0.073	25.53	0.345	1.593
Early Fruit No.	23.00	24.67	1.667	0.947	19.53	1.578	6.862
Early Yield/plant	101.6	116.7	15.03	0.877	117.1	13.18	12.97
Total No. of Fruits	48.00	57.83	9.833	0.896	54.40	8.811	18.36
Average fruit weight	7.600	7.874	0.274	0.416	8.030	0.114	1.500
Fruit Set (%)	75.00	86.33	11.33	0.498	85.08	5.642	7.523
Yield/Plant	383.3	407.4	24.03	0.706	403.5	16.96	4.425
Yield/Fed.	2850	3239	388.8	0.876	3090	340.6	11.95
Marketable Y/Fed.	2167	3054	886.8	0.790	3027	700.57	32.33
Fruit length	2.067	2.367	0.300	0.285	2.277	0.086	4.137
Fruit Diameter	2.203	3054	0.137	0.139	2.253	0.019	0.862
Shape Index	0.942	1.023	0.081	0.010	1.020	0.001	0.086
T.SS at 45d	3.400	3.647	0.247	0.212	3.607	0.052	1.538
T.SS at 60d	5.267	5.653	0.387	0.765	5.497	0.296	5.616

X_0 : Original mean of basic population; X_s: general mean of selected individuals; SD: Selection Differential h^2: heritability in broad Sense; ΔG: Selection gain; X_m: general mean after first cycle of selection. Selection realized towards the highest values.

yield per plant estimated by 420.4 grams by the next cycle of selection. Also, an increasing in early yield per plant would be used in selection enhancement for yield in tomatillo if there was enough evidence of the association between this characters and fruit yield under field conditions.

Simple and Combined Analysis of Variance

Significant and non-significant differences for the mean squares of the genotypes including the basic population and the individual plants selected phenotypically were recorded. For plant height, number of branches, number of flowers, average fruit weight, fruit length and its diameter and shape index, no significant differences were observed among the genotypes could be attributed to the relative high coefficient of variation within the same treatment (replicates). On the other hand, highly significant differences in mean squares for the genotypes were recorded for number of leaves, early fruit number, early yield per plant, total number of fruits, fruit set, yield and marketable yield (Table 2). Regarding the grouped analysis of variance that included more details about the basic population and its behavior cross the experiments, was obtained and presented in Tables 3, 4 and 5.

Vegetative Growth and Early Yield Traits

Regarding the source of variance (Table 3), experiment (E), no significant differences were observed between the two experiments for most vegetative growth and early yield traits except early fruit number which was highly significant.

Table 2. Analysis of variance and mean squares for different vegetative growth, fruit and yield traits in tomatillo resulted from the phenotypic selection of individual plants during 2020

Traits	S.V			Mean	CV (%)
	Blocks D.F (2)	Gen. D.F (20)	Error D.F (40)		
Plant height	210.5	291.1^{ns}	239.5	134.41	11.51
No. of leaves	153.2	2310.6**	358.4	224.6	8.42
No. of branches	18.47	7.685^{ns}	8.776	20.80	14.23
No. of flowers	12.76	31.77^{ns}	29.46	25.76	21.06
Early Fruit No.	41.44	121.5**	6.411	20.50	12.34
Early Yield/plant	168.8	1067.7**	130.9	115.6	9.893
Total No. of Fruits	4.777	431.7**	44.82	55.26	12.11
Average fruit weight	0.141	1.137^{ns}	0.663	7.935	10.26
Fruit Set (%)	6.339	63.41*	31.77	85.19	6.616
Yield/Plant	719.8	15335.7**	4504.4	416.5	16.11
Yield/Fed.	55073.3	524601**	64703.2	3202.6	7.941
Marketable Y/Fed.	177836	368576**	77125	2998	9.260
Fruit length	0.066	0.110^{ns}	0.078	2.309	12.15
Fruit Diameter	0.002	0.078^{ns}	0.067	2.292	11.31
Shape Index	0.017	0.023^{ns}	0.027	1.017	16.21
TSS at 45d	0.138	0.188^{ns}	0.148	3.615	10.66
TSS at 60d	0.114	0.328**	0.077	5.530	5.020

ns, *, and ** are insignificant, significant, and highly significant at 5% and 1% levels of probability, respectively.

Table 3. Grouped analysis of variance for different vegetative and early yield traits in tomatillo obtained by phenotypic selection of individual plants during 2019/2020

s.v	d.f	*MS*					
		Plant height	No of leaves	No of branches	No of flowers	Early fruit number	Early Y/P
Blocks	4	183.39	59.57	12.36	17.56	21.69	200.0
Experiment	1	0.0139ns	62.35ns	0.125ns	9.389ns	325.1**	2.000ns
Population(P)	1	5.3333ns	3.000ns	0.000ns	0.000ns	52.08**	0.000ns
P xE	1	54136.3**	91176.3**	1541.3**	1408.3**	1102.1**	25098.5**
Genotype/Exp	18	322.97ns	2101.6**	7.928ns	31.74ns	118.5**	1083.8**
(P vs G)/Exp	2	22660.7**	98084.7**	440.2**	1146.1**	581.4**	25299.9**
Error	44	217.81	331.5	8.619	26.01	5.922	115.36
Total	71						

ns, *, and ** are insignificant, significant, and highly significant at 5% and 1% levels of probability, respectively.

The same behavior was observed for effect of population (P) also. Regarding the P x E interaction, all the studied traits showed highly significant interaction. While the behavior of the different genotypes across the experiments did not differ for plant height, number of branches and number of flowers.

On the other hand, the reaction of tomatillo genotypes differed significatively according to experiment for both early fruit number and early yield per plant. Finally, significant differences in the mean squares of P vs G were observed for all these traits.

Yield Components and Marketable Yield

No significant differences were observed between the two experiments in addition to population behavior for most yield component traits except fruit set % that its mean square has highly significant defenses at 1% for these sources of variance. This fact could be interpreted as a result of macro and micro environmental factors that affect in a direct way on the fruit set percentage.

Regarding the P x E interaction, all the studied traits showed highly significant interaction. Regarding genotypes and P vs G, as sources of variance, they showed significant or highly significant of their mean squares for all yield components and marketable yield (Table 4).

Fruit shape and total soluble solids

No significant differences in mean squares for neither experiment nor population could be observed for fruit length, and diameter, shape index and TSS at 45 and 60 old days. On the other hand, P x E interaction and P *vc* G showed highly significant mean squares revealed the impact of this source of variance on the fruit shape characters besides total soluble solids. While the behavior of genotype did not differ according to experiment for the most studied traits in this group except TSS at 60 old days (Table 5).

Table 4. Grouped analysis of variance for yield components in tomatillo obtained by phenotypic selection of individual plants during 2019 and 2020

s.v	d.f	*MS*					
		Total No. of fruits	AFW	Fruit set %	Y/P	Y/Fed	Marketable Y/Fed
Blocks	4	17.06	1.079	36.00	2767.3	39010.3	97412.0
Experiment	1	159.0ns	0.049ns	937.9**	3889.8ns	34104.0ns	55112.0ns
Population (P)	1	1.333ns	0.653ns	4120.3**	2790.8ns	6210.8ns	116821.3ns
P x E	1	4256.3**	152.7**	4318.3**	245674.1**	12247260.8**	11638760.3**
Genotype/Exp.	18	419.7**	1.223*	50.97*	14823.4**	355225.1**	288304.4**
(P v.s G)/Exp.	2	6959.8**	96.64**	23870.7**	391432.6**	25296385**	21161696**
Error	44	39.60	0.518	25.90	3898.0	59295.9	69370.0
Total	71						

ns, *, and ** are insignificant, significant, and highly significant at 5% and 1% levels of probability, respectively.

Table 5. Grouped analysis of variance for fruit shape and total soluble solids in tomatillo obtained by phenotypic selection of individual plants during 2019 and 2020

s.v	d.f	*MS*				
		Fruit length	**Fruit Diameter**	**Shape index**	**TSS at 45d.**	**TSS at 60d.**
Blocks	4	0.063	0.011	0.016	0.107	0.092
Experiment	1	0.101ns	0.212ns	0.006ns	0.020ns	0.125ns
Population (P)	1	0.000ns	0.143ns	0.042ns	0.000ns	0.000ns
P x E	1	12.81**	11.82**	3.369**	34.68**	71.05**
Genotype/Exp.	18	0.106ns	0.079ns	0.025ns	0.200ns	0.280**
(P vs G)/Exp.	2	8.309**	8.525**	1.227**	18.56**	48.99**
Error	44	0.069	0.061	0.025	0.134	0.068
Total	71					

ns, *, and ** are insignificant, significant, and highly significant at 5% and 1% levels of probability, respectively.

For a better understanding of the population structure, as the genetic variability and expected genetic gain, the knowledge of population genetic parameters is of great interest and consequently possible success in the breeding program (**Elsayed *et al.*, 2015**). The high heritability values estimates for earliness parameters (94.72%, 87.73%) demonstrate highly selection gain. In addition, the direct selection based on these traits could achieve great progress attributed to the insignificant impact of these traits by the environment (**Falconer and Mackay, 1996**). The low heritability estimates for TSS at 45 old days (0.212) revealed a favorable influence of environment rather than genotype, and hence selection gain for these traits would not be rewarding in early generations. In contrast, at 60 old days, the same trait gave high relative estimates of heritability (0.765) under those conditions of current study that could be used as a new estimator for selection of high content of total soluble solids in tomatillo for future investigation.

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بشرى أمين عبد السلام حسان[1]– احمد يوسف عبدالنبى السيد[1]
عبدالله عبدالعظيم حسانين[2] - هانى السيد محمد على اسماعيل[3]

1- قسم بحوث تربية الخضر – معهد بحوث البساتين– مركز البحوث الزراعية

2- قسم الوراثة – كلية الزراعة – جامعة الزقازيق – مصر

3- قسم البساتين – كلية الزراعة – جامعة الزقازيق – مصر

أجريت هذه التجربة خلال موسمين متتالين 2019 و2020 في المزرعة البحثية بالبرامون التابعة لمعهد بحوث البساتين بالمنصورة بالدقهلية - مركز البحوث الزراعية لانتخاب تراكيب وراثية تستخدم كنواه لبرنامج التربية في الحرنكش بغرض تحسين الإنتاجية و التبكير وبعض صفات الجودة باستخدام عشيرة مفتوحة التلقيح من الحرنكرش البلدى. بالاضافة الى تقدير المكسب الانتخابى لمكونات المحصول ومحتوي الماده الصلبة الذائبة وبعض صفات الثمرة المظهرية. تم تصميم التجربة بطريقة القطاعات الكاملة العشوائية من خلال ثلاث مكررات. أظهرت النتائج المتحصل عليها بعد اول دورة من الانتخاب بتفوق تراوح بين 0.086% الي 32.33% لمعامل شكل الثمرة والمحصول القابل للتسويق على التوالى. بينما تراوحت قيم المكسب الانتخابى بين % 6.862 و % 12.97 لعدد الثمار والمحصول المبكر علي التوالى. بالإضافة إلى ذلك، أظهرت صفه المحصول القابل للتسويق اعلى مكسب انتخابى مقارنه ببقية الصفات الأخرى بنسبة 33.32%. بينما تفاوت المكسب الانتخابى لصفه المواد الصلبه الكلية بناءاً على عمر النباتات حيث أعطت هذه الصفة اعلى مكسب انتخابى عند عمر 60 يوم من الشتل مقارنه عند 45 يوم بزيادة 5.616%. تم تحديد عشرون نبات بكثافة انتخاب 8% من حجم العشيرة الاصلية. ومن خلال الدراسة الحالية أوضحت النتائج المتحصل عليها بجدوى تطبيق الانتخاب الفردى المظهرى لتحسين بعض صفات الجودة في الحرنكش بجانب المحصول المبكر من خلال عدد من الأجيال حتى الثبات الوراثى حتى الوصول الى سلالات داخلية التربية اعلى نقاوة و مختلفة فيما بينها كنواة لبرامج التحسين الوراثى لهذا المحصول.

المحكمـــــون:

1- أ.د. لطفي عبدالفتاح بـــدر رئيس قسم البساتين – كلية الزراعة بمشتهر – جامعة بنها.

2- أ.د. عبدالله برديسي أحمد أستاذ الخضر المتفرغ – كلية الزراعة – جامعة الزقازيق.