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Evaluation of Some Indeterminate Exotic Genotypes of Tomato

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Abstract: The study aimed to evaluate the performance of 15 exotic indeterminate genotypes of tomato (*Solanum lycopersicum* L.) to determine their suitability for cultivation under greenhouse conditions. The study material was obtained from two globally known gene banks, namely, the Center for Genetic Resources of the Netherlands and the U.S. National Plant Germplasm System (GRIN-Global) of the United States Department of Agriculture. One locally registered hybrid, Asya, was used as the control. The experimental layout was a complete randomized block design with three replications. The data collected were vegetative, flowering, and fruit characteristics as well as the number of fruits and both early and total yield per plant. High significant differences were observed among the exotic genotypes and control for all the studied attributes. The mean control values of fruit weight, firmness and pericarp thickness were significantly high, and several of the exotic genotypes exceeded the control values for vegetative, flowering, and yield characteristics under study. The genotypes coded as G.21 (Allround), G.18 (Alicante), G.6 (Marsol), G.7 (Harzer Kind) and G.3 (Robar) are promising for their overall performance in the total yield per plant and can be recommended for further exploitation to produce hybrids.

1 Introduction

Tomato, a member of the family Solanaceae is considered a dominant vegetable crop grown and widely consumed throughout the world. In addition, tomato is particularly appreciated for its nutritional properties resulting from its contents of vitamins (A, and C) lycopene, flavonoid and other minerals, which are important for human health (Bhowmik et al 2012).

In Egypt, tomatoes are cultivated in open fields and/or under greenhouse conditions. The cultivated area of tomatoes reaches 428,175 feddans, producing 6,751,856 tons with an average productivity of 15.7 tons per feddan (FAOSTAT 2019). In the season of 2018/2019, the number of greenhouses that cultivated tomatoes reached 4,100 (1,267,251 m^2), producing 18,021 tons, with an average productivity ranging between 8.5 and 16.3 kg/m^2, according to the statistics of the Ministry of Agriculture and Land Reclamation, Egypt. One of the main obstacles in the cultivation of the crop in Egypt is the high annual cost of imported seeds. Other hindrances include the absence of good strains and high-yielding varieties that can improve the yield in breeding programs.

In Pakistan, the availability of suitable high-yielding varieties not only increases the tomato yield and profits of a farmer but also fills the gap in production (Khan et al 2017). In Egypt, few studies have been carried out on the development of indeterminate tomato lines. Consequently, new indeterminate lines or cultivars suitable for cultivation under a greenhouse with high yield and fruit quality should be developed (Mahmoud and Khalil 2019). A common observation in most genotypes with superior performances in fruit yield is the high score for one or more yield component traits, including the number of fruits per plant, the number of clusters per plant, fruit weight, and the total yield per plant. The differences recorded by various authors may be due to the differences in the genetic materials and locations evaluated (Ochar et al 2019). Tomato production faces the significant problem of low yield due to various biotic and abiotic stresses. Therefore, the introduction and evaluation of exotic tomato germplasm have become necessary to acquire elite materials to develop future breeding programs (Hassan et al 2021).

Several exotic genotypes have excellent adaptation, whereas others are valuable sources of diversity in breeding materials. Given this condition, the present investigation was undertaken to evaluate the performance of several exotic genotypes of tomatoes for growth and cultivation under our agro-climatic greenhouse conditions to determine their value for use as parents in tomato breeding programs in order to produce hybrids.

2 Materials and Methods

The experiment was conducted in unheated plastic greenhouses at Kaha Research Farm, Qalyubia Governorate, belonging to the Horticultural Research Institute, Agricultural Research Center, Egypt, in three seasons (2018/2019, 2019/2020, and 2020/2021).

2.1 Plant materials and experimental design

The basic materials used in this study consisted of 15 indeterminate genotypes of tomato obtained from two globally known gene banks, namely, the Center for Genetic Resources of the Netherlands and U.S. National Plant Germplasm System (NPGS) of United States Department of Agriculture, and the registered hybrid was used as the control (**Table 1**).

In the first season (2018/2019), the seeds of exotic genotypes were sown in seedling trays containing a mixture of peat moss and vermiculite at 1:1 volume. The mixture was enriched with different required nutrient elements and added with fungicide. The trays were kept in the greenhouse nursery, whereas all the recommended practices to obtain well-developed and high-quality tomato transplants were carried out.

The soil in the greenhouse was prepared by adding 0.4 m^3 chicken manure/100 m^2 of the area; besides regular agricultural such as basic fertilization, pruning, and pesticide application as recommended by the Ministry of Agriculture and Land Reclamation, Egypt. The plastic house was divided into five ridges. Tomato seedlings with three true leaves were transplanted in the ridges inside the greenhouse under natural light and seasonal temperature. Two rows of plants were transplanted on each ridge. The distance between plants was 50 cm, with a plant population of 2.2 plants/m^2. The plastic house was equipped with a drip irrigation system.

After hardening, the seedlings completed their growth in the plastic greenhouse for self-propagation, and all observations of each genotype were recorded to determine the best vegetative growth, flowering characteristics, earliness, and yield which was indicated by the -number of fruits with good characteristics per cluster. At the ripening stage of the fruits, the seeds from each genotype were extracted using the fermentation method for 3–5 days under predominant temperature conditions and saved after washing and cleaning. The 15 genotypes showed a high adaptation to grow and produce seeds under the local climatic conditions of the greenhouses in which they were planted.

During the seasons of 2019/2020 and 2020/2021, the seeds of the 15 genotypes plus the control were planted first in the nursery. Then, the seedlings were transplanted to a plastic greenhouse. The evaluation experiments were established in a complete randomized block design with three replications.

The specifications of the registered hybrid (Asya) used for comparison are indeterminate tomato hybrid, grown in greenhouses, vigorous and early, and excellent setting percentage under high temperatures. The fruits are red, spherical, and solid, with an average weight of 280–320 g, and tolerant of TYLCV, TOMV, FOL 0, 1.

Table 1. Names and sources of indeterminate genotypes used in the present study

Study Code	Genotype Name	Source	Fruit Color
G.3	Robar	CGN(1)	Red
G.4	Chvatikovo Uslechtile	CGN(1)	Red
G.6	Marsol	CGN(1)	Red
G.7	Harzer Kind	CGN(1)	Red
G.17	Isogenic line Moneymaker; F4T5	CGN(1)	Red
G.18	Alicante	CGN(1)	Red
G.21	Allround	CGN(1)	Red
G.26	Hollandia's Glorie	CGN(1)	Red
G.33	Portia	CGN(1)	Red
G.38	Ano no.4	CGN(1)	Pink
G.45	E.S. 1	USDA(2)	Red
G.46	Huando	USDA(2)	Red
G.55	G 9808S	USDA(2)	Red
G.60	Ch'ang-ch'un No. 2	USDA(2)	Red
G.62	Hongza No. 20	USDA(2)	Pink
Cont.	Asya	Registered hybrid (3)	Red

(1) Netherlands, (2): United States and (3): Registered hybrid for Agrimar Company.

In the three continuous seasons, the seed sowing dates in the nursery were in the 2nd week of August, and the transplanting dates in the greenhouse were in mid-September. The plastic greenhouse had an area of 540 m^2.

2.2 Data recorded

2.2.1 Growth characteristics

The growth characteristics included plant length (cm) and the number of leaves per plant (180 days after transplanting).

2.2.2 Flowering characteristics

The flowering characteristics, i.e., the number of days to flowering (number of days from transplanting until the flowering of 50% of the plants per experimental plot). The number of clusters per plant (180 days after transplanting). The number of flowers per cluster (five plants/plot were chosen randomly and tagged after flowering, and it was calculated as an average of the first three clusters of each tagged plant). The number of fruits per cluster (it was counted from each pre-tagged plant to calculate the number of flowers per cluster), and fruit set percentage (it was calculated by using this formula: fruit set percentage = (number of fruits per cluster/number of flowers per cluster) X 100).

2.2.3 Fruit characteristics

A sample of ten fruits/plot were taken randomly in the third harvest to measure the physical characteristics of fruits, and the averages were calculated. The fruit characteristics comprised fruit weight (g), fruit shape index (expressed as the ratio of fruit length to diameter, fruit firmness (determined using a pocket penetrometer, kg/cm²), the number of locules per fruit, pericarp thickness (cm), and the total soluble solids (TSS) (determined using a hand refractometer, °brix).

2.2.4 Yield characteristics

The yield characteristics included the number of fruits per plant, early yield per plant, kg (the average total weight of the first three harvests), and total yield per plant, kg (the average total weight for all harvests during a period of 180 days from transplanting, kg).

2.3 Statistical and genetic analysis

The combined data for two seasons (2019/2020 and 2020/2021) were calculated and subjected to statistical analysis of variance in accordance with the work of Snedecor and Cochran (1980) and means separation was performed following the work of Duncan (1955). A dendrogram was constructed based on the Euclidean distance procedure. Genotypes were clustered using an unweighted pair group method using arithmetic average as outlined by Kovach (1995).

3 Results and Discussion

Table 2 shows the results from the analysis of variance, which illustrated that the exotic genotypes and control were significantly different in terms of all the studied characters. Similar results were previously reported by other researchers (Kena et al 2018, Mahmoud and Khalil 2019, Hassan et al 2021).

3.1 Vegetative characteristics

The data in **Table 3** show the combined mean performance of the exotic genotypes and control for the vegetative characteristics under study. The mean values for plant length lay between 180.7 and 289.2 cm. The tallest plant was G.38 (289.2 cm), and the shortest were G.60 and G.46 (182 and 180.7 cm, respectively). The control had a plant length of 260.2 cm.

The mean values for the number of leaves per plant lay between 33.4 and 40.8. The maximum significant values were observed in genotypes G.17, G.18, and G.7 (40.8, 40.5, and 40.4, respectively) with no significant differences between them, and the minimum significant value was noticed in genotype G.46 (33.4). The control exhibited a mean value of 36.8, which is equal in significance with G.33 (37.2) and G.6 (36.8). Our results differ from those of Dunsin et al (2016) who reported no significant difference among the varieties used with respect to the growth parameters, such as plant height and the number of leaves. Meanwhile, other researchers previously reported similar results regarding the significant differences for both traits (Mehraj et al 2014, Mahmoud and Khalil 2019).

The results of the differences between vegetative averages confirmed the superiority of exotic genotypes, including G.17, G.18, G.21, G.7 and G.38, over the control in terms of the vegetative characteristics under study.

3.2 Flowering characteristics

The data in **Table 3** present the combined mean performance of the exotic genotypes and control for the flowering characteristics. The mean values for the number of days to flowering ranged from 31 days to 37.5 days. Among the different genotypes, G.6 showed the earliest flowering (31 days), whereas G.60 (37.5 days) showed a statistically late flowering, followed by G.3 and G.4 (37 days). The variability among tomato genotypes for a certain number of days to flowering has been reported in earlier studies. Khan et al (2017) and Mahmoud and Khalil (2019) reported that the period between transplanting and flowering ranged between 24.67–47.66 and 31–45 days.

The mean number of clusters per plant ranged from 7.7 (G.46) to 11.1 (G.18). Ten genotypes exceeded the value of the control, whereas the two genotypes G.55 and G.26 were identical with the control (9.3). This result was in line with that of Kena et al (2018), who reported the highest (13.31) and lowest (7.625) numbers of clusters per plant.

For the number of flowers per cluster, the mean values lay between 7 (G.46) and 14.3 (G.38). The mean value of the control was 7.1, with no significant difference from that of G.46, which showed the minimum value of the trait. The number of flowers per cluster was significantly different among varieties (Khan et al 2017, Ochar et al 2019).

The mean number of fruits per cluster ranged from 6 to 12.1. The highest significant value was observed in both genotypes G.17 and G.7 (12.1), whereas the lowest was noticed in G.46 (6), with equal significance with the control (6.2). Significant differences between the examined lines for this character were recorded by Khan et al (2017), Kena et al (2018), Hassan et al (2021).

The data of fruit set percentage revealed that the highest significant value was 0.932 for G.17, whereas the lowest was 0.635 for G.38. The control mean value was 0.877 with the same significance as genotypes G.60 and G.62. Ochar et al (2019) observed the maximum and minimum significant values (72.93% and 47.76%, respectively) for percent fruit set.

Table 2. Mean square values of 15 genotypes and control of tomato (combined data for two consecutive seasons, namely, 2019–2020 and 2020–2021)

Traits	Mean square values due to genotypes (DF=15)	CV%	Grand mean	Range Min. -Max.
1- Vegetative characters				
Plant length (cm)	10282.1**	0.86	241.38	178–295
No. of leaves per plant	33.71**	1.28	37.34	32–42
2-Flowering characters				
No. of days to flowering	20.21**	1.70	34.63	30–38
No. of clusters per plant	6.28**	3.88	9.70	7–12
No. of flowers per cluster	25.25**	4.33	10.27	6–16
No. of fruits per cluster	18.55**	4.72	9.04	5–14
Fruit set (%)	0.03**	1.17	0.88	0.6–1.0
3-Fruit characters				
Fruit weight (g)	9790.6**	0.88	118.83	74 -227
Fruit shape index	0.13**	1.11	0.88	0.7–1.4
Fruit firmness (kg/cm²)	0.91**	1.75	2.68	2.1 – 3.7
No. of locules per fruit	30.95**	3.95	3.81	2–10
Pericarp thickness (cm)	0.029**	3.08	0.65	0.5–0.9
Total soluble solids (°brix)	0.04**	2.26	4.30	4–5
4-Yield characters				
No. of fruits per plant	2991.3**	4.17	66.03	35–101
Early yield per plant (kg)	0.546**	5.31	0.70	0.25–1.55
Total yield per plant (kg)	2.184**	3.33	3.57	2.35–4.6

** Significant at 1% probability level.

Table 3. Combined mean performances (2019–2020 and 2020–2021) of the exotic genotypes and control for several vegetative and flowering characters in tomato

Study code	1- Vegetative characters		2- Flowering characters				
	PL	**NLPP**	**NDF**	**NCPP**	**NFPC**	**FPC**	**SP%**
G.3	250.2 g	38.7 c	37.0 ab	10.1 d	11.2 c	10.3 b	0.920 ab
G.4	245.5 h	38.0 d	37.0 ab	10.2 cd	10.6 d	9.7 cd	0.917 bc
G.6	256.5 f	36.9 e	31.0 f	10 d	9.3 f	8.3 g	0.892 g
G.7	283.2 c	40.4 a	34.5 c	10.7 ab	13.1 b	12.1 a	0.920 ab
G.17	283.7 c	40.8 a	33.7 d	10.9 a	13.0 b	12.1 a	0.932 a
G.18	286.7 b	40.5 a	34.5 c	11.1 a	11.2 c	10.2 bc	0.910 b-e
G.21	283.2 c	39.3 b	34.7 c	10.5 bc	10.4 de	9.6 d	0.913 b-d
G.26	190.8 k	34.9 fg	34.3 cd	9.3 e	9.4 f	8.4 g	0.895 fg
G.33	264.2 d	37.2 e	33.7 d	9.9 d	10.4 de	9.4 d-f	0.903 d-g
G.38	289.2 a	38.6 c	35.0 c	10.1 d	14.3 a	9.1 ef	0.635 j
G.45	219.2 i	38.0 d	32.2 e	10.0 d	10.5 de	9.5 de	0.905 c-f
G.46	180.7 l	33.4 i	32.3 e	7.7 g	7.0 h	6.0 i	0.855 i
G.55	198.5 j	35.3 f	35.0 c	9.3 e	10.0 e	9.0 f	0.898 e-g
G.60	182.0 l	34.1 h	37.5 a	7.8 g	8.3 g	7.3 h	0.878 h
G.62	188.5 k	34.6 g	35.0 c	8.3 f	8.4 g	7.4 h	0.878 h
Cont.	260.2 e	36.8 e	36.7 b	9.3 e	7.1 h	6.2 i	0.877 h

Means followed by the same alphabetical letter (s) within each column are not significantly different at the 5% level according to Duncan's multiple range test.

PL: plant length (cm); NLPP: the number of leaves per plant; NDF: the number of days to flowering; NCPP: the number of clusters per plant; NFPC: the number of flowers per cluster; FPC: the number of fruits per cluster; SP%: fruit set (%).

For the mean performance of flowering characteristics, the obtained results indicated that most genotypes, namely, G.7, G.17, G.18, G.21, G.33 and G.45, exceeded the control in all flowering characteristics under study. In addition to each of (G3 & G4), (G26 & G55) and (G6 & G38) also exceeded the control in all flowering traits except NDF, NCPP and SP%, respectively.

3.3 Fruit characteristics

The data in **Table 4** present the combined mean performance of the exotic genotypes and control for the fruit characteristics under study. The average fruit weight ranged from 75.5 g to 225 g. The control showed the significantly heaviest fruit (225 g), followed by G.6 and G.38 (161 and 160.8 g, respectively). Meanwhile, the lightest fruit (75.5 g) was recorded by G.17. The variation in fruit weight by different cultivars has also been reported by Khan et al (2017), Kena et al (2018), Shah et al (2019), Hassan et al (2021).

The data of the fruit shape index revealed that the highest value was 1.37 for G.4 (oblong fruit), whereas the lowest was 0.68 for G.6 (oblate fruit). The differences among the genotypes for fruit shape index were due to the genetic differences between the examined materials. These results were confirmed by Mahmoud and Khalil (2019) who detected high genetic differences among genotypes in terms of fruit shape index.

Fruit firmness mean values ranged between a minimum of 2.22 for G.60 to a maximum of 3.58 for the control. Genotype G.4 (3.34) followed the control in terms of significance for this trait. Shah et al (2019) reported a similar variation in fruit firmness of different cultivars.

The mean number of locules per fruit ranged between 2.0 (G.4) and 8.945 (G.38), the control had a recorded value of 4.425. Similar results were recorded by Dar et al (2012) and Mahmoud and Khalil (2019) who observed that the number of locules per fruit in the selected genotypes ranged between 2–3.67 and 2.03–4, respectively.

The mean pericarp thickness ranged from 0.580 cm to 0.858 cm. The highest significant value was that of the control, whereas the lowest was that of G.60. Several researchers, such as Dar et al (2012), Khan et al (2017) and Mahmoud and Khalil (2019), confirmed these results**.**

Regarding TSS, the mean values were 4.138 for G.55 and 4.428 for G.33. Meanwhile, a value of 4.305 was observed the control average for this trait, showing equal significance with G.46. Our results differ from those of Naz et al (2011), who found non-significant differences between cultivars. Parmar et al (2018), Shah et al (2019) and Hassan et al (2021) recorded similar results on the significant differences for this trait.

For the studied fruit characteristics, the control mean values were significantly higher in fruit weight, firmness, and pericarp thickness, whereas the other studied genotypes showed distinct characteristics in this respect. Therefore, given that each genotype has its characteristics, they can be exploited for different purposes to improve crops.

3.4 Yield characteristics

The data in **Table 4** present the combined mean performance of the exotic genotypes and control for the yield characteristics under study. The mean number of fruits per plant ranged between 36.5 and 98.5. The values were significantly higher in G.17 followed by G.7 (98.5 and 97.2, respectively), and the lowest was observed in G.60 (36.5). Most of the studied genotypes outperformed the control (45) in terms of this character. Hussain et al (2001), Dunsin et al (2016), Khan et al (2017), Rangnamei et al (2017) and Ochar et al (2019) mentioned similar variations in the number of fruits per plant.

Early yield per plant average ranged from 1.5 kg to 0.28 kg. Genotype G.6 exhibited the highest significant value, whereas G.60 showed the lowest. Except for G.60, all the exotic genotypes had higher values than the control, which exhibited a mean of 0.30 kg for this trait. Mahmoud and Khalil (2019) previously reported similar observations.

For the average total yield per plant, the data in **Table 4** reveal that the means were between 2.47 kg to 4.43 kg. The data showed that four genotypes (G.21, G.18, G.6 and G.7) significantly surpassed the control, which was in equal significance with G.3. The lowest significant values for this trait were for G.60 and G.62 (2.58 and 2.47 kg, respectively). Different tomato genotypes were studied, and similar results were obtained for the yield per plant (Hussain et al 2001, Khan et al 2017, Mahmoud and Khalil 2019, Ochar et al 2019).

3.5 Brief comparison of results

Field experiments were carried out to study the performance of 15 exotic indeterminate genotypes of tomato (*Solanum lycopersicum* L.) under greenhouse conditions. Accordingly, comparing the performance

Table 4. Combined mean performances (2019–2020 and 2020–2021) of the exotic genotypes and control for several fruit and yield characteristics

Study code	3- Fruit characters						4- Yield characters		
	FW	**FSI**	**FF**	**NLPF**	**PT**	**TSS**	**NFPP**	**EYPP**	**TYPP**
G.3	87.7 l	0.92 b	2.67 ef	2.33 i	0.645 e	4.193 d-f	92.0 c	0.54 h	3.96 cd
G.4	77.0 n	1.37 a	3.34 b	2.0 k	0.715 c	4.335 a-c	79.8 d	0.34 i	3.40 fg
G.6	161.0 b	0.68 i	2.33 i	8.275 b	0.610 gh	4.387 ab	56.5 f	1.50 a	4.28 b
G.7	86.0 m	0.83 f	2.36 i	2.89 g	0.643 ef	4.260 c-e	97.2 ab	0.76 d	3.97 c
G.17	75.5 o	0.92 b	2.44 h	2.22 ij	0.610 gh	4.308 bc	98.5 a	0.77 d	3.83 de
G.18	101.3 i	0.83 f	2.69 e	2.33 i	0.675 d	4.380 ab	94.3 bc	0.73 de	4.42 a
G.21	119.0 e	0.86 e	3.02 c	2.275 ij	0.750 b	4.377 ab	82.5 d	0.69 ef	4.43 a
G.26	107.3 f	0.88 d	2.81 d	3.67 f	0.620 g	4.258 c-e	55.0 f	0.69 ef	3.01 j
G.33	99.5 j	0.79 h	2.37 i	2.67 h	0.620 g	4.428 a	67.2 e	0.93 c	3.52 f
G.38	160.8 b	0.80 gh	2.25 j	8.945 a	0.595 hi	4.175 ef	40.5 hi	0.65 f	3.31 gh
G.45	92.2 k	0.86 e	2.54 g	2.11 jk	0.620 g	4.347 a-c	65.3 e	0.99 b	3.21 hi
G.46	157.7 c	0.83 f	2.62 f	6.22 c	0.622 fg	4.290 b-d	38.3 ij	0.94 c	3.08 ij
G.55	103.2 h	0.90 c	3.02 c	2.22 ij	0.668 d	4.138 f	65.7 e	0.54 h	3.70 e
G.60	142.2 d	0.81 g	2.22 j	5.67 d	0.580 i	4.320 a-c	36.5 j	0.28 j	2.58 k
G.62	106.0 g	0.90 c	2.71 e	2.67 h	0.632 e-g	4.362 a-c	42.2 gh	0.59 g	2.47 k
Cont.	225.0 a	0.84 f	3.58 a	4.425 e	0.858 a	4.305 b-d	45.0 g	0.30 ij	3.94 cd

Means followed by the same alphabetical letter (s) within each column are not significantly different at the 5% level according to Duncan's multiple range test.

FW: fruit weight (g); FSI: fruit shape index; FF: fruit firmness (kg/cm²); NLPF: the number of locules per fruit; PT: pericarp thickness (cm); TSS: total soluble solids (°brix); NFPP: the number of fruits per plant; EYPP: early yield per plant (kg); TYPP: total yield per plant (kg).

of the 15th exotic genotypes based on total yield per plant (kg/plant) and highest desirable increment of yield (% over the general mean of all genotypes under greenhouse conditions as well as the performance of other traits was done. The best genotypes, which are classified based on these parameters, are shown in **Table 5**. Six out of the 15 studied genotypes were classified as the heaviest genotypes for yield and exhibited significant increases in total yield, plant length, number of clusters and fruit set (%) compared with the general average of the exotic genotypes in addition to surpassing or significantly equal to the check genotype for most studied traits. Five out of these six genotypes exhibited significant desirable positive increments for the number of leaves, fruit number per cluster and fruit number per plant compared with the general mean. Four out of these five genotypes (G.17, G.18, G.7 and G.21) recorded the highest desirable increment for the earliness over the general mean.

Three out of the four earliest genotypes exhibited positive increment in the number of flowers/cluster and early yield, two of them namely, G.17 and G.18 along with the heaviest genotype (G.21) displayed significant positive increment for TSS compared with the general mean or significantly equal with the check genotype. These results indicated the possibility of combining both high-yield and good-quality characters under greenhouse conditions. The five genotypes, which exhibited significant positive increment for yield/plant, were also combined with significant/highly significant desirable negative or positive (due to the point of view) three or more important studied characters particularly vegetative growth, average fruit weight …. etc.

However, genotypes with high yield did not necessarily produce high other traits, especially qualitative traits and *vice versa*. Our results reveal that the abovementioned genotypes might be of prime importance in breeding programs and for traditional agricultural procedures for high yield and/or some of its important components under greenhouse conditions.

3.6 Cluster analysis and genetic distance

The clustering pattern of studied genotypes was graphically obtained as a dendrogram that provides a visual idea about clusters and variability existing in each tomato population. Accordingly, cluster analysis distributed the 15th exotic genotypes along with the control into three clusters comparison (**Fig 1**). Five

Table 5. The best genotypes were chosen based on mean yield/plant (over two seasons) along with desirable significant effect for other traits comparing with the average of all exotic genotypes under greenhouse conditions

Genotypes	Yield Kg/plant	Increment over the average of all genotypes under greenhouse conditions							DSI/E
		% yield/plant	Range % of traits groupes as well as both No fruits and early yield per plant						
			Vegetative traits	Flowering traits	Fruit traits	yield traits	No. of fruits	Early yield (kg)	
G.21	4.43	25	5.1% to 17.9%	(-) 0.8% to 8%	(-) 39% to 17.9%	(-) 5% to 25%	22.30%	(-)5%	(a-d),(f-h),j,(l-n)
G.18	4.42	24.7	8.4% to 19.4%	0.02% to 14.1%	(-) 39% to 6.9%	0.5% to 39.8%	39.80%	0.50%	(a-g),j,l,m,o
G.6	4.28	20.7	(-)1.3% to 6.8%	(-) 11.3% to 2.8%	(-) 23% to 120.1%	(-) 16.2% to 106.4%	-16.20%	106.40%	a,c,d,g,h,k,m,o
G.7	3.97	12	8.1% to 17.9%	0.02% to 31.1%	(-) 23.1% to 0.6%	4.6% to 44.1%	44.10%	4.60%	(a-g),l,n,o
G.3	3.96	11.7	3.5% to 4.2%	3.8% to 11.6%	(-) 39% to 4.2%	(-) 25.7% to 36.4%	36.40%	(-)25.7%	a,b,(d-g),i,j,l,n
G.17	3.83	8	9.2% to 18.1%	(-) 2.3% to 31.1%	(-) 41.7% to 4.2%	6% to 46.1%	46.10%	6%	(a-g),i,m,o

DSI E: Desirable significant increasing or equal for other traits due to compare with the check a:PL, b:NLPP, c:NDF, d:NCPP, e:NFPC, f:FPC, g:SP%, h:FW, i:FSI, j:FF, k:NLPF, l:PT, m:TSS, n:NFPP, o:EYPP

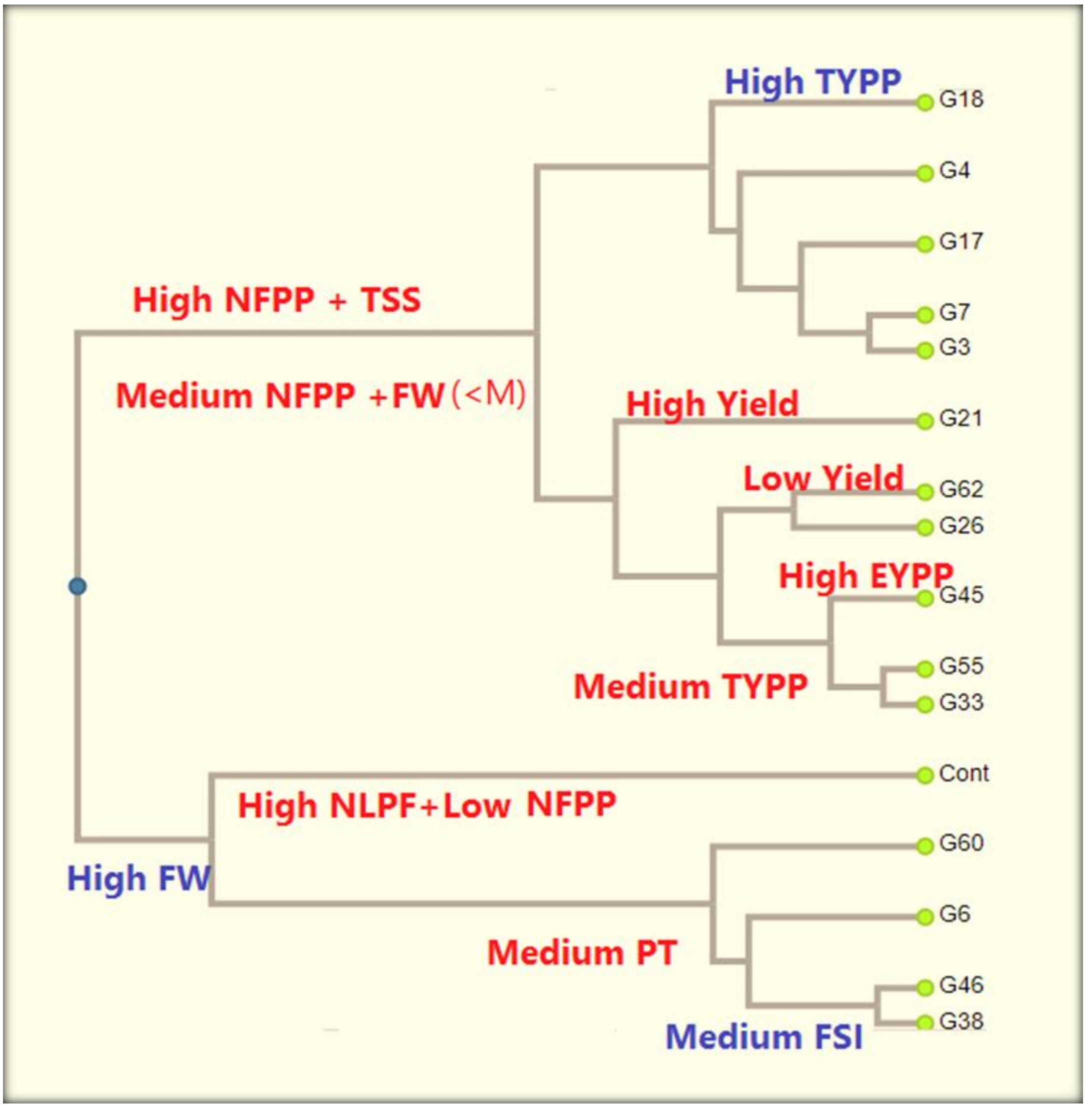

Fig 1. Dendrogram, using average linkage (Between Groups), for sixteen genotypes of tomato based on 9 fruits and yield traits

Table 6. Euclidean distance among sixteen genotypes of tomato

Genotypes	G4	G6	G7	G17	G18	G21	G26	G33	G38	G45	G46	G55	G60	G62	Cont
G3	16.3	81.7	5.5	13.8	13.8	32.7	41.9	27.5	89.7	27.1	88.3	30.5	77.9	53.1	145.1
G4	0	87.4	19.7	18.8	28.3	42.1	39.2	25.8	92.8	21	90.9	29.8	78.4	47.5	152.1
G6		0	85.5	95.5	70.9	49.8	53.9	62.7	16.1	69.6	18.7	58.9	27.7	57.1	65.2
G7			0	10.6	15.6	36.1	47.3	32.9	94.1	32.5	92.9	35.9	82.8	58.5	148.5
G17				0	26.1	46.4	53.9	39.4	103.4	37.2	102	42.9	91.1	64	158.8
G18					0	21.3	39.8	27.2	80.5	30.4	79.6	28.7	70.9	52.4	133.2
G21						0	30	24.8	59.6	31.9	58.9	23.1	51.7	42.4	112.5
G26							0	14.5	55.7	18.4	53.2	11.6	39.6	12.9	118.1
G33								0	67.2	7.6	65.1	4.1	52.7	25.9	127.5
G38									0	73.3	4.7	63.2	19.3	55.2	64.5
G45										0	71	11	57.8	26.9	134.4
G46											0	61.1	15.6	52	67.7
G55												0	48.9	23.7	123.6
G60													0	36.8	83.3
G62														0	119.1

genotypes (31.25%) were grouped in cluster-I (G.18, G.4, G.17, G.7 and G.3) and cluster III (G.38, G.46, G.6, G.60 and Control). Cluster-II was relatively the largest among all the three clusters, where six (37.5%) genotypes were grouped. Our results were comparable to the findings of Krasteva et al (2010) wherein they grouped determinate accessions of tomato using cluster analysis. Based on similarity and dissimilarity (**Table 6**), Euclidean distance values among 16 tomato genotypes (15 exotic genotypes plus the control hybrid) were significant for all pairs of comparison. The dissimilarity coefficient ranged from 4.11 to 158.8, G.33 and G.55 were the nearest genotypes with the lowest dissimilarity followed by G.38 and G.46 (4.7) as well as G.3 and G.7 (5.518) in ascending order. On the other hand, pairs of genotypes (G.17 and Control), (G.4 and Control) showed the highest dissimilarity index (158.8 and 152.1, respectively). Excluding the control, the dissimilarity coefficient ranged from 4.11 to 103.4 and pairs of genotypes (G.17 and G.38), (G.17 and G.46) showed the highest dissimilarity index (103.4 and 102, respectively), followed by G.6 and G.17 (95.5) as well as G.7 and G.38 (94.1). These pairs of greatest divergence could be used in breeding programs for developing new cultivars and hybrids with high yielding and adapted to greenhouse conditions.

Most fruits' numerous genotypes (about 80-99 fruits per plant) were grouped in cluster I whereas minimum low yielding (about 36-56 fruits per plant) combined with high values for average fruit weight (142-225 g) in cluster II. However, genotypes of cluster-II had medium mean values for fruit number per plant combined with <medium values for average fruit weight, indicating the degree of diversity among the different clusters for these traits.

4 Conclusion

The total yield per plant was considered the outcome that reflects the interaction of all traits with each other and with the environment in which they are located. The exotic indeterminate genotypes of tomato G.21, G.18, G.6, G.7, and G.3 versus control succeeded in giving a high yield under the conditions of cultivation in Egyptian greenhouses and thus can be exploited to improve the yield in tomato breeding programs and produce promising hybrids. In addition, given the lowest value of the studied genotypes (G.4, G.17, G.26, G.33, G.38, G.45, G.46, G.55, G.60, and G.62), each characteristic can be exploited as a genetic base for different purposes in breeding programs.

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