Egypt. J. Plant Breed. 24(3):517– 539(2020)

GENETIC VARIABILITY AND GENETIC ADVANCE FROM SELECTION IN MUNICIPAL GARLIC (*Allium sativum* L.) FOR ECONOMIC AND QUALITY TRAITS

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ABSTRACT

Ten Egyptian garlic clones were assessed for genetic variability and genetic advance for yield and some quality characteristics during four seasons [first season (S1), second season (S2), third season (S3) and fourth season (S4) in 2016-2017, 2017-2018, 2018-2019 and 2019-2020 respectively] at Vegetable Research Farm, Horticultural Research Institute and Crops Technology Research Department, Food Technology Institute, Agricultural Research Center (ARC), Kaha, Dokki and Giza Egypt. All genotypes were collected from various governorates in Egypt, i.e. Elmnofia (Ba.1), Elminia (Ba.2), El sharkia (Ba.3), El giza (Ba.4), El fayoum a (Ba.5), El fayoum b (Ba.6), Benisuif (Ba.7), Sohag (Ba.8), kalubia (Ba.9) and Asuit (Ba.10). The results showed that clone Ba.7 produced the highest bulb diameter, dry weight of leaves, bulb and plant leaves weight, total cured yield, as well as, clove weight, bulb weight and diameter after curing. Clone Ba.10 produced the tallest plants and also, contains the highest content of pungency content, followed by clone Ba.2. Estimated coefficient of variance (CV %) values indicated that most of clones had good homogeneity in all studied characters. The large portion of phenotypic variance (σ^2p) was due to the genetic variance (σ^2g). High genetic advance in all traits indicated that the observed significant phenotypic differences among the studied genotypes are of genetic nature and there are small environmental effects on the phenotypic variation. Therefore, simple selection can lead to improvement in these characters. The selected Beni suif (Ba.7) genotype had homogeneity, high productivity and high quality, so, it could be considered promising new clone of garlic.

Key words: ***Garlic, yield, pungency, TSS, PCV, GCV, Genetic advance.***

INTRODUCTION

Garlic (*Allium sativum* L.) is one of the most important vegetable bulb crops and the next to onion in importance in Egypt. It is consumed all over the world. Garlic can be successfully grown within a wide range of climates, but it does best where it receives some rainfall, dry sunny summers and moderate winters. Hard neck cultivars do best in colder climates and produce elongated stamen (flowering stalk) that produce a scape at the top of the plant. The growing season for hard neck garlic is nine months. Hard neck garlic is the choice of many garlic lovers. The cloves are easier to peel and have more flavor than soft neck garlic. Soft neck cultivars are grown in warmer climates and do not produce medicinal effects. It has been widely used throughout history as a food additive for both its flavor and medicinal effect. Recent research indicated that fresh and processed garlic may have some health benefits on human health such as anti-carcinogenic, anti-fungal and anti-bacterial properties (Clemente *et al* 2012). Panthee *et al* (2006) collected 179 accessions of garlic from various

parts of Nepal and revealed that the level of variation found in the collection showed the great potentiality of improving agronomic characters in garlic. Many investigators studied the growth and yield variations among garlic genotypes; of them Waterer and Schmitz (1994), Kasim and El-Ghadban (2002), Gvozdanovic *et al* (2002), Gowda *et al* (2007), Soto Vargas *et al* (2010), Clemente *et al* (2012), Gouda (2012), Ali (2013), Yadav *et al* (2018), (Umamaheswarappa *et al* (2018) and Ahmed *et al* (2019). Wang *et al* (2014) showed that the garlic clones from China had a wide diversity for all traits. In addition, Sharma *et al* (2016) reported that the characteristics like equatorial diameter of bulb, clove weight, number of cloves per bulb showed that they are the most important bulb weight determinants because of their high direct and indirect effects via many other yield component characteristic. The study indicated that these traits can be used as key traits for improving the bulb weight of garlic. The composition of garlic bulb varies greatly depending on cultivar, agronomic practice, climate, soil fertility and postharvest storage conditions that determine the quality and intensity of garlic flavor as well as its nutritional and nutraceutical value. Nutrient management with these factors plays a significant role in improving productivity and quality of crops (Zhou *et al* 2005). Volatile organosulfur compounds are responsible for the characteristic smell and taste of Allium (Keusgen *et al* 2002). These compounds are pharmacologically active substances that exhibit antibiotic (Corzo-Martínez *et al* 2007), lipid-lowering effects, antioxidant and antitumor activities (Shukla and Kalra 2007). Correlations among traits influence effectiveness of selection. Das *et al* (2010) stated that phenotypic variations with high genetic variability for different traits means less influence of environment. Therefore, selection on the basis of phenotype alone can be effective for the improvement of the traits (Yeshiwas and Negash, 2017). They found that High heritability coupled with moderate genetic advance from selection observed for diameter of bulb and bulb yield per plant and moderate heritability coupled with moderate genetic advance is observed for number of leaves per plant and plant length. While total soluble solids (TSS) showed

lowest heritability (Singh *et al* 2018). High heritability for traits clarified that, they were least effected by environmental modifications and selection based on phenotypic performance would be reliable (Chatoo *et al* 2018). Estimates of phenotypic coefficient of variation (PCV) were found higher in magnitude than corresponding genotypic coefficient of variation (GCV) for all the traits studied (Ranjitha *et al* 2018). As a result, the present investigation is aimed to evaluate variability and genetic advance of yield and its component characters in ten garlic genotypes to provide necessary information that could be useful in garlic improvement programmes aimed to improve yield character.

MATERIALS AND METHODS

Plant Materials

Ten local garlic genotypes (10 Balady genotypes) were used in the present study. All genotypes were collected from various governorates in Egypt i.e. Elmnofia (Ba.1), Elminia (Ba.2), El sharkia (Ba.3), El giza (Ba.4), El fayoum a (Ba.5), El fayoum b (Ba.6), Benisuif (Ba.7), Sohag (Ba.8), kalubia (Ba.9) and Asuit (Ba.10) where they have been commonly grown for several decades.

Field Trial Layout

Field experiments started to asses genetic variability and genetic advance for yield and some quality characteristics as per cent of mean during four seasons first season (S1), second season (S2), third season (S3) and fourth season (S4) 2016-2017, 2017-2018, 2018-2019 and 2019-2020 at Vegetable Research Farm, Horticultural Research Institute and Crops Technology Research Department, Food Technology Institute, Agricultural Research Center (ARC), Kaha, Dokki and Giza Egypt. The cloves were planted in the last week of September in a randomized complete blocks design with three replicates. The experimental plot was 10.50 m^2 which contained 3 rows, with 5 m length and 0.70 m width. Garlic cloves were planted on both sides of the rows at 10 cm apart. All agricultural practices for cultivation were applied as recommended by Ministry of Agriculture.

Recorded data

Random samples of three plants from each experimental sub-plot were uprooted after 150 days from planting to determine plant length (cm), number of leaves per-plant, neck and bulb diameter (cm), bulbing ratio, and dry weight of leaves, bulb and plant (g). Total yield was determined (ton/ fed). The plants were placed for 15 days in an aerated area for curing. After curing five bulbs were randomly taken from each experimental sub-plot to determine the averages of bulb diameter (cm), bulb weight (g), cloves number per bulb and clove weight (g).

Determination of total soluble solids (TSS) and pungency

Total soluble solids – found directly from the homogenized garlic juice through readings on a refractometer (Bellingham Stanley Limited - England). The results were expressed as % (ºBrix) according to the methodology proposed by AOAC (2012). Pungency - quantified as a function of pyruvic acid content using the colorimetric method described by Schwimmer and Weston (1961), thus, 0.2 mL of garlic juice, 1.5 mL of trichloroacetic acid (5%) and 18.3 mL of distilled water were placed to an Erlenmeyer flask and stirred. Then, 1 mL of this sample was placed in a tube test, in which was added 1 mL of 2,4-dinitrophenylhydrazine (DNPH) and 1 mL of distilled water, and stirred in vortex. The test tubes were placed in a water bath at 37°C for 10 minutes and then immediately cooled in water with ice. Subsequently, 5 mL of Na OH 0.6 N was added, stirred in vortex and left for five minutes to the yellow color develop. The absorbance was read in a spectrophotometer (6705 UV/Vis spectrophotometer - Jenway - England) at 420 nm, using sodium pyruvate as standard. The pungency was assessed by the sodium pyruvate standard curve. The results were expressed in μmol of pyruvic acid per mL of garlic juice.

Statistical analysis

An analysis of variance (ANOVA) for all characters was carried out to determine the significant differences between evaluated genotypes and mean comparisons were based on the LSD test according to Snedecor and Cochran (1995). Coefficient of variance, Genotypic and phenotypic coefficients of variation were estimated according to Singh and Chaudhary

(1995).Genetic advance was worked out as percent of mean according to the formula of Johnson *et al* (1955).

RESULTS AND DISCUSSION

Vegetative growth measurements

Plant length

It is obvious from Table (1) that there were significant differences among genotypes in 2016-2017, 2017-2018, 2018-2019 and 2019-2020 seasons. Clone Ba.1 produced plants of the highest plant length followed by clone Ba.3 the first season (S1). While in second season (S2) clone Ba.9 produced plants of the highest plant length followed by clone Ba.2. Concerning plant length in the third season (S3), Ba.9 produced plants of the highest values followed by clone Ba.5. As fourth season (S4) Ba.10 produced plants of the highest values followed by clone Ba.9, while, clone Ba.6 produced plants of the lowest length at S1 and S4 seasons. Ba.3 produced plants of the lowest length in S2 and S3 seasons.

Number of leaves per plant

Data presented in Table (1) showed that the highest values were obtained from clone Ba.6 followed by clones Ba.7, Ba.4 and Ba.1 in the first season (S1). While, clone Ba.9 produced plants of the lowest leaves number while there were no significant differences among S2, S3 and S4 seasons.

Neck diameter

It is clear from data shown in Table (1) that there were significant differences among the studied clones in the seasons S1, S2, S3 and S4. The highest values of neck diameter were obtained from clone Ba.5 followed by clone Ba.8 in first season (S1). While the highest values of neck diameter were obtained from clone Ba.9 followed by clone Ba.3 in the S3 season. Concerning neck diameter in the S3, it was clear that clone Ba.2 produced the highest neck diameter followed by clone Ba.8. As for S4, Ba.8 produced the highest values of neck diameter followed by clone Ba.7. While, clones Ba.7, Ba.4, Ba.5 and Ba.6 produced plants of the lowest values of neck diameter in the S1, S2, S3 and S4 seasons, respectively.

Table 1. Mean performances of the studied clones of garlic for plant length, number of leaves, neck diameter (cm), bulb diameter (cm), and bulbing ratio in four seasons (S1, S2, S3 and S4).

Genotypes	Plant length				Number of leaves				Neck diameter (cm)			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Ba1	117.67	83.33	90.00	93.33	8.33	7.67	8.00	9.33	1.63	1.20	1.53	1.23
Ba 2	109.00	92.00	92.67	94.00	7.67	7.67	9.00	8.33	1.73	1.27	2.23	1.27
Ba 3	116.00	78.00	89.33	94.33	7.67	8.00	8.67	8.33	1.53	1.33	1.47	1.30
Ba 4	112.33	82.67	92.67	92.33	8.67	7.67	8.67	9.00	1.53	0.97	1.77	1.07
Ba 5	112.67	83.67	96.67	94.67	8.33	6.67	8.33	8.00	1.87	1.30	1.30	1.27
Ba 6	80.67	89.33	94.67	84.67	9.33	7.67	8.67	8.67	1.70	1.00	1.80	1.00
Ba 7	114.00	80.33	92.00	93.33	9.00	8.00	9.33	8.00	1.37	1.20	1.67	1.33
Ba 8	109.33	90.00	96.00	92.00	8.00	7.33	10.00	9.67	1.77	1.07	2.10	1.50
Ba 9	115.00	104.33	97.00	95.33	7.00	8.33	9.33	9.33	1.60	1.33	1.93	1.07
Ba 10	97.50	90.67	94.67	96.33	7.33	7.33	8.33	9.33	1.40	1.20	1.70	1.10
LSD 0.05	7.56	7.63	4.55	3.75	1.02	N.S.	N.S.	N.S.	0.26	0.23	0.31	0.19

Genotypes	Bulb diameter (cm)				Bulbing ratio			
	S1	S2	S3	S4	S1	S2	S3	S4
Ba1	3.73	3.00	4.63	5.10	0.44	0.40	0.33	0.24
Ba 2	3.80	3.40	4.70	5.40	0.46	0.37	0.48	0.23
Ba 3	3.63	2.77	4.50	4.93	0.42	0.48	0.33	0.26
Ba 4	3.87	2.80	3.73	4.77	0.40	0.35	0.47	0.22
Ba 5	3.87	3.07	4.23	5.10	0.48	0.42	0.31	0.25
Ba 6	3.77	2.83	4.37	4.57	0.45	0.35	0.42	0.22
Ba 7	3.80	3.43	4.47	5.57	0.36	0.35	0.37	0.24
Ba 8	3.67	3.07	4.13	5.27	0.48	0.35	0.51	0.28
Ba 9	3.50	3.47	4.43	4.70	0.46	0.39	0.44	0.22
Ba 10	3.30	2.93	4.13	5.57	0.42	0.41	0.41	0.20
LSD 0.05	0.34	0.33	0.51	0.42	N.S.	0.08	0.09	0.04

Bulb diameter

It is clear from data presented in Table (1) that there were significant differences among the studied clones in bulb diameter in all seasons (S1, S2,

S3 and S4). The highest values of bulb diameter were obtained from clone Ba.4 followed by clone Ba.5 in the first season (S1). While, the highest values of bulb diameter were obtained from clone Ba.9 followed by clone Ba.7 in the S2 season. Concerning bulb diameter in the S3 season, it is clear that clone Ba.2 produced the highest bulb diameter followed by clone Ba.1. As for S4 season, Ba.7 produced the highest values of bulb diameter followed by clone Ba.10. While, clones Ba.10, Ba.3, Ba.4 and Ba.6 produced plants of the lowest values of bulb diameter in the seasons S1, S2, S3 and S4, respectively.

Bulbing ratio

Data presented in Table (1) indicated that there were significant differences among the values of bulbing ratio of the selected clones in S2, S3 and S4 seasons. While, there were no significant differences between the studied clones in the first season (S1). Clone Ba.3 produced the highest values of bulbing ratio followed by clone Ba.5 in the S3 season, while in the S3 season, clone Ba.8 produced the highest value of bulbing ratio followed by clones Ba.2 and Ba.4. As for S4, Ba.8 produced the highest values of bulbing ratio followed by clones Ba.3. While clones Ba.4, Ba.5, Ba.10 produced the lowest values of bulbing ratio in S2, S3 and S4, respectively.

Leaves dry weight

It is clear from data shown in Table (2) that there were significant differences among studied clones for values of leaves dry weight in all seasons (S1, S2, S3 and S4). The highest values of leaves dry weight were obtained from clone Ba.7 followed by clone Ba.4 in first season (S1). While, the highest values of leaves dry weight were obtained from clone Ba.2 followed by clones Ba.9 and Ba.7 in the S3. Concerning leaves dry weight in the S3, it is clear that clone Ba.7 produced the highest leaves dry weight followed by clone Ba.8. As for S4, Ba.7 produced the highest values of leaves dry weight followed by clone Ba.8. While, clones Ba.10, Ba.4, Ba.3 and Ba.6 produced the lowest values of leaves dry weight in S1, S2, S3 and S4, respectively.

Table 2. Mean performances of the studied clones of garlic for leaves dry weight (g), bulb dry weight (g), plant dry weight (g) and total yield after curing (ton/fed) in four seasons (S1, S2, S3 and S4).

Genotypes	Leaves dry weight (g)				Bulb dry weight (g)			
	S1	S2	S3	S4	S1	S2	S3	S4
Ba1	8.48	9.55	12.43	12.07	5.58	5.38	9.26	11.50
Ba 2	8.19	10.01	12.88	10.98	4.31	6.95	8.51	13.57
Ba 3	8.81	9.47	9.33	10.50	4.25	5.67	5.27	8.23
Ba 4	8.97	7.14	10.71	9.42	5.20	4.82	9.42	8.78
Ba 5	8.81	8.40	11.74	11.62	5.15	4.94	8.00	9.46
Ba 6	7.50	7.38	10.10	7.78	4.50	4.56	5.62	8.14
Ba 7	9.33	9.68	14.01	13.73	6.86	5.46	9.26	13.59
Ba 8	8.59	8.17	13.49	13.54	4.93	5.26	6.91	10.77
Ba 9	8.00	9.76	13.45	9.39	5.17	6.74	9.61	12.30
Ba 10	7.00	7.52	12.08	12.62	4.67	5.14	8.49	10.00
L.S.D. 0.05	1.09	1.40	2.91	2.70	1.36	0.95	1.06	1.26
Genotypes	Plant dry weight (g)				Total yield after curing(ton/fed)			
	S1	S2	S3	S4	S1	S2	S3	S4
Ba1	14.06	14.93	21.69	23.56	5.046	3.990	6.424	4.832
Ba 2	12.50	16.96	21.39	24.55	4.396	4.699	6.441	6.207
Ba 3	13.06	15.13	14.60	18.73	5.305	4.655	5.276	5.675
Ba 4	14.17	11.96	20.13	18.20	5.079	3.192	5.416	5.364
Ba 5	13.96	13.34	19.74	21.08	5.819	3.702	4.663	6.074
Ba 6	12.00	11.94	15.72	15.92	5.912	4.389	4.892	4.699
Ba 7	16.19	15.14	23.27	27.32	6.284	4.744	6.666	7.138
Ba 8	13.52	13.43	20.40	24.31	4.509	3.392	6.901	6.185
Ba 9	13.17	16.50	23.06	21.69	4.555	4.256	5.992	7.093
Ba 10	11.67	12.66	20.57	22.62	4.444	3.347	6.724	7.005
L.S.D. 0.05	1.97	1.81	2.86	3.02	0.950	0.247	1.231	0.378

Bulb dry weight

Data presented in Table (2) showed that there were significant differences among studied genotypes for the values of bulb dry weight in the four seasons. The highest values of bulb dry weight was obtained from clone Ba.7 followed by clone Ba.1 in the first season (S1). While, the highest values of bulb dry weight were obtained from clone Ba.2 followed by clone Ba.9 in the S2. Concerning bulb dry weight in the S3, it was clear tha+t clone Ba.9 produced the highest bulb dry weight followed by clone Ba.4. As for S4, Ba.7 produced the highest values of bulb dry weight followed by clone Ba.2. While, clones Ba.3, Ba.6, Ba.3 and Ba.6 produced the lowest values of bulb dry weight in the seasons S1, S2, S3 and S4, respectively.

Plant dry weight

It is obvious from Table (2) that there were significant differences among studied genotypes for the values of plant dry weight, where clone Ba.7 produced the highest plant dry weight followed by clones Ba.4, Ba.1 and Ba.5, in the first season (S1). While, in the S2 clone Ba.2 produced the highest plant dry weight followed by clones Ba.9, Ba.7 and Ba.3. Concerning plant dry weight in the S3 season, Ba.7 produced the highest plant dry weight followed by clones Ba.9, Ba.1 and Ba.2. As for S4, Ba.7 produced the highest plant dry weight followed by clones Ba.2, Ba.8 and Ba.1, while clones Ba.10, Ba.6, Ba.3, and Ba.6 produced of the lowest plant dry weight in S1, S2, S3 and S4, respectively. The obtained results were similar to these reported by Waterer and Schmitz (1994), Kasim and El-Ghadban (2002), Gvozdanovic *et al* (2002), Gowda *et al* (2007), Soto Vargas *et al* (2010), Clemente *et al* (2012), Gouda (2012), Ali (2013), Wang *et al* (2014), Yadav *et al* (2018), Umamaheswarappa *et al* (2018) and Ahmed *et al* (2019) who found varietal differences on growth characters among the selected garlic clones.

Yield and its components

Total cured Yield

It is clear from data shown in Table (2) that there were significant differences among clones in total cured yield per feddan (4200 m^2) in the seasons S1, S2, S3 and S4. Clone Ba.7 produced the highest total cured yield followed by clones Ba.6, Ba.5, Ba.3 and Ba.4, which they produced 6.2838, 5.9123, 5.8192, 5.3045 and 5.0793 ton/fed, respectively in the first season (S1), while, in S2, Ba.7 produced the highest total cured yield followed by clones Ba.2, Ba.3, Ba.6 and Ba.9 that produced 4.7437, 4.6993, 4.6550, 4.3890 and 4.2560 ton/fed., respectively. While, S3 of Ba.8 produced the highest total cured yield followed by clones Ba.10, Ba.7, Ba.2 and Ba.1 that produced 6.9009, 6.7236, 6.6664, 6.4407 and 6.4243 ton/fed, respectively. As for S4, Ba.7 produced the highest total cured yield followed by clones Ba.9, Ba.10, Ba.2 and Ba.8 that produced 7.1377, 7.0933, 7.0047, 6.2067 and 6.1845 ton/fed, respectively. While, clones Ba.2, Ba.4, Ba.5 and Ba.6 produced the lowest total cured yield in all seasons. These results are in agreement with those obtained by Waterer and Schmitz (1994), Kasim and El-Ghadban (2002), Gvozdanovic *et al* (2002), Gowda *et al* (2007), Soto Vargas *et al* (2010), Clemente *et al* (2012), Gouda (2012), Ali (2013), Wang *et al* (2014), Yadav *et al* (2018), Umamaheswarappa *et al* (2018) and Ahmed *et al* (2019) who reported the presence of significant differences due to the differences in source potentials and sink capacities among the tested genotypes.

Bulb weight

Data presented in Table (3) showed that there were significant differences among genotypes for the values of bulb weight of the studied clones. The highest values of bulb weight were obtained from clone Ba.7 followed by clone Ba.6 in the first season (S1). While, the highest values of bulb weight were obtained from clone Ba.7 followed by clone Ba.2 in the S3. Concerning bulb weight in S3, it was clear that clone Ba.8 produced the highest bulb weight followed by clone Ba.10. As for S4, Ba.7 produced the highest values of bulb weight followed by clone Ba.9. While, clones Ba.2, Ba. 4, Ba. 5 and Ba.6 produced the lowest values of bulb weight in the first season (S1), S2, S3 and S4, respectively.

Table 3. Mean performances of the studied clones of garlic for bulb weight after curing (g), neck diameter after curing (cm), and bulb diameter after curing (cm) and bulbing ratio after curing in four seasons (S1, S2, S3 and S4).

Genotypes	Bulb weight after curing (g)				Neck diameter after curing (cm)			
	S1	S2	S3	S4	S1	S2	S3	S4
Ba1	37.94	30.00	48.30	36.33	0.94	0.93	0.83	0.67
Ba 2	33.05	35.33	48.43	46.67	0.84	0.80	0.60	0.90
Ba 3	39.88	35.00	39.67	42.67	0.80	0.89	0.85	0.76
Ba 4	38.19	24.00	40.72	40.33	0.95	0.80	0.83	0.80
Ba 5	43.75	27.83	35.06	45.67	0.95	0.80	0.83	0.70
Ba 6	44.45	33.00	36.78	35.33	0.96	0.90	0.93	0.70
Ba 7	47.25	35.67	50.12	53.67	0.80	0.93	0.93	0.77
Ba 8	33.90	25.50	51.89	46.50	0.80	0.97	0.83	0.70
Ba 9	34.25	32.00	45.05	53.33	0.74	0.90	0.87	0.93
Ba 10	33.41	25.17	50.55	52.67	0.76	0.97	1.03	0.63
L.S.D. 0.05	7.14	1.85	9.25	3.05	0.14	N.S.	0.19	N.S.
Genotypes	Bulb diameter after curing (cm)				Bulbing ratio after curing			
	S1	S2	S3	S4	S1	S2	S3	S4
Ba1	5.04	4.00	5.40	4.83	0.19	0.23	0.15	0.14
Ba 2	4.44	4.23	5.23	4.90	0.19	0.19	0.12	0.19
Ba 3	4.92	3.73	5.60	5.25	0.16	0.24	0.15	0.15
Ba 4	4.78	3.00	5.60	5.07	0.20	0.27	0.15	0.16
Ba 5	5.11	3.20	4.63	5.47	0.19	0.25	0.18	0.13
Ba 6	5.06	4.07	5.40	4.50	0.19	0.22	0.17	0.16
Ba 7	5.28	4.27	5.63	5.80	0.15	0.22	0.17	0.13
Ba 8	4.78	4.13	6.10	5.10	0.17	0.23	0.14	0.14
Ba 9	4.64	3.97	4.93	5.77	0.16	0.23	0.18	0.16
Ba 10	3.61	4.10	5.97	5.77	0.21	0.24	0.17	0.11
L.S.D. 0.05	0.55	0.31	0.56	0.35	0.02	N.S.	N.S.	0.04

Table 4. Mean performances of the studied clones of garlic for cloves number after curing, cloves weight after curing, pungency (µ mol/ 1g fresh) and total soluble solids (TSS) in four seasons (S1, S2, S3 and S4).

Genotypes	Cloves number after curing				Cloves weight after curing (g)			
	S1	S2	S3	S4	S1	S2	S3	S4
Ba1	41.67	45.00	45.00	36.33	0.91	0.67	1.07	1.00
Ba 2	44.33	39.33	41.33	37.33	0.75	0.90	1.17	1.25
Ba 3	37.33	40.00	40.00	32.00	1.06	0.87	0.99	1.34
Ba 4	41.00	28.33	44.67	35.33	0.94	0.85	0.92	1.15
Ba 5	42.33	27.00	38.00	29.33	1.04	1.03	0.93	1.56
Ba 6	46.00	32.00	41.00	29.00	0.96	1.03	0.90	1.25
Ba 7	35.33	32.00	24.33	28.33	1.35	1.12	2.10	1.90
Ba 8	38.33	31.33	46.00	34.67	0.89	0.81	1.13	1.35
Ba 9	35.00	28.00	38.67	35.67	0.98	1.15	1.16	1.52
Ba 10	40.00	33.00	43.00	29.00	0.84	0.76	1.20	1.82
L.S.D. 0.05	6.13	1.78	5.69	5.57	0.18	0.07	0.30	0.23
Genotypes	Pungency (µ mol/1g fresh)				Total soluble solids (TSS)			
	S1	S2	S3	S4	S1	S2	S3	S4
Ba1	8.11	8.22	8.28	7.77	34.33	37.00	39.97	38.13
Ba 2	7.62	8.56	8.06	8.56	38.50	38.42	35.57	40.03
Ba 3	6.04	8.10	8.05	6.85	39.50	38.33	36.07	36.13
Ba 4	6.77	8.54	7.96	8.17	36.33	36.27	34.17	40.87
Ba 5	6.92	8.40	8.07	7.95	38.00	37.67	36.50	39.07
Ba 6	7.43	8.44	8.25	8.41	38.83	36.17	38.70	37.63
Ba 7	8.82	7.83	8.16	7.59	39.00	36.17	36.23	38.27
Ba 8	8.14	8.55	7.93	7.67	35.67	35.50	38.47	38.20
Ba 9	9.16	7.92	7.96	7.86	38.17	38.33	34.20	40.57
Ba 10	8.22	8.64	8.12	9.38	39.17	38.50	36.57	39.53
L.S.D. 0.05	0.26	0.40	0.19	0.13	0.86	0.69	0.56	0.80

Neck diameter

It is clear from data shown in Table (3) that there were significant differences among the studied clones in the first season (S1) and S3, while, there were no significant differences between the studied clones in the S2 and S4. The highest values of neck diameter were obtained from clone Ba.6 followed by clone Ba.4 in the first season (S1). Concerning neck diameter in the S3 it was clear that clone Ba.10 produced the highest neck diameter followed by clone Ba.6. While, clones Ba.9 and Ba.2 produced plants of the lowest values of neck diameter in the first season (S1) and S3, respectively.

Bulb diameter

Data presented in Table (3) show that there were significant differences among the studied clones in bulb diameter in the first season (S1). The highest values of bulb diameter were obtained from clone Ba.7 followed by clone Ba.5 in the first season (S1). While, the highest values of bulb diameter were obtained from clone Ba.7 followed by clones Ba.2 in the S2. Concerning bulb diameter in S3, it was clear that clone Ba.8 produced the highest bulb diameter followed by clone Ba.10. As for S4, Ba.7 produced the highest values of bulb diameter followed by clone Ba.10. While, clones Ba.10, Ba.4, Ba.5 and Ba.6 produced plants of the lowest values of bulb diameter in S1, S2, S3 and S4, respectively.

Bulbing ratio:

It is clear from data shown in Table (3) that there were significant differences among the studied clones in first season (S1) and S4, while, there were no significant differences between the clones in the S2 and S3. The highest values of bulbing ratio were obtained from clone Ba.10 followed by clone Ba.4 in the first season (S1). Concerning bulbing ratio in S4, it was clear that clone Ba.2 produced the highest bulbing ratio followed by clone Ba.4. While, clones Ba.7 and Ba.10 produced plants of the lowest values of bulbing ratio in S1 and S4, respectively.

Cloves number

Data presented in Table (4) show that there were significant differences among the studied clones in cloves number per bulb. The

highest values of cloves number per bulb were obtained from clone Ba.6 followed by clone Ba.2 in the first season (S1). While, the highest values of cloves number per bulb were obtained from clone Ba.1 followed by clone Ba.3 in S3. Concerning cloves number per bulb in S3, it was clear that clone Ba.8 produced the highest cloves number per bulb followed by clone Ba.1. As for S4, Ba.2 produced the highest value of cloves number per bulb followed by clone Ba.1. While, clones Ba.9, Ba.5, Ba.7, and Ba.7 produced the lowest values of cloves number per bulb in S1, S2, S3 and S4 seasons, respectively.

Clove weight

It is clear from data presented in Table (4) that there were significant differences among all genotypes. The highest values of clove weight were obtained from clone Ba.7 followed by clone Ba.3 in the first season (S1). While, the highest values of clove weight were obtained from clone Ba.9 followed by clone Ba.7 in S2. Concerning clove weight in the S3, it was clear that clone Ba.7 produced the highest clove weight followed by clone Ba.10. As for S4, Ba.7 produced the highest values of clove weight followed by clone Ba.10. While, clones Ba.2, Ba.1, Ba.6 and Ba.1 produced the lowest values of clove weight in S1, S2, S3 and S4, respectively.

Chemical composition

Total soluble solids (TSS) and pungency

Data presented in Table (4) showed significant differences among all genotypes clones for total soluble solids (TSS) content and pungency that are important attributes of bulb quality for processing and storage. The data observed ranged from 40.86 to 34.16°Brix. Significant differences were found between all the cultivars for (TSS) content. These differences may be related to genotype. Moreover, the highest values of total soluble solids (TSS) content was obtained from clone Ba.3 followed by clone Ba.10 in the first season (S1). While, the highest values of (TSS) content were obtained from clone Ba.10 followed by clone Ba.2 in the S2. Concerning (TSS) content in S3, it was clear that clone Ba.1 produced the highest (TSS) content followed by clone Ba.6. As for S4, Ba.4 produced the highest values

of)TSS) content followed by clone Ba.9. While, clones Ba.1, Ba.8, Ba.4 and Ba.3 produced the lowest values of (TSS) content in S1, S2, S3 and S4 seasons, respectively.

Pungency is one of the most important quality aspects in garlic. The data in Table (4) show that all clones differed in the content of pyruvic acid, ranging between 6.04 and 9.38 µmol/g. These values are consistent with those reported by González *et al* (2009). Also, the results showed that the highest content of pungency content were obtained from clone Ba.9 (9.16 µmol /g) followed by clone Ba.7 (8.82 µmol /g) in the first season(S1). While, the highest values of pungency content were obtained from clone Ba.10 (8.64 µmol /g) followed by clones Ba.2 (8.56 µmol /g) in the S2. Concerning pungency content in S3, it was clear that clone Ba.1 (8.28 µmol /g) produced the highest pungency content followed by clone Ba.6. (8.25 µmol /g). As for S4, Ba.10 (9.38 µmol /g) produced the highest values of pungency content followed by clone Ba.2. (8.56 µmol /g). While, clones Ba.3, Ba.7, Ba.8 and Ba.3 produced the lowest values of pungency content in S1, S2, S3 and S4, respectively. These findings are in agreement with Singh *et al* (2018)

Analysis of variance

The analysis of variance for plant length, bulb dry weight, plant dry weight, bulb weight After curing, cloves number after curing showed highly significant ($p<0.01$) differences among the garlic genotypes (Table 5). This indicates to the existence of large variability among genotypes. Generally, the present result indicates the existence of sufficient genetic variability. Awel *et al* (2011) reported the existence of genetic diversity within shallot produced in Ethiopia which is in agreement with present findings. In addition, Abebech (2011) found variability in garlic for tested characters which supports the present result. Yeshiwas and Negash (2017) found that analysis of variance showed highly significant ($p<0.01$) differences among the garlic genotypes for all studied characters, except number of leaves per plant which was non-significant.

Table 5. Analysis of variance for fifteen characters in garlic germplasms for different traits.

SOV	df	Mean square of characters							
		Plant length	Number of leaves	Neck diameter	Bulb diameter	Bulbing ratio	Bulb dry weight	Plant dry weight	Bulb weight after curing
Replications	2	218**	1.93	0.01	1.32	0.011	88.33**	19.66**	4.80**
Genotypes	10	64.55**	1. 09	0.23	0.73	0.020	48.44**	35.19**	134.52**
Error	20	33.64	0.77	0.02	0.27	0.003	9.88	3.10	3.16

Sov	df	Mean square of characters						
		Neck diameter after curing	Cloves number After curing	Cloves weight After curing	Bulb diameter After curing	Pungency (µ mol/1g fresh)	TSS	Total yield after curing
Replications	2	0.03	7.60**	0.006	0.07	0.55	0.034	0.07
Genotypes	10	0.02	37.50**	0.245	0.58	10.79**	0.044	2.37
Error	20	0.01	10.52	0.018	0.10	0.10	0.012	0.05

****indicate significant at p≤ 0.01**

Estimates of phenotypic and genotypic coefficient of variability

Table (6) presents coefficient of variance (CV%), environmental (σ^2e), genotypic (σ^2g) and phenotypic variance (σ^2p), genotypic and phenotypic coefficient of variance (G.C.V.% and P.C.V%) and the ratio of G.C.V. /P.C.V. genetic advance (G A) and genetic advance as percent of mean (GAM) for all the studied traits. In general, the degree of homogeneity differed among the studied genotypes in the same character. The data showed that all the studied lines reflected low or close CV% values, indicating high homogeneity for all studied traits of these lines.

Table 6. Coefficient of variation (CV), components of variance (environmental б²e, genotypic б²g and phenotypic б²p), genotypic and phenotypic coefficient of variation (GCV% and PCV%), genetic advance (GA) from selection and genetic advance as percent of mean (GAM) in garlic germplasms for different traits.

Parameter	Plant length	Number of leaves	Neck diameter	Bulb diameter	Bulbing ratio	Bulb dry weight	Plant dry weight	Bulb weight after curing
CV%	4.17	6.75	8.99	7.66	11.71	6.88	8.08	3.92
σ^2e	20.595	0.77	0.02	0.27	0.004	0.31	3.11	3.16
σ^2 g	109.47	0.10	0.06	0.15	0.005	0.51	10.7	43.8
σ^2 p	130.07	0.87	0.09	0.43	0.009	0.82	13.8	46.9
GCV%	9.6507	3.68	15.02	7.94	20.65	13	59.5	120
PCV%	10.519	10.59	17.92	13.27	27.13	16.5	67.6	125
GCV/ PCV	0.91	0.34	0.84	0.59	0.761	0.79	0.88	0.97
G A	1973	22.04	41.12	47.03	10.83	115.7	592.1	1314
GAM%	2121	262.8	3568.7	938.5	4786	1097	2715	2898

Parameter	Neck diameter after curing	Cloves number after curing	Cloves weight after curing	Bulb diameter after curing	Pungency (µ mol/1g fresh)	TSS	Total yield after curing
CV%	17.27	9.92	9.58	3.84	0.91	1.20	3.66
σ2e	0.02	10.53	0.02	0.04	0.01	0.216	0.05
σ2 g	0.004	8.99	0.08	0.19	0.01	2.046	0.78
σ2 p	0.02	19.52	0.09	0.23	0.02	2.262	0.83
GCV%	1.14	54.61	5.01	7.86	29.31	403.2	16.1
PCV%	2.64	80.45	5.58	8.67	42.79	423.9	16.5
GCV/ PCV	0.43	0.67	0.9	0.91	0.68	0.95	0.97
G A	5.81	418	54.82	81.45	14.53	279.6	176.0
GAM%	723.0	1280	3511	1543	170.2	720.1	2924

All studied traits showed low difference between phenotypic and genotypic variance, indicating that the large portion of the phenotypic variance (σ^2p) was due to the genetic variance (σ^2g) and the significant differences among the selected lines are of genetic nature. It is noticed that the differences between phenotypic and genotypic variance for all studied traits were low, since the estimated GCV/PCV ratios were high (ranged from 0.34 to 0.97). In other words, the large portion of phenotypic variance (σ^2p) was due to the genetic variance (σ^2g). These results are in partial agreement with those obtained by Ranjitha *et al* (2018), Panthee *et al* (2006) who stated that data indicated there was a high level of variation in characters of interest e.g. maturity and yield, Figliuolo *et al* (2001) stated that the accessions were significantly different from each other except for leaf width. The accessions were quite homogeneous for plant length, internode length, number of dry leaves, neck height, number of cloves per bulb, bulb height, cloves weight and diameter ($p < 0.05$). Genetic advance (GA) from selection was high by expressed as percentage of mean for all characters except bulbing ratio, neck diameter after curing and pungency. These findings are in partial agreement with Yeshiwas and Negash, (2017) who stated that, genetic advance is classified as low (<20%), moderate (10-20%) and high (>20%). Genetic advance expressed as percentage of mean was high for all characters except clove weight, and Ranjitha *et al* (2018) who found that the highest genetic advance was recorded for bulb yield, while clove weight had high heritability coupled with moderate genetic advance as per cent of mean. It is suggested that selection for these traits will directly increase bulb yield per plant, in garlic crop.

Correlation Study

The results (Table 7) showed the existence of significant and positive correlation of yield and yield related parameters. Total yield after curing was positively and significantly correlated with Bulb weight after curing ($r = 0.99^{**}$), Plant length was positively and significantly correlated with total yield after curing ($r = 0.71^{**}$) and with cloves weight after curing ($r = 0.73^{**}$).

Table 7. Phenotypic correlation among different traits in garlic.

Traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1														
2	0.06	1													
3	0.04	0.28	1												
4	0.34**	0.18	0.38**	1											
5	-0.13	0.18	0.86**	-0.13	1										
6	0.31**	0.26	0.26	0.34**	0.07	1									
7	0.37**	0.19	0.38**	0.56**	0.08	0.75**	1								
8	0.71**	0.17	0.09	0.48**	-0.16	0.66**	0.63**	1							
9	-0.30	-0.11	0.24	-0.30	0.40**	0.01	-0.12	-0.23	1						
10	0.13	0.30**	-0.11	-0.31	0.03	0.13	-0.04	-0.01	0.20	1					
11	0.44**	-0.08	0.15	0.59**	-0.14	0.40**	0.49	0.73**	-0.32	-0.67	1				
12	-0.16	0.14	-0.06	0.16	-0.17	0.33**	0.13	0.08	0.04	0.09	-0.01	1			
13	0.03	-0.47	-0.29	0.01	-0.32**	-0.35**	-0.38	-0.11	0.11	-0.67	0.00	0.02	1		
14	0.05	-0.09	0.14	0.06	0.12	-0.22	0.47	-0.12	0.01	-0.10	0.01	-0.15	0.53**	1	
15	0.71**	0.17	0.09	0.48**	-0.16	0.66**	0.63	0.99**	-0.23	-0.01	0.73**	0.08	-0.11	-0.12	1

1 = Plant length, 2 = Number of leaves, 3 = Neck diameter, 4 = Bulb diameter, 5 = Bulbing ratio, 6 = Bulb dry weight, 7 = Plant dry weight, 8 = Bulb weight after curing, 9 = Neck diameter after curing, 10 = Cloves number after curing, 11 = Cloves weight after curing, 12 = Bulb diameter after curing, 13 = Pungency (µ mol/1g fresh, 14 = TSS and 15 = Total yield after curing.

*** = Correlation is significant at the 0.05 level, ** = Correlation is significant at the 0.01 level**

In the same way, bulb weight after curing was positively and significantly correlated with cloves weight after curing (r =0.73**). Meanwhile there was no correlation between pungency and cloves weight after curing (r =00). In line with the present study, Yeshiwas and Negash (2017) found significant and positive correlation between yield and yield

related parameters. Plant length was positively and significantly correlated with leaf length (r=0.43*), leaf number (r=0.29*), clove weight (r=0.32*), and total yield per hectare (r=0.23*).

CONCLUSION

It can be concluded that genetic advance expressed as percentage of mean was for high most of studied characteristics, so selection would be effective for improving yield and quality traits in garlic. Also, data indicated that Benisuif (Ba.7) had homogeneity, high productivity and high quality, so, it could be considered promising new clone of garlic.

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التباين الوراثي والتقدم الوراثي بالانتخاب فى الثوم البلدي للصفات الاقتصادية والجودة

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في هذه الدراسة تم دراسة التباين الوراثي والتقدم الوراثي بالانتخاب في ١٠ سلالات من الثوم البلدي لمدة أربعة مواسم متتالية للمحصول وبعض صفات الجودة في مزرعة بحوث الخضرفي قها وأقسام بحوث الخضر بالدقي ومعهد بحوث تكنولوجيا الاغذية مركز البحوث الزراعيه بالجيزة خلال أربعة مواسم هي ٢٠١٦-٢٠١٧، ٢٠١٧-٢٠١٨، ٢٠١٨-٢٠١٩، و٢٠١٩-٢٠٢٠ حيث تم الحصول علي هذه السلالات من محافظات مصر المختلفة وهي السلالة١ (المنوفية)، السلالة٢ (المنيا)، السلالة٣ (الشرقية)، السلالة٤ (الجيزة)، السلالة ٥ و ٦ (الفيوم)، السلالة ٧ (بني سويف)، السلالة ٨ (سوهاج)، السلالة ٩ (القليوبية)، السلالة ١٠ (أسيوط). أظهرت النتائج أن السلاله ٧ انتجت أعلى قطر للبصلة، ووزن جاف للأوراق، والبصلة، والنبات، والمحصول الكلي المعالج، وكذلك وزن الفص، ووزن البصلة وقطرها. وانتجت السلالة ١٠ أطول النباتات وتحتوي أيضًا على أعلى محتوى من الحرافة، ثم يليها السلاله ٢. أشارت قيم معامل التباين المقدرة إلى أن معظم السلالات الجديدة المختارة لديها تجانس جيد في جميع الصفات المدروسة.كما أنه يرجع الجزء الأكبر من التباين المظهرى إلى التباين الوراثي. يمكن أن يؤدي الانتخاب البسيط إلى تحسين الصفات المرغوبة في هذه السلالات. وفي نهاية هذه الدراسة يمكن التوصيه بالسلالة٧ (بني سويف) التي تتميز بالتجانس والإنتاجية العالية والجودة العالية .

المجلة المصرية لتربية النبات ٢٤(٣): ٥١٧- ٥٣٩ (٢٠٢٠)