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GENETIC VARIABILITY AND CORRELATION STUDIES IN SOME GENOTYPES OF EGGPLANT

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ABSTRACT: Assessment of genetic variability is crucial in developing new genotypes with desired yield and quality traits. This evaluation allows breeders to identify superior germplasm, breeding genotypes with specific combinations, and enhance crop performance across diverse environmental conditions. Hence, this study aimed to study the performance of ten eggplant genotypes (*Solanum melongen*a L.); *i.e*., Little Fingers (LF), Ping Tung (PT), Antigua (An), Aswad (As), Japanese White Egg (JWE), Apple Green (AG), Rotonda Bianca Stumata di Rosa (BSR), Korean Red (KR), Black Oblong (BO) and Black Very Long (BL). In addition, to explore genetic advance and correlation among studied traits under three intra-row plant spacings, (30, 45 and 60 cm). The study was performed at Zagazig District, Egypt during the two successive summer seasons of 2017 and 2018. The results indicated significant variation among the tested genotypes.The broad sense heritability (h_b^2) exhibited the highest percentage at narrow planting spaces and decreased with increased spaces in all studied traits. Broad sense heritabilities were moderate magnitude for number of branches (39% and 30.9%) at 45 and 60 cm spaces, respectively. Genetic advance (GA %) was high for all studied traits except number of branches. High heritability estimates and a high predicted genetic advance indicated that these qualities and genotypes could be effective in developing breeding programs to increase fruit quality and yield. Strong genetic correlations between morphological and yield-related variables were found via correlation studies. The path analysis results showed that the fruit weight had the largest direct effect on yield/ plant (2.984 and 3.11) followed by number of fruits (0.579 and 1.525), and branches number/ plant (0.161 and 0.304) at 30 and 45 cm planting spaces, respectively. While the branches number/ plant exhibited the largest direct effect on yield/ plant (5.341) followed by fruit length (3.328), and fruit diameter (0.625) at 60 cm planting space, indicating the effectiveness of direct selection for these traits for developing high yielding genotypes of eggplant under different planting spaces.

Key words: Eggplant, genotypes, heritability, genetic variability, correlation, yield traits.

INTRODUCTION

The production potential of cultivated varieties of eggplant is lower and the choice of eggplant size, shape and skin color varies in in different locations according to the consumer. For the development of eggplant varieties with high productivity and environmental resistances, a systematic breeding plane is required. Evaluation of the most important traits helps to collect information for the development of the crop, and also provides breeders with a picture of genotypes about genetic variance and diversity. Therefore, in order to determine the optimum genotypes for economic features, calculate the breeding value of the available germplasm, and comprehend genetic background, germplasm assessment at various planting locations is required. For any crop development to be ultimately successful, variability is desperately needed. Increased degree of population variability, greater chance for effective selection **(Vavilov, 1951)**. The level of genetic variety that exists determines whether selection is

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successful. Therefore, by estimating certain genetic factors as phenotypic (PCV), it is important to partition total variability into main components (non-heritable and heritable) and genotypic (GCV) coefficient of variability, heritability and expected genetic advance that gave complete indication of genetic variations of the studied traits. Heritability is important in helping the plant breeder plan and executes effective breeding strategy. Knowledge of correlation among characters is important in deciding on what selection strategy to use. Hence, there is the need to determine genetic parameters in order to design selection programmers aimed at improving the crop through selection among accessions or through hybridization. Correlation analysis measure the relationship between any pairs of traits and determines the component characters that selection can be based for improvement the economic traits. Plant height was positively correlated with average fruit weight, total yield/ plant, Fruit diameter and Fruit length **(Muniappan *et al.*, 2010; Shekar *et al*., 2014; Ullah *et al.*, 2014; Prabakaran *et al.*, 2015)**. Also, significant positive correlations were found between number of branches and total fruit weight **(Tripathy *et al*., 2018)**. The objectives of this study were undertaken to assessment ten genotypes of eggplant for vegetative growth, yield and fruit quality, as well as estimate superior genotypes for future use.

MATERIALS AND METHODS

The current study was completed in a private Farm at Bani Amer Village, Zagazig district, Sharqia Governorate, Egypt (30°35'51.3"N 31°34' 24.9"E) during the summers of 2017 and 2018 to assess the performance of various eggplant genotypes (Table 1) at various plant spacings of 30, 45, and 60 cm. In the summer seasons of 2017 and 2018, seeds of the genotypes were sown in speedling trays (209 sells) under greenhouses as a nursery at 1st Feb. in the both seasons. This experiment was set up as a split plot with three replicates using a randomized complete block design. Each genotype was grown in a plot of 3 rows, 3 meter long and 80 cm apart. The entries in each experimental unit consisted of 30, 20 and 15 plants, planted at a spacing of 30 x 80 cm; 45 x 80 cm and 60 x 80 cm, respectively. Plants were thinned to one plants/hill; the plot area was (7.2 m²). The prescribed cultural measures for eggplant were implemented, including fertilization, irrigation, and insect control.

Recorded Data

Ten plants at random from each plot were measured for the following traits:

Plant growth traits

Four plants from every experimental unit were randomly selected to measure the following traits:

- Plant height (PH, cm): it was measured at the season's end.
- Branches number / plant (BN): it was counted at the season's end.
- Leaves number / plant (LN): it was counted at the flowering stage.
- Leaf area (LA): leaf length × average leaf width.

Yield traits

- Plant/ yield (yield, kg/ plant): it was determined by summing weight of all picked fruits during the productivity stage and presented as yield per plant (kg).
- Fruit number per plant (FN)
- Total yield/fed. (yield, ton/ fed.)

Fruit quality traits:

- Fruit length (FL, cm)
- Fruit diameter (Dim, cm)
- Fruit weight (FW, g): (Fruit yield of each plant/Total number of fruits)
- Dry matter (DM)

Statistical Analysis

Broad sense heritability (h_b^2) was estimated according to **Allard (1960) and Falconer (1989)**. Heritability based on **(Stansfield, 1983)** $0 \le x \le 0.2$ = low, $0.2 \le x \le 0.5$ = medium and $x > 0.50$ = high. Phenotypic (PCV%) and genotypic (GCV %) Coefficient of variability were calculated according to **Singh and Chaudhary (1985)**. Genetic advance (GA) was calculated with

Table1. Variability among the cultivars under study and their sources

Code	Cultivars	Abbriv.	Fruit shape	Fruit colour	Source
1	Little Fingers	L.F.	Long	Purple Black	BGHSC[1]
2	Ping Tung	P.T.	Long	Purple Rose	BGHSC[1]
3	Antigua	An.	Long	White Purple with Strips	BGHSC[1]
4	Black Very Long	B.V.L.	Long	Dark Black	Metwally[2]
5	Aswad	As.	Like a squat teardrop	Black Purple	BGHSC[1]
6	Japanese White Egg	J.W.E.	Oval	Snow White	BGHSC[1]
7	Apple Green	A.G.	Oval	Light Green	BGHSC[1]
8	Rotonda Bianca Stumata di Rosa	R.B.S.	Round	White - Rose - Pink	BGHSC[1]
9	Korean Red	K.R.	Round	Red – Orange	BGHSC[1]
10	Black Oblong	B.O.	Oval	Black	Metwally[2]

1: BGHSC: Baker Greek Heiriool Seed Company, 2278 Baker Greek Road Mansfield, MO-65704 World Wide Web: *RareSeeds.com*
2: Prof. Dr. E. I. Metwally, Fac, Agric,Kafr El-Sheikh Univ. Kafr El-Sheikh, Egypt

the method suggested by **Johnson *et al*. (1955)** as: GA = K . $h^2_{(b)}$. σ_p , where: K= 1.76, constant (On the basis of intensity of the selection 10%), h^2 (b) = heritability in broad sense and σp = phenotypic standard deviation. Genetic advance as percent of mean (expected genetic advance) GAM% = $(GA/\bar{X})$ x100. GAM% based on **Hadiati *et al*. (2003)**, 0 - 7% = low, 7 - 14% = medium and > 14 = high.

The interrelationships among the 11 studied traits were studied overall genotypes using two statistical procedures which differ in their mathematical background, goals and final outputs. These used models are summarized as follows:

1. Using the formula provided by **Al-Jibouri *et al.* (1958)** estimates of the correlation between genotype and phenotype.
2. Following the instructions provided by **Dewey and Lu (1959)**, the path coefficient analysis was conducted among seven traits: yield/plant and each of plant height, branch number/plant, fruit number per plant, fruit length, fruit diameter, and fruit weight. The statistical computer program PATHCA was used to calculate the correlation and path coefficients **(Atia, 2007)**.

RESULTS AND DISCUSSION

Genetic Variability

Data information in Table 2 showed that for every trait, the size of the genotypic (GCV) and phenotypic (PCV) coefficients of variance were differed. The highest PCV and GCV were observed for all studied traits in the three spaces, indicating the high potential for effective selection **(Burton, 1952; Hamed, 2012; El-Dakkak *et al*., 2014; Dash *et al*., 2020; Kumar *et al.*, 2020; Khan *et al.*, 2023)**. The majority of features under study were found to have high GCV and PCV. For the majority of traits, there were slight variations between GCV% and PCV% at the three spaces, suggesting the significance of genetic factors in regulating the inheritance of these traits. According to our findings, the majority of the examined qualities exhibited high GCV/PCV percent in all three spaces. Such values ranged from (75.3, 62.4 and 55.5%) for branches to (98.6, 98.4 and 97.0%) for fruit weight at narrow (30 cm), mediate (45 cm) and wide (60 cm) planting spaces, respectively. These findings showed that genetic variations accounted for roughly 55% of phenotypic variability. As a result, there may

Table 2. Different genetic parameters for eleven vegetative and quantitative traits at three planting spaces

	PH	BN	FL	Dim.	FN	FW	Y kg/p	DM	Y/fed	LN	LA
						30 cm					
Mean	87.7	5.6	9.8	6.1	13.8	138.2	1.5	9.5	26.7	80.06	47.01
SE	2.4	0.3	0.2	0.3	0.3	1.9	0.0	0.3	0.4	1.68	1.66
PCV	9.79	10.96	28.22	41.4	35.94	23.11	113.95	12.48	35.45	23.24	20.20
GCV	9.62	8.26	27.68	40.4	35.10	22.79	95.34	12.07	32.27	22.34	19.84
GCV/PCV	98.24	75.3	98.1	97.6	97.7	98.6	83.7	96.7	91.0	96.13	98.23
GAM%	16.63	10.9	47.8	69.4	60.4	39.6	140.1	20.6	51.4	37.80	34.29
$h^2_{(b)}$	96.52	56.8	96.2	95.3	95.4	97.2	70.0	93.6	82.8	92.42	96.49
						45 cm					
Mean	85.0	5.5	9.8	6.1	17.2	137.3	1.8	9.5	24.2	94.43	48.82
SE	2.3	0.5	0.3	0.3	0.5	2.5	0.0	0.4	0.3	1.60	1.45
PCV	11.34	13.86	26.46	41.47	38.48	22.50	103.12	11.41	32.52	26.27	17.87
GCV	10.18	8.66	25.84	40.42	36.26	22.13	80.98	10.81	23.73	23.74	17.50
GCV/PCV	89.8	62.4	97.7	97.5	94.2	98.4	78.5	94.8	73.0	90.37	97.92
GAM%	16.1	9.5	44.4	69.4	60.1	38.3	112.0	18.1	30.5	37.76	30.16
$h^2_{(b)}$	80.6	39.0	95.4	95.0	88.8	96.8	61.7	89.8	53.2	81.67	95.87
						60 cm					
Mean	83.8	6.4	9.8	6.1	21.0	135.2	2.3	9.4	19.7	114.81	43.47
SE	1.1	0.4	0.3	0.3	0.5	2.7	0.0	0.2	0.3	1.97	1.69
PCV	11.54	10.66	28.64	39.88	37.62	21.71	101.35	10.98	32.03	22.53	22.33
GCV	9.60	5.92	26.12	38.03	35.32	21.06	68.85	10.40	22.09	20.30	19.24
GCV/PCV	83.2	55.5	91.2	95.4	93.9	97.0	67.9	94.7	69.0	90.11	86.15
GAM%	14.0	5.8	42.0	63.9	58.4	36.0	82.2	17.3	26.8	32.19	29.17
$h^2_{(b)}$	69.2	30.9	83.2	90.9	88.1	94.1	46.2	89.7	47.6	81.19	74.23

PH: plant height, BN: branch number/plant, FL: fruit length (cm), Dim: fruit diameter (cm), FN: fruit number/plant, FW: fruit weight (g), Y/p: yield (kg/ plant), DM: fruit dry matter, Y/fed.: yield (ton/fed.), LN: leaves number/plant, and LA: leaf area.

be room for improvement in certain traits, which may be more genotypically dominant. In general, the GCV/PCV exhibited the highest percentage at narrow planting spaces and decreased with increasing spaces in all studied traits (Table 2).

Plant breeders use the heritable proportion of variation as a foundation for their selection process based on phenotypic performances. Data demonstrated that broad sense heritability (h^2) exhibited the highest percentage at narrow planting spaces and decreased with increasing spaces in all studied traits (Table 2). Broad sense heritability based on **Stansfield (1983)**, were moderate magnitude for number of branches (39% and 30.9%) at 45 and 60 cm spaces, respectively as well as yield/plant (46.2%) and yield/fed. (47.6%) at 45 and 60 cm space and high for each of all other traits in all traits at the three planting spaces. High heritability suggested that these features would advance quickly through selection. These findings suggested that environmental influences had little bearing on the inheritance of these qualities and that mean-based selection would be effective in enhancing these features. These parameters have a high heritability, which suggests that choosing them would be more beneficial than choosing the other factors. At 30, 45, and 60 centimeter spacing, the genotypes showed a significant and nearly equivalent genetic gain in yield/plant, ranging from 140.1, 112.0, and 82.2%, respectively. Genetic advance based on **Hadiati *et al*. (2003)** was low for number of branches (5.8%) at wider space (60 cm), and moderate magnitude at both 30 cm (10.9%) and 45 cm (9.5%) and high for all other studied traits (Table 2).

Johnson *et al.* (1955) found that in order to predict the impact of selection, heritability values in conjunction with estimates of genetic advancement were more helpful than heredity alone.

In general, high heritability was achieved with all traits except number of branches (30 and 45 cm) and both yield/plant and yield/ fed. (60 cm) along with high genetic advance as percent of the mean (GAM%). It follows that choosing these characters would be more successful due to their high genetic advance percentage and heritability. Based on the current study's findings, it can be said that there was a significant range of variability among various genotypes for practically all of the features that were investigated. There is some similarity between these findings and those of **Yadav *et al.* (2016), Pujer *et al.* (2017), Samlindsujin *et al.* (2017), Mahmoud *et al*. (2018), Tirkey *et al*. (2018) and Hassan *et al*. (2021)**.

Correlation

Phenotypic, genotypic and environmental correlation coefficients among traits over the two years under 30, 45 and 60 cm intra row spacing's were estimated (Tables 3 and 4). The findings showed that the signals and magnitudes of the values were either equivalent or quite near to one another for every pair of traits. The genotypic coefficient values were higher than the phenotypic one for almost all the studied traits (in each of the three spaces) revealing that environment plays minor role in the modification of the expression of the genes, thereby establishing strong inherent relationship among the traits studied under all spaces, and these results agree with those obtained by **Khan *et al.* (2023), Kumar *et al.* (2020), Onyia *et al*. (2020) and Tiwari and Upadhyay (2011)**.

The positive and highly significant correlation of yield/fed., with diameter, fruit weight and yield/plant was obtained in the three spaces implying that these traits have stable relations and these traits are yield indicators, hence could be selected simultaneously for improvement in breeding programs **(Tasisa *et al*., 2012)** and corroborated with results obtained by **Ghosh *et al*. (2010)**. Therefore, the selection for fruit weight or yield/plant, simultaneously or individually should improve yielding ability of the genotypes **(Mpayo, 2010).** These results were in conformity with findings of **Alam and Paul (2019), Jeberson *et al*. (2016), Khan *et al.* (2023), Tadesse *et al.* (2014) and Yadav *et al*. (2010).** However, the picture was different under various spaces, the correlation of yield/ plant was high positive with both fruit diameter (0.946) and average fruit weight (0.929), low and positive with leaf area (+0.320) under narrow spacing (30 cm) and decreased to 0.687, 0.701 and - 0.359, respectively under the wider spacing (60 cm) where, correlation decreased with increasing spaces as mentioned above. On the opposite, the correlation of yield/plant was negative with dry matter (-0.362) and number of branches (-0.294) as well as weak or neglected correlation with leaves number (0.07) under narrow space (30 cm) increased under wider one to positive [0.012 (dry matter), 0.336 (leaves number) and 0.322 (branches number)] correlated values. Furthermore, both genotypic and phenotypic correlations were larger in the majority of 45 and 60 cm spacing cases than in the environmental ones (Table 4), suggesting an innate link between multiple traits independent of environmental factors effect under wide spaces.

In fact, out of a total of 55 possible combinations between the nine traits studied, only 27, 18 and 27 environmental correlation coefficients in 30, 45 and 60 cm spacing, respectively were greater than their corresponding genotypic correlation coefficient.

While there was a negative association with the other growth and yield parameters examined, the fruit diameter, fruit weight, yield/plant, and yield/fed. all shown extremely strong and significant positive correlation values with each other (Table 3). Fruit diameter and average fruit weight were substantially positively correlated. These results confirmed by **Danquah and Ofori (2012) and Muniappan *et al*. (2010)** both for fruit diameter. Branches number was significantly

Table 3. Phenotypic (above diagonal) and genotypic (below diagonal) correlations among yield and its attributes of eggplant

		PH	BN	FL	Dim.	FN	FW	Y/p	DM	Y/fed	LN	LA
	30 cm		0.386	0.127	-0.186	0.061	-0.087	-0.32	-0.424	-0.324	-0.041	0.35
PH	5cm	1	-0.08	0.432	-0.034	-0.198	0.071	-0.273	-0.411	-0.274	0.166	-0.039
	60 cm		-0.141	0.281	0.048	-0.564	0.222	-0.375	-0.425	-0.376	-0.151	0.017
	30 cm	0.375		-0.004	-0.243	0.441	-0.298	-0.205	0.148	-0.207	0.373	0.53
BN	45cm	-0.004	1	-0.375	0.014	0.147	-0.117	-0.052	0.189	-0.06	-0.151	0.216
	60 cm	-0.351		-0.594*	0.118	0.323	-0.113	0.208	0.181	0.201	0.465	0.116
	30 cm	0.147	0.014		-0.273	-0.319	0.071	-0.128	-0.144	-0.125	-0.496	-0.27
FL	45cm	0.446	-0.589*	1	-0.27	-0.441	0.116	-0.234	-0.126	-0.235	-0.218	-0.181
	60 cm	0.292	-0.913**		-0.389	-0.262	-0.055	-0.31	-0.249	-0.31	-0.217	-0.328
	30 cm	-0.202	-0.35	-0.283		-0.655*	0.916**	0.940**	-0.328	0.938**	0.04	0.368
Dim.	45cm	-0.042	0.064	-0.267	1	-0.650*	0.887**	0.701*	-0.481	0.701*	-0.357	0.751*
	60 cm	0.05	0.153	-0.398		-0.651*	0.881**	0.680*	-0.223	0.679*	-0.025	0.086
	30 cm	0.054	0.56*	-0.32	-0.663*		-0.868**	-0.703*	0.573*	-0.702*	0.151	0.172
FN	45cm	-0.195	0.221	-0.443	-0.657*	1	-0.882**	-0.438	0.392	-0.439	0.582	-0.528*
	60 cm	-0.576*	0.504	-0.265	-0.663*		-0.877**	-0.359	0.395	-0.359	0.141	0.223
	30 cm	-0.09	-0.396	0.07	0.923**	-0.871**		0.927**	-0.523	0.928**	-0.118	0.22
FW	45cm	0.074	-0.196	0.117	0.894**	-0.885**	1	0.728*	-0.524	0.728*	-0.434	0.640*
	60 cm	0.228	-0.165	-0.056*	0.895**	-0.878**		0.700*	-0.219	0.701*	-0.093	-0.113
	30 cm	-0.34	-0.294	-0.131	0.946**	-0.708*	0.929**		-0.35	0.999**	0.07	0.313
Y/p	45cm	-0.285	-0.098	-0.236	0.707*	-0.441	0.729*	1	-0.291	0.999**	-0.011	0.221
	60 cm	-0.38	0.322	-0.314	0.687*	-0.361	0.701*		0.016	1.000**	0.334	-0.348
	30 cm	-0.468	0.148	-0.14	-0.348	0.595*	-0.539*	-0.362		-0.35	-0.006	-0.054
DM	45cm	-0.494	0.414	-0.154	-0.522*	0.431	-0.567*	-0.313	1	-0.288	0.077	-0.297
	60 cm	-0.453	0.354	-0.268	-0.232	0.414	-0.229	0.012		0.016	-0.131	0.333
	30 cm	-0.341	-0.293	-0.127	0.947**	-0.707*	0.929**	1.000**	-0.357		0.067	0.314
Y/fed.	45cm	-0.285	-0.092	-0.236	0.707*	-0.441	0.728*	1.000**	-0.315	1	-0.011	0.222
	60 cm	-0.379	0.327	-0.314	0.688*	-0.361	0.701*	1.000**	0.012		0.334	-0.35
	30 cm	-0.038	0.526*	-0.502*	0.04	0.157	-0.12	0.07	-0.005	0.068		0.335
LN	45cm	0.18	-0.24	-0.222	-0.36	0.585*	-0.435	-0.011	0.083	-0.011	1	-0.728*
	60 cm	-0.156	0.692*	-0.219	-0.029	0.141	-0.092	0.336	-0.143	0.336		-0.482
	30 cm	0.380	0.732*	-0.281	0.374	0.171	0.225	0.320	-0.043	0.320	0.347	
LA	45cm	-0.021	0.295	-0.186	0.764*	-0.541*	0.653*	0.225	-0.343	0.225	-0.746*	1
	60 cm	0.019	0.105	-0.331	0.08	0.227	-0.114	-0.359	0.37	-0.358	-0.499	

** Significant at 1 % level of significance; * Significant at 5% level of significance.

PH: plant height, BN: branch number/plant, FL: fruit length (cm), Dim: fruit diameter (cm), FN: fruit number/ plant, FW: fruit weight (g), Y/p: yield (kg/plant), DM: fruit dry matter, Y/fed: yield (ton/fed.), LN: leaves number/plant, and LA: leaf area.

Table 4. Environmental correlations among yield and its attributes of eggplant

		PH	BN	FL	Dim.	FN	FW	Y kg/p	FDM	Y/fed.	LN	LA
	30 cm		0.61	-0.437	0.145	0.413	-0.194	0.214	0.12	0.126	-0.14	-0.091
PH	45cm	1	-0.355	0.216	0.176	-0.459	0.026	0.011	0.226	-0.104	-0.279	-0.337
	60 cm		0.568	-0.131	-0.002	0.032	-0.336	-0.267	0.037	-0.465	0.071	-0.029
	30 cm			-0.212	0.196	0.446	-0.119	0.298	0.243	0.338	-0.238	-0.042
BN	45cm		1	-0.109	-0.261	0.151	0.176	0.21	-0.155	-0.06	-0.037	0.226
	60 cm			-0.068	0.18	-0.041	-0.229	-0.008	-0.188	-0.25	0.259	0.305
	30 cm				-0.431	-0.279	-0.032	-0.131	0.281	-0.16	0.14	-0.045
FL	45cm			1	-0.431	-0.279	-0.032	-0.131	0.281	-0.16	0.14	-0.045
	60 cm				0.04	0.013	-0.039	0.045	0.179	0.217	0.011	-0.258
	30 cm					0.092	0.201	0.413	0.164	0.076	0.02	0.237
Dim.	45cm				1	-0.073	0.029	0.158	-0.111	0.077	-0.093	0.358
	60 cm					0.207	-0.628*	0.176	-0.073	-0.075	0.304	0.281
	30 cm						-0.253	0.094	-0.037	0.35	-0.434	0.322
FN	45cm					1	-0.218	0.072	-0.082	-0.066	0.155	0.034
	60 cm						-0.218	0.072	-0.082	-0.066	0.155	0.034
	30 cm							0.292	-0.36	0.289	0.103	0.137
FW	45cm						1	0.417	-0.252	0.375	-0.375	0.257
	60 cm							0.283	0.056	0.485	-0.282	-0.136
	30 cm								-0.079	0.737*	0.087	0.09
Y/p	45cm							1	-0.184	0.615	-0.143	0.132
	60 cm								0.321	0.823**	0.048	0.151
	30 cm									-0.43	-0.037	-0.249
FDM	45cm								1	-0.43	-0.037	-0.249
	60 cm									0.29	0.229	-0.24
	30 cm										0.025	0.149
Y/fed.	45cm									1	-0.121	0.196
	60 cm										0.092	-0.081
	30 cm											-0.074
LN	45cm										1	0.029
	60 cm											0.128

PH: plant height, BN: branch number/ plant, FL: fruit length (cm), Dim: fruit diameter (cm), FN: fruit number/plant, FW: fruit weight (g), Y/p: yield (kg/plant), DM: fruit dry matter, Y/fed: yield (ton/fed.), LN: leaves number/plant, and LA: leaf area.

positive related with leaf area (30 cm) and leaf number (both 30 and 60 cm intra-row spaces). Also, leaf area was significantly positive genotypic correlated with fruit diameter and average fruit weight as well as Leaves number was significantly positive related with fruit number under 45 cm intra-row spaces.

The average fruit weight was positively correlated with plant height (60 cm), fruit yield per plant, and fruit yield per feed (all spaces). The fruit diameter had positive significant correlation with fruit weight and yield (all spaces) as well as number of branches per plant (45 and 60 cm) at both the genotypic and phenotypic levels. A highly substantial and strong correlation coefficient was found between fruit weight and yield by **Islam *et al.* (2010)**, **Dash *et al*. (2020), Khan *et al.* (2023) and Onyia *et al*. (2020)**. Also, Fruit diameter and fruit production per plant were found to be positively associated by **Akpan *et al*. (2016)**, suggesting that selecting for these features may indirectly increase the amount of fruit produced by eggplant plants.This outcome is consistent with the findings of **Danquah and Ofori (2012)** who found a positive correlation between fruit diameter and fruit weight.

Fruit number is positively correlated with branches and fruit dry matter under 30 cm spacing and with leaves number in case of 45 cm. In the same time fruit number is negatively correlated with fruit diameter and fruit weight in all studied spaces. These relations of number of fruits with both fruit diameter and fruit weight were specific to genotypes and thus such associations depend on the fruit diameter. These findings are consistent with those of **Prabhu and Natarajan (2007), Manna and Paul (2012) and Parihar *et al.* (2014)**, who found that yield was positively and significantly correlated with the majority of the attributes.

Path Coefficient Analysis

To identify the specific factor causing the association, the phenotypic and genotypic correlation between yield and yield components were divided into direct and indirect effects (Tables 5 and 6 as well as Figs. 1-4). Both direct negative impacts (-0.408) on yield/plant and indirect beneficial effects (number of branches, fruit diameter, and number of fruits) were attributed to plant height. The number of branches had a direct, positive impact on plant yield (0.1613). Via plant height, fruit length, and fruit weight, it also shown detrimental indirect impacts. Fruit length shown favorable indirect impacts via fruit weight, fruit diameter, and number of branches, and a negative direct effect (-0.552) on yield/plant. Fruit diameter applied negative direct effect (-1.607) on yield/plant and also showed positive indirect effects via Plant height, fruit length and fruit weight (Table 5). On the other hand, fruit number showed genotypic positive direct effect (0.579) on yield/ plant under 30 cm. It also showed negative indirect effects via plant height at 30 cm; fruit length at 45 cm and fruit weight at all planting spaces as well as positive indirect effects via corresponding other traits of 30, 45 and 60 cm spacing. Fruit weight showed positive direct effect (2.984, 3.11 and -4.897) on yield/ plant and also showed negative indirect effects via number of branches in all spaces, fruit diameter and fruit number in in 30 and 45 cm, plant height in 30 cm and fruit length in both 45 and 60 cm.

Our findings and those of previous researchers have some similarities and differences, which could be related to the diverse environmental factors and breeding materials. Because of this anomalous circumstance, it was suggested that a restricted simultaneous selection model could be used to properly utilize the direct benefit while eliminating the unwanted indirect consequences. After examining the significant correlation and the desired direct effect of fruit weight, number of branches, and number of fruits on yield/plant, it is possible to draw the conclusion that these parameters could be taken into account for the creation of inbred lines through pure line selection in subsequent generations, or for the development of elite hybrids through heterosis breeding.

There have been prior reports providing supporting evidence of a direct positive relationship between the quantity of fruits on a plant and its yield **(Singh *et al.*, 2006; Rani *et al.*, 2008; Eslam *et al.*, 2010; Alam and Paul, 2019; Khan *et al.*, 2023)**. The outcome agreed with the findings of **(Hayadar *et al*., 2007; Saleem *et al*., 2013)**. Noticed a positive direct relationship between plant height and yield/plant, in contrast to **Ghosh *et al.* (2010)** finding of a negative relationship between plant height and yield/plant in tomatoes. To increase yield, direct selection of these qualities would be beneficial.

Table 5. Path coefficient analysis of fruit yield/plant (Y/p) *vs* plant height, branches number, fruit length, fruit diameter, average fruit weight and fruits number/plant at 30, 45 and 60 cm planting spaces

Pathways of association	30 cm	45 cm	60 cm
Y/P *vs*. Plant height (PH)			
Direct effect (P17)	-0.408	-0.311	-2.815
Indirect effect via BN (P27*r12)	0.061	-0.001	-1.875
Indirect effect via FL (P37*r13)	-0.081	0.049	0.972
Indirect effect via Dim. (P47*r14)	0.325	0.045	0.031
Indirect effect via FN (P57*r15)	0.032	-0.297	4.424
Indirect effect via FW (P67*r16)	-0.269	0.23	-1.117
Total (r)	-0.34	-0.285	-0.38
Y/P *vs*. Number of branches (BN)			
Direct effect (P27)	0.161	0.304	5.341
Indirect effect via PH (P17*r12)	-0.153	0.001	0.988
Indirect effect via FL (P37*r23)	-0.008	-0.061	-3.038
Indirect effect via Dim. (P47*r24)	0.563	-0.069	0.094
Indirect effect via FN (P57*r25)	0.324	0.337	-3.871
Indirect effect via FW (P67*r26)	-1.181	-0.61	0.808
Total (r)	-0.294	-0.098	0.322
Y/P *vs*. Fruit length (FL)			
Direct effect (P37)	-0.552	0.108	3.328
Indirect effect via PH (P17*r13)	-0.06	-0.14	-0.823
Indirect effect via BN (P27*r23)	0.002	-0.18	-4.876
Indirect effect via Dim. (P47*r34)	0.455	0.287	-0.251
Indirect effect via FN (P57*r35)	-0.185	-0.675	2.035
Indirect effect via FW (P67*r36)	0.209	0.364	0.273
Total (r)	-0.131	-0.236	-0.314
Y/P *vs*. Fruit diameter (Dim)			
Direct effect (P47)	-1.607	-1.076	0.625
Indirect effect via PH (P17*r14)	0.083	0.013	-0.141
Indirect effect via BN (P27*r24)	-0.056	0.02	0.817
Indirect effect via FL (P37*r34)	0.156	-0.029	-1.324
Indirect effect via FN (P57*r45)	-0.384	-1.002	5.093
Indirect effect via FW (P67*r46)	2.754	2.781	-4.383
Total (r)	0.946	0.707	0.687
Y/P *vs*. Number of fruits (FN)			
Direct effect (P57)	0.579	1.525	-7.679
Indirect effect via PH (P17*r15)	-0.022	0.061	1.622
Indirect effect via BN (P27*r25)	0.09	0.067	2.692
Indirect effect via FL (P37*r35)	0.177	-0.048	-0.882
Indirect effect via Dim. (P47*r45)	1.066	0.707	-0.414
Indirect effect via FW (P67*r56)	-2.598	-2.753	4.3
Total (r)	-0.708	-0.441	-0.361
Y/P *vs*. Average fruit weight (FW)			
Direct effect (P67)	2.984	3.11	-4.896
Indirect effect via PH (P17*r16)	0.037	-0.023	-0.642
Indirect effect via BN (P27*r26)	-0.064	-0.06	-0.881
Indirect effect via FL (P37*r36)	-0.039	0.013	-0.186
Indirect effect via Dim. (P47*r46)	-1.484	-0.962	0.562
Indirect effect via FN (P57*r56)	-0.505	-1.349	6.744
Total (r)	0.929	0.729	0.701

Table 6. Partitioning of the phenotypic and genotypic correlation coefficients into direct effects (main diagonal, bold) and indirect effects (above and below the main diagonal) in ten eggplant genotypes

Item		PH	BN	FL	Dim	FN	FW	Correlation
					Phenotypic level			
	30 cm	-0.299	0.063	-0.024	0.048	0.014	-0.121	-0.320
PH	45 cm	-0.185	0.001	-0.092	0.026	-0.185	0.162	-0.273
	60 cm	-0.485	-0.034	-0.026	-0.026	-0.145	0.341	-0.375
	30 cm	-0.116	0.163	0.001	0.062	0.100	-0.416	-0.205
BN	45 cm	0.015	-0.008	0.080	-0.010	0.138	-0.266	-0.052
	60 cm	0.068	0.240	0.055	-0.065	0.083	-0.174	0.208
	30 cm	-0.038	-0.001	-0.186	0.070	-0.073	0.100	-0.128
FL	45 cm	-0.080	0.003	-0.213	0.206	-0.412	0.262	-0.234
	60 cm	-0.136	-0.143	-0.093	0.214	-0.067	-0.085	-0.311
	30 cm	0.056	-0.040	0.051	-0.255	-0.149	1.277	0.940
Dim	45 cm	0.006	0.000	0.057	-0.763	-0.607	2.008	0.701
	60 cm	-0.023	0.028	0.036	-0.549	-0.167	1.355	0.680
	30 cm	-0.018	0.072	0.059	0.167	0.228	-1.211	-0.703
FN	45 cm	0.037	-0.001	0.094	0.496	0.934	-1.998	-0.438
	60 cm	0.273	0.078	0.024	0.358	0.257	-1.349	-0.359
	30 cm	0.026	-0.049	-0.013	-0.234	-0.198	1.394	0.927
FW	45 cm	-0.013	0.001	-0.025	-0.677	-0.824	2.265	0.728
	60 cm	-0.108	-0.027	0.005	-0.483	-0.225	1.538	0.700
					Genotypic level			
	30 cm	-0.408	0.060	-0.081	0.325	0.031	-0.268	-0.340
PH	45 cm	-0.311	-0.001	0.048	0.045	-0.298	0.231	-0.285
	60 cm	-2.816	-1.874	0.971	0.031	4.426	-1.118	-0.380
	30 cm	-0.153	0.161	-0.008	0.563	0.325	-1.182	-0.294
BN	45 cm	0.001	0.304	-0.063	-0.069	0.337	-0.609	-0.098
	60 cm	0.988	5.341	-3.039	0.095	-3.870	0.807	0.322
	30 cm	-0.060	0.002	-0.552	0.455	-0.186	0.210	-0.131
FL	45 cm	-0.139	-0.179	0.108	0.287	-0.676	0.363	-0.236
	60 cm	-0.821	-4.878	3.328	-0.248	2.033	0.273	-0.314
	30 cm	0.083	-0.057	0.156	-1.607	-0.384	2.756	0.946
Dim	45 cm	0.013	0.019	-0.029	-1.076	-1.002	2.781	0.707
	60 cm	-0.140	0.816	-1.323	0.625	5.090	-4.381	0.687
	30 cm	-0.022	0.090	0.177	1.066	0.579	-2.599	-0.708
FN	45 cm	0.061	0.067	-0.048	0.707	1.525	-2.753	-0.441
	60 cm	1.622	2.691	-0.881	-0.414	-7.681	4.302	-0.361
	30 cm	0.037	-0.064	-0.039	-1.484	-0.505	2.984	0.929
FW	45 cm	-0.023	-0.060	0.013	-0.962	-1.350	3.110	0.729
	60 cm	-0.643	-0.880	-0.186	0.559	6.748	-4.897	0.701

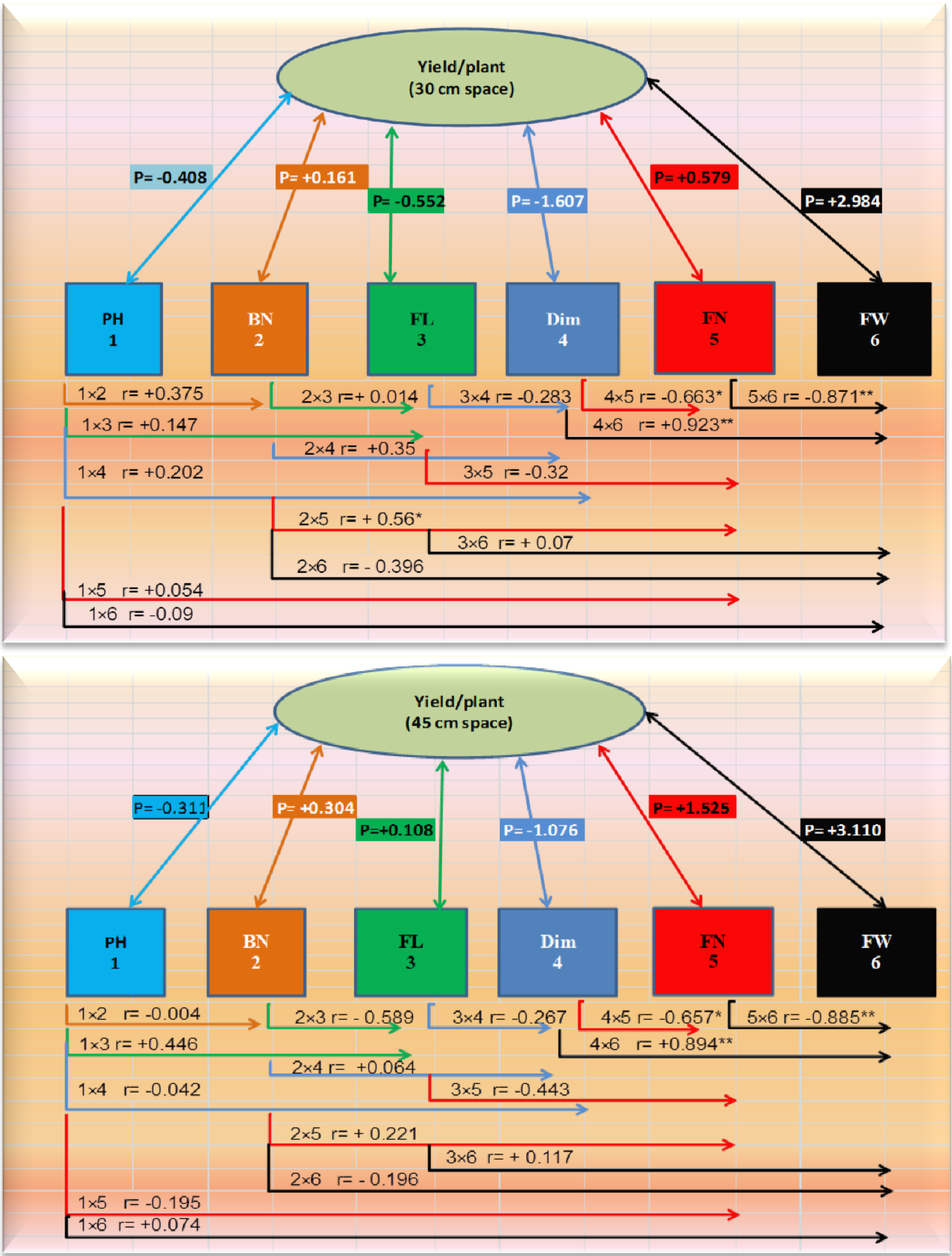

Fig. 1. **Genotypic path coefficient diagram representing cause and effect relationships among some vegetative and fruit traits with yield/plant [PH (1): plant height; BN (2): branches number; FL (3): fruit length; Dim. (4): fruit diameter; FN (5): number of fruits per plant; FW (6): average fruit weight)] at 30 cm (Upper) and 45 cm planting spaces (Down)**

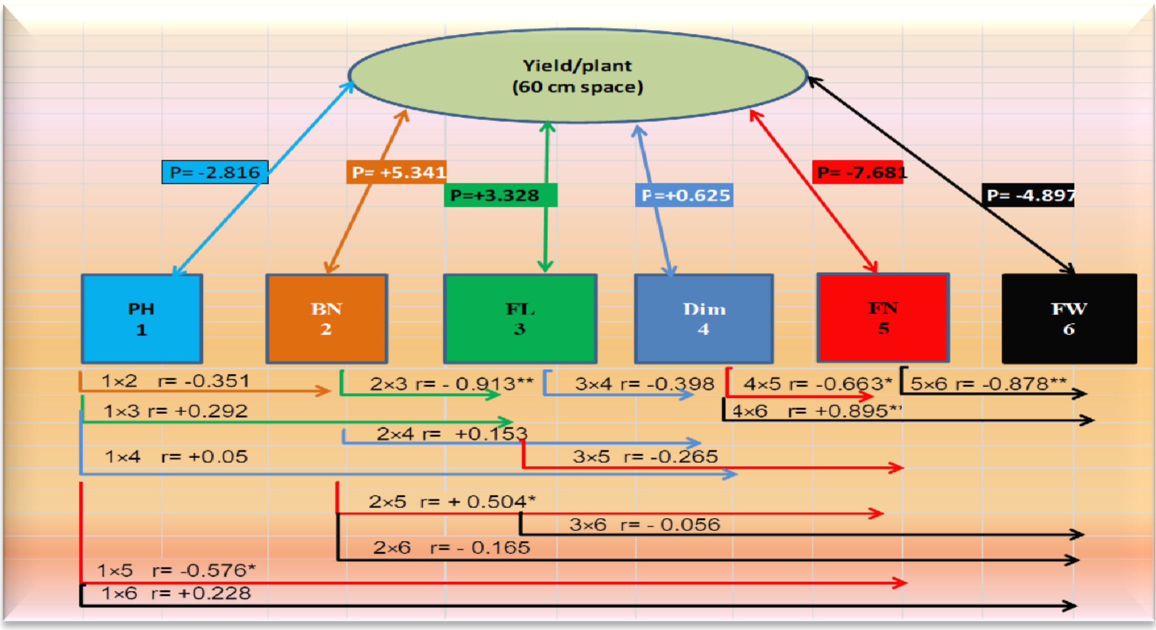

Fig. 2. Average genotypic path coefficient diagram representing cause and effect relationships among some vegetative and fruit traits with yield/ plant [(PH (1): plant height; BN (2): branches number; FL (3): fruit length; Dim (4): fruit diameter; FN (5): number of fruits per plant; FW (6): average fruit weight] at 60 cm planting spaces

Fig. 3. Percentage contribution of fruit yield and its attributing traits based on path coefficient analysis for three intra-row spacing.

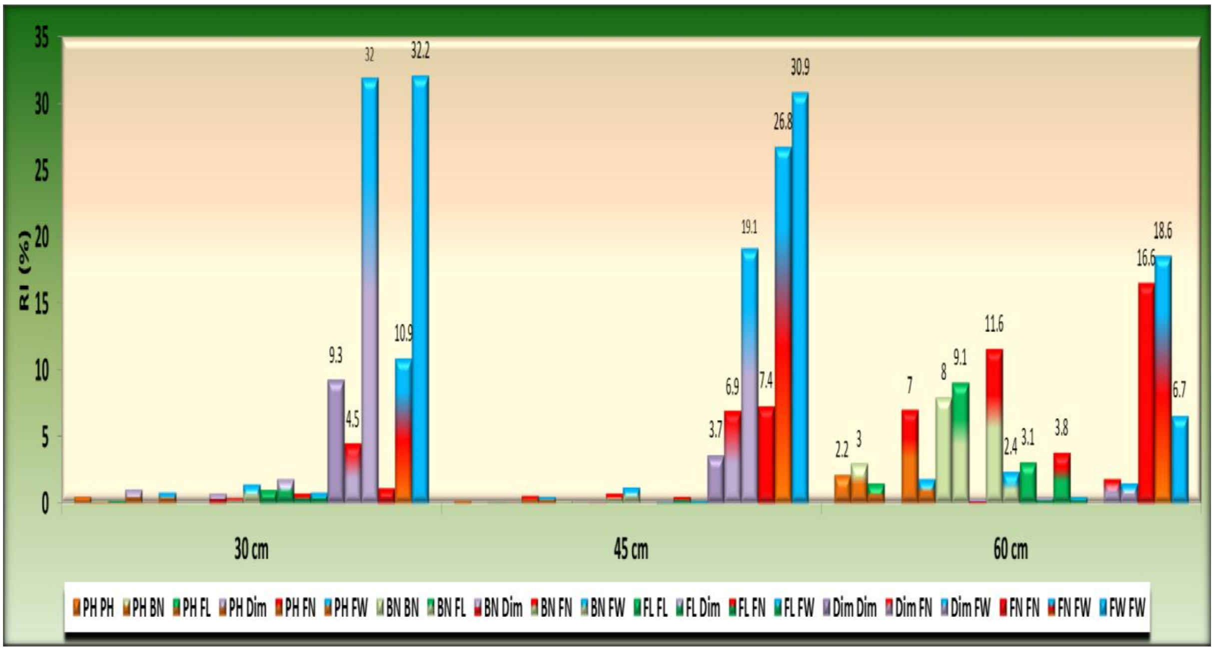

Fig. 4. Relative importance (R%) according to path analysis of fruit yield/plant and its attributed traits in eggplant at 30, 45 and 60 cm planting spaces

Consequently, these traits may be taken into account while choosing genotypes to increase yield. Conversely, in all spaces (phenotypic and/or genotypic level), fruit diameter, fruit length, and plant height had a negative direct effect on yield. All characters' negative direct effects, however, were offset by their indirect effects through other characters, leading to a highly substantial positive association with yield in the end. The direct effect points out that, with other variables held constant, increasing any of these traits will decrease yield. However, the more suitable indirect effects play a more important part and mask the direct influence **(Dewey and Lu, 1959)**. A positive phenotypic (1.277 and 2.008) and genotypic (2.756 and 2.781) effects of 30 and 45 cm, respectively (Table 6), as well as the phenotypic of 60 cm (1.355) were recorded indirectly by fruit diameter on yield per plant through fruit weight due to fact the diameter was positively correlated (r = 0.916** and 0.923**), (0.887** and 0.894**) and (0.881** and 0.895**) in 30, 45 and 60 cm spaces, respectively with fruit weight (Table 2 and Figs. 1, 2 and 3) which in turn had a large direct effects (1.394 and 2.984), (2.265 and 3.110) upon yield in 30 and 45 cm, respectively as well as 1.538 in phenotypic level of 60 cm.

Relative importance (R%) according to path analysis of fruit yield/plant and its attributed traits in eggplant at 30, 45 and 60 cm planting spaces are shown in Fig. 5. The results revealed that the greatest parts of yield/plant variation were explained by the direct effect for fruit weight at 30 cm (32.2%) and 45 cm (30.9%) planting spaces followed by fruit diameter (9.3%) and both number of fruits/ plant (7.4%) and fruit diameter (3.7%) at 30 and 45 cm planting spaces, respectively. As for 60 cm spaces, the direct effect of number fruits/plant (16.6%) exhibited the highest part of yield/ plant variation followed by number of branches (8%) and average fruit weight (6.7%). These traits showed significant contributions to plant yield demonstrate their importance as selection factors in eggplant breeding programs. The other traits, however, noted insignificant or nonexistent direct effects on fruit yield.

Regarding the relative importance of joint effects, it is obvious that their effective parts were obtained by fruit diameter on yield/ plant through its associations with each of number of fruits/plant (4.5 and 6.9%) and average of fruit weight (32 and 19.1%) as well as fruit number via its association with average fruit weight

(10.9 and 26.8%) at 30 and 45 cm planting spaces, respectively. As for 60 cm planting space, the effective parts of the relative importance of joint effects were obtained by fruit number via its association with average fruit weight (18.6%), number of branches through its associations with each of number of fruits/plant (11.6%), fruit length (9.1%) and average of fruit weight (2.1%) as well as by plant height via both fruit number (7%) and branches (3%) and fruit length through its association with fruit number (3.8%). The highest value of the indirect effects was recorded by fruit diameter via average of fruit weight (32%) at 30 cm space and fruit number via fruit weight (26.8 and 18.6%) at 45 and 60 cm spaces, respectively. Small values of relative importance ranging from 0.0 to 1.2% (45 cm) and 1.8% (30 and 60 cm) were obtained by the other direct and indirect effects.

The picture was different under various spaces where, total direct effects decreased with increasing plant spaces from 30 cm (44.6%), 45 cm (42.6%) to 60 cm (36.8%) and reverse trend was observes for total indirect effects which increased with increasing plant spaces; *i.e.*, 55.5 (30 cm), 57 (45 cm) and 63.4% (60 cm) as shown in Figs. 3 and 4.

It is clear from the present work that the correlation analysis gave a different picture of the role of number of fruit per plant, branches and fruit diameter on fruit yield than that the given by path coefficient analysis. Consequently, it is suggested to use indirect selection using other component qualities that also have similar traits and have good indirect impacts in order to increase yield. At the phenotypic level, it was shown that the majority of the direct effects were smaller than one, suggesting that phenotypic inflation resulting from multi-collinearity was negligible. Totally, the studied characters accounted for 100.02, 99.57 and 100.14% of fruit yield/ plant variability. The residual content (0.02, 0.43 and 0.14%) may be returned to unknown factors (random error) and/or some other traits that were not included in the present study.

Conclusion

In conclusion: There is a wide range of phenotypic diversity for morphological, yield and quality traits among the genotypes. Some genotypes produced higher yields and desirable traits compared to others. Almost all traits showed strong associations with other agronomic and yield traits, and higher values of expected genetic advances (GAM%) were observed for those traits, indicating higher genetic gains in the breeding programme. In general, it is proposed to expand the genetic base of the existing Egyptian germplasm using these genotypes to develop a successful and sustainable breeding programme.

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دراســـــة الاختــلافـــات الـوراثية والارتباط في بعض التراكيب الوراثية للباذنجان

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يعد تقدير الاختلافات الوراثية هام لتطوير تراكيب وراثية جديدة ذات صفات محصولية وجودة مرتفعة، ويساعد مربي النبات في تحديد التراكيب الوراثية المتفوقة والتربية لبيئات خاصة وتحسين أداء المحصول تحت ظروف بيئية مختلفة، لذلك تهدف هذه الدراسة تقييم سلوك عشرة أصناف باذنجان هي ليتيل فينجرز (LF)، بينج تونج (PT)، أنتيجوا (An)، بلاك لونج (BVL)، أسود (As)، جابانيز وايت ايج (JWE)، ابل جرين (AG)، روتوندا بيانكا ستوماتا دي روزا (RSB)، كورين ريد (KR) و بلاك اوبلنج (BO)، تحت ثلاثة مسافات بين النباتات داخل الخط (30، 45 و 60 سم)، وأجريت هذه الدراسة تحت ظروف منطقة الزقازيق - مصر أثناء الموسمي الصيف 2017 و 2018 ، وتم حساب التقدم الوراثي المتوقع والإرتباط ومعامل المرور للصفات تحت الدراسة. أظهرت النتائج وجود إختلافات عالية المعنوية بين التراكيب الوراثية تحت الدراسة، أعطت درجة التوريث بالمعني الواسع (h_b^2) أعلي نسبة في المسافات الزراعية الضيقة وانخفضت مع زيادة المسافات في جميع الصفات المدروسة، وكانت نسبة درجة التوريث بالمعني الواسع (h_b^2) لصفة عدد الأفرع (39 و30,9%) تحت مسافات زراعة 45 و 60 سم علي التوالي، كان التقدم الوراثي كنسبة مئوية (GA%) مرتفعاً لجميع الصفات المدروسة باستثناء عدد الأفرع، وكانت قيم GCV/PCV عالية في معظم الصفات المدروسة لجميع المسافات، أظهرت التراكيب الوراثية قيم عالية لمقدار التحسين الوراثي لصفات المحصول وجودة الثمار، أظهر معامل الإرتباط الوراثي إرتباط قوي بين الصفات المحصولية والمورفولوجية. أظهرت نتائج تحليل معامل المرور أن صفة وزن الثمار كان لها التأثير المباشر الأكبر على محصول النبات (2.984 و3.11) يليها صفات عدد الثمار/ النبات (0.579 و1.525)، وعدد الأفرع/نبات (0.161 و0.304) عند مسافات الزراعة 30 و45 سم ، علي التوالي. في حين أعطت صفة عدد الفروع/نبات أكبر تأثير مباشر علي محصول النبات (5.341) يليها صفات طول الثمرة (3.328)، وقطر الثمرة (0.625) عند مسافة الزراعة 60 سم، مما يدل على فعالية الانتخاب المباشر لهذه الصفات في تحسين وإنتاج تراكيب وراثية عالية المحصول تحت كثافات زراعة مختلفة.

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