# Interrelationship of squash characteristics under different environmental conditions

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***Received:*** 30/*05/2023*

**ABSTRACT:** Two locations trials were conducted to evaluate 14 imported genotypes of summer squash (*Cucurbita pepo*) for some vegetative growth, flowering and yield traits during the summer seasons of 2019 and 2020 under open field conditions. According to correlation studies, estimations of the genotypic correlation coefficient were higher than the equivalent phenotypic correlation coefficient, indicating a significant underlying association between the various traits being studied. The decreased phenotypic values could result from interactions with the environment. A negative and significant correlation of days to 1st female flowering was observed with the number of fruits per plant, fruits yield/plant, TSS and average fruit weight in both localities. A very weak association was observed between average fruit weight and yield per plant in this study, which suggested that environment played role in determining average fruit weight. The path coefficient analysis among seven traits fruit yield and each of vine length, fruit diameter, fruit length, number of fruits per plant, average fruit weight and total soluble solids percentage were performed. However, the picture was different under various environments where, total direct effects increased from 37.3% (Dumah Al-Jandal) to 39.0 % (Rafha) and the reverse trend was observed for total indirect effects which increased in Dumah Al-Jandal (63.5%) than 52.6% in Rafha.

**Keywords***: Squash, correlation, locations, genotypes, environments.*

## INTRODUCTION

In Asia, the majority of the world's area used to grow pumpkins and squash is used for their production (Albrifcany, 2015). Squash is grown in all major world regions, and it is once a year plant and a common vegetable in many Arab nations, particularly in the summer and early spring. Abdein, (2016 a and b), Hikal and Abdein (2018 and 2021). Due to inadequate fruit setting and poor cross-pollination of flowers as a result of the short blooming season, certain production zones had low summer squash production (Abdein, 2005, Albrifcany, 2015 and Abdein, 2016 b). To enhance crop output with the necessary quality, these restrictions require additional research in the areas of breeding genetic studies, environmental factors, and cultural practices (Mohammed, 1996, Abdein *et al*., 2017, Mohamed *et al*., 2018, Abdein 2018 and Abdelkader *et al.*, 2022). Although high yield potential is a primary concern, earliness and quality features are also important factors to take into account when choosing a genotype for a production system. Several writers, including Ferreira *et al*. (2003), Al-Araby (2004), Abdein (2005), Abd El-Hadi, *et al*., (2005 a and b) Al-Araby (2010), Fayeun *et al*., (2012), Tamil *et al*., (2012), El-Adl *et al*., (2012 and 2014), Abd El-Hadi, *et al*., (2014 a and b), Abdein *et al*., (2021), Al-Harbi *et al.* (2021) and Abdelkader *et al.* (2022) evaluated the performance of plants that were cultivated in several sites with varying environmental conditions. A shift in the ordering of genotypes from one environment to another is the outcome of inconsistent genotypic responses to environmental stimuli from one site to another. Given that environmental factors have a significant influence, direct selection for yield would not be a viable strategy. In order to create a useful selection criterion for yield, it is necessary to pinpoint the component qualities whose connections with yield are crucial. Among the objectives of these studies was to study Phenotypic and genotypic correlations as well as the path coefficient analysis among traits in both 1st and 2nd locations over the two years.

## MATERIALS AND METHODS

Fourteen genotypes of summer squash (*Cucurbita pepo*) genotypes (Table 1) were evaluated for certain growth, flowering, and yield traits throughout the two successive summer seasons 2019 and 2020 in open fields at the two private farms on the locations (Dumah Al-Jandal, L1 and Rafha, L2) at Saudi Arabia. On February 8th, seeds were sown in both locations. A randomized complete block design with three repetitions was used to sow two seeds per hill (on one side of the ridge), and after two weeks, the plants were thinned to one plant per hill. The experimental unit consisted of two ridges that were 5.0 m long and 1.2 m wide. In the bed, the plants were spaced 50 cm apart and were treated using standard agricultural methods. Thus, each plot had 20 plants totaling 12 $m^2$ in size. Data on vegetative and reproductive growth were taken at 90 days after sowing and fruits at full maturity as following traits: 1) vine length (VL, cm), 2) fruit diameter (FD, cm), 3) days to the first male flower ($D^1MF$), 4) days to the first female flower ($D^1FF$), 5) the number of fruits per plant (NoF/P), 6) fruit yield (FYP, kg/plant), 7) total soluble solids percentage (TSS%), 8) average fruit weight (WF, g) and 9) fruit length (FL, cm).

**Table 1: Genotypes code, origin and names of 14 squash genotypes**

| Code | SQ 1 | SQ 2 | SQ 3 | SQ 4 | SQ 5 | SQ 6 | SQ 7 |
|---|---|---|---|---|---|---|---|
| Name | Mariam 1 | Mariam 2 | Mariam 3 | Mariam 4 | Mariam 5 | Mariam 6 | Mariam 7 |
| Code | SQ 8 | SQ 9 | SQ 10 | SQ 11 | SQ 12 | SQ 13 | SQ 14 |
| Name | Mariam 8 | Mariam 9 | Mariam 10 | Mariam 11 | Mariam 12 | Mariam 13 | Mariam 14 |

**Statistical Analysis:**

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

1- Phenotypic and Genotypic correlation coefficients among the traits (due to combined season's data) were calculated according to Falconer and Mackay (1995).
2- The path coefficient analysis among 7 traits [Fruit yield (FYP, kg/plant) and each of vine length (VL), fruit diameter (FD), fruit length (FL), number of fruits per plant (NoF/P), average fruit weight (WF) and total soluble solids percentage (% TSS)] was done as outlined by Dewey and Lu (1959). Correlation and path coefficients were calculated by using PATHCA Statistical Computer Program.

## RESULTS

The genotypic correlation coefficient values (Table 2) were higher than the phenotypic ones for almost all the studied traits (in both locations) revealing that environment plays a minor role in the modification of the expression of the genes. In general estimates of genotypic correlation coefficient were higher than the corresponding phenotypic correlation coefficient, which indicated a strong inherent association among different traits under study.

A significant negative correlation of days to $1^{st}$ female flowering was observed with a number of fruits per plant (NoF/P, -0.69 and -0.75), fruits yield/plant (FYP, -0.75 and -0.68), TSS (-0.71 and -0.70) and average fruit weight (WF, -0.54 and -0.54) in $1^{st}$ and $2^{nd}$ localities, respectively which indicated that decrease in days to $1^{st}$ female flowering ($D^1FF$) would lead to a significant increase in a number of fruits per plant (NoF/P), fruits yield/plant (FYP), TSS percentage and average fruit weight (FW) in both locations. On the other hand, positive and significant associations of vine length (VL) with fruits yield/plant (FYP, 0.66 and 0.59), average fruit weight (FW, 0.55 and 0.54) and fruit length (FL, 0.62 and 0.62) were detected. However, fruit length showed negative and significant phenotypic and genotypic correlations with fruit diameter (FD, -0.82 and -0.83 in phenotypic level) and (-0.84 and -0.84 in genotypic level) in $1^{st}$ and $2^{nd}$ localities, respectively. A positive and significant correlation between a number of fruits per plant (NoF/P) and fruit yield per plant (FYP) was also noted at phenotypic and genotypic levels (0.54 and 0.73) in the $1^{st}$ location and (0.74 and 0.77) in the $2^{nd}$ location indicating that these two traits are directly correlated. Also, this trait showed positive and significant phenotypic and genotypic correlations with fruit length (FL) in both phenotypic (0.60 and 0.59) and genotypic (0.63 and 0.61) levels in $1^{st}$ and $2^{nd}$ localities, respectively. In case of number of fruits (NoF/P), as abovementioned results, a negative and significant correlation existed between fruit length (FL) and fruit diameter (FD) at both levels which clearly indicated that increase in number of fruits (NoF/P) would provide more fruit length (FL) which would ultimately affects the fruit shape (FshI).

A significant negative correlation of days to $1^{st}$ female flowering was observed with a number of fruits per plant (NoF/P, -0.69 and -0.75), fruits yield/plant (FYP, -0.75 and -0.68), TSS (-0.71 and -0.70) and average fruit weight (WF, -0.54 and -0.54) in $1^{st}$ and $2^{nd}$ localities, respectively which indicated that decrease in days to $1^{st}$ female flowering ($D^1FF$) would lead to a significant increase in a number of fruits per plant (NoF/P), fruits yield/plant (FYP), TSS percentage and average fruit weight (FW) in both locations. On the other hand, positive and significant associations of vine length (VL) with fruits yield/plant (FYP, 0.66 and 0.59), average fruit weight (FW, 0.55 and 0.54) and fruit length (FL, 0.62 and 0.62) were detected. However, fruit length showed negative and significant phenotypic and genotypic correlations with fruit diameter (FD, -0.82 and -0.83 in phenotypic level) and (-0.84 and -0.84 in genotypic level) in $1^{st}$ and $2^{nd}$ localities, respectively. A positive and significant correlation between a number of fruits per plant (NoF/P) and fruit yield per plant (FYP) was also noted at phenotypic and genotypic levels (0.54 and 0.73) in the $1^{st}$ location and (0.74 and 0.77) in the $2^{nd}$ location indicating that these two traits are directly correlated. Also, this trait showed positive and significant phenotypic and genotypic correlations with fruit length (FL) in both phenotypic (0.60 and 0.59) and genotypic (0.63 and 0.61) levels in $1^{st}$ and $2^{nd}$ localities, respectively. In case of number of fruits (NoF/P), as abovementioned results, a negative and significant correlation existed between fruit length (FL) and fruit diameter (FD) at both levels which clearly indicated that increase in number of fruits (NoF/P) would provide more fruit length (FL) which would ultimately affects the fruit shape (FshI).

**Table 2: Phenotypic (Upper) and genotypic (below) correlations of the studied traits in both 1st and 2nd locations over the two years**

| Studied traits | VLcm | FDcm | D1MF | D1FF | NoF/P | FYPkg | TSS | WFg | FLcm |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | **1st location** | | | | |
| **VLcm** | 1.000 | -0.300 | -0.438 | -0.343 | 0.453 | 0.507 | -0.113 | 0.55* | 0.616* |
| **FDcm** | -0.309 | 1.000 | 0.179 | 0.036 | -0.56* | -0.261 | 0.489 | 0.356 | -0.82** |
| **D1MF** | -0.468 | 0.185 | 1.000 | 0.93** | -0.66* | -0.64* | -0.56* | -0.458 | -0.271 |
| **D1FF** | -0.344 | 0.038 | 0.97** | 1.000 | -0.665** | -0.58* | -0.700** | -0.53* | -0.150 |
| **NoF/P** | 0.477 | -0.60* | -0.72** | -0.69** | 1.000 | 0.54* | 0.255 | 0.224 | 0.604* |
| **FYPkg** | 0.661* | -0.340 | -0.84** | -0.75** | 0.73** | 1.000 | 0.203 | 0.257 | 0.493 |
| **TSS** | -0.110 | 0.499 | -0.59* | -0.71** | 0.271 | 0.259 | 1.000 | 0.579 | -0.467 |
| **WFg** | 0.55* | 0.360 | -0.480 | -0.540* | 0.235 | 0.332 | 0.582 | 1.000 | -0.045 |
| **FLcm** | 0.62* | -0.84** | -0.290 | -0.150 | 0.628* | 0.676 | -0.470 | -0.046 | 1.000 |
| | | | | | **2nd location** | | | | |
| **VLcm** | 1.000 | -0.310 | -0.440 | -0.330 | 0.400 | 0.580* | -0.130 | 0.540* | 0.62* |
| **FDcm** | -0.310 | 1.000 | 0.180 | 0.040 | -0.580* | -0.350 | 0.490 | 0.360 | -0.83** |
| **D1MF** | -0.440 | 0.180 | 1.000 | 0.96** | -0.75** | -0.73** | -0.59* | -0.480 | -0.270 |
| **D1FF** | -0.330 | 0.040 | 0.96** | 1.000 | -0.73** | -0.67** | -0.70** | -0.54* | -0.150 |
| **NoF/P** | 0.420 | -0.60* | -0.77** | -0.75** | 1.000 | 0.740* | 0.280 | 0.170 | 0.59* |
| **FYPkg** | 0.59* | -0.360 | -0.74** | -0.68** | 0.77** | 1.000 | 0.330 | 0.320 | 0.520 |
| **TSS** | -0.130 | 0.490 | -0.590* | -0.70** | 0.280 | 0.340 | 1.000 | 0.580 | -0.470 |
| **WFg** | 0.540* | 0.360 | -0.480 | -0.54* | 0.180 | 0.330 | 0.580 | 1.000 | -0.050 |
| **FLcm** | 0.620* | -0.84** | -0.270 | -0.150 | 0.610* | 0.520 | -0.470 | -0.050 | 1.000 |

*,** Significant and highly significant at 0.05 and 0.01% probability levels, respectively.

**Path coefficient analysis:**

The phenotypic and genetic association between yield and its components was divided into direct and indirect effects (Table 3 and 4 and Figs. 1-3) to find out the specific factor responsible for this association. VL used a direct positive genotype effect (0.8386, L1, 0.9372, L2) on crop/plant as well as indirect negative effects via FD, NoF/P, WF and TSS. FD showed a direct positive effect (0.5475, L1, 0.0018, L2) on yield/plant. It also showed indirect negative effects across VL, FL and WF. Fruit length (FL) affected a direct positive effect (1.9667, L1, 0.8411, L2) on yield/plant and also showed indirect negative effects via FD, NF and TSS. NoF/P applied a direct negative effect -0.8201, L1 and -0.3893, L2) on yield/plant and also showed indirect positive effects via VL, fruit length (FL) and TSS (Table 3). On the other hand, fruit weight (FW) showed a significant negative genotypic effect (-1.1431, L1, -0.941, L2) on yield/plant under Dumah Al-Jandal (L1) and Rafha (L2) site conditions, respectively. It also showed indirect positive effects through TSS and VL in L1 and L2 as well as FD in L1 and a negligible value in L2, in addition to slight indirect negative effects through other traits corresponding to Dumah Al Jandal (L1) and Rafha (L2) sites. TDS showed a direct positive effect (1.8899, L1, 1.511, L2) on yield/plant and also showed indirect negative effects via VL, FL, NoF/P and WF at both sites. Figure 3 shows the relative importance (R%) according to the fruit yield /plant path analysis and its attributed traits in summer squash under Dumah Al-Jandal (L1) and Rafha (L2) site conditions. that the bulk of the yield/plant variance was explained by the direct effect of TSS (20%) followed by WF (7.8%), VL (7.7%) and FL (6.2%) in Rafha and FL (13.8%) followed by TSS (12.8%) ), WF (4.7%), VL (2.5%) and NoF/P (2.4%) at Dumah Al-Jandal site. The valuable contributions of these traits to the yield/plant prove their size as selection criteria in a squash breeding program. However, other traits recorded small or negligible direct effects on fruit yield. Regarding the relative importance of joint effects (Fig.3), it is obvious that their effective parts were obtained by FL on yield/plant through its associations with TSS (12.5 and 10.5%) followed by WF *via* TSS (9 and 14.5%) and VL *via* FL (7.3 and 8.6%) at Dumah Al-Jandal (L1) and Rafha (L2) locations, respectively and FL *via* NF (7.3%), FD *via* FL (6.5%), VL *via* WF (3.8%), FD *via* TSS (3.7%), NF *via* TSS (3%), VL *via* NF (2.3%), FD *via* both NF (1.9%) and WF (1.6%), NF *via* WF (1.6%), VL *via* both TSS (1.2%) and FD (1%) and FL *via* WF (0.7%) at Dumah Al-Jandal (L1). As for Rafha (L2) location, the effective parts of the relative importance of joint effects (next to the above) were obtained by VL *via* WF (8.3%), FL *via* NF (3.5%), VL *via* TSS (3.2%), NF *via* TSS (2.9%), VL *via* NF (2.7%), NF *via* WF (1.2%) and FL *via* WF (0.7%). The highest value of the indirect effects was recorded by WF *via* TSS (14.5 and 12.5%) at L2 and L1, respectively. Small values of relative importance ranging from 0.0 (L2) to <0.7 % (L1) were obtained by the other direct and indirect effects.

## DISCUSSION

For the 2019 and 2020 growing summer seasons, 14 studied genotypes of summer squash (Cucurbita pepo) were evaluated in two environmental experiments (Dumah Al-Jandal, L1 and Rafha, L2) for some traits of

**Table 3: Path coefficient analysis of fruit yield *vs* vine length (VL, cm), fruit diameter (FD, cm), fruit length (FL, cm), 4) the number of fruits per plant (NF), average fruit weight (WF, g), total soluble solids percentage (% TSS) in 1st and 2nd locations spaces.**

| Pathways of association | | Phenotypic | | Genotypic | |
|---|---|---|---|---|---|
| **FYP *vs.* VLcm** | | **1st Location** | **2nd Location** | **1st Location** | **2nd Location** |
| Direct effect | P17 | 0.6192 | 0.8805 | 0.8386 | 0.9372 |
| Indirect effect *via* FD | P27*r12 | -0.1022 | -0.0231 | -0.1692 | -0.0006 |
| Indirect effect *via* FL | p37*r13 | 0.6457 | 0.5071 | 1.2193 | 0.5215 |
| Indirect effect *via* NF | p47*r14 | -0.1355 | -0.1157 | -0.3912 | -0.1635 |
| Indirect effect *via* WF | p57*r15 | -0.3970 | -0.4873 | -0.6287 | -0.5081 |
| Indirect effect *via* TSS | p67*r16 | -0.1232 | -0.1816 | -0.2079 | -0.1964 |
| Total | r | 0.5070 | 0.5800 | 0.6610 | 0.5900 |
| **FYP *vs.* FDcm** | | | | | |
| Direct effect | P27 | 0.3407 | 0.0745 | 0.5475 | 0.0018 |
| Indirect effect *via* VL | p17*r12 | -0.1858 | -0.2730 | -0.2591 | -0.2905 |
| Indirect effect *via* FL | p37*r23 | -0.8595 | -0.6789 | -1.6520 | -0.7065 |
| Indirect effect *via* NF | p47*r24 | 0.1675 | 0.1678 | 0.4921 | 0.2336 |
| Indirect effect *via* WF | p57*r25 | -0.2570 | -0.3249 | -0.4115 | -0.3388 |
| Indirect effect *via* TSS | p67*r26 | 0.5331 | 0.6844 | 0.9431 | 0.7404 |
| Total | r | -0.2610 | -0.3500 | -0.3400 | -0.3600 |
| **FYP *vs.* FLcm** | | | | | |
| Direct effect | P37 | 1.0482 | 0.8180 | 1.9667 | 0.8411 |
| Indirect effect *via* VL | P17*r13 | 0.3815 | 0.5459 | 0.5199 | 0.5810 |
| Indirect effect *via* FD | p27*r23 | -0.2794 | -0.0619 | -0.4599 | -0.0015 |
| Indirect effect *via* NF | p47*r34 | -0.1806 | -0.1707 | -0.5151 | -0.2375 |
| Indirect effect *via* WF | p57*r35 | 0.0325 | 0.0451 | 0.0526 | 0.0470 |
| Indirect effect *via* TSS | p67*r36 | -0.5091 | -0.6565 | -0.8883 | -0.7102 |
| Total | r | 0.4930 | 0.5200 | 0.6760 | 0.5200 |
| **FYP *vs.* NF** | | | | | |
| Direct effect | p47 | -0.2991 | -0.2893 | -0.8201 | -0.3893 |
| Indirect effect *via* VL | p17*r14 | 0.2805 | 0.3522 | 0.4000 | 0.3936 |
| Indirect effect *via* FD | p27*r24 | -0.1908 | -0.0432 | -0.3285 | -0.0011 |
| Indirect effect *via* FL | p37*r34 | 0.6331 | 0.4826 | 1.2351 | 0.5131 |
| Indirect effect *via* WF | p57*r45 | -0.1617 | -0.1534 | -0.2686 | -0.1694 |
| Indirect effect *via* TSS | p67*r46 | 0.2780 | 0.3911 | 0.5122 | 0.4231 |
| Total | r | 0.5400 | 0.7400 | 0.7300 | 0.7700 |
| **FYP *vs.* WFg** | | | | | |
| Direct effect | p57 | -0.7219 | -0.9024 | -1.1431 | -0.9410 |
| Indirect effect *via* VL | p17*r15 | 0.3406 | 0.4755 | 0.4612 | 0.5061 |
| Indirect effect *via* FD | p27*r25 | 0.1213 | 0.0268 | 0.1971 | 0.0006 |
| Indirect effect *via* FL | p37*r35 | -0.0472 | -0.0409 | -0.0905 | -0.0421 |
| Indirect effect *via* NF | p47*r45 | -0.0670 | -0.0492 | -0.1927 | -0.0701 |
| Indirect effect *via* TSS | p67*r56 | 0.6312 | 0.8101 | 1.0999 | 0.8764 |
| Total | r | 0.2570 | 0.3200 | 0.3320 | 0.3300 |
| **FYP *vs.* TSS** | | | | | |
| Direct effect | P67 | 1.0901 | 1.3967 | 1.8899 | 1.5110 |
| Indirect effect *via* VL | p17*r16 | -0.0700 | -0.1145 | -0.0922 | -0.1218 |
| Indirect effect *via* FD | p27*r26 | 0.1666 | 0.0365 | 0.2732 | 0.0009 |
| Indirect effect *via* FL | p37*r36 | -0.4895 | -0.3844 | -0.9243 | -0.3953 |
| Indirect effect *via* NF | p47*r46 | -0.0763 | -0.0810 | -0.2223 | -0.1090 |
| Indirect effect *via* WF | p57*r56 | -0.4180 | -0.5234 | -0.6653 | -0.5458 |
| Total | r | 0.2030 | 0.3300 | 0.2590 | 0.3400 |

**Table 4: Breakdown of phenotypic and genetic correlation coefficients into direct effects (main diagonal, bold) and indirect effects (upper and lower main diagonal) in fourteen imported squash genotypes**

| Item | | VL | FD | FL | NF | WF | TSS | Correlation |
|---|---|---|---|---|---|---|---|---|
| **Phenotypic level** | | | | | | | | |
| VL | L1 | 0.6192 | -0.1022 | 0.6457 | -0.1355 | -0.397 | -0.1232 | 0.507 |
| | L2 | 0.8805 | -0.0231 | 0.5071 | -0.1157 | -0.4873 | -0.1816 | 0.58 |
| FD | L1 | -0.1858 | 0.3407 | -0.8595 | 0.1675 | -0.257 | 0.5331 | -0.261 |
| | L2 | -0.273 | 0.0745 | -0.6789 | 0.1678 | -0.3249 | 0.6844 | -0.35 |
| FL | L1 | 0.3815 | -0.2794 | 1.0482 | -0.1806 | 0.0325 | -0.5091 | 0.493 |
| | L2 | 0.5459 | -0.0619 | 0.818 | -0.1707 | 0.0451 | -0.6565 | 0.52 |
| NF | L1 | 0.2805 | -0.1908 | 0.6331 | -0.2991 | -0.1617 | 0.278 | 0.54 |
| | L2 | 0.3522 | -0.0432 | 0.4826 | -0.2893 | -0.1534 | 0.3911 | 0.74 |
| WF | L1 | 0.3406 | 0.1213 | -0.0472 | -0.067 | -0.7219 | 0.6312 | 0.257 |
| | L2 | 0.4755 | 0.0268 | -0.0409 | -0.0492 | -0.9024 | 0.8101 | 0.32 |
| TSS | L1 | -0.07 | 0.1666 | -0.4895 | -0.0763 | -0.418 | 1.0901 | 0.203 |
| | L2 | -0.1145 | 0.0365 | -0.3844 | -0.081 | -0.5234 | 1.3967 | 0.33 |
| **Genotypic level** | | | | | | | | |
| VL | L1 | 0.8386 | -0.1692 | 1.2193 | -0.3912 | -0.6287 | -0.2079 | 0.661 |
| | L2 | 0.65 | 0.000 | -0.1991 | 0.341 | -0.1814 | -0.0205 | 0.59 |
| FD | L1 | -0.2591 | 0.5475 | -1.652 | 0.4921 | -0.4115 | 0.9431 | -0.34 |
| | L2 | 0.000 | 0.171 | 0.000 | -0.4871 | -0.121 | 0.0771 | -0.36 |
| FL | L1 | 0.5199 | -0.4599 | 1.9667 | -0.5151 | 0.0526 | -0.8883 | 0.676 |
| | L2 | 0.403 | 0.000 | -0.3211 | 0.4953 | 0.0168 | -0.074 | 0.52 |
| NF | L1 | 0.400 | -0.3285 | 1.2351 | -0.8201 | -0.2686 | 0.5122 | 0.73 |
| | L2 | 0.273 | -0.1026 | -0.1959 | 0.8119 | -0.0605 | 0.0441 | 0.77 |
| WF | L1 | 0.4612 | 0.1971 | -0.0905 | -0.1927 | -1.1431 | 1.0999 | 0.332 |
| | L2 | 0.351 | 0.0616 | 0.0161 | 0.1461 | -0.336 | 0.0913 | 0.33 |
| TSS | L1 | -0.0922 | 0.2732 | -0.9243 | -0.2223 | -0.6653 | 1.8899 | 0.259 |
| | L2 | -0.0845 | 0.0838 | 0.1509 | 0.2273 | -0.1949 | 0.1573 | 0.34 |

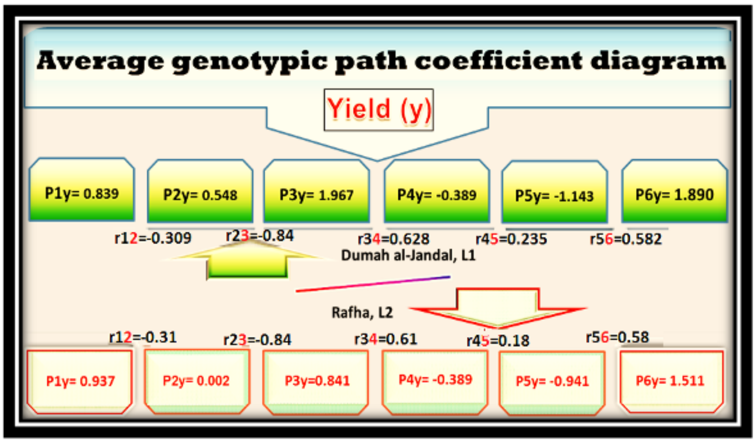


**Fig. 1: Genotypic path coefficient diagram representing cause and effect relationships among quantitative traits and yield of summer squash (*Cucurbita pepo*) genotypes. Here, Pij is the direct effects and rij are the correlation coefficients. (1: VL, 2: FD, 3:FL, 4: NoF/P, 5: FW and 6: TSS)**

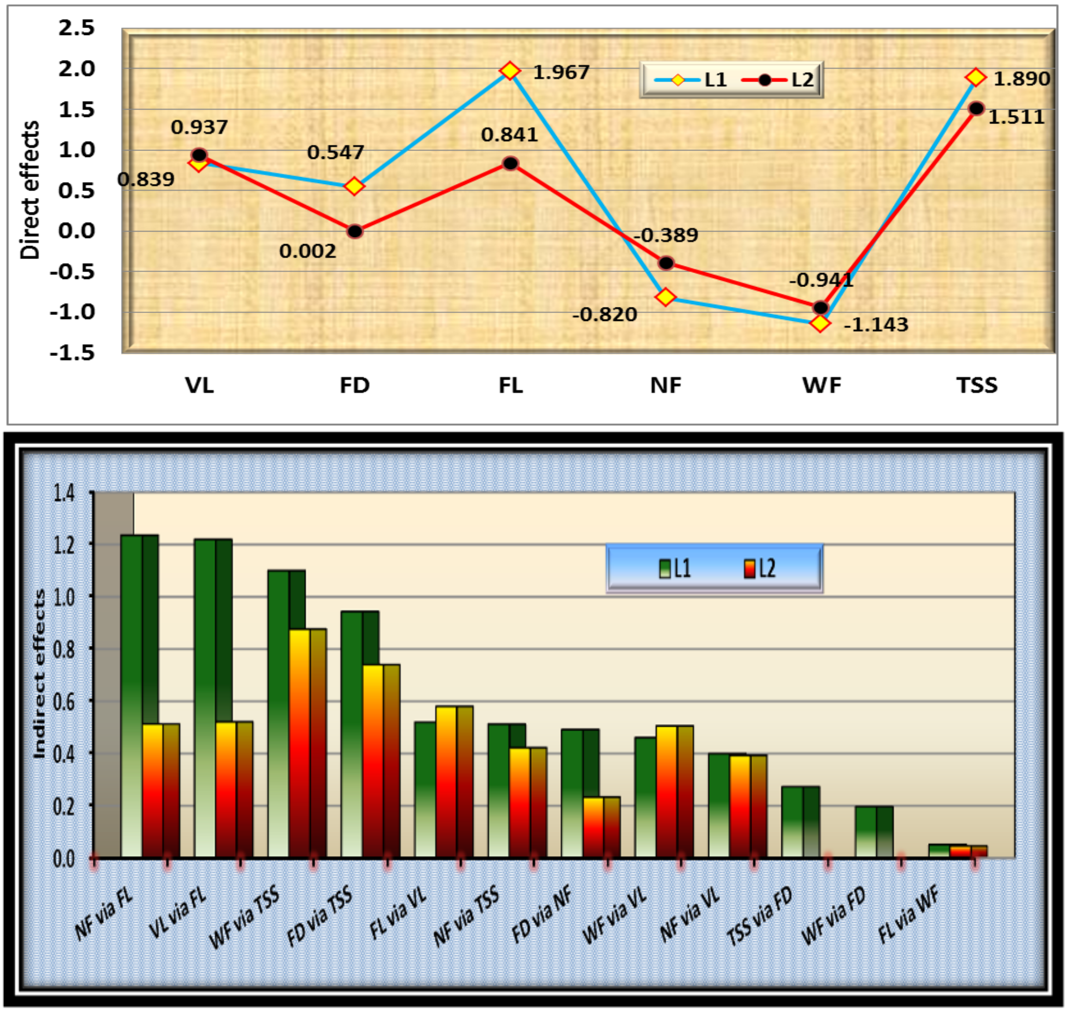


**Fig. 2: Direct (Up) and indirect (Down) Path coefficient among quantitative traits and yield of summer squash (*Cucurbita pepo*) genotypes**

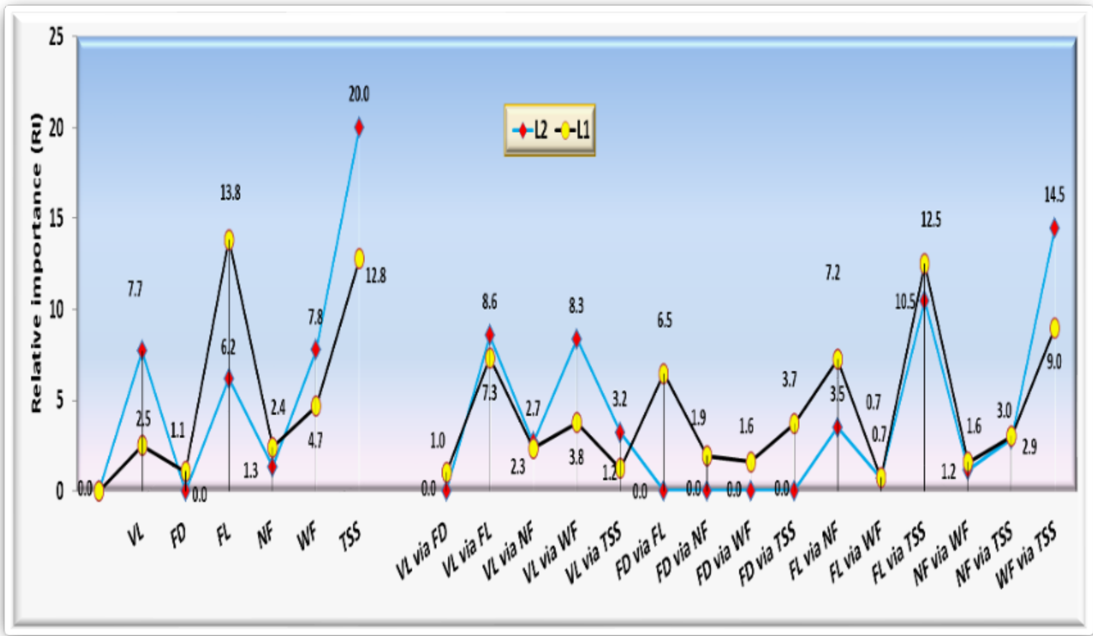


**Fig. 3: Relative importance (R%) according to path analysis of fruit yield/plant and its attributed traits in summer squash under Dumah Al-Jandal (L1) and Rafha (L2) locations**

vegetative growth, flowering, and yield (vine length, fruit diameter, days until the first male flower, days until the first female flower, number of fruits per plant, fruit yield, percentage of total soluble solids, average fruit weight, and fruit length) such as (Falconer and Mackay (1995). This study found a very modest association between average fruit weight and yield, suggesting that average fruit weight was influenced by the environment. Given that the number of fruits and fruit length are two key factors that contribute to the yield, the ultimate goal of boosting the yield per plant was accomplished. Thus, for effective yield improvement in squash selection, higher values of fruit number and fruit length should be made. Therefore, selecting the number of fruits, individually or simultaneously, should increase the productive capacity of genotypes. The results are generally consistent with those reported by Waleed and Al-Hamdani (2011). In summer squash, they found that there were significant, positive, phenotypic and genetic correlations between total yield, number of fruits/plant, and early yield. Analysis of the genetic path coefficient showed that the number of fruits/plant had a higher direct and indirect effect through other traits, and the weight of the fruit (g) can be arranged in the second level. In this regard, Dara et al. (2002) in pointed gourds, Blessing *et al*. (2012), Tamil *et al.* (2012), Abdein, *et al*., (2017) and Abdein (2018) found in gourds that days for the appearance of the first female flower, the weight of the fruit, and the number of nodes per plant. , vine length and the node at which the first flower appeared showed a negative correlation with yield/plant.

The picture was different in different environments as the total genetically direct effects increased from 37.3% (L1) to 39.% (L2) and the opposite trend was observed for the sum of indirect effects which increased in L1 (63.5%) than L2 (52.6%) as shown in Table 3 and Fig. 2 and 3. It is clear from the present work that the correlation analysis gave a different picture of the role of the number of fruits per plant, branches and fruit diameter in the fruit yield than that provided by the path coefficient analysis. Therefore, indirect selection through other constituent traits with these traits showing positive indirect effects can be recommended so as to cause improvement in yield. It can be seen that most of the direct effects were below the phenotypic level in L2 indicating that hypertrophy due to polylinearity was minimal phenotypically. In all, the studied traits accounted for 100.75 and 91.93% of the fruit yield/plant diversity in Dumah Al-Jandal (L1) and Rafha (L2) sites, respectively. The remaining content (-0.75 and 8.07%) could be attributed to unknown factors (random error) and/or some other trait that was not included in the current study.

Previous reports have provided evidence that the number of fruits or plants has a direct, favorable impact on yield/plant (Rani et al., 2008, Islam et al., 2010). The outcome was in line with Saleem *et al*. (2013) findings. In contrast to Ghosh *et al*. (2010) who observed a direct negative influence of plant height on yield/plant in tomatoes, Singh *et al*. (2006) and Haydar *et al*. (2007) obtained a positive direct effect of plant height on yield/plant. For increasing yield, direct selection of these qualities will work well. The previous researchers' and our findings shared certain parallels and variances that could be attributable to various rearing materials and environmental factors. This anomaly shows that a limited simultaneous selection model can be used to exclude undesirable indirect effects so that the direct effect can be used properly. The conclusion that can be drawn from the significant correlation and direct desired effect of VL, NoF/P, and fruit length on crop/plant is that these parameters can be considered when creating elite hybrids through heterosis breeding or when creating inbred progeny after pure line selection in the future. So these traits can be considered for selecting genotypes for yield improvement. Conversely, WF had a direct negative effect on yield at both sites (phenotypic level and/or genotype) as well as NoF/P (genetically in L1 and phenotype in both sites) and FL (genetically in L1).

## CONCLUSION

There is a wide range of phenotypic diversity for yield and quality traits among the genotypes. Almost all traits showed strong associations with other agronomic and yield traits. 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 program.

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## الإرتباط بين بعض صفات الكوسة تحت ظروف بيئية مختلفة

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تم تقييم أربعة عشرة تركيباً وراثياً من الكوسة فى بيئتين وأظهرت النتائج محل الدراسة على أن دراسات الإرتباط في التقديرات العامة لمعامل الإرتباط الوراثي كانت أعلى من معامل الإرتباط المظهري المقابل، مما يدل على وجود ارتباط قوي متأصل بين الصفات المختلفة قيد الدراسة. قد تكون القيم المظهرية المنخفضة بسبب التفاعلات البيئية. لوحظ وجود علاقة سلبية وهامة بين عدد الأيام وخروج أول زهرة مؤنثة بعدد الثمار، ومحصول النبات، و نسبة السكريات الكلية الذائبة ومتوسط وزن الثمرة في كلا الموقعين. من دراسة الإرتباط بين الصفات لوحظ وجود ارتباط ضعيف للغاية بين متوسط وزن الثمرة ومحصول النبات في هذه الدراسة ، مما يشير إلى أن البيئة لعبت دورًا في تحديد متوسط وزن الثمرة .كانت الصورة مختلفة في البيئات المختلفة حيث زاد إجمالي التأثيرات المباشرة وراثيًا من 37.3٪ (دومة الجندل) إلى 39.٪ (رفحاء) ولوحظ الاتجاه العكسي لمجموع التأثيرات غير المباشرة التي زادت في دومة الجندل (63.5٪) عن رفحاء (52.6٪). يتضح من العمل الحالي أن تحليل الإرتباط أعطى صورة مختلفة لدور عدد الثمار لكل نبات وفروع وقطر الثمرة في محصول الثمرة عن تلك التي قدمها تحليل معامل المسار. لذلك، يمكن التوصية بالانتخاب غير المباشر من خلال الصفات المكونة الأخرى مع هذه الصفات التي تظهر آثاراً إيجابية غير مباشرة وذلك لإحداث تحسن في المحصول. وإجمالا، شكلت الصفات المدروسة 100.75% من محصول الثمار في موقع دومة الجندل فى حين كان 91.93٪ فى رفحاء ويمكن إرجاع المحتوى المتبقي (-0.75 و 8.07٪) إلى عوامل غير معروفة (خطأ عشوائي) و / أو بعض الصفات الأخرى التي لم يتم تضمينها في الدراسة الحالية.