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# Genetic Variability and Heritability of Horticultural Traits, Impact on Susceptibility to Two Sap-Sucking Pests and Efficacy of *Beauveria Bassiana* and Lemongrass Oil as Biocontrol Agents in Six Inbred Lines of Summer Squash

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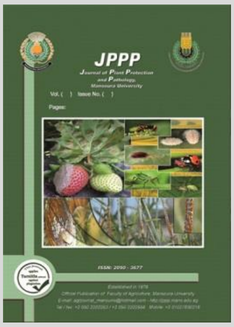


## ABSTRACT

Six inbred line of summer squash were cultivated in open field to deterred horticulture traits. Under unheated plastic house, the sensitivity of six inbred lines to the red spider mite *Tetranychus urticae* Koch and the white fly *Bemisia tabaci* (Gennadius) were evaluated in two successive seasons (2023 and 2024). Significant differences among inbred lines were observed in mean performance for all studied traits. High heritability was observed for all traits, viz., days to female flower anthesis DFF (80.45%), days to male flower anthesis DMF (89.20%), fruit weight FW (95.14%), fruit number/ plant FN (96.96%), fruit length FL (83.08%), fruit diameter FD (8.65%), early yield EY (91.02%) and total yield TY (97.93%). Inbred, 280/9 (P2) was the most resistant to the red spider mite, while inbred 270/5 (P3) was the highest resistant to the white fly in two growing seasons. When *Beauveria bassiana* fungi was used to control the red spider mite and whitefly, inbred line 240/3 (P5) showed the highest reduction rate at 88.05% and inbred line 270/5 (P3) also achieved significant control with a reduction rate of 83.50%, in red spider mite, for two seasons, respectively. *B. bassiana* fungi was the most effective in controlling whiteflies on inbred line 280/9 (P2), achieving reduction rates of 81.45% in 2023 and 73.26% in 2024. Similarly, lemongrass oil reduced red spider mite populations on inbred 222/2 (P1) by 90.44% in 2023 and 84.55% in 2024. Additionally, lemongrass oil reduced whitefly populations by 86.46% and 81.52% in 2023 and 2024, respectively.

***Keywords:*** Summer squash, Heritability, red spider mite, whitefly

## INTRODUCTION

Summer squash *(Cucurbita pepo* L.) is a prominent member of the Cucurbitaceae family, a group of important vegetables cultivated worldwide. In Egypt, summer squash reigns as one of the most popular choices among growers.

These delicious vegetables are actually the immature fruits of the Cucurbitaceae family. Renowned for their high content of carotenoids, antioxidants, and anti-inflammatory properties, summer squash fruits offer a range of health benefits. Studies have shown their potential in treating skin disorders, improving vision, and even aiding in weight loss due to their low-calorie count (Deppe, 2015; Burrows and Tyrl, 2013). Additionally, summer squash boasts the advantage of being fat- and cholesterol-free.

However, it's important to be aware that these beneficial plants also contain cucurmosin and cucurbitacin, which are both toxins.

Most breeding programs aim to produce new hybrids with better traits such as plant architecture, flower optimization, diversification fruit type, attractive fruit color and resistance to diseases. Before planning any breeding program, the assessment of genetic variability in germplasm and relationship between characters are necessary step. Genetic improvement for quantitative and qualitative traits depends on the nature and amount of variability present in the genetic stock, if desirable traits having high heritability more are the chances of improvement through selection (Bhagasara *et al*. 2017). Breeding for increase yields in summer squash has been one of the important objectives of many breeding programs since1900s.Yield of summer squash has also been improved by breeding for diseases resistance and increasing yield in summer squash cultivars has also been due to the improvement of qualitative traits such as gynoecious sex expression, improved fruit color and direct yield improvement through development of high yielding varieties or $F_1$ hybrids, so genetic improvement of different crops have very often been attempted with great success, particularly through a proper understanding of the mode of inheritance of economic traits. Moreover, it is important to have acknowledge of the genetic structure as the parental material at hand in order to plan a successful breeding program (Abd El-Hadi *et al*. 2020). In a study conducted by Singh (2012) on eight genotypes of zucchini, the researchers aimed to analyze the genetic variance of these genotypes. The study results revealed that the mean sum of squares due to genotype for all sixteen traits was highly significant. Across the sixteen economic traits examined, there were varying levels of phenotypic and genotypic variance, average fruit weight and yield per plant.

From germination to harvest, squash plants are plagued by severe infestations of various phytophagous pests. These pests, including the melon aphid (*Aphis gossypii* Glover), the cotton whitefly *Bemisia tabaci* (Gennadius)

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(Hemiptera: Aleyrodidae), the two-spotted spider mite *Tetranychus urticae* (Koch) (Acari: Tetranychidae), the onion thrips (*Thrips tabaci* Lind.), and the green leafhopper (*Empoasca decipiens* (Paoli), all cause extensive damage to the plants, primarily in Cucurbitaceae, Fabaceae, and Solanaceae (Oliveira *et al.* 2001). This damage goes beyond the sucking of plant juices, as these pests can also transmit phytopathogenic agents, resulting in a significant reduction in crop yield. **(Hegab, 2018; Saad, 2020).**

The spider mite, *T. urticae* and the whitefly, *B. tabaci*, are globally distributed pests that inflict significant economic damage on agricultural crops. These pests plague both field-grown and greenhouse-grown crops. The rapid growth rate and high reproductive potential of *T. urticae* allow it to quickly colonize crops (Farazmand and Amir-Maafi, 2018). These mites damage plants by using a stylet to pierce and feed on the contents of leaf mesophyll cells (Park and Lee, 2002).

Whiteflies cause direct and indirect threats to squash crops. These piercing -sucking insects cause direct damage by feeding on leaves and fruits, leaving behind small yellow spots. Additionally, they secrete a sugary substance called honeydew, which promotes the growth of sooty mold. This mold acts like a dark film on the leaves, blocking sunlight and hindering the plant's ability to photosynthesize (Solanki and Jha, 2018). But the real danger lies in their role as virus vectors. Whiteflies act indirectly as the primary carriers for several devastating viruses that plague squash crops. Two such examples are Cucurbit Leaf Crumple Virus (CuLCrV) and Cucurbit Yellow Stunting Disorder Virus (CYSDV). (BenMohamed *et al.* 2019; Momol *et al.* 2008).

The heavy reliance on chemical pesticides has created significant challenges. On one hand, it poses a significant threat to human health and the environment (Basit, 2019). On the other hand, pests are developing resistance at an alarming rate. Their rapid reproduction and short life cycles, combined with frequent exposure to pesticides, have led to the emergence of highly resistant strains (Wu *et al.* 2016).

The urgency to find safer and more sustainable pest control methods has led researchers to explore biological control agents. One particularly promising candidate is entomopathogenic fungi (EPF), which offer an ecological alternative to traditional chemical control methods (Vega, 2018). EPF are naturally occurring fungi that infect and kill insects and other arthropods. They are among the first organisms ever employed in biological pest management (Topuz *et al.* 2016). Notably, different isolates of *B. bassiana*, have proven effectiveness against sap-sucking insects (Hesketh *et al.* 2008).

Furthermore, essential oils (EOs) emerge as a promising eco-friendly alternative to traditional pesticides. Their role in Integrated Pest Management (IPM) and organic agriculture is increasingly recognized (Scheff and Phillips, 2022). EOs volatile nature makes them effective fumigants for enclosed spaces and stored goods, while their efficacy against pests in horticultural crops is well-documented. Many components of EOs, including monoterpenes and sesquiterpenes, directly harm various pests, (Devrnja *et al.* 2022).

IPM involves a coordinated use of multiple techniques to keep pest populations below their economic injury level (Radcliffe *et al.* 2008). A major principle of IPM is to promote a balance between pests with their natural enemies, resorting to pesticides only when absolutely necessary. Plant-derived products, especially essential oils (EOs), offer a promising alternative due to their biodegradable, widespread availability, low mammalian toxicity, and targeted efficacy without promoting pest resistance (Khater, 2012; Devrnja *et al.* 2022).

This study evaluated six inbred lines of summer squash under open field conditions, to measure certain horticultural traits. Additionally, we investigated the efficacy of *B. bassiana* as a representative entomopathogenic fungus and lemon grass essential oil against two key sucking pests of cucurbit crops: the whitefly, *B. tabaci*, and the spider mite, *T. urticae.* These pests co-exist on squash (*C. pepo L.*) under plastic greenhouse conditions.

## MATERIALS AND METHODS

This study was carried out at Kaha Research Farm, Kaliobia Governorate. The genetic materials used in the present investigation included six summer squash inbred lines belong to species *Cucurbita pepo*, L. Seeds of these inbred lines were developed by the first author. These inbred lines were named; 222/2 (P1) 280/9 (P2), 270/5 (P3), 264 (P4), 240/3 (P5) and 207/5(P6). In the summer season of 2022, seeds of the parental plants, six inbred lines were specifically chosen and cultivated within an unheated plastic greenhouse to maintain homozygosity and increase. Seeds of six inbred lines were planted in seedling trays beneath an unheated plastic house on February 15$^{th}$, 2023 and 2024. After 21 days, the plants were divided in two groups, the first group was used in the open field and the second one used in the green-house experiment.

**A- Experimental design:**

**1-Open field experiment:**

In the open field experiment, a randomized complete block design was employed with three replicates. Each plot was comprised of four rows, measuring one meter in width and four meters in length, with a spacing of 50 centimeters between them. All agricultural treatments were implemented in accordance with the recommendations of the Ministry of Agriculture in Egypt.

Data were recorded on 10 individual plants of each inbred line and measurements were as follows: days to female flower anthesis (DFF), days to male flower anthesis (DMF), fruit weight (FW)(g), fruits number/ plant (FN), fruit length (FL), fruit diameter (FD) (cm), early yield per plant (EY) (kg), and total yield per plant (TY) (kg).

**2-Plastic house experiment:**

Under unheated plastic house (9 m L x 59 m W x 4m H), the effect of entomopathogenic fungi *Beauveria bassiana* (Bals.) Vuill and essential plant oils lemon grass *Cymbopogoncitratus Stapf* (poaceae) were evaluated and compared against two major sucking pests of cucurbit crops (whitefly, *Bemisia tabaci*, and the spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae).

Seedling of the tested inbred lines transplanted under plastic house in complete randomized block design, divided into 3 sections (first section for the control, second treated with the entomopathogenic fungi *B. bassiana* and the third one treated with the lemon grass *C. Stapf* essential oil. Each section is completely isolated from the others using Plastic sheets. Six inbred lines were planted in each plot. Ten plants for each inbred line were planted and every single plant considered as a replicate. Plants were left for natural infestation.

Two weeks after transplanting squash seedlings into the greenhouse, the control section received water supplemented with 0.01% Tween 80, the second section was sprayed by 1x $10^8$ spores /ml of *B. bassiana*, while the third section sprayed by lemon grass essential-oil 15ml/L. 2 liters for each treatment was applied using a hand sprayer compressor machine. The spraying regimen consisted of three applications over eight weeks, repeated seasonally. The initial spray was administered following a pre-count sample, with subsequent applications occurring every two weeks (weeks three and five).

Ten leaves were picked up randomly from each plant and this process was repeated for each of these six parental genotypes, as replicates. Samples were kept in tightly closed paper bags and transferred to the laboratory at the same day. The total number of mobiles of *T. urticae* stages and of *B. tabaci* nymphs were counted within randomly selected two-square-inch areas on the lower leaf surface using a stereomicroscope. Samples were picked weekly.

Ten leaves were randomly collected from each plant and this process was repeated for each of the six parental genotypes. Each collection represented a replicate. Samples were stored in tightly sealed paper bags and transported to the laboratory on the same day. The total number of mobile *T. urticae* stages and *B. tabaci* nymphs were counted within randomly selected two-square-inch areas on the lower leaf surface using a stereomicroscope. Sampling occurred weekly.

**B- Production of entomopathogenic fungi conidiospores:**

Boiled rice was sterilized in a 500ml Erlenmeyer flask using an autoclave at 121°C for 20 minutes. After cooling at room temperature, the flasks were inoculated with 1ml of conidia suspension containing $10^8$ spores/ml. The inoculated flasks were then placed in the dark at 25±1°C for 2-3 weeks. Subsequently, the conidia were harvested by suspending them in a solution of 100ml distilled water and 0.01% Triton X-100. To establish the concentration of $10^8$ spores/ ml for field treatment, the total spores were quantified using a hemocytometer. (Gaber, 2016).

**C- Lemon grass extraction:**

The percentages of volatile oil were determined in the fresh herb using 100 g samples for each cut per plant. Distillation of the volatile oil was as described by Miller, (1963).

The volatile oil obtained from the fresh herb was analyzed using DsChrom 6200 Gas Chromatograph equipped with a flame ionization detector for separation of volatile oil constituents. The analysis conditions were as follows: -

The chromatograph apparatus was fitted with capillary column BPX-5, 5% phenyl (equiv.) polysillphenylene-siloxane 30m x 0.25mm ID x 0.25µm film. Temperature program ramp increase with a rate of 10º C / min from 70º to 200º C. Flow rates of gases were nitrogen at 1 ml / min, hydrogen at 30 ml / min and 330 ml /min for air.

Detector and injector temperatures were 300º C and 250º C, respectively. The obtained chromatogram and report of GC analysis for each sample were analyzed to calculate the percentage of main components of volatile oil.

**Report**

1-From the attached chromatogram, two main compounds were identified as shown from Table (1).

2-The relative percentages areas matched with those mentioned in the references.

3- The citral content (a+b) was 82.93572%.

4- The sample is considered as good sample.

**Table 1. Gass Chromatography analysis of Lemongrass volatile oil**

| CHROMATOGRM ANALYSIS | | |
|---|---|---|
| **PK.NO.** | **Compounds** | **%** |
| 1 | Myrcene | 3.71212 |
| 2 | Ocimene | 4.01410 |
| 3 | Limonene | 1.23386 |
| 4 | Unknown | 0.89820 |
| 5 | Linalool | 0.76067 |
| 6 | Geraniol | 2.69847 |
| 7 | Neral (Citral-b) | 38.57105 |
| 8 | Geranial (Citral-a) | 44.36467 |
| 9 | Geranyl acetate | 2.21649 |
| 10 | β-caryophyllene | 1.53037 |
| TOTAL | | 100.00 |

**D-Statistical analysis:**

The statistical analysis was carried out for each measured parameter using Mstat-C ver, 1 and MS-Excel. The mean values of treatments were subjected to analysis of variance (ANOVA) as described by Gomez and Gomez (1984) for Randomized Complete Block Design.

The phenotypic and genotypic coefficients of variability were calculated based on formula given by Burton and De-Vane (1953).

**- Phenotypic coefficient of variability (PCV):**

$$\mathbf{PCV}\ (\%) = \frac{\sqrt{\textbf{Phenotypic Variance (VP)}}}{\textbf{General men of population } (\bar{x})} \mathbf{X\ 100}$$

**-Genotypic coefficient of variability (GCV):**

$$\mathbf{GCV}\ (\%) = \frac{\sqrt{\textbf{Genotypic Variance (VP)}}}{\textbf{General men of population } (\bar{x})} \mathbf{X\ 100}$$

**Heritability (in broad sense):**

Heritability in broad sense was calculated by the formula as suggested by Allard (1960).

$$\mathbf{Heritability}(\%) = \frac{\textbf{Genotypic Variance (Vg)}}{\textbf{Phenotypic Variance (Vp)}} \mathbf{X100}$$

For studying the sensitivity and controlling the pests, the percentage of mortality was determined and corrected by Hendrson and Tilton (1955). Data were analyzed using two-way analysis of variance (ANOVA) and compared using LSD test by SAS statistical software. (SAS Institute, 2003).

## RESULTS AND DISCUSSION

**1.Open field experiment:**

**-Mean performance:**

Table (2 and 3) displays the data acquired from the evaluation of six inbred lines of summer squash of two years, specifically in 2023 and 2024. The results of this evaluation, along with their respective ranks, have been presented. Notably, significant differences were observed in all the studied characteristics during both years.

For DFF trait the inbreed lines values ranged from 26.3 (P2 280/9) to 32.3 days (P5 240/3) with mean 29.1 days in 2023 and the inbreed lines values ranged from 26.7(P2 280/9 and P6 207/5) to 31.7 days (P5 240/3) with mean 29.2 days in 2024.

For DMF trait the inbreed lines values ranged from 24.0 (P1 222/2) to 31.0 days (P4 264) with a mean of 28.2 days in 2023.Morover, the inbreed lines values ranged from

23.6 (P1 222/2) to30.6 days (P4 264) with a mean of 28.4 days in 2024.

Regarding FW the inbreed lines values ranged from 76.0 (P4 264) to 85.2 g (P1 222/2) with a mean of 75.0 g in 2023. Also, in 2024 the inbreed lines values ranged from73.5(P4 264) to87.7 g (P1 222/2) with a mean of 78.7 g.

For FN the inbreed lines values ranged from 8.0 (P6 207/5) to 12.0 (P4 264) with a mean of 10.0 in 2023. Meanwhile, in 2024 the inbreed lines values ranged from 7.9(P6 207/5) to12.5 (P4 264) with a mean of10.2.

Regarding FL trait the inbreed lines values ranged from 11.4 (P4 264) to 12.9 cm (P3 270/5) with a mean of 12.4 cm in the first season. Also, the inbreed lines values ranged from 11.2(P4 264) to 13.4 cm (P3 270/5) with a mean of 12.5 in the second season.

For FD the inbreed lines values ranged from 2.0 (P3 270/5) to 2.9 cm (P1 222/2 and) with a mean of 2.4 cm in 2023.In 2024 the inbreed lines values ranged from 2.2 (P2 280/9 and P3270/5) to 3.0 cm (P1 222/2 and P6 207/5) with mean 2.5 cm.

For EY the inbreed lines values ranged from 0.10 (P6 207/5) to 0.17 kg (P1 222/2) with a mean of 0.15 kg in first season. Also, the inbreed lines values ranged from 0.10 (P6 207/5) to0.19 kg (P1 222/2) with mean 0.15 kg.

Regarding TY the inbreed lines values ranged from 0.54 (P6 207/5) to 0.88 kg (P1 222/2) with a mean of 0.75kg in 2023. In 2024 the inbreed lines values ranged from 0.57 (P6 207/5) to 0.90 kg (P1 222/2) with a mean of 0.77 kg in 2024.

Similar to these results, the findings of Soliman (2022) and Hussein *et al.* (2013) who found significant differences between all inbred lines of summer squash Cucurbita pepo, L. under study traits i.e. days to female flowers, fruits length and diameter, fruit weight, number of fruit/plants and total yield / plant.

**Table 2. Mean performance of the six inbred lines of summer squash for days to female flower anthesis (DFF), days to male flower anthesis (DMF), fruit weight (FW)fruits number/ plant (FN), in open field in two seasons 2023 and 2024.**

| Inbred | DFF | | DMF | | FW (g) | | FN | |
|---|---|---|---|---|---|---|---|---|
| lines | 2023 | 2024 | 2023 | 2024 | 2023 | 2024 | 2023 | 2024 |
| 222/2 (P1) | 27.6 | 29.0 | 24.0 | 23.6 | 85.2 | 87.7 | 10.8 | 10.5 |
| 280/9 (P2) | 26.3 | 26.7 | 25.6 | 26.3 | 83.9 | 80.4 | 10.50 | 11.1 |
| 270/5 (P3) | 30.3 | 30.3 | 30.6 | 30.3 | 76.7 | 75.2 | 9.4 | 9.5 |
| 264 (P4) | 31.6 | 31.0 | 31.0 | 30.6 | 76.0 | 73.5 | 12.0 | 12.5 |
| 240/3 (P5) | 32.3 | 31.7 | 29.3 | 30.0 | 76.2 | 75.9 | 9.5 | 9.6 |
| 207/5(P6) | 26.6 | 26.7 | 29.0 | 29.6 | 76.3 | 79.3 | 8.0 | 7.9 |
| Mean | 29.1 | 29.2 | 28.2 | 28.4 | 79.0 | 78.7 | 10.0 | 10.2 |
| CD (0.05) | 1.5 | 1.6 | 2.0 | 1.7 | 3.0 | 2.0 | 0.76 | 0.50 |

**CD (0.05) = Critical difference at 5 per cent level of significance**

**Table 3. Mean performance of the six inbred lines of summer squash fruit length (FL), fruit diameter (FD), early yield per plant (EY) and total yield per plant (TY), in open field in two seasons 2023 and 2024.**

| Inbred | FL(cm) | | FD(cm) | | EY(kg)/plant | | TY(kg)/plant | |
|---|---|---|---|---|---|---|---|---|
| lines | 2023 | 2024 | 2023 | 2024 | 2023 | 2024 | 2023 | 2024 |
| 222/2 (P1) | 12.8 | 13.0 | 2.9 | 3.0 | 0.17 | 0.19 | 0.88 | 0.90 |
| 280/9 (P2) | 12.4 | 12.6 | 2.1 | 2.2 | 0.15 | 0.14 | 0.86 | 0.87 |
| 270/5 (P3) | 12.9 | 13.4 | 2.0 | 2.2 | 0.16 | 0.17 | 0.68 | 0.67 |
| 264 (P4) | 11.4 | 11.2 | 2.2 | 2.3 | 0.16 | 0.16 | 0.87 | 0.89 |
| 240/3 (P5) | 12.7 | 12.8 | 2.6 | 2.6 | 0.15 | 0.14 | 0.68 | 0.70 |
| 207/5(P6) | 12.2 | 12.2 | 2.8 | 3.0 | 0.10 | 0.10 | 0.54 | 0.57 |
| Mean | 12.4 | 12.5 | 2.4 | 2.5 | 0.15 | 0.15 | 0.75 | 0.77 |
| CD (0.05) | 0.64 | 0.60 | 0.20 | 0.70 | 0.01 | 0.01 | 0.01 | 0.01 |

**CD (0.05) = Critical difference at 5 per cent level of significance**

**- Parameters of variability**

**Coefficients of variability**

The achievement of genetic crop enhancement is reliant on the availability of various genetic resources (Arriel *et al.* 2007). The utilization of efficient evaluation techniques, like screening criteria, is vital in defining genetic resources for different traits. The data obtained on genetic diversity among the genotypes can assist in the selection process and provide breeding materials for high-yielding, superior genotypes that can optimize production. The current study revealed a significant level of variability in the traits under investigation. The variability observed across different genotypes in relation to various traits was influenced by both genotype and environment. Conversely, the variations caused by the environment were unavoidable. Consequently, this study employed genotypic and phenotypic coefficients of variation to determine the magnitude of genotypic and phenotypic variability, as presented in the accompanying table (4).

The analysis results showed that the phenotypic coefficient of variation (PCV) exceeded the genotypic coefficient of variation (GCV) for all traits investigated. The traits appeared to be largely unaffected by environmental factors, as evidenced by the small gap between PCV and GCV values. These findings imply that genetic factors may impact the expression of these traits, suggesting that selection based on phenotypic performance would be more successful.

A moderate genotypic and phenotypic coefficient of variation was exhibited by FN (18.37 % and 18.69 %), EY (18.95 % and 19.87 %) and TY (15.80 % and 16.05 %) In contrast, low GCV and PCV were observed for traits such as DFF (7.14 % and 7.96 %), DMF (9.71 % and 10.26 %), FW (6.38 % and 6.54%) and FL (5.89 % and 6.46 %).

These results are agreed with Singh (2023) who found moderate PCV and GCV for traits such as number of fruits per plant (22.16 % and 20.29 %) and yield per plant (28.91 % and 28.12 %).

A high PCV indicates the existence of a greater scope of selection for the trait being considered, which depends on the amount of variability present (Khan *et al*. 2010). On the other hand, a high GCV indicates the presence of exploitable genetic variability for the traits, which can facilitate selection (Yadav *et al*. 2009). Similarly moderate GCV and PCV for some important traits such as number of fruits per plant and yield per plant were noticed by Bartaula *et al*. (2019) in cucumber. The expression of these traits was found to be significantly influenced by the environment, indicating a greater role of the environment in shaping them. Consequently, hybridization followed by selection emerges as a powerful approach for enhancing these traits. Nevertheless, the disparities observed between the phenotypic and genotypic coefficients of variation were relatively minimal. The characters under investigation exhibited a lesser degree of susceptibility to environmental influences, thereby establishing the reliability of selecting individuals based on their phenotypic performance.

**Table 4. Variability parameters of the six parents of summer squash for yield and some fruit traits, in open field season 2024.**

| Characters | GCV (%) | PCV (%) | $h^2$ (%) |
|---|---|---|---|
| DFF | 7.14 | 7.96 | 80.45 |
| DMF | 9.71 | 10.28 | 89.20 |
| FW | 6.38 | 6.54 | 95.14 |
| FN | 18.37 | 18.69 | 96.96 |
| FL | 5.89 | 6.46 | 83.08 |
| FD | 14.80 | 15.65 | 89.65 |
| EY | 18.95 | 19.87 | 91.02 |
| TY | 15.80 | 16.05 | 97.93 |

**- Heritability**

Heritability, which quantifies the ratio of genotypic variance to phenotypic variance or total variance, is a vital measure in understanding character transmission across generations. It represents the heritable component of variance and plays a pivotal role in facilitating effective selection and crop improvement programs (Anandhi and Oommen, 2007). In our investigation, estimates of heritability (in the broad sense) revealed that the range of heritability varies from 80.45 to 97.93 percent. The heritability of different characters is presented in table 2. High heritability was observed for all traits under study, viz., DFF (80.45%), DMF (89.20%), FW (95.14%), FN (96.96%), FL (83.08%), FD (8.65%), EY (91.02%) and TY (97.93%).

The high value of heritability suggests the major role of the genetic constitution in the expression of traits, and such traits are considered to be reliable from a breeding point of view. In our study the all traits under study that exhibited high heritability estimates indicated that more additive genes were acting for these traits and that was less influenced by the environment. Considering the diverse nature of the material, the genotypes under investigation had a greater quantity of heritable variation and there is a possibility for improvement of these traits by selection. In addition, selecting the genotypes based on such traits could be worthwhile.

Similar to these results, the findings of Singh, (2023) who found high heritability was observed for all traits under study, viz., fruit weight (97.09 %), fruit length (94.89%), yield per plant (94.65 %), days to first female flower (87.63 %), fruit diameter (85.49 %), and number of fruits per plant (83.85 %).

**2. Green house experiment:**

**- Susceptibility of different squash varieties to infestation by two Sap-Sucking pests:**

**A. *Tetranychus urticae*:**

*T. urticae*, resistance was studied in two successive seasons, 2023 and 2024, in six parents genotype according to *T. urticae* abundance shown in Table (5), the parent 280/9 (P2) was the most resistance genotype with average number 10.87±0.64 and 12.57±0.69 mites per 2 inches$^2$ during two successive seasons 2023 and 2024, respectively. Followed by 222/2 (P1), 240/3 (P5), 270/5 (P3), 207/5 (P6) and 264 (P4) was the most susceptible genotypes with average number 31.09±0.77A and 32.61±0.77 mites per 2 inches$^2$ during 2023 and 2024, respectively. It was observed from our results that the infestation of *T. urticae* varied across the different squash varieties. These results were in agreement with those obtained by, **Abdallah *et al.* (2009)** indicated that the infestation by spider mite, *T. urticae* was significantly different among the three different squash cultivars. Eskandarani was the most susceptible harbored, While Hytech cultivar was intermediate and the lowest average number of spider mite infestations was recorded in case of American cultivar. Also, **Abdallah *et al.*(2018)** found that three squash cultivars, Mabroka, Brencessa, and Eskandarani, were susceptible to spider mite infestation in Balaktar and Om Saber villages, Behera Governorate. Mabroka was the most resistant and yielded higher than Eskandarani, while Brencessa had moderate spider mite numbers but higher yields. Eskandarani suffered the highest infestation, resulting in weak fruit yield.

In addition to the results of Abou-Zaid *et al.* (2019) who reported that Andro 174 variety was the most susceptible, while Sama 740 and Arkam were the most tolerant varieties during the investigated period. In addition, Rasha *et al.* (2020) studied the infestation levels of *T. urticae* on three squash varieties over two successive seasons, 2017 and 2018. Eskandarian, variety displayed the highest susceptibility to infestation, while Hytech and Milet verities showed moderate and low levels of infestation, respectively.

Moreover, Ullah *et al.* (2006), Tested forty-three cucumber (*Cucumis sativus* L.) accessions (cultivars and lines) against *T. urticae*. The highest number of *T. urticae* eggs /female/ day (5.98) was recorded on the cucumber genotype Blackish Green, while the lowest (2.95) was recorded on Winter Long Green (WLG) for *T. urticae*. On a scale of 1 to 5, the highest visual damage rating was recorded on Blackish Green (4.75 for *T. urticae*) and the lowest damages rating of 1.50 were recorded on WLG for *T. urticae*. Blackish Green was found to be a susceptible cultivar and Winter Long Green proved to be a resistant one. Among the Korean cucumber lines, K-4, K-6, and K-20 were found susceptible while K-1, K-2, K13, and K-15 exhibited some type of resistance to the two mite species.

**B. *Bemisia tabaci*:**

The resistance of previous six parental genotypes to *B. tabaci* was assessed over two consecutive seasons, 2023 and

2024. As shown in Table 5, genotype 270/5 (P3) exhibited the highest resistance, with average *B. tabaci* nymph counts of 6.33 ± 0.70 and 8.24 ± 0.61 per 2 square inches in 2023 and 2024, respectively. In contrast, genotypes 207/5 (P6), 222/2 (P1), 240/3 (P5), 280/9 (P2), and 264 (P4) were the most susceptible, with average nymph counts ranging from 18.00 ± 1.39 to 19.71 ± 1.25 per 2 square inches during the same period. Our findings indicate that *B. tabaci* infestation levels varied significantly among the different squash varieties.

These results align with those of Abou El-Saad *et al*. (2020), who reported average *B. tabaci* populations on squash plantations during the 2018 and 2019 growing seasons. Peak infestation occurred in the second and third weeks of April, with a monthly high of 529.67 individuals. Hegab (2018) investigated the susceptibility of various squash varieties to *B. tabaci* under field conditions at the experimental farm of faculty of agriculture, zagazig university and found Aziad hybrid to be the least susceptible, with mean populations of 84.282 and 102.026 individuals per sample in 2016 and 2017, respectively. In contrast, Daphne hybrid was the most susceptible. These findings emphasize the importance of resistant varieties in integrated pest management programs to control *B. tabaci* populations. Our results are consistent with those of El-Mesawy (2018), who reported higher *B. tabaci* populations on squash compared to cotton aphid. Additionally, El-Naggar *et al*. (2014) observed significant differences in aphid and *B. tabaci* populations across various cucurbit crops.

**Table 5. Average numbers (±SE) of *Tetranychus urticae* Koch movable stages and *Bemisia tabaci* nymph infesting tested squash and susceptibility degrees appeared by squash cultivars during 2023 and 2024 growing seasons.**

| | ***Tetranychus urticae* Koch** | | | | ***Bemisia tabaci*** | | |
|---|---|---|---|---|---|---|---|
| | **2023** | **2024** | | | **2023** | **2024** | |
| **Genotypes** | **Mean ± SE** | **Mean ± SE** | **Resistance Rank** | **Genotypes** | **Mean ± SE** | **Mean ± SE** | **Resistance Rank** |
| 222/2 (P1) | 14.28±0.54 | 15.79±0.58 | 2 | 222/2 (P1) | 10.7±1.08b | 12.23±1.06 | 3 |
| 280/9 (P2) | 10.87±0.64 | 12.57±0.69 | 1 | 280/9 (P2) | 17.21±1.60 | 19.51±1.50 | 5 |
| 270/5 (P3) | 18.96±0.36 | 20.29±0.36 | 4 | 270/5 (P3) | 6.33±0.70 | 8.24±0.61 | 1 |
| 264 (P4) | 31.09±0.77 | 32.61±0.77 | 6 | 264 (P4) | 18.00±1.39 | 19.71±1.25 | 6 |
| 240/3 (P5) | 15.90±1.10 | 17.63±1.09 | 3 | 240/3 (P5) | 12.06±2.53 | 14.07±2.29 | 4 |
| 207/5(P6) | 22.59±0.99 | 24.17±0.95 | 5 | 207/5(P6) | 9.76±1.83 | 12.04±1.48 | 2 |
| L.S.D | 2.2241 | 2.2317 | | L.S.D | 4.6651 | 4.181 | |

**SE= standard error.**

Results in Table (6) shows the percentage reduction of *T. urticae* populations after treated with *B. bassaina* ($1x10^8$ spores/ml).

Genotypes 240/3 (P5) and 270/5 (P3) exhibited the highest reduction rates, at 88.05 ± 3.35% and 83.50 ± 1.39%, respectively, across the 2023 and 2024 seasons. Conversely, genotypes 222/2 (P1) and 207/5 (P6) showed the lowest reduction rates, with values of 77.99 ± 2.09% and 74.03 ± 4.27%, respectively. The percentage reduction among the remaining genotypes fell within this range (77.99-88.04% and 74.03-83.5%).

**Table 6. Reduction percentage in the population of *T. urticae* after treated with *B. bassaina* during 2023 and 2024 growing seasons.**

| | **Reduction % of *T. urticae* treated by *B. bassaina*** | |
|---|---|---|
| | **2023** | **2024** |
| **Genotypes** | **Mean ± SE** | **Mean ± SE** |
| 222/2 (P1) | 77.99±2.09 | 77.21±1.71 |
| 280/9 (P2) | 84.51±1.65 | 81.75±1.44 |
| 270/5 (P3) | 88.04±2.21 | 83.50±1.39 |
| 264 (P4) | 86.46±2.06 | 79.90±1.74 |
| 240/3 (P5) | 88.05±3.35 | 81.58±1.66 |
| 207/5(P6) | 81.11±4.55 | 74.03±4.27 |

**SE= standard error**

The highest percentage reduction of *B. tabaci* populations after treated with *B. bassaina* was observed in genotype 280/9 (P2), with values of 81.45 ± 2.57% and 72.36 ± 1.27% in 2023 and 2024, respectively. In contrast, genotype 222/2 (P1) showed the lowest reduction, with percentages of 57.31 ± 6.83% and 44.61 ± 5.87% in the same years. The reduction percentages for the remaining genotypes fell between these extremes (81.45-57.31% and 72.36-44.61%), as shown in Table (7).

The results demonstrate the effectiveness of EPF in controlling *T. urticae* and *B. tabaci*. These findings align with Chouikhi *et al*. (2022) who reported significant efficacy of *B. bassiana* and *Lecanicillium muscarium* against both pests. These fungi effectively reduced *B. tabaci* eggs by 42.65-58.52% and larvae by 55.52-65.04%, respectively. Furthermore, they exhibited exceptional control of *T. urticae* eggs and mobile forms, with reduction rates exceeding 92.86% and 95.11%, respectively.

**Table 7. Reduction percentage in the population of *B. tabaci* after treated with *B. bassaina* during 2023 and 2024 growing seasons.**

| | **Reduction %of *B. tabaci* treated by *B. bassaina*** | |
|---|---|---|
| | **2023** | **2024** |
| **Genotypes** | **Mean ± SE** | **Mean ± SE** |
| 222/2 (P1) | 57.31±6.83 | 44.61±5.87 |
| 280/9 (P2) | 81.45±2.57 | 72.36±1.27 |
| 270/5 (P3) | 62.26±1.09 | 47.95±2.96 |
| 264 (P4) | 69.76±2.14 | 68.10±1.34 |
| 240/3 (P5) | 75.40±2.15 | 67.45±4.29 |
| 207/5(P6) | 74.91±1.33 | 59.21±2.87 |
| L.S.D | 9.4691 | 10.019 |

**SE= standard error**

Yanar *et al*. (2018) identified three *B. bassiana* isolates (F-12, F-53, and F-56) effective against *T. urticae* adult females. Mortality and fungal infection increased with higher spore concentrations. Isolate F-53 achieved 43.3-83% mortality within 72 hours at $1x10^8$ conidia/ml. These findings support the potential of *B. bassiana* as a *T. urticae* control agent.

Al Khoury *et al*. (2020) reported high mortality rates for *T. urticae* eggs, mobile forms, and adults following *B. bassiana* application. However, the fungus also reduced adult fecundity. Wu *et al.* (2020) confirmed these findings, demonstrating a decline in *T. urticae* populations on bean plants treated with *B. bassiana*. Espinosa *et al.* (2019) evaluated the efficacy of different fungal isolates against *B.*

*tabaci* eggs and nymphs. *B. bassiana* isolate JAB07 and *L. muscarium* isolate LCMAP3790 exhibited the highest nymph mortality rates, exceeding 96%.

Numerous studies have highlighted the efficacy of (EPF) in controlling whiteflies. For instance, Keerio *et al.* (2020) found that *B. bassiana* and *L. lecanii* strains caused significant *B. tabaci* mortality after 12 days. Similarly, Wari *et al*. (2020) observed a substantial reduction in *B. tabaci* populations following *B. bassiana* application in greenhouses. Sain *et al.* (2021) reported high larval mortality of *B. tabaci* using *B. bassiana* and *M. anisopliae* in greenhouse conditions. Assadi *et al.* (2021) demonstrated the effectiveness of *B. bassiana* and *L. muscarium* against all *B. tabaci* life stages in controlled environments.

Moreover, Table (8) percentage reduction in *T. urticae* populations after treated with lemon grass oils (15ml/L). Genotype 222/2 (P1) exhibited the highest reduction, reaching 90.44 ± 2.86% and 84.55 ± 1.47% in 2023 and 2024, respectively. Conversely, genotype 280/9 (P2) showed the lowest reduction, with values of 54.02 ± 7.17% and 63.43 ± 4.86% in the same years. The reduction percentages for the remaining genotypes ranged from 54.02% to 90.44% and 63.43% to 84.55% in 2023 and 2024, respectively.

**Table 8. Reduction percentage in the population of *T. urticae* after treated with essential plant oil lemon grass during 2023 and 2024 growing seasons.**

| Reduction % of *T. urticae* treated by plant oil lemon grass | | |
|---|---|---|
| | 2023 | 2024 |
| Genotypes | Mean ± SE | Mean ± SE |
| 222/2 (P1) | 90.44±2.86 | 84.55±1.47 |
| 280/9 (P2) | 54.02±7.17 | 63.43±4.86 |
| 270/5 (P3) | 88.53±2.04 | 83.48±1.66 |
| 264 (P4) | 81.58±0.67 | 75.11±0.75 |
| 240/3 (P5) | 79.59±7.35 | 74.93±4.68 |
| 207/5(P6) | 83.53±2.26 | 74.02±2.00 |
| L.S.D | 13.006 | 8.6834 |

SE= standard error

Table (9) presents the percentage reduction in *B. tabaci* populations following treatment with lemon grass oil (15 ml/L). Genotype 280/9 (P2) exhibited the highest reduction, with values of 86.46 ± 3.27% and 81.52 ± 2.04% in 2023 and 2024, respectively. In contrast, the lowest reduction was observed in genotype 222/2 (P1) at 68.36 ± 4.26% in 2023, and in genotype 207/5 (P6) at 61.02 ± 2.55% in 2024. The reduction percentages for the remaining genotypes ranged from 68.36% to 86.46% and 61.02% to 81.52% in 2023 and 2024, respectively.

**Table 9. Reduction percentage in the population of *B. tabaci* after treated with essential plant oils lemon grass during 2023 and 2024 growing seasons.**

| Reduction % of *B. tabaci* treated by plant oil lemon grass | | |
|---|---|---|
| | 2023 | 2024 |
| Genotypes | Mean ± SE | Mean ± SE |
| 222/2 (P1) | 68.36±4.26 | 62.32±3.41 |
| 280/9 (P2) | 86.46±3.27 | 81.52±2.04 |
| 270/5 (P3) | 77.78±2.26 | 62.74±1.91 |
| 264 (P4) | 85.84±1.08 | 70.28±1.66 |
| 240/3 (P5) | 79.87±3.89 | 71.13±4.46 |
| 207/5(P6) | 78.88±1.41 | 61.02±2.55 |
| L.S.D | 8.4617 | 8.16 |

SE= standard error

Numerous studies have reported that plant extracts have shown promise as effective alternatives for controlling *T. urticae*. For instance, Dahroug *et al*. (2000) reported a camphor-olive oil mixture's high acaricidal activity against female *T. urticae* in lima bean fields. Similarly, EL-Zemity *et al.* (2009) evaluated various plant extracts, including Chenopodium, caraway, cinnamon, clove, eucalyptus, fennel, Geranium, garlic, lemon, matercary, peppermint, rosemary, and thyme essential oils, along with fourteen major monoterpenoids. Their findings revealed that these plant extracts exhibited high potency against *T. urticae*, with thymol, carvacrol, and cinnam aldehyde showing particularly strong effects after 24 hours. Furthermore, Wu *et al.* (2017) conducted experiments using essential oils derived from thyme against carmine spider squashs (*T. cinnabarinus*). The results demonstrated that the superior acaricidal activity of natural thyme oil compared to its individual components, with thymol identified as the most potent compound.

Aslan *et al*. (2004) found that essential oil vapors from Satureja hortensis, Ocimum basilicum, and Thymus vulgaris increased in toxicity against *T. urticae* and *B. tabaci* with higher doses and exposure times. However, *T. urticae* exhibited greater tolerance. These findings suggest the potential of these essential oils for managing both pests in greenhouse environments.

In addition, Hassan (2008) tested the effect of four oils against egg and adult stages of *T. urticae*, spearmint was the most effective tested oil against egg stage, followed by geranium, sweet basil and lemon grass. In case of adult stage, sweet basil and lemon grass were the most effective tested oils, followed by geranium and spearmint.

Mona *et al.* (2017) evaluated the efficacy of plant extracts and chemical insecticides against *B. tabaci* nymphs and *T. urticae* mobile stages at the Faculty of Moshothor Agricultural, Banha University under open field conditions during April of 2015 and 2016. Rosemary oil demonstrated the highest efficacy against *B. tabaci* nymphs, with a 100% reduction, followed closely by Final oil and Acetamiprid. Lemon oil was the most effective against *T. urticae* mobile stages, achieving a 99% reduction, followed by Imidacloprid and Rosemary oil. Statistical analysis revealed significant differences in the efficacy of treatments against both pests.

El-sayed *et al.* (2023) investigated the efficacy of plant extracts (camphor, menthol, thymol, and citric acid) against *T. urticae* in squash, comparing them to synthetic insecticides. Citric acid demonstrated the highest initial reduction rate (88.5%) in the winter, maintaining effectiveness over time. While synthetic insecticides showed slightly higher overall reduction, plant extracts offered a promising natural alternative.

## CONCLUSION

The study evaluated six inbred lines of summer squash over two years (2023 and 2024). Significant differences were found in all traits. Significant genetic variability was found in the traits studied, influenced by both genotype and environment. The study employed genotypic and phenotypic coefficients of variation (GCV and PCV) to determine variability. Traits showed higher PCV than GCV, indicating that environmental factors had a limited effect. Moderate GCV and PCV were observed for FN, EY, and TY, while low GCV and PCV were seen for DFF, DMF, FW, and FL. High heritability was noted for all traits, ranging from 80.45% to 97.93%. This suggests that these traits are primarily influenced by genetic factors, making selection based on phenotypic performance reliable.

The most resistant genotype to *T. urticae*, was 280/9 (P2), while 270/5 (P3) was highest resistant to the *B. tabaci*. Infestation levels varied across different genotypes. Genotypes 240/3 (P5) and 270/5 (P3) showed the highest reduction rates of *T. urticae* when treated with *B. bassiana.* Genotype 280/9 (P2) showed the highest reduction rates of *B. tabaci* when treated with *B. bassiana*. Similarly, when lemongrass oil was used, the reduction rate in the red spider mite was 90.44 % and 84.55 % for 222/2. (P1). And 86.46 % and 81.52 % for the white fly, in seasons (2023 and 2024), respectively.

These results highlight the potential for genetic selection in summer squash breeding programs to enhance resistance to pests and optimize yield. Entomopathogenic fungi and lemon grass, provide a viable and efficient method of managing *T. urticae* and *B. tabaci* under plastic house conditions.

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# التباين الوراثى والتوريث لبعض الصفات البستانية وحساسية الاصابة بنوعين من الحشرات الثاقبة الماصة وفاعلية فطر البوفاريا وزيت حشيشة الليمون كعوامل مكافحة حيوية فى ست سلالات من الكوسة


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## الملخص


تم تقييم ستة سلالات من الكوسة في تجربتين احداها فى الحقل المفتوح لتقييم اداء السلالات وتقدير بعض الصفات الوراثية واخري فى صوبة بلاستيكية غير مدفأ ة لتقييم مدى حساسية السلالات للعنكبوت الاحمر وايضا للذبابة البيضاء وتاثير الرش بفطر *B. bassiana* وزيت حشيشة الليمون خلال الموسمين الصيفيين المتتاليين 2023 و2024. وقد لوحظت فروق معنوية بين السلالات في متوسط الأداء لجميع الصفات المدروسة. في هذه الدراسة تجاوز معامل التباين المظهري **(PCV)** معامل التباين الوراثي **(GCV)** لجميع الصفات المدروسة. لوحظت نسبة توريث عالية لجميع الصفات قيد الدراسة، وهي عدد الايام اللازمة لتفتح اول زهرة مؤنثة (80.45% DFF، عدد الايام اللازمة لتفتح اول زهرة مذكرة (89.20% DMF، وزن الثمرة (95.14% FW، عدد الثمار (96.96% FN، طول الثمرةFL(83.08%) ، قطر الثمرة FD (8.65%)، المحصول المبكر EY (91.02%) والمحصول الكلى(97.93%).كما لوحظ إن الصنف **(**P2**)** 280/9 الأكثر مقاومة لاصابة بالعنكبوت الأحمر بينما كان الصنف **(**P3**)** 270/5 الأكثر مقاومة للذبابة البيضاء. باستخدام فطر *B. bassiana* لمقاومة العنكبوت الأحمر والذبابة البيضاء وصلت نسبة الخفض فى العنكبوت الأحمر الى 88.05% للصنف (P5) 240/3 و 83.50% للصنف (P3) 270/5**.** بينما نسبة الخفض فى تعداد الذبابة البيضاء وصلت %81.45 و73.26% للصنف (P2) 280/9. وعند استخدام زيت حشيشة الليمون وصلت نسبة الخفض فى العنكبوت الأحمر الى 90.44% و84.55 % للصنف (P1) 222/2**.** وبالنسبة للذبابة البيضاء كانت 86.46 % و 81.52% فى الموسمين 2023 و2024 على التوالى.