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RESEARCH ARTICLE

Gen action and heterosis for morphological traits related to heat stress tolerance in pea. – a review.

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Abstract

In tropical climes, the sensitivity of pea (*Pisum sativum* L.) to high temperatures as well as its underlying genotypic potential with regard to high-temperature ambient/tolerance at field scale remain unknown. The fraction of the hybrids' (F_1) means values that increase or decrease relative to those of their best and middle parents is known as heterosis. "Heterobeltiosis" is the term used to describe how an F1 hybrid has improved over its superior parent.
The selection of parental genotypes benefits from an understanding of general combining ability (GCA), specific combining ability (SCA), narrow-sense heritability (h2 n.s.), and broad-sense heritability (h2 b.s.). A significant improvement in salinity tolerance may be attainable through selection by the order of high heat stress tolerance values in the pea (*Pisum sativum* L.). The selection of parental genotypes benefits from an understanding of general combining ability (GCA), specific combining ability (SCA), narrow-sense heritability (h2 n.s.), and broad-sense heritability (h2 b.s.). The Pea (*Pisum sativum* L.) has high heritability values of the type that confer heat stress resistance, which suggests that a significant improvement in heat stress tolerance may be attainable by selection under conditions of intense selection pressure. *Pisum sativum* L. characteristics were mostly regulated by the additive and non-additive (dominance) gene activity under both normal conditions and heat stress.

Keywords: Heat stress: Heterosis; Heritability; Pea; *Pisum sativum* L.

1. Introduction

The pea (*Pisum sativum* L.), a self-pollinating crop with 14 chromosomes (2x=2n=14), is a diploid crop. one of the main vegetable crops grown for its green pods in temperate and subtropical regions of the world, belonging to the family fabaceae (*Leguminosae*). According to Jaiswal *et al.* (2015), it is the second most significant food legume in the world after Phaseolus vulgaris. Garden peas are grown on 2.3 million hectares of land worldwide, yielding 17.43 million metric tonnes (Anonymous, 2018). It is one of the most significant legume crops in Egypt and is farmed for both domestic and international markets as a vegetable crop for the green pod stage or for dried seeds (Elsaman, 2022). The total cultivated area of fresh pods pea crop in Egypt was estimated at 42142 feddan, yielded 183732 ton, with an average of 4.38 ton per feddan.

Peas are sensitive to drought and high temperatures (Ney *et al.*, 1994; Guilioni *et al.*, 1997); the most detrimental effect on younger reproductive growth flowers and pods developed later; and during flowering there was a differential impact on female and male reproductive organ viability leading to losing yield in field crops.

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Pea is sensitively to drought and high temperature (Ney *et al.,* 1994 and Guilioni *et al.,* 1997) and the most damaging effect on younger reproductive growth flowers and pods developed later (Jiang *et al.,* 2019 and Krishna Jagadish, 2020) and during flowering was differential impact on female and male reproductive organ viability leading to losing yield in field crops and Their yields are erratic from year to year, with significant economic impact on growers, processors and the pea industry (Dixit *et al.,* 2006 and Parihar *et al.,* 2022). The spring-habit pea, which typically plants earlier, has fewer reproductive nodes, and matures later than the winter-habit pea, is the only one used for pea production in the prairies (Annicchiarico & Iannucci, 2008). *Pisum sativum* L.'s productivity declines when the maximum ambient temperature during flowering is higher than 25 °C. The percentage difference between the mean value of the F_1 hybrids and the value of their mid parents is known as heterosis. Contrarily, heterosis is the proportional increase or reduction in the average F_1 hybrid value over the best parent. Khaled *et al.* (2020) and Elshazly *et al.* (2021).

2. Effect of Heat Stress

Throughout their life cycles, all crops are vulnerable to heat stress, but this is especially true of the reproductive stage (Zinn *et al.,* 2010; Vadez *et al.,* 2012). However, the severity, length of exposure, and rate of temperature change all have a role in how heat stress affects plants (Peet *et al.,* 1998; Sato *et al.,* 2002; Young *et al.,* 2004; Wahid *et al.,* 2007; Bueckert *et al.,* 2015). the 2-4 °C increase in average global temperature anticipated by the end of the twenty-first century (IPCC, 2013).

Additionally, the flowering to seed-filling stage of the pea plant shown to be sensitive to heat stress (Jeufroy *et al.,* 2010; Jiang *et al.,* 2019). According to earlier research (Guilioni *et al.,* 2003, Sadras *et al.,* 2012, and Bueckert *et al.,* 2015), a greater ambient temperature above the threshold limit might reduce crop biomass, blooming, and the number of pods/plant, which ultimately lowers agricultural yields. In tropical regions, there is still debate regarding the sensitivity of pea to high temperatures and its underlying genotypic potential with regard to high-temperature ambient/tolerance at field scale (Gaur *et al.,* 2019; Gowda *et al.,* 2009). The crop is frequently exposed to high ambient temperatures greater than 25 °C during blooming and the interval of grain filling, which is unique to pea growing regions in subtropical climates (Dixit *et al.,* 2006). It is alarming that in crop enhancement programmes, putative heat resistant lines are being strategically used for this delicate crop (Sita *et al.,* 2017; Gogoi *et al.,* 2018). To successfully select genotypes that are resistant to heat stress in vivo conditions, a straightforward screening strategy and well-defend characteristics are required (Devasirvatham *et al.,* 2013). In winter season legumes like chickpea and lentil, much research is being done to use and characterise the heat-sensitive/tolerant characteristics (Pareek *et al.,* 2019; Kumar *et al.,* 2020). In order to confirm the effect of high-temperature environments, genotypes, and genotype X interactions of environments on various plant traits, Parihar *et al.* (2022) studied those 150 different genotypes of pea that were tested under 3 different temperature environments and attempted to explain their significance in conditioning/tolerance to heat stress. Through the flowering stage, the delayed sowing exposed pea crops to high temperatures of +3.5 °C and +8.1 °C in the late sowing-I and late sowing-II, respectively. The maximum ambient temperature during the grain-filling period was also greater in the late sowing-I and late sowing-II compared to the regular sowing, by +3.3 °C and +6.1 °C, respectively.

In contrast to the regular sowing, the grain yield missed due to heat stress was 25.82.2% in late sowing-I and 59.31.5% in late sowing-II. According to the results, under normal conditions, plant biomass was largely responsible for yield potential, however under heat stress circumstances, a lower sink capacity pod/plant, seed/pod was the main reason of yield missing. The genotypes G-112, G-114, and G-33 were found by the GGE biplot to have a larger capacity to sustain yield together with greater stability across the environments and, as a result, should be used as a source for breeding heat-tolerant excessive producing cultivars.

3. Heterosis

Singh *et al.* (2007) exhibited that heterosis over best parent for all the characters under study. The results showed that 38 crosses for days to flowering, 39 hybrids for diameter of pod, 42 crosses for length of pod, 42 crosses for no. of branches/plant, 44 hybrids for no. of seed /pod, 40 crosses for no. of pod / plant, 27 crosses for yield per plant and 39 crosses for seed/shell ratio were significantly for best parent i.e heterobeltiosis. also, In line x tester fashion, Singh *et al.* (2013) calculated heterosis in the garden pea (*Pisum sativum* L.) using 19 parents for seed yield and its contributing qualities in 48 hybrids. Three testers and sixteen lines of parents were employed. To measure heterosis, the hybrids and their parents were examined. With 337.50 and 136 percent heterosis over the better parent and standard variety, respectively, EC322748 x Rachna among the hybrids has recorded the highest heterosis as well as good performance for grain yield, followed by EC-322748 x Pant P-5 with 300.0 and 116.22 percent heterosis over the better parent and standard check, respectively. In terms of plant height and productive branches per plant, these crosses were likewise discovered to be strong performers. In terms of plant height and productive branches per plant, these crosses were likewise discovered to be strong performers. High seed yield heterosis indicates the presence of economically exploitable heterosis of a scale that can significantly increase field pea productivity.

Kosev (2014). The F_1 generations of hybrids showed estimated heterosis for the examined characteristics. The cross (Rosacrono Pleven 4) had the highest positive heterosis for pod length (17.11%), plant height (31.54%), and height to first pod (15.44%), according to the data. The cross (Shtambovii Pleven 10) scored highest in terms of nods per plant (56.10) and pod diameter (20.38%). The hybrid between Pleven 4 and Rosacrono and Pleven 10 and Shtambovii for 1000 seed mass (14.6%) and number of seeds per pod.

The greatest F_1 hybrids are Entesar1 x Entesar2, Little Marvel Master, Master Little Marvel, and Entesar1 Little Marvel. The hybrids' mean performance, heterosis, and potency ratio results showed a positive and substantial correlation between pod yield per plant and plant height, pod width, number of pods per plant, and pod weight, according to Galal *et al.* (2019). However, the basis of heterosis estimated over superior parent and standard check (Palam Triloki) was explored by Katoch *et al.* (2019). The hybrid (line 17 x Palam Triloki) displayed the highest significant and negative heterosis over the best parent for the characters, including the node at which the first flower opens, the days until 50% of the flowers have opened, and the days until the first picking, with heterotic responses of -26.09%, 5.62%, -5.66, respectively. The hybrid (line 17 x Palam Triloki) showed the highest significant and negative heterosis over the best parent for the characters, namely the node at which the first flower appears, the days to 50% flowering, and the days to the first picking, with heterotic responses of -26.09%, 5.62%, and 5.66, respectively, and -5.61% and -5.66% over the standard check for 50% days to flowering and days to the first picking, respectively. For pod yield and related parameters like number of pods/plant, hybrids (line 17 x Arkel) showed the highest heterosis of 177.61% over superior parent and 145.37% above standard check.

4. Gene action

The genotypic coefficient of variation was determined by Fikreselassie (2012), and it varied from 11.19% for days to mature to 25.72% for the quantity of seeds per plant. Garden pea (*Pisum sativum* L.) 28 F1s produced by crossing 8 different genotypes were evaluated by Sharma and Sharma (2012) to determine the effects of genetic analysis on earliness and yield attributes. Highly significant differences between experimental genotypes were found by analysis of variance, showing that the parents of the investigated features were different. For the majority of qualities, overdominance was prevalent. For days up to 50% flowering, however, additive and dominant genetic variance were very significant. for plant-level production of green pods. Five pea cultivars (Master, Palmoral, Jaguar, Lincoln, and Little Marvel) were crossed in Galal *et al.* (2014) using a 5X5 diallel set. For all parameters under study, mean squares of the parents and crossings were very significant, indicating the presence of a sizable amount of genetic diversity among the genotypes. For all examined attributes, the general combining ability (GCA) and specific combining ability (SCA) mean squares were very significant. The best general combiner for all examined features, with the exception of pod length, was Palmoral (P2), followed by Jaguar (P3) and Master (P1). For all examined traits, the GCA was more than the SCA and the GCA/SCA variance ratio was greater than one, demonstrating the preponderance of additive gene effects. Field pea [*Pisum sativum* (L.) vararvense.] was researched by Dhaval *et al.* (2016) using a 10 × 10 half diallel to combine ability for yield and yield related parameters. Effects of high general combining ability linked to additive gene action and additive x additive interaction effects, which indicate the genetic component of variation that can be fixed. Mean squares of GCA and SCA for yield and its components were highly significant, according to Elsaman (2022), confirming the significance of all types of gene action in the inheritance of all traits. Additionally, it was discovered that for all traits, the GCA/SCA ratio exceeded unity. The findings showed that for days to blooming, plant height, and number of branches per plant, additive genetic variance (σ^2A) magnitudes were greater than non-additive ones (σ^2D). The findings showed that for all examined variables, the magnitudes of additive genetic variance (σ^2A) were greater than non-additive genetic variance (σ^2D). The outcomes demonstrated the significance of additive gene activity in the transmission of these traits. She recommended that under the circumstances of the Sohag governorate, a selection process could be employed to improve pea qualities.

5. Heritability

Mousa (2010) The ratio of additive genetic portion to the phenotypic genetic variance as indicated by heritability in narrow sense (T_n) was high and amounted to be 87.5% for pod length, 69.6% for number of seeds/pod, 67.2% for stem length and 65.7% for pod width. On the other hand, T_n values were moderate for number of pods/plant (56.2%), seed weight of 10-pods (48%), flowering date (42.1%) and pod yield (39.9%) (Mousa, 2010). However, the estimates of narrow sense heritability were low and valued 27.1% (shellout %), 31.8% (seed yield/plant) and 32.9% (100-seeds weight), hereby selection was difficult and should be delayed to later segregating generations. Also, the broad sense heritability was higher for all characters, the line regression between (W\Vr) cut the head line over the original point for all characters (Esho *et al.*, 2012).

According to Patel et al. (2017), the number of pods per plant and the number of seeds per plant both showed strong heritabilities together with substantial genetic advance, indicating the primacy of additive gene action in the expression of these traits. According to Elsaman (2022), the values of broad sense heritability were 98.89%, 99.54%, and 97.84% for the number of branches per plant, plant height, and days to flowering, respectively. For these variables, the narrow sense heritability was comparable to the broad sense heritability. While for the same qualities, the narrow sense estimates were 83.10, 80.13, and 85.27%, respectively. The range of broad sense heritability estimates was from 96.30% for 100 seeds to 99.89% for the weight of fresh pods per plant. In the same time, the estimates of narrow sense heritability ranged from 94.60% for 100- seeds weight to 91.83% for number of pods per plant.

6. Conclusion

Pisum sativum L. characteristics were mostly regulated by the additive and non-additive (dominance) gene activity under both normal conditions and heat stress. High heat stress tolerance heritability levels in the pea (*Pisum sativum* L.) nevertheless, fixed that a significant improvement in heat stress tolerance may be feasible by selection under high selection pressure.

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Data presented in this study are available on fair request from the respective author.
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The authors disclosed no conflict of interest.

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