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Heritability for Growth, Flowering, Fruit, Yield and Disease-Related Traits in Cucumber (*Cucumis sativus* L.)

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ABSTRACT

Heritability is an important genetic parameter for assessing the relative contribution of genetic and environmental factors to phenotypic variation and for understanding the potential usefulness of phenotypic selection in crop improvement. The present investigation was conducted to estimate and compare broad-sense heritability for growth, flowering, harvesting, fruit, yield and disease-related traits in cucumber (*Cucumis sativus* L.) during Kharif 2024 and Summer 2025 at the All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. The experimental material consisted of 11 inbred genotypes and 55 F1 hybrids generated through an 11 × 11 half-diallel mating design excluding reciprocals. The 55 crosses, 11 parents and one standard check, comprising 67 treatments, were evaluated in a randomized block design with two replications. Broad-sense heritability was estimated for 20 traits. Heritability estimates varied considerably among traits and seasons. During Kharif 2024, estimates ranged from 7% for number of branches per vine to 49% for number of nodes per vine, whereas during Summer 2025 they ranged from 14% for number of fruits per vine and yield per hectare to 57% for number of nodes per vine. Number of nodes per vine recorded the highest heritability in both seasons, with estimates of 49 and 57%, respectively. Fruit length also exhibited comparatively high heritability, with estimates of 46 and 52%. Flowering and earliness traits showed considerable seasonal variation, particularly days to first female flower appearance, days to 50% flowering and days to first fruit harvest. Yield traits exhibited relatively low heritability in both seasons, with estimates of 11 and 18% for yield per vine, 9 and 16% for yield per plot, and 9 and 14% for yield per hectare during Kharif and Summer, respectively. Among disease-related traits, powdery mildew showed 42% heritability during Kharif but only 18% during Summer. The results demonstrated strong trait- and environment-dependent variation in broad-sense heritability. Number of nodes per vine and fruit length showed comparatively greater and more consistent genetic contribution, whereas yield traits were strongly influenced by environmental variation. These findings emphasize the importance of multi-season evaluation and the combined use of heritability with other genetic parameters for effective cucumber improvement.

Keywords: Cucumber, *Cucumis sativus* L., Broad-sense heritability, Genetic variability, Fruit traits, Yield, Disease resistance, Selection

1. Introduction

Cucumber (*Cucumis sativus* L.) is an economically important vegetable crop belonging to the family Cucurbitaceae and is widely cultivated for fresh consumption and other uses. Productivity and market value of cucumber are determined by a complex combination of quantitative characters, including vine growth, branching, flowering behaviour, fruit number, fruit size, fruit weight and total yield. Resistance or tolerance to insect pests and diseases is also an important consideration in cucumber improvement programmes.

The observed phenotypic performance of a genotype is determined by its genetic constitution, environmental effects and their interaction. Consequently, phenotypic differences among genotypes do not necessarily represent differences of equivalent magnitude in their genetic constitution. Estimation of genetic parameters is therefore essential for developing appropriate breeding and selection strategies.

Heritability is one of the important genetic parameters used to estimate the proportion of phenotypic variation attributable to genetic differences within a particular population and environment. It may be expressed as broad-sense or narrow-sense heritability. Broad-sense heritability includes the effects of additive, dominance and epistatic genetic variance, whereas narrow-sense heritability primarily represents additive genetic variance. Broad-sense heritability is therefore useful for assessing the overall genetic contribution to pheno

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typic variation, particularly when diverse genetic materials including parents and hybrids are evaluated (Burton *et al.*, 1953) [1].

The usefulness of heritability for selection, however, depends on the magnitude and nature of genetic variation associated with the trait. Johnson *et al.*, (1955) [2] emphasized that heritability should be considered together with genetic advance and other measures of genetic variability when assessing the prospects of selection. Thus, a high heritability estimate by itself does not necessarily indicate high expected genetic gain because broad-sense heritability includes both additive and non-additive genetic components.

Several studies have demonstrated substantial variation in heritability among cucumber traits. Pushpalatha *et al.*, (2016) [3], while evaluating 24 diverse cucumber genotypes, reported high heritability coupled with high genetic advance for several growth and yield characters, whereas flowering and earliness traits showed different patterns of inheritance. Yadav *et al.*, (2009) [4] also reported considerable genetic variability and high broad-sense heritability for several characters in cucumber. Basavarajeshwari *et al.*, (2014) [5] reported high heritability accompanied by high genetic advance for number of fruits per vine and fruit yield per vine, while fruit length and flesh thickness showed different relationships between heritability and genetic advance.

Heritability is not an intrinsic and constant property of a trait. It depends upon the genetic material, population structure, experimental design and environmental conditions under which the material is evaluated. Therefore, comparison of heritability estimates across seasons can provide useful information about the relative stability of genetic expression of important traits.

The present investigation was therefore undertaken to estimate and compare broad-sense heritability for important growth, flowering, harvesting, fruit, yield and disease-related traits of cucumber during Kharif 2024 and Summer 2025.

Objective

The objective of the present study was to estimate and compare broad-sense heritability for 20 horticultural and disease-related traits in cucumber under Kharif and Summer growing conditions and to identify traits showing relatively greater and more consistent genetic contribution for use in future breeding programmes.

2. Materials and Methods

2.1 Experimental site

The investigation entitled “Genetic Studies in Cucumber (*Cucumis sativus* L.)” was conducted at the All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India, during Kharif 2024 and Summer 2025. The experimental site is situated at approximately 532 m above mean sea level. The region has an arid to tropical climate. The experimental soil was medium black with adequate drainage.

2.2 Experimental material

The experimental material consisted of 11 cucumber inbred genotypes obtained from the All India Coordinated Research Project on Vegetable Crops, MPKV, Rahuri.

The parental genotypes were crossed in an 11 × 11 half-diallel mating design excluding reciprocals, resulting in 55 F₁ hybrids.

Thus, the experimental material consisted of:

- 11 parental lines
- 55 F₁ hybrids
- 1 standard check

giving a total of 67 treatments.

2.3 Experimental design and crop management

The experiment was laid out in a randomized block design with two replications during Kharif 2024 and Summer 2025. Plants were maintained at a spacing of 1.50 × 0.50 m. The plot size was 1.50 × 5.00 m, accommodating 10 plants per plot per replication. The crop was trained using a trellis system. Farmyard manure was applied at 20 t ha⁻¹, while fertilizers were applied at 100:50:50 kg N:P₂O₅:K₂O ha⁻¹ according to the experimental protocol. Seeds were treated with carbendazim @ 1 g kg⁻¹ seed before sowing. The parental lines and their hybrids were evaluated under the respective seasonal environments.

2.4 Observations recorded

Observations were recorded for the following 20 characters:

2.5 Estimation of broad-sense heritability

Broad-sense heritability was estimated as the ratio of genotypic variance to phenotypic variance and expressed as percentage following the general quantitative-genetic approach of Burton *et al.* (1953) [1]:

$$H^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

where:

1. Vine length (m)	11. Fruit length (cm)
2. Number of nodes per vine	12. Fruit diameter (cm)
3. Number of branches per vine	13. Average fruit weight (g)
4. Peduncle length (cm)	14. Yield per vine (kg)
5. Days to first male flower appearance	15. Yield per plot (kg)
6. Days to first female flower appearance	16. Yield per hectare (q)
7. Days to 50% flowering	17. Fruit fly incidence (%)
8. Days to first fruit harvest	18. Powdery mildew incidence (%)
9. Days to last fruit harvest	19. Downy mildew incidence (%)
10. Number of fruits per vine	20. Cucumber mosaic virus incidence (%)

• H^2 = broad-sense heritability (%)

• σ_g^2 = genotypic variance

• σ_p^2 = phenotypic variance.

The estimates were interpreted comparatively among traits and seasons. Because broad-sense heritability includes both additive and non-additive genetic components, the estimates were not used alone to infer the type of gene action or expected genetic gain. Interpretation was made in conjunction with the magnitude and seasonal stability of the estimates, following the principles described by Johnson *et al.*, (1955) [2].

3. Results and Discussion

3.1 Variation in broad-sense heritability among traits and seasons

Broad-sense heritability estimates for the 20 characters during Kharif 2024 and Summer 2025 are presented in Table 1.

Broad-sense heritability varied considerably among traits and between seasons. During Kharif 2024, estimates ranged from 7% for number of branches per vine to 49% for number of nodes per vine. During Summer 2025, estimates ranged from 14% for number of

fruits per vine and yield per hectare to 57% for number of nodes per vine.

Table 1. Broad-sense heritability estimates (%) for different traits in cucumber during *Kharif* 2024 and Summer 2025

Sr. No.	Character	<i>Kharif</i> 2024	Summer 2025
1	Vine length (m)	24	25
2	Number of nodes per vine	49	57
3	Number of branches per vine	7	28
4	Peduncle length (cm)	36	37
5	Days to first male flower appearance	32	31
6	Days to first female flower appearance	10	41
7	Days to 50% flowering	10	46
8	Days to first fruit harvest	17	50
9	Days to last fruit harvest	9	15
10	Number of fruits per vine	30	14
11	Fruit length (cm)	46	52
12	Fruit diameter (cm)	9	23
13	Average fruit weight (g)	26	29
14	Yield per vine (kg)	11	18
15	Yield per plot (kg)	9	16
16	Yield per hectare (t)	9	14
17	Fruit fly incidence (%)	28	16
18	Powdery mildew incidence (%)	42	18
19	Downy mildew incidence (%)	17	18
20	Cucumber mosaic virus incidence (%)	12	18

The variation in heritability among traits indicates that the relative contributions of genetic and environmental variation differed according to character. The seasonal changes further indicate that the expression of several traits was sensitive to environmental conditions. Such variation is expected because heritability is a property of a population evaluated under a particular environmental condition rather than an immutable characteristic of the trait.

3.2 Heritability for growth traits

Vine length exhibited heritability estimates of 24% during *Kharif* and 25% during Summer. The close estimates across seasons indicate relatively similar genetic contribution to phenotypic variation for this character under the two environments.

Number of nodes per vine recorded the highest heritability among all the traits evaluated, with estimates of 49% during *Kharif* and 57% during Summer. The relatively high and consistent estimates suggest that genetic differences among the evaluated cucumber material contributed substantially to the phenotypic variation for node number.

The comparatively higher heritability of node number agrees with previous cucumber studies in which substantial genetic variation and heritability were reported for growth-related traits. Pushpalatha *et al.*, (2016) [3] reported high heritability for several growth characters, including vine-related traits, in cucumber.

Number of branches per vine showed a marked seasonal difference. Heritability was only 7% during *Kharif* but increased to 28% during Summer. The low estimate during *Kharif* suggests a relatively greater environmental contribution to phenotypic variation in branch number, whereas the higher Summer estimate indicates a greater relative contribution of genetic differences under that environment.

The pronounced seasonal variation in branch number emphasizes the importance of repeated evaluation when this trait is considered in selection programmes.

3.3 Heritability for flowering and harvesting traits

Days to first male flower appearance showed comparatively stable heritability estimates of 32% during *Kharif* and 31% during Summer. The similarity between seasons indicates comparatively consistent genetic contribution to variation in male flowering time.

In contrast, days to first female flower appearance showed a substantial increase in heritability from 10% during *Kharif* to 41% during Summer. Similarly, heritability for days to 50% flowering increased from 10 to 46%.

Days to first fruit harvest also showed a considerable seasonal increase, from 17% during *Kharif* to 50% during Summer. These results suggest that the expression of female flowering, 50% flowering and early harvest was more strongly influenced by environmental conditions during *Kharif* than during Summer.

Pushpalatha *et al.*, (2016) [3] similarly reported different genetic parameter estimates for flowering and earliness traits compared with growth and yield characters. Their study indicated that days to first female flower opening, days to 50% flowering and days to first fruit harvest differed in their genetic behaviour from several other characters.

Days to last fruit harvest recorded low estimates in both seasons, with heritability of 9% during *Kharif* and 15% during Summer. The consistently lower estimates suggest a substantial environmental component in the phenotypic expression of harvest duration under the present experimental conditions.

3.4 Heritability for fruit characters

Number of fruits per vine showed a reduction in heritability from 30% during *Kharif* to 14% during Summer. The *Kharif* estimate indicates a comparatively greater genetic contribution, whereas the Summer estimate suggests a relatively larger environmental contribution.

Fruit length exhibited comparatively high and consistent heritability, with estimates of 46% during *Kharif* and 52% during Summer. The relatively high estimates in both seasons indicate that genetic differences contributed substantially to phenotypic variation for fruit length. Previous investigations have also demonstrated substantial heritability for fruit characters in cucumber. Pushpalatha *et al.*, (2016) [3] reported high heritability for several fruit-related characters, while Basavarajeshwari *et al.*, (2014) [5] reported high heritability for fruit length.

Fruit diameter exhibited lower heritability, increasing from 9% during *Kharif* to 23% during Summer. Thus, compared with fruit length, fruit diameter appeared to be more strongly affected by environmental variation.

Average fruit weight showed relatively similar estimates of 26% and 29% during *Kharif* and Summer, respectively. The comparatively small seasonal difference suggests relatively consistent genetic contribution, although environmental effects remained substantial. Yadav *et al.*, (2009) [4] reported considerable genetic variability and substantial heritability for several fruit characters in cucumber, demonstrating that genetic parameter estimates can differ considerably among individual fruit traits and experimental populations.

3.5 Heritability for yield traits

Yield-related characters exhibited relatively low broad-sense heritability in both seasons.

Heritability for yield per vine was 11% during *Kharif* and 18% during Summer. Yield per plot recorded estimates of 9% and 16%, while yield per hectare showed estimates of 9% and 14% during *Kharif* and Summer, respectively. Thus, all three yield measures exhibited comparatively low heritability in both environments. The results indicate that a relatively large proportion of the observed phenotypic variation in yield was associated with environmental and non-genetic sources under the conditions of the present experiment.

Low heritability does not indicate an absence of genetic variation for yield. Rather, it indicates that the proportion of total phenotypic variation attributable to genotypic variance was comparatively small.

Because yield is a complex quantitative trait influenced by several component characters and environmental factors, direct phenotypic selection may be less consistent when heritability is low. The present results differ from some earlier cucumber investigations. Pushpalatha *et al.*, (2016) [3] reported high heritability coupled with high genetic advance for several yield-related traits, whereas Basavarajeshwari *et al.*, (2014) [5] reported high heritability and genetic advance for fruit yield per vine.

Such differences demonstrate the population- and environment-specific nature of heritability estimates. Therefore, yield selection in the present material should be supported by replicated and multi-season evaluation and by consideration of yield components and additional genetic parameters.

3.6 Heritability for insect and disease-related traits

Fruit fly incidence showed heritability of 28% during *Kharif*, which declined to 16% during Summer. Thus, the relative contribution of genetic variation was greater under *Kharif* conditions than under Summer conditions.

Powdery mildew incidence recorded 42% heritability during *Kharif* but only 18% during Summer. This substantial seasonal difference indicates that disease expression and the relative contribution of genotype and environment changed between the two growing conditions.

Downy mildew incidence showed consistently low estimates of 17% during *Kharif* and 18% during Summer. Cucumber mosaic virus incidence similarly recorded relatively low estimates of 12% and 18%, respectively. The comparatively low heritability estimates for downy mildew and cucumber mosaic virus indicate substantial environmental influence on disease expression under the conditions of the experiment. Disease incidence can be influenced by environmental conditions, pathogen pressure, crop stage and interactions between host genotype and environment. Therefore, disease-related traits should preferably be evaluated over multiple environments and seasons before drawing conclusions about the stability of genetic resistance or tolerance.

4. Comparative seasonal analysis

Comparison of the two seasons showed that several traits exhibited higher heritability during Summer than during *Kharif*.

The most pronounced increases were observed for:

- Days to first fruit harvest: 17 to 50%
- Days to 50% flowering: 10 to 46%
- Days to first female flower appearance: 10 to 41%
- Number of branches per vine: 7 to 28%
- Fruit diameter: 9 to 23%

Conversely, marked reductions from *Kharif* to Summer were observed for:

- Number of fruits per vine: 30 to 14%
- Fruit fly incidence: 28 to 16%
- Powdery mildew incidence: 42 to 18%

Vine length, peduncle length, days to first male flower appearance and average fruit weight showed comparatively smaller seasonal differences.

Number of nodes per vine recorded the highest heritability in both seasons, followed by fruit length. In contrast, yield-related characters consistently recorded comparatively low estimates. The seasonal differences demonstrate that genetic expression of cucumber traits is character-specific and environment-dependent. Consequently, evaluation across seasons can provide more reliable information than a single-season assessment when selecting material for cucumber improvement.

5. Implications for cucumber breeding

The present findings indicate that number of nodes per vine and fruit length showed comparatively greater and more consistent broad-sense heritability across the two seasons. These traits may therefore provide useful phenotypic indicators of genetic differences within the evaluated material.

Vine length, peduncle length, days to first male flower appearance and average fruit weight also showed relatively similar estimates between seasons, suggesting comparatively stable genetic contribution under the two environments.

In contrast, yield per vine, yield per plot and yield per hectare exhibited low heritability in both seasons. Consequently, selection based solely on phenotypic yield performance may be less reliable in the present material. Selection for yield should be supported by evaluation of component traits, replicated trials and multi-season testing.

It is important to emphasize that broad-sense heritability alone cannot establish the predominance of additive gene action or accurately predict response to selection. Broad-sense heritability incorporates additive, dominance and epistatic genetic effects. Therefore, genetic advance, genotypic and phenotypic coefficients of variation, general and specific combining ability and other genetic parameters should be considered together when developing a comprehensive breeding strategy (Johnson *et al.*, 1955) [2].

The importance of considering heritability together with genetic advance has also been demonstrated in cucumber. Basavarajeshwari *et al.*, (2014) [5] showed that the combination of heritability and genetic advance provided additional information regarding the probable nature of genetic variation for yield and yield-related traits.

6. Conclusion

The present investigation demonstrated considerable variation in broad-sense heritability among growth, flowering, harvesting, fruit, yield and disease-related traits of cucumber across *Kharif* 2024 and Summer 2025.

Heritability estimates ranged from 7 to 49% during *Kharif* and from 14 to 57% during Summer. Number of nodes per vine recorded the highest estimate in both seasons, with values of 49 and 57%, respectively. Fruit length also showed comparatively high and consistent heritability, with estimates of 46 and 52%.

Flowering and earliness traits exhibited pronounced seasonal variation, particularly days to first female flower appearance, days to 50% flowering and days to first fruit harvest. In contrast, yield traits showed relatively low heritability in both seasons, indicating substantial environmental influence on their phenotypic expression.

Overall, the results demonstrate that broad-sense heritability in cucumber is strongly trait- and environment-dependent. Number of nodes per vine and fruit length showed comparatively greater and more stable genetic contribution and may therefore be useful characteristics for selection within the evaluated material. Improvement of yield should involve integrated selection using yield components, replicated multi-season evaluation and complementary genetic parameters such as GCV, PCV, genetic advance and combining ability.

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