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Genetic variability, heritability and gene action for yield and quality traits in ridge gourd [*Luffa acutangula* (L.) Roxb.] using half-diallel analysis

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Abstract

The present investigation was conducted at the Vegetable Research Farm, Department of Vegetable Science, C.S. Azad University of Agriculture and Technology, Kanpur, during the summer (*Zaid*) Season 2024-2026. The study aimed at estimating genetic parameters of variability, heritability, genetic advance, and gene action for 24 yield and quality traits in ridge gourd *Luffa acutangula* (L.) Roxb. Using a half-diallel design involving 10 parental lines and their 45 F_1 crosses along with one standard check (Pusa Nasdar). Analysis of genetic variability revealed that the phenotypic coefficient of variation (PCV) was consistently higher than the genotypic coefficient of variation (GCV) for all traits, with high GCV and PCV observed for vine length at flowering (25.15%, 25.81%), number of primary branches (20.71%, 21.42%), and shelf life (20.85%, 21.02%). Broad-sense heritability ranged from 37.28% (vine length at seedling stage) to 98.38% (shelf life), with the majority of traits exhibiting high heritability, indicating minimal environmental influence. Genetic advance as percentage of mean was highest for vine length at flowering (50.50%), shelf life (42.60%), and number of primary branches (41.24%), suggesting substantial scope for selection. Diallel analysis revealed that the specific combining ability variance (σ^2_{SCA}) exceeded general combining ability variance (σ^2_{GCA}) for all 24 traits, with $\sigma^2_{GCA}/\sigma^2_{SCA}$ ratios below unity, confirming the predominance of non-additive gene action. These findings suggest that hybrid breeding approaches are most appropriate for genetic improvement of ridge gourd.

Keywords: Ridge gourd, *Luffa acutangula*, genetic variability, heritability, combining ability, non-additive gene action, half-diallel analysis

Introduction

Ridge gourd (*Luffa acutangula* (L.) Roxb. is an economically important cucurbitaceous vegetable crop widely cultivated in tropical and subtropical regions of India and South-East Asia. Belonging to the genus *Luffa* of the family Cucurbitaceae with a chromosome number of $2n = 26$, it is commonly known as kalitori, angled gourd, angled loofah, Chinese okra, silky gourd, or ribbed gourd. Crop is popularly known by different names such as Kalitori, angled gourd, angled loofah and ribbed gourd and believed to have originated from Subtropical Asian region including India (Yadav *et al.*, 2015; Swarup, 2016) [6, 7]. Tender green fruits are extensively used in soups, curries, and as cooked vegetables, while dried fruits serve as bathing sponges, doormats, and cleaning utensils (Narasannavar *et al.*, 2014) [21]. The nutritional, phytochemical, and medicinal importance of ridge gourd (*Luffa acutangula* L. Roxb.). The authors reported that ridge gourd is an important cucurbit vegetable rich in vitamins, minerals, flavonoids, and bioactive compounds. Yasmin *et al.* (2019) Ridge gourd acts as an appetizer and considered as a healthy food that contains 0.5 g of fiber, 0.5% of protein, 0.35% of carbohydrate, 37 mg of carotene, 5.0 mg of vitamin C, 18 mg of calcium and 0.5 mg of Iron in 100 g of the edible portion (Hazra and Som, 2005) [19]. They form a low-calorie diet, which is good for diabetes (Harshitha *et al.*, 2019, and found to be helpful as a natural remedy for the treatment of jaundice (Panicker *et al.*, 2019) [5]. Ridge gourd (*Luffa acutangula* Roxb.) is an important warm season cucurbitaceous vegetable crop grown in diverse regions of India and tropical areas of Asia and Africa (Chaudhary *et al.*, 2014; Haldhar *et al.*, 2015) [4, 14] for its tender fruits.

It belongs to family Cucurbitaceae and bears a chromosome number $2n = 2x = 26$ (Sen *et al.*, 2023; Mithila *et al.*, 2024) [12, 13]. India is the second largest producer of vegetables in the world with an annual production of 185 million tonnes from an area of 10.20 million hectares (NHB, 2018-19) [22], with ridge gourd contributing approximately 983 metric tonnes from 90 hectares. The total area under vegetable cultivation in India is approximately 11 million hectares. Total production stands at around 205-210 million tonnes annually. The average productivity of vegetables is about 19 tonnes per hectare. Vegetables account for nearly 60% of India's total horticultural output. (National Horticulture Board (NHB) and Ministry of Agriculture) 2023-24. Ridge gourd cultivation in India covers an area of 9920 ha generating a substantial production of about 3.17 lakh t with a productivity of 31.95 t ha^{-1} . India ranks second globally in vegetable production, occupying 11.35 million hectares with a total annual output of 219.67 million tonnes. India ranks second globally in vegetable production, after China, contributing approximately 15-16% of global output (Anonymous, 2024-25) [2]. Cucurbits collectively represent a major share of this production, with India cultivating cucurbit crops over approximately 5.98 lakh hectares yielding 93.73 lakh tons annually. Ridge gourd fruits are nutritionally rich, containing Vitamin A, C, iron, carbohydrates, calcium (18 mg), phosphorus (26 mg), and carotene (33 g per 100 g edible portion), and are particularly recommended for individuals suffering from malaria and seasonal fevers due to their easy digestibility (Gautama *et al.*, 2017) [17]. Evaluation and identification of superior genotypes among the existing germplasm is considered very imperative to utilize and improve the plant genetic resources in various crop improvement programmes (Terfa and Gurnu, 2020) [11].

Improvement of any crop depends upon the degree of genetic variability present and the level of heritability associated with economically significant traits. Saisupriya *et al.* (2022) [9], The significant degree of natural variation or extensive variability in multiple characteristics across genotypes enhances greater opportunity of identifying new genotypes and suggests a strong potential for improvement in economic traits (Jonah *et al.*, 2024) [8]. Being a monoecious and highly cross-pollinated crop, ridge gourd exhibits abundant heterozygosity and natural variability in populations. Most commercially released hybrids produce large-sized fruits that are not preferred by consumers, adversely affecting marketability (Narasannavar *et al.*, 2014) [21]. Genetic variability is the foundation of any crop improvement programme because it provides the essential raw material for selection and hybridization. In vegetable crops, particularly cucurbits like ridge gourd (*Luffa acutangula* L. Roxb.), the assessment of genetic variability helps in understanding the extent of heritable variation available within the germplasm. Burton, G.W. DeVane, E.H. (1953) [15]. Rai *et al.* (2008) [23] studied the contribution of different quantitative traits toward yield improvement in ridge gourd through component analysis. The authors reported considerable variability among ridge gourd genotypes for important growth and yield characters. Traits such as fruit weight, number of fruits per plant, and fruit length showed positive association with yield and contributed significantly to total variation. Johnson *et al.* (1955) [20] reported that the combined study of genotypic coefficient of variation, heritability, and genetic advance

provides reliable information regarding the nature and magnitude of gene action controlling quantitative traits. The progenitor of cultivated ridge gourd is considered to be *Luffa graveolens*, and South and South-East Asia are known centers of diversity for *Luffa* species (Yadav and Singh, 2022) [25]. When combined with diallel analysis for estimating general combining ability (GCA) and specific combining ability (SCA) variances, breeders can effectively identify the nature of gene action — additive or non-additive — governing trait expression (Varalakshmi *et al.*, 2016) [24]. The present study was therefore designed to estimate genetic parameters of variability and gene action for 24 yield and quality traits in ridge gourd using a half-diallel mating design, with the objective of identifying traits amenable to direct selection and determining the most effective breeding strategies for crop improvement.

2. Materials and Methods

2.1 Experimental Location and Season

The experiment was conducted at the Vegetable Research Farm, Department of Vegetable Science, Kalyanpur, C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India, during the summer (*Zaid*) Season 2024-2026. The experimental site is located in the Indo-Gangetic Plain, characterized by hot and semi-arid climate conditions suitable for cucurbit cultivation.

2.2 Genetic Material and Mating Design

The genetic material comprised 10 diverse parental lines of ridge gourd. A half-diallel mating design was employed, generating 45 F_1 hybrid combinations [$n(n-1)/2 = 10 \times 9/2 = 45$ crosses]. All 45 crosses along with one standard commercial check variety, Kashi shivani, were evaluated in a Randomized Complete Block Design (RCBD) with three replications. The crop was planted in rows spaced at 3.0 meters apart with a Plant-Plant spacing of 0.60 meter.

2.3 Observations Recorded

Twenty-four yield and quality traits were recorded for each genotype across replications. Vine growth traits were measured at 30, 45, 60, and 75 days after sowing (DAS). All traits, their units, and abbreviations are summarized in Table 1.

2.4 Statistical Analysis

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were estimated following the formulae proposed by Burton and de Vane (1953) [15]. Broad-sense heritability (h^2_{bs}) was estimated as the ratio of genotypic variance to phenotypic variance and expressed as a percentage (Hanson *et al.*, 1956) [18]. Genetic advance (GA) and genetic advance as percent of mean (GAM) were computed following the method of Johnson *et al.* (1955) [20], assuming a selection intensity of 5% ($k = 2.06$). The GCV and PCV values were classified as low (<10%), moderate (10-20%), and high (>20%). Heritability values were categorized as low (<50%), moderate (50-75%), and high (>75%). Genetic advance as percentage of mean was classified as low (<10%), moderate (10-20%), and high (>20%). Diallel analysis was performed following Griffing's (1956) Method II, Model I (fixed effects), to estimate GCA and SCA variances. The ratio $\sigma^2_{GCA}/\sigma^2_{SCA}$ was used to determine the relative importance of additive versus non-additive gene action. A ratio less than 1.0 indicates the

predominance of non-additive gene action (dominance and epistasis).

3. Results and Discussion

3.1 Coefficient of Variation (GCV and PCV)

The estimates of GCV and PCV for all 24 traits are presented in (Table 2. and figure 1.) The PCV was higher than GCV for all traits, indicating the influence of environmental factors on trait expression. However, the narrow difference between PCV and GCV for most traits suggested that genetic factors predominated over environmental effects in controlling these characters, consistent with earlier reports in cucurbit crops (Chandan *et al.*, 2018) [16]. High GCV and PCV (>20%) were observed for vine length at flowering (GCV: 25.15%, PCV: 25.81%), number of primary branches (20.71%, 21.42%), and shelf life (20.85%, 21.02%). High variability for vine length at flowering suggests that this trait is highly responsive to selection pressure. Moderate GCV and PCV (10-20%) were recorded for fruit yield (13.06%, 14.38%), fruit length (10.88%, 13.27%), secondary branch number (13.48%, 13.67%), and flesh thickness (18.23%, 18.44%). Low GCV and PCV (<10%) were recorded for number of fruits per vine (3.97%, 4.71%), days to 50% flowering (4.22%, 6.88%), and days to first harvest (4.73%, 6.99%), indicating limited genetic variability and lesser scope for direct improvement through selection for these traits.

3.2 Heritability in Broad Sense

Heritability estimates ranged from 37.28% for vine length at seedling stage (VLSF) to 98.38% for shelf life, as presented in (Table 2 and figure 1) High heritability (>75%) was recorded for shelf life (98.38%), flesh thickness (97.68%), secondary branches (97.22%), vine length at flowering (94.99%), vine length at 30 DAS (94.99%), ascorbic acid (94.23%), dry matter (93.61%), number of primary branches (93.46%), total soluble solids (88.98%), nodes per branch (85.86%), and fruit yield (82.44%). High heritability for these traits indicated minimal environmental influence and suggested that phenotypic selection would be reliable and effective for their improvement (Johnson *et al.*, 1955) [20]. Moderate heritability (50-75%) was recorded for fruit length (67.23%), sex ratio (66.47%), internodal length (65.73%), and days to first male flower initiation (56.23%), indicating moderate environmental influence on these traits. Low heritability (<50%) was recorded for vine length at seedling stage (37.28%), days to 50% flowering (37.65%), number of leaves per plant (40.56%), and days to first female flower initiation (47.18%), suggesting strong environmental control and limiting the effectiveness of direct selection for these traits.

3.3 Genetic Advance as Percentage of Mean

Genetic advance as percentage of mean (GAM) ranged from 5.33% for days to 50% flowering to 50.50% for vine length at flowering (Table 2 and figure 1). High genetic advance (>20%) was observed for vine length at flowering (50.50%), shelf life (42.60%), number of primary branches (41.24%), flesh thickness (37.11%), secondary branches (27.38%), fruit yield (24.43%), vine length at 30 DAS (23.12%), and ascorbic acid (19.78%, approaching high range). High GAM coupled with high heritability for traits such as shelf life, flesh thickness, vine length at flowering, and number of

primary branches indicated the preponderance of additive gene effects and confirmed the effectiveness of direct phenotypic selection for improvement of these characters (Burton and de Vane, 1953) [15]. Moderate GAM (10-20%) was observed for fruit diameter (14.02%), fruit weight (15.66%), total soluble solids (14.67%), dry matter (19.22%), internodal length (15.98%), sex ratio (12.80%), and nodes per branch (11.38%). Low GAM (<10%) was recorded for days to 50% flowering (5.33%), days to first female flower initiation (6.13%), number of fruits per vine (6.91%), and days to first harvest (6.61%), indicating limited genetic progress achievable through simple selection for these traits.

3.4 Gene Action: GCA and SCA Variance

The estimates of genetic components of variance from half-diallel analysis are presented in (Table 3 and figure 2) For all 24 traits under study, the σ^2_{SCA} was higher in magnitude than σ^2_{GCA} , with the $\sigma^2_{GCA}/\sigma^2_{SCA}$ ratio being less than unity across all characters. This unequivocally confirmed the predominance of non-additive gene action — including dominance and epistatic effects — in the inheritance of these traits in ridge gourd. For vine growth traits, σ^2_{SCA} far exceeded σ^2_{GCA} : vine length at 45 DAS (1605.422 vs 338.767), vine length at 60 DAS (867.256 vs. 123.710), and vine length at 30 DAS (113.036 vs 11.383). Similarly, for yield-contributing traits, fruit length showed $\sigma^2_{SCA} = 4.848$ versus $\sigma^2_{GCA} = 0.272$, and fruit weight exhibited $\sigma^2_{SCA} = 78.054$ versus $\sigma^2_{GCA} = 11.837$. Among quality traits, shelf life (σ^2_{SCA} : 0.991 vs. σ^2_{GCA} : 0.122) and flesh thickness (σ^2_{SCA} : 2.394 vs σ^2_{GCA} : 0.280) also reflected the dominance of non-additive gene effects. The lowest $\sigma^2_{GCA}/\sigma^2_{SCA}$ ratio was observed for ascorbic acid (0.025), days to first harvest (0.053), and fruit length (0.056), indicating the strongest non-additive gene action for these traits. These findings are consistent with reports by Varalakshmi *et al.*, (2016) [24] and Chandan *et al.*, (2018) [16] in cucurbit crops, who similarly reported the predominance of dominance effects for fruit yield and quality characters. The predominance of non-additive gene action for most traits implies that exploitation of heterosis through hybrid breeding would be the most appropriate and effective strategy for genetic improvement of ridge gourd. The superior F_1 combinations identified in this study can be utilized for the development of high-yielding hybrids with improved fruit quality and shelf life.

Table 1: Abbreviations and description of traits recorded

Vine Length at 30 DAS (cm)	Vine Length at 45 DAS
Vine Length at 60 DAS	Vine Length at 75 DAS
No. of Primary Branches	No. of Secondary Branches
Nodes per Branch	No. of Leaves per Plant
Internodal Length (cm)	Days to 1st Male Flower Init.
Days to 1st Female Flower Init.	Days to 50% Flowering
Sex Ratio	Days to First Harvest
Fruit Length (cm)	Fruit Diameter (cm)
Fruit Weight (g)	No. of Fruits per Vine
Fruit Yield (kg/vine)	Ascorbic Acid (mg/100g)
Total Soluble Solids (°Brix)	Dry Matter Content (%)
Shelf Life (days)	Flesh Thickness (cm)

Table 2: Estimates of genetic variability parameters for yield and quality traits in ridge gourd

Character	Grand Mean	Range	GCV (%)	PCV (%)	Heritability (%)	GA as% Mean
VLT	93.07	58.51-111.45	11.52	11.82	94.99	23.12
VLF	178.16	86.84-271.08	25.15	25.81	94.99	50.50
VLS	282.06	177.50-377.22	11.08	12.57	77.68	20.12
VLSF	362.93	243.86-461.07	5.17	8.47	37.28	6.51
NPB	0.97	0.31-1.66	20.71	21.42	93.46	41.24
NSB	1.64	1.08-2.38	13.48	13.67	97.22	27.38
NNPB	37.25	31.73-42.08	5.96	6.43	85.86	11.38
NLP	43.67	30.00-58.27	5.13	8.05	40.56	6.73
IL	18.63	10.61-28.54	9.57	11.80	65.73	15.98
DFMFI	36.96	30.25-44.97	4.67	6.23	56.23	7.22
DFFFI	41.21	34.67-50.94	4.33	6.31	47.18	6.13
FIFTY	45.83	33.74-59.89	4.22	6.88	37.65	5.33
SR	30.84	20.06-36.47	7.62	9.35	66.47	12.80
DFH	52.02	42.99-68.60	4.73	6.99	45.90	6.61
FL	19.61	11.32-30.76	10.88	13.27	67.23	18.38
FD	2.90	1.80-3.80	8.04	9.50	71.58	14.02
FW	103.70	79.53-147.76	9.06	10.80	70.36	15.66
NFPV	13.71	11.35-15.14	3.97	4.71	71.22	6.91
ASC	4.85	3.11-6.00	9.89	10.19	94.23	19.78
TSS	4.49	3.36-5.07	7.55	8.00	88.98	14.67
DRM	8.05	6.22-10.10	9.64	9.97	93.61	19.22
SLF	4.92	3.07-7.42	20.85	21.02	98.38	42.60
FT	8.69	5.93-12.57	18.23	18.44	97.68	37.11
FY	1.50	1.09-2.20	13.06	14.38	82.44	24.43

GCV: Genotypic Coefficient of Variation; PCV: Phenotypic Coefficient of Variation; GA: Genetic Advance

Table 3: Estimates of genetic components of variance for yield and quality traits in ridge gourd

Sr.	Character	$\sigma^2\text{GCA}$	$\sigma^2\text{SCA}$	$\sigma^2\text{GCA}/\sigma^2\text{SCA}$	$\sigma^2\text{A}$
1	Vine length 30 DAS	11.383	113.036	0.101	22.767
2	Vine length 45 DAS	338.767	1605.422	0.211	677.533
3	Vine length 60 DAS	123.710	867.256	0.143	247.421
4	Vine length 75 DAS	70.493	230.676	0.306	140.985
5	No. of primary branches (NPB)	0.005	0.037	0.132	0.010
6	No. of secondary branches (NSB)	0.007	0.044	0.150	0.013
7	Node number per branch (NNPB)	0.851	3.978	0.214	1.702
8	No. of leaves per plant (NLP)	0.905	3.958	0.229	1.810
9	Intermodal length (IL)	0.259	3.265	0.079	0.517
10	Days to 1st male flower init. (DFMFI)	0.490	2.415	0.203	0.981
11	Days to 1st female flower init. (DFFFI)	0.413	2.907	0.142	0.826
12	Days to 50% flowering (FIFTY)	0.329	3.811	0.086	0.658
13	Sex ratio (SR)	1.003	4.346	0.231	2.006
14	Days to first harvest (DFH)	0.352	6.607	0.053	0.703
15	Fruit length (FL)	0.272	4.848	0.056	0.544
16	Fruit diameter (FD)	0.007	0.048	0.135	0.013
17	Fruit weight (FW)	11.837	78.054	0.152	23.674
18	No. of fruits per vine (NFPV)	0.049	0.237	0.208	0.098
19	Fruit yield (FY)	0.003	0.040	0.073	0.006
20	Ascorbic acid (ASC)	0.006	0.258	0.025	0.013
21	Total soluble solids (TSS)	0.019	0.091	0.209	0.038
22	Dry matter (DRM)	0.077	0.549	0.140	0.153
23	Shelf life (SLF)	0.122	0.991	0.123	0.244
24	Flesh thickness (FT)	0.280	2.394	0.117	0.559

 $\sigma^2\text{GCA}$: Variance due to general combining ability; $\sigma^2\text{SCA}$: Variance due to specific combining ability

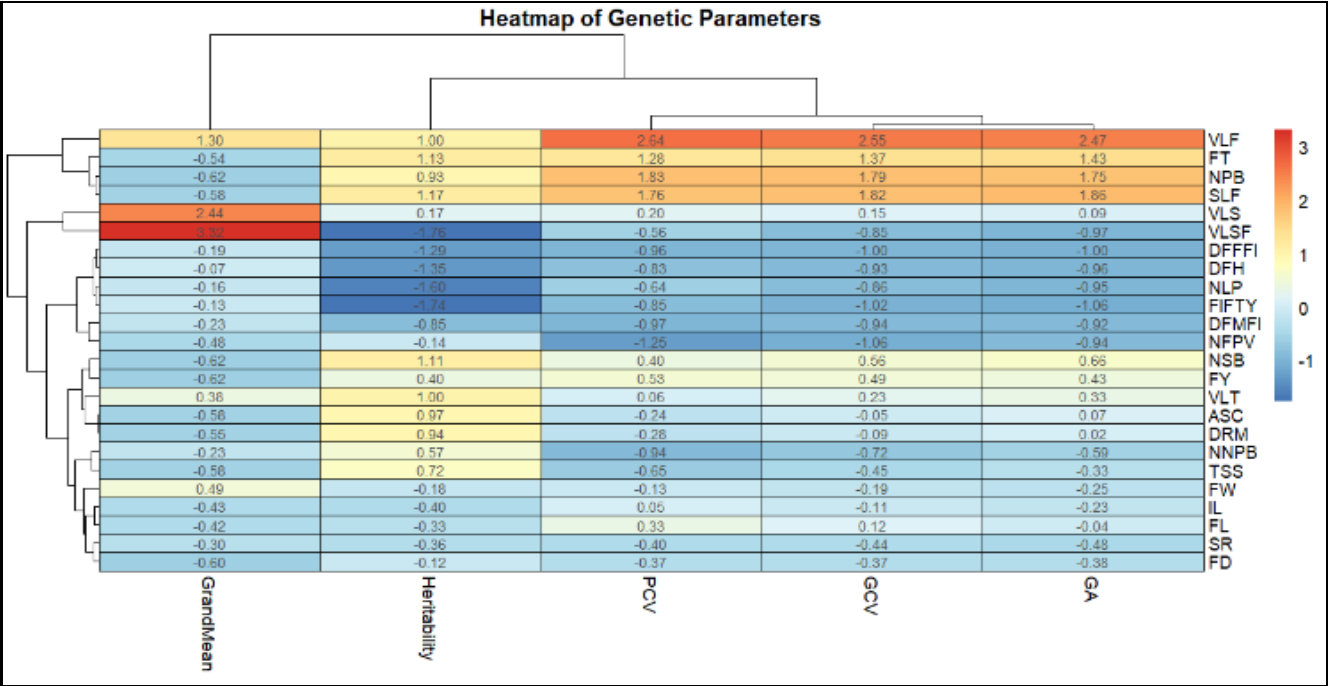


Fig 1: Estimates of genetic variability parameters for yield and quality traits in ridge gourd

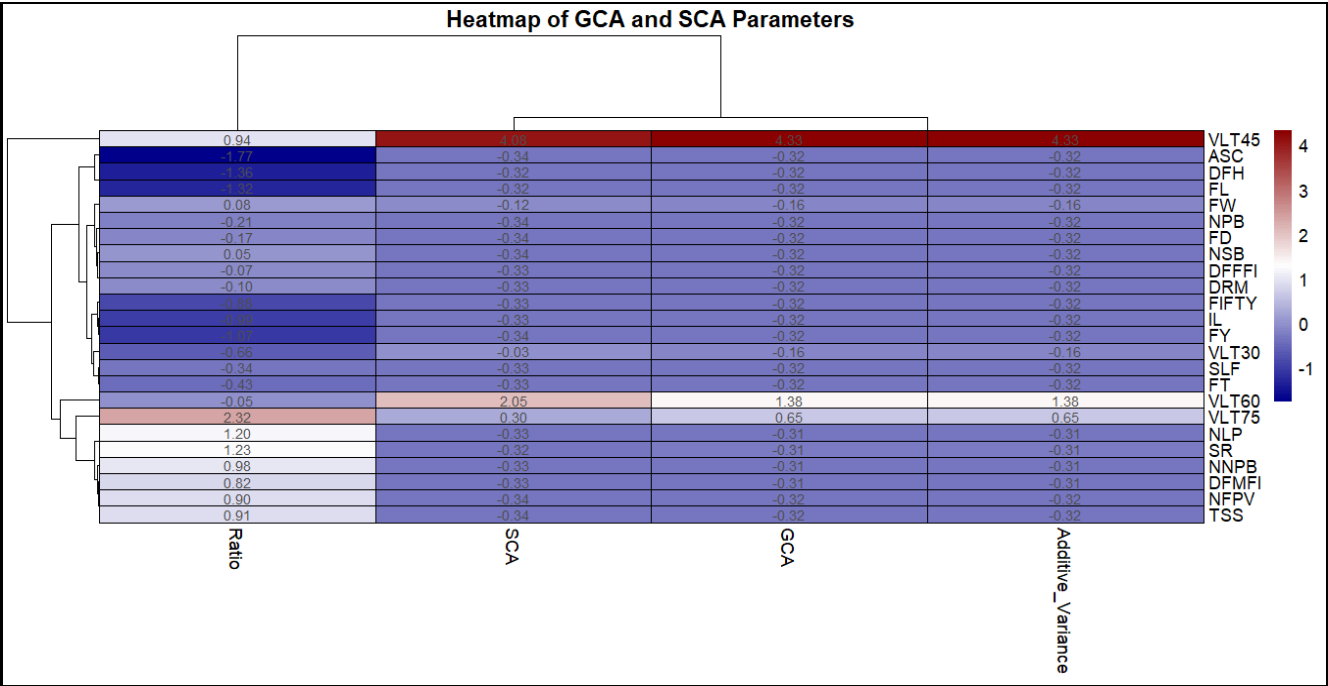


Fig 2: Estimates of genetic components of variance for yield and quality traits in ridge gourd

4. Conclusions

The present study provides comprehensive insights into the genetic architecture of yield and quality traits in ridge gourd. High GCV and PCV coupled with high heritability and high genetic advance for traits such as vine length at flowering, shelf life, flesh thickness, and number of primary branches confirmed the preponderance of additive gene effects and suggested that these traits can be effectively improved through direct phenotypic selection. The predominance of non-additive gene action — as evidenced by $\sigma^2SCA > \sigma^2GCA$ for all 24 traits in diallel analysis — clearly indicated that hybrid breeding is the most promising approach for the genetic improvement of ridge gourd. Future research should focus on identifying superior specific cross combinations and evaluating their stability across

environments for the development of high-yielding, quality-rich hybrids suitable for tropical and subtropical cultivation.

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