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Genetic variability studies in F_3, F_4 and F_5 generations of okra (*Abelmoschus esculentus* (L.) cross VRO-6 x TCR-1674 under Gangetic plains of Andhra Pradesh

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Abstract
The present investigation entitled "Genetic variability studies in F_3, F_4 and F_5 generations of okra (*Abelmoschus esculentus* (L.) cross VRO-6 x TCR-1674 under gangetic plains of Andhra Pradesh" was conducted at Horticultural Research Station, Lam, Guntur, Andhra Pradesh during, *Summer*-2022, *Rabi*-2022 and *Summer*-2023. The F_3, F_4 and F_5 generations of the cross VRO-6 x TCR-1674 were evaluated with the objective of selecting superior genotypes through pedigree method of selection for economically important traits and to assess the various genetic parameters for the okra crop improvement. The data from advanced generations were collected and statistically analysed to compute mean, range, phenotypic and genotypic coefficients of variance, heritability, expected genetic advance, genetic advance as per cent mean and genetic gain. The pedigree of the cross VRO-6 x TCR-1674 recorded the genetic gain from F_3 to F_4 and F_4 to F_5 generation;fruit yield per plant (4.46 and 2.62), number of fruits per plant (7.60 and 18.39), fruit length (6.08 and 2.41), fruit girth (6.93 and 3.42), fruit weight (8.82 and 10.04), number of seeds per fruit (4.02 and 0.29), test weight of seeds (2.82 and 3.72), ascorbic acid content fruits (7.45 and 1.26), shelf-life of fruits (13.89 and 12.54) respectively. Best promising plants were selected in F_5 generation and selfed for further preliminary yield trials.

Keywords: Variability, mean, range, PCV, GCV, heritability, genetic advance and genetic gain

Introduction
Okra (*Abelmoschus esculentus* L.) is a Malvaceae vegetable with chromosome number 2n=2x=130. It is an annual vegetable crop, commercially grown for edible vegetable. Because of its highest production potential and availability to consumers, okra is cultivated throughout the tropical and warm temperate regions of the world for its fruits or pods. It is a short duration crop and grown as spring-summer and rainy season crop in Northern India while in South India, it is possible to grow throughout the year and native to Tropical Asia and also considered as native place of India. Tender okra fruits are used as vegetable in countries like India, Brazil, West Africa. Okra fruit contains 90% water, 3% dietary fibre, 7% carbohydrates, 2% protein, with good quantities of minerals, Vitamin-C and A and had moderate contents of thiamin, folate and magnesium (Chopra *et al*., 1956) [4]. In India, the area under okra cultivation is 5.19 lakh ha with an annual production of 63.71 lakh tonnes and productivity of 12.17 MT/ha. West Bengal, Orissa, Bihar, Gujarat, Andhra Pradesh, Telangana, Maharashtra, Assam and Uttar Pradesh are the major okra producing states in the country. Andhra Pradesh with a production of 2.05 lakh tonnes from 13,670 ha ranks fourth in the country with a productivity of 15 t/ha (NHB, 2019-20) [17].

The initial days of crop improvement, mass selection was practiced by the breeders and resulting progenies were non-uniform in terms of many traits. Consumer demand for uniform, good quality produce is increasing day by day and obviously the farmer should produce high yielding, biotic and abiotic stress resistant genotypes. For achieving the uniformity, pure line selection, hybridization followed by pedigree/bulk selection and heterosis breeding (F_1 hybrids) are best methods.

But in often cross-pollinated crops like okra, the pure lines selection is mostly preferred by the farmers because of ease of seed production. Hybridization followed by selection is widely followed method for developing high yielding genotypes in Malvaceace vegetables. After hybridization, selfing is done to get the variability. Recombination and segregation lead to release of genetic variability in segregating populations. Estimation of nature and magnitude of variability, heritability for yield contributing and other traits are immense importance. The available variability can be portioned into heritable and non-heritable components.
The greater available of genetic variability is more chance to getting better genotypes by direct selection (Vavilov, 1951) [36]. Heritability can have measured by the genetic relationship between the parent and offspring. The greater heritable variation, the possibility of fixing the characters by selection methods is higher. Genetic advance is helpful to devise the effective selection. Heritability and genetic advance studies are immense use to identify whether the observed variation for a particular character is due to genotype or environment. Hybridization is followed by selection in the segregation generations (Pedigree/bulk method of breeding) is one of the widely used breeding methods to develop varieties in shelf-pollinated crops as well as often cross-pollinated vegetable crops including okra. There are fair chances to isolation of transgressive segregants also in this procedure (Briggs and Allard, 1953) [3]. Many high yielding varieties in okra viz., Pusa Sawani, Punjab Padmini, Arka Anamika, Arka Abhay, Varsha Upkar, Hissar Barsati, Pusa-A-4, etc., have been developed through hybridization followed by pedigree selection.

Materials and methods

To develop superior recombinant genotypes in okra, hybridization programme was initiated with the cross VRO-6 x TCR-1674 at Horticultural Research Station, Lam, Guntur, A.P, during *Kharif*, 2019 and selection was exercised in F_1, F_2 generations during in *Kharif* and *Rabi*, 2020 respectively. The top ten good performed plants were selected from F_2 generation were selfed to get F_3 generation for the present study.

Evaluation of F_3 generation

During *Summer*, 2021-22, best progenies of VRO-6 x TCR-1674 were raised with a spacing of 60 cm x 30 cm in a best performing single plant selections in F_3 generation from 100 plant population. Each progeny in each generation had 100 individual plants and a total of 300 plants over with three lines per progeny were accommodated to exercise selection and best good performing plants were selected and selfed to get F_4 generation for the present study.

Evaluation of F_4 generation

During *Kharif*, 2022-23, best progenies of VRO-6 x TCR-1674 were raised with a spacing of 60 cm x 30 cm in a best performing single plant selections in F_4 generation from 100 plant population. Each progeny in each generation had 100 individual plants and a total of 300 plants over with three lines per progeny were accommodated to exercise selection and best good performing plants were selected and selfed to get F_5 generation for the present study.
About 5 - 55% of all women suffer from breast disorders in their lifetime. Benign disorders of the breast is usually seen in reproductive period of life, is thought to be largely hormone induced and there is a dramatic fall in the incidence, after menopause due to cessation of clinical ovarian stimulation. Benign breast disease is 4 -5 times more common than breast cancer [3].
The concept of ANDI – Abberations of Normal Development and Involution is gaining acceptance [4]. Benign proliferation of the breast are often considered as aberrations of normal development and involution. The cyclical changes due to variations in estrogen and progesterone result in increased mitosis around days 22–24 of the menstrual cycle but apoptosis restores the balance across the cycle. ANDI, first proposed by Huges is now universally accepted. This concept allows conditions of the breast to be mapped between normality, through benign.

Evaluation of F_5 generation

During *Rabi*, 2022-23, best progenies of VRO-6 x TCR-1674 were raised with a spacing of 60 cm x 30 cm in a best performing single plant selections in F_5 generation from 100 plant population. Each progeny in each generation had 100 individual plants and a total of 300 plants over with three lines population per progeny were accommodated to exercise selection and best good performing plants were selected and selfed to get F_6 generation seeds.

Observations recorded

Observations were taken on the best performing single plant selections in three generations *i.e.* F_3, F_4 and F_5 from the cross VRO-6 x TCR-1674 of okra for various growth, yield and quality characters like plant height (cm), days to first flowering, internodal length, days to 50% flowering, first flowering node, first flowering node, days to first picking, days to last picking (days), fruit girth (cm), Fruit girth (cm), number of fruits per plant, fruit yield per plant (g), number of seeds per fruit, test weight of seeds (g), yellow vein mosaic virus (YVMV) incidence (%).

Biochemical analysis

Fibre content (g 100 g-^{1})

Crude fibre consists largely of cellulose and lignin in addition to minute quantities of mineral matter. It represents only 60-80 per cent of the cellulose and 4-6 per cent of the lignin. The crude fibre content is commonly used as a measure of the nutritive value of various foods and food products. It was estimated according to the methods described by Sadasivam and Manikam (2008)[23]. During the acid and subsequent alkali treatment, oxidative hydrolytic degradation of the native cellulose and degradation of lignin occur considerably. The residue obtained after final filtration was weighed, incinerated, cooled and weighed again. The loss in weight was recorded as the crude fibre content.

Reagents and Materials

Sulphuric acid solution (0.255 N): 1.25 g concentrated sulphuric acid diluted to 100 ml distilled water. (Concentration was checked by titration).

Sodium hydroxide solution (0.313 N): 1.25 g sodium hydroxide in 100 ml distilled water (concentration was checked by titration with standard acid).

Procedure

Ground homogenized fresh fruit sample of 2.0 g was taken with petroleum ether to remove the fat. After extraction, 2 g of dried material was taken with 200 ml of sulphuric acid solution for 30 minutes with bumping chips, filtered through muslin and washed with boiling water until washings were no longer acidic. It was boiled with 200 ml of sodium hydroxide solution for 30 minutes, filtered through muslin cloth again and washed with 25 ml of boiling 1.25 per cent H_2SO_4, 75 ml water and 25 ml alcohol. Residue was removed and transferred to pre-weighed ashing dish (W_1). The residue was dried for 2 hours at 1300 °C. Dish was cooled in dessicator and weighed (W_2). It was ignited for 30 minute at 6000 °C, cooled in dessicators and reweighed (W_3) and percentage of crude fibre was calculated as detailed below

$$\text{Crude fibre (g 100 g}^{-1}) = \frac{\text{Loss in weight on ignition } (W_2\text{-}W_1) - (W_3\text{-}W_1)}{\text{Weight of the sample}} \times 100$$

Ascorbic acid content (mg 100 g^{-1})

Ascorbic acid content of mature green fruits was estimated by volumetric method described by Sadasivam and Balasubramanian (1987) [22]. Ascorbic acid reduces 2, 6-dichlorophenol indophenol dye to a colourless leuco-base. The ascorbic acid gets oxidized to dehydro-ascorbic acid. Though the dye is a blue coloured compound, the end point is the appearance of pink colour. The dye is pink coloured in acid medium. Oxalic acid was used as the titrating medium.

Dye solution

Forty-two mg of sodium bicarbonate was weighed into a 200 ml volumetric flask in distilled water and 52 mg of 2,6 - dichlorophenol indophenol was dissolved in it and then the volume was made up with distilled water.

Standard stock solution

Stock solution was prepared by dissolving 100 mg ascorbic acid in 100 ml of 4% oxalic acid solution. Ten ml of stock solution was diluted to 100 ml with 4% oxalic acid to get the working standard of 100 mg per ml.

Procedure

4.0 ml of the working standard solution was pipetted into a 100 ml conical flask to which 10 ml of 4% oxalic acid was added. The contents were titrated against the dye (V_1ml) to get a pink end point which persisted for a few minutes. The okra sample (5 g) was extracted in 4% oxalic acid and the volume was made up to 100 ml and the contents were centrifuged. Five ml of this supernatant was pipetted out, to which 10 ml of 4 % oxalic acid was added and titrated against the dye (V_2 ml). The ascorbic acid content was calculated using the formula given below

$$\text{Ascorbic acid (mg 100 g}^{-1}\text{) sample} = \frac{0.5 \text{ mg}}{V_1} \times \frac{V_2}{5 \text{ ml}} \times \frac{100 \text{ ml}}{\text{Weight of the sample}} \times 100$$

Shelf-life (days)

Shelf-life of fruits was observed at ambient temperatures under laboratory conditions. Each sample consisted of 20 marketable fruits arranged and stored in paper plates. The shelf-life in days was counted from the day of harvested to 50 per cent of fruits each sample showing the symptoms of shrivelling.

Results

Observations were taken for all the individual plants separately and the data was statistically analyzed to compute mean, range, phenotypic and genotypic coefficients of variance, heritability, expected genetic advance, genetic advance as per cent mean and genetic gain in F_3, F_4 and F_5 generation for the cross VRO-6 x TCR-1674 was presented as follows.

Growth attributes

The plant height varied from 101 to 137 with a mean of 117.26 in F_3 generation. In F_4 generation, the values for plant height ranged from 93 to 132 with a mean of 111.17 whereas in F_5 generation, it ranged from 85 to 122 with a mean of 103.96. The estimates of PCV and GCV were low in F_3 (8.36 and 7.28 respectively), F_4 (8.55 and 4.94 respectively) and F_5 (7.72 and 6.09 respectively) generations. The trait plant height had high heritability in F_3 (75.78), moderate in F_4 (33.31) and high in F_5 (62.12) generations. Moderate genetic advance as per cent of mean was recorded in F_3 (13.05) whereas low in F_4 (5.87) and F_5 (9.88) generations. The per cent genetic gain for plant height was -5.19 from F_3 to F_4 generation whereas -6.48 from F_4 to F_5 generation

Days to first flowering ranged from 41 to 48 with a mean of 44.69 in F_3 generation whereas in F_4 generation, it varied 38 to 47 with a mean of 42.85. Days to first flowering varied from 37 to 46 with a mean of 41.09 in F_5 generation. The estimates of PCV and GCV were low in F_3 (4.12 and 3.18 respectively), F_4 (4.85 and 2.57 respectively) and F_5 (4.21 and 3.23 respectively) generations.

Moderate heritability was observed in F_3 (59.71) and F_5 (59.05) generations whereas low heritability (28.20) in F_4 generation. Genetic advance as per cent of mean were recorded as low in F_3 (5.07), F_4 (2.81) and F_5 (5.12) generations. The per cent genetic gain for this character was -4.11 from F_3 to F_4 generation whereas -4.10 from F_4 to F_5 generation.

Internodal length ranged from 4.5 to 7.8 with an average of 6.23. The PCV (13.46) and GCV (10.00) were moderate in F_3 generation whereas in F_4 generation internodal length varied from 4.01 to 7.01 with a mean of 5.33 and it had moderate PCV (12.47) and low GCV (8.43). In F_5 generation, internodal length ranged from 3.6 to 6.7 with a mean of 5.07. The estimates of PCV and GCV were moderate and low (12.46 and 8.47 respectively) in F_5 generation.

Moderate heritability (55.22, 45.68 and 46.18) coupled with moderate genetic advance as per cent of mean (15.31, 11.74 and 11.86) were observed in F_3, F_4 and F_5 generations respectively. The per cent genetic gain for this trait was -14.44 from F_3 to F_4 generation whereas -4.87 from F_4 to F_5 generation.

Flowering and earliness attributes

Days to 50% flowering varied from 49 to 61 with a mean of 55.94 and the estimates of PCV (5.57) and GCV (4.23) were low in F_3 generation whereas in F_4 generation, days to 50% flowering varied from 48 to 58 with a mean of 53.36 and the PCV (4.81) and GCV (3.34) were low. The days to 50% flowering varied from 47 to 57 with a mean of 51.48. The estimates of PCV (4.39) and GCV (2.79) were low in F_5 generation. Moderate heritability (57.70, 48.08 and 40.30) coupled with low genetic advance as per cent of mean (6.62, 4.77 and 3.64) were observed in F_3, F_4 and F_5 generations respectively. The per cent genetic gain for this trait was -4.61 from F_3 to F_4 generation whereas -3.52 from F_4 to F_5 generation.

The trait first flowering node ranged from 2 to 5 with a mean of 3.94 and the it had high PCV (21.89) and low GCV (14.44) F_3 generation whereas in F_4 generation, it varied from 2 to 5 with a mean of 3.58 and the PCV and GCV were high and moderate (25.79 and 18.57 respectively). The first flowering node varied from 2 to 5 with a mean of 3.50 and the estimates of PCV and GCV were high and moderate (27.09 and 15.75 respectively) in F_5 generation. Moderate heritability was recorded in F_3 (43.54) and F_4 (51.88) whereas low recorded in F_5 (3.81) generation. Genetic advance as per cent of mean was recorded as moderate in F_3 (19.63), high in F_4 (27.56) and moderate in F_5 (18.87) generations. The per cent genetic gain for this trait was -9.13 from F_3 to F_4 generation and -2.23 from F_4 to F_5 generation.

Days to first picking ranged from 59 to 70 with a mean of 64.44 and the PCV (4.76) and GCV (2.70) were low in F_3 generation whereas in F_4 generation, it ranged from 59 to 68 with mean of 62.56 and the PCV and GCV were low (3.51 and 2.31 respectively). The trait days to first picking ranged from 57 to 67 with a mean of 60.60 and the estimates of PCV and GCV were low (3.36 and 1.94 respectively in F_5 generation. Moderate heritability (32.22, 43.33 and 33.48) coupled with low genetic advance as per cent of mean (3.16, 3.14 and 2.32) were observed in F_3, F_4 and F_5 generations respectively for days to first picking. The per cent genetic gain for this trait was -2.91 from F_3 to F_4 generation and -3.13 from F_4 to F_5 generation.

Days to last picking ranged from 77 to 93 with a mean of 85.52 and the PCV (4.99) and GCV (2.40) recorded were low in F_3 generation whereas in F_4 generation, days to last picking ranged from 76 to 89 with a mean of 82.70 and PCV and GCV were low (3.25 and 2.11 respectively). In F_5 generation, the days to last picking ranged from 75 to 86 days with a mean of 80.77 and the estimates of PCV and GCV were low (3.13 and 1.78 respectively). Low to moderate heritability (23.13, 42.10 and 32.38) coupled with low genetic advance as per cent of mean (2.38, 2.81 and 2.09) were observed in F_3, F_4 and F_5 generations respectively. The per cent genetic gain for this trait was -3.29 from F_3 to F_4 generation and -2.33 from F_4 to F_5 generation.

Yield attributes

Number of fruits per plant ranged from 14 to 25 with a mean of 18.14 and it exhibited moderate PCV (12.68) and low GCV (8.03) in F_3 generation. However, moderate heritability (40.11) coupled with moderate genetic advance as per cent of mean (10.48) was recorded for this character in F_3 generation. In F_4 generation, number of fruits per plant ranged from 15 to 27 with a mean of 19.52 and it displayed moderate PCV (15.69) and low GCV (8.86). However, moderate heritability (31.90) coupled with moderate genetic advance as per cent of mean (10.31) was observed for this character. In F_5 generation, number of fruits per plant ranged from 17 to 29 with a mean of 23.11 and it exhibited moderate PCV (12.16) and low GCV (6.51). However, low heritability (28.68) coupled with low genetic advance as per cent of mean (7.19) was observed in F_5 generation. The per cent genetic gain for this trait was 7.60 from F_3 to F_4 generation and 18.39 from F_4 to F_5 generation

The length of fruit ranged from 11.8 to 21.2 with a mean of 16.75 and moderate PCV (13.75) and GCV (10.40) were recorded in F_3 generation whereas in F_4 generation, it ranged from 12.9 to 22.0 with a mean of 17.77 and the estimates of PCV (12.55) and GCV (8.83) were moderate and low respectively. The fruit length ranged from 13.0 to 22.6 with a mean of 18.20 in F_5 generation and the estimates of PCV and GCV were recorded as moderate and low (10.67 and 7.47 respectively) for this trait. Moderate heritability (57.21, 49.45 and 48.96) coupled with moderate genetic advance as per cent of mean (16.21, 12.78 and 10.76) were observed in F_3, F_4 and F_5 generation respectively. The per cent genetic gain for this trait was 6.08 from F_3 to F_4 generation and 2.41 from F_4 to F_5 generation. Fruit girth ranged from 3.6 to 7.0 with a mean of 5.19 and had moderate PCV (16.64) and GCV (12.41) in F_3 generation whereas in F_4 generation, it ranged from 3.9 to 7.3 with a mean of 5.55 and the estimates of PCV and GCV (17.18 and 10.93) were moderate respectively. The fruit girth ranged from 4.0 to 7.5 with a mean of 5.74 and it exhibited moderate PCV and GCV (16.36 and 12.75 respectively) in F_5 generation. Moderate to high heritability (55.65, 40.49 and 60.80) coupled with moderate to high genetic advance as per cent of mean (19.07, 14.33 and 20.48) were observed in F_3, F_4 and F_5 generation for fruit girth respectively. The per cent genetic gain for this trait was 6.93 from F_3 to F_4 generation and 3.42 from F_4 to F_5 generation.

Fruit weight ranged from 14.0 to 25.3 with a mean of 19.03 and the estimates of PCV and GCV were moderate (12.52) and low (8.11). Moderate heritability (42.01) coupled with moderate (10.83) genetic advance as per cent of mean was observed in F_3 generation. In F_4 generation, it ranged from 15.8 to 27.4 with a mean of 20.71 and the estimates of PCV and GCV were moderate (11.46 and low 8.83 respectively). However, moderate heritability (59.33) coupled with moderate (14.01) genetic advance as per cent of mean was observed for this attribute. The fruit weight varied from 16.01 to 28.0 with a mean of 22.79 and the estimates of PCV and GCV were moderate and low (10.47 and 7.90 respectively). However, moderate heritability (56.83) coupled with moderate (12.26) genetic advance as per cent of mean was observed in F_5 generation. The per cent genetic gain for this trait was 8.82 from F_3 to F_4 generation and 10.04 from F_4 to F_5 generation.

Fruit yield per plant ranged from 182 to 256 with a mean of 227.55 and it had low estimates of PCV (7.67) and GCV (6.85). High heritability (79.84) coupled with moderate genetic advance as per cent of mean (12.61) was observed in F_3 generation. In F_4 generation, yield per plant ranged from 185 to 274 with a mean of 237.71 and it recorded moderate PCV (10.34) and low GCV (9.88). High heritability (91.26) coupled with moderate of genetic advance as per cent of mean (19.44) was observed for this character. Fruit yield per plant ranged from 190 to 280 with a mean of 243.95 and estimates of PCV (9.09) and GCV (8.58) were low. High heritability (89.04) coupled with moderate genetic advance as per cent of mean (16.68) was observed in F_5 generation. The per cent genetic gain for this trait was 4.46 from F_3 to F_4 generation and 2.62 from F_4 to F_5 generation.

Number of seeds per fruit varied from 35 to 58 with a mean of 48.99 and estimates of PCV (12.61) and GCV (8.67) were moderate and low respectively. This trait recorded moderate heritability (47.21) coupled with moderate (12.27) genetic advance as per cent of mean in F_3 generation. In F_4 generation, it varied from 38 to 62 with a mean of 50.96 and the estimates of PCV and GCV were moderate and low (12.35 and 8.49 respectively). This trait recorded moderate heritability (47.25) coupled with moderate genetic advance as per cent of mean (12.02). In F_5 generation, number of seeds per fruit varied from 39 to 65 with a mean of 51.11 and estimates of PCV and GCV were moderate (12.70) and low GCV (9.14). This trait recorded moderate heritability (51.84) coupled with moderate genetic advance as per cent of mean (13.56) in F_5 generation. The per cent genetic gain for this trait was 4.02 from F_3 to F_4 generation and 0.29 from F_4 to F_5 generation.

Test weight of seeds ranged from 4.9 to 6.9 with a mean of 6.01 in F_3 generation. In F_4 generation, the values for this trait ranged from 5.1 to 7.2 with a mean of 6.18 whereas in F_5 generation, it ranged from 5.5 to 7.2 with a mean of 6.41. The estimates of PCV and GCV were low in F_3 (9.15 and 6.81 respectively), F_4 (8.20 and 5.75 respectively) and F_5 (7.26 and 4.02 respectively) generations. Moderate heritability (55.39, 49.30 and 30.70) was recorded in F_3, F_4 and F_5 generations respectively. Genetic advance expressed as per cent of mean was moderate in F_3

(10.44) whereas low in F_4 (8.32) and F_5 (4.59) generations. The per cent of genetic gain for this trait was 2.82 from F_3 to F_4 generation whereas 3.72 from F_4 to F_5 generation

The per cent incidence of trait yellow vein mosaic virus ranged from 6.5 to 8.1 with a mean of 7.39 and the estimates of PCV (6.09) and GCV (4.01) were low. This trait recorded moderate heritability (43.29) coupled with low genetic advance as per cent of mean (5.43) in F_3 generation. In F_4 generation, it varied from 4.2 to 7.1 with a mean of 5.98 and it had moderate PCV (12.20) and low GCV (8.23). This trait recorded moderate heritability (45.56) coupled with moderate genetic advance as per cent of mean (11.45). The trait yellow vein mosaic virus incidence varied from 4.01 to 7.01 with a mean of 5.86 and the estimates of PCV (11.54) and GCV (7.95) were moderate and low respectively. This trait recorded moderate heritability (47.51) coupled with moderate genetic advance as per cent of mean (11.29) in F_5 generation. The per cent of genetic gain for this trait was -19.07 from F_3 to F_4 generation and -2.00 from F_4 to F_5 generation.

Biochemical attributes

The fibre content ranged from 1.5 to 3.0 with a mean of 2.10 in F_3 generation. In F_4 generation, the values for the trait ranged from 1.4 to 2.9 with a mean of 2.09 whereas in F_5 generation, it ranged from 1.3 to 2.8 with a mean of 2.07. In F_3 population, high PCV (22.71) and moderate GCV (15.98) were recorded. The estimates of PCV (16.09) and GCV (11.51) were moderate in F_4 whereas moderate PCV (13.46) and low GCV (8.71) were recorded in F_5 generation. Moderate heritability (49.53, 51.15 and 41.85) coupled with high to moderate genetic advance as per cent of mean (23.17, 16.96 and 11.60) in F_4 and F_5 generations respectively. The per cent of genetic gain for this trait was -0.47 from F_3 to F_4 generation and -0.95 from F_4 to F_5 generation.

The ascorbic acid content ranged from 10 to 16 with a mean of 13.28 in F_3 generation. In F_4 generation, the values for the trait ranged from 11 to 17 with a mean of 14.27 whereas in F_5 generation, it ranged from 11 to 18 with a mean of 14.45. The trait ascorbic acid content had moderate PCV and low GCV in F_3 (12.58 and 9.08 respectively), F_4 (12.03 and 8.70 respectively) and F_5 (10.84 and 8.30 respectively) generations. Moderate heritability (52.14, 52.29 and 58.61) coupled with moderate genetic advance as per cent of mean (13.51, 12.96 and 13.08) were observed in F_3, F_4 and F_5 generations respectively. The per cent of genetic gain for this trait was 7.45 from F_3 to F_4 generation whereas1.26 from F_4 to F_5 generation.

Shelf life varied from 2 to 4 with a mean of 2.59 and it exhibited high PCV (22.69) and moderate GCV (14.97). However, moderate heritability (43.54) coupled with high genetic advance as per cent of mean (20.35) was observed in F_3 generation. In F_4 generation, shelf life varied from 2 to 4 with a mean of 2.95 and it showed high PCV (24.74) and moderate GCV (18.03). However, it had moderate heritability (53.08) coupled with high genetic advance as per cent of mean (27.06). Shelf life ranged from 2 to 5 with a mean of 3.32 and it recorded high PCV and moderate GCV (20.92 and 15.28). However, moderate heritability (53.36) coupled with high genetic advance as per cent of mean (23.0) was recorded in F_5 generation. The per cent genetic gain for this trait was 13.89 from F_3 to F_4 generation and 12.54 from F_4 to F_5 generation.

Discussion

The phenotypic coefficient of variation was higher than corresponding genotypic coefficient of variation in F_3, F_4 and F_5 of this cross VRO-6 x TCR-1674 indicating the influence of environmental factors in the expression of these characters. Similar results were reported by Kavya *et al.* (2019) [12], Sundaram *et al.* (2020) [31], Manjuvani *et al.* (2021) [14], Kharat *et al.* (2022) [13], Shreya *et al.* (2022) [26], Pranay *et al.* (2022) [19], Shwetha *et al.* (2022) [27] and Justina *et al.* (2023) [11].

High PCV and moderate GCV were observed for first flowering node and shelf life in all three generations along with fibre content in F_3 indicating the existence of variability. These results are contradictory with the findings of Demelie *et al.* (2015) [5], Kavya *et al.* (2019) [12], Tukaram *et al.* (2019) [34], Sundaram *et al.* (2020) [31] and Jemal *et al.* (2022) [10].

Moderate PCV and GCV were recorded for fruit girth in all three generations along with fruit length in F_3 and fibre content in F_4. These results are in line with the earlier findings of Shwetha *et al.* (2022) [27], Pranay *et al.* (2022) [19], Prakash *et al.* (2022) [18], Shreya *et al.* (2022) [26] and Jadhav *et al.* (2022) [8].

Moderate PCV and low GCV were observed for internodal length, number of fruits per plant, fruit weight, number of seeds per fruit and ascorbic acid in in all three generations along with fruit length and YVMV incidence in F_4 and $F_5$for fruit yield per plant in F_4 and for fibre content in F_5. These results are similar to those reported by Pravin *et al.* (2016) [20], Dhaval *et al.* (2019) [6], Kavya *et al.* (2019) [12], Anteneh *et al.* (2020) [1] and Manjuvani *et al.* (2021) [14].

Low PCV and GCV were recorded for plant height, days to first flowering, days to 50% flowering, days to first picking, days to last picking, test weight of seed in all the three generations for fruit yield per plant in F_3 and F_5 and for YVMV incidence in F_3. This indicated the low variability for these characters which is the constraint for genetic improvement through selection. Similar results were observed by Rekha *et al.* (2015) [21], Thulasiram *et al.* (2017) [33], Arun *et al.* (2019) [2], Manjuvani *et al.* (2021) [14] and Kharat *et al.* (2022) [13].

The success of improvement of characters through selection depends on the heritability coupled with its genetic advance. Once the relative amount of variability in population is assessed, it becomes necessary to partition the overall variability into heritable and non-heritable components. Magnitude of heritability indicates the effectiveness with which selection of genotypes can be based on phenotypic performance. High value of heritability indicates that phenotype of the trait strongly reflects the genotype and suggests the major role of genotypic constitution in the expression of the character. Such traits are considered dependable from breeding point of view.

High heritability along with high genetic advance was observed for fruit girth in F_5 indicating heritability was mainly due to additive gene effect and hence selection can be highly effective for these characters. These results are in line with the findings of Kavya *et al*. (2019) [12], Gurve *et al*. (2021) [7], Jadhav *et al*. (2022) [8], Prakash *et al.* (2022) [18], Shreya *et al.* (2022) [26], Pranay *et al*. (2022) [19] and Justina *et al*. (2023) [11].

High heritability along with moderate genetic advance was observed for fruit yield per plant in F_3, F_4 and F_5 populations and for plant height in F_3 populations indicating the presence of additive gene action and selection may be effective for this character. Similar results were obtained by Dhaval *et al.* (2019) [6], Manjuvani *et al*. (2021) [14], Shwetha *et al.* (2022) [27], Kharat *et al.* (2022) [13] and Jemal *et al*. (2022) [10].

High heritability along with low genetic advance was observed for plant height in F_5 populations indicating the presence of additive gene action and selection may be effective for this character. Similar results were obtained by Sateesh *et al.* (2011) [25], Shreya *et al.* (2022) [26], Prakash *et al.* (2022) [18] and Kharat *et al.* (2022) [13].

Moderate heritability and high genetic advance were observed for shelf life in F_3, F_4 and F_5 populations for fibre content in F_3 and for first flowering node in F_4 pop lations indicating that these characters are influenced by environmental factors. Similar results were reported by Soyab *et al*. (2013) [29], Vijaya *et al.* (2013) [37], Jagan *et al*. (2013) [9], Demelie *et al.* (2015) [5] and Thulasiram *et al.* (2017) [33].

Moderate heritability and moderate genetic advance were observed for internodal length, fruit length, fruit weight, number of seeds per fruit, ascorbic acid in F_3, F_4 and F_5 populations for number of fruits per plant, fruit girth in F_3 and F_4;for first flowering node in F_3 and F_5;for fruit weight, YVMV incidence, fibre content and ascorbic acid in F_4 and F_5 and for test weight of seed in F_3 populations. These results are contradictory with the findings of Salesh *et al*. (2010) [24], Jagan *et al*. (2013) [9], Rekha *et al.* (2015) [21], Pravin *et al* (2016) [20] and Tukaram *et al*. (2019) [34].

Moderate heritability and low genetic advance were observed for days to 50% flowering, days to first picking in all the three generations along with days to first flowering in F_3 and F_5;for days to last picking, test weight of seed in F_4 and F_5;for YVMV incidence in F_3 and for plant height in F_4 populations indicating that these characters are influenced by environmental factors and governed by non-additive gene action. Similar results were reported by Salesh *et al* (2010) [24], Soyab *et al.* (2013) [29], Thulasiram *et al.* (2017) [33], Sundharam *et al.* (2020) [31] and Shwetha *et al*. (2022) [27].

Low heritability and low genetic advance were observed for days to last picking in F_3 for days to first flowering in F_4 and number of fruits per plant in F_5 populations indicating selection may not be effective due to non-additive gene action. Similar results were reported by Soyab *et al*. (2013) [29], Pravin *et al*. (2016) [20], Thukaram *et al.* (2019) [34] and Pranay *et al*. (2022) [19].

In the cross VRO-6 x TCR-1674, values of PCV and GCV of almost all the traits in F_5 generation were less than those in F_3 and F_4 generation indicating decrease in variability due to selection. Similar results were reported by Kavya *et al*. (2019)[12], Kharat *et al*. (2022) [13], Prakash *et al.* (2022)[18] and Jadhav *et al.* (2022) [8].

Heritability values varied from generation to generation, there is an increased tendency of heritability from F_3 to F_5 for number of seeds per fruit, ascorbic acid and shelf life whereas remaining traits showed inconsistent tendency of increase or decrease from F_3 to F_5 generations which may be due to varying magnitude of genotypic x environmental interactions. The traits *i.e.* plant height, internodal length, days to 50% flowering, first flowering node, days to first picking, days to last picking, number of fruits per plant, fruit length, test weight of seeds, fibre content and ascorbic acid were showed less values of genetic advance as per cent of mean in F_5 when compared to that of F_3 and F_4 generation which may be due to reduction in variance. These are inline with the findings of Kavya *et al*. (2019) [12], Pranay *et al*. (2022) [19], Jadhav *et al.* (2022) [8] and Kharat *et al.* (2022) [13].

Selection was exercised in each generation in the cross VRO-6 x TCR -1674 with the objective of improvement in economically important traits. Negative genetic gain was observed in the traits *viz.,* days to first flowering, internodal length, days to 50% flowering, first flowering node, days to first picking, days to last picking and YVMV incidence which is also in the desirable direction whereas positive genetic gain was observed in remaining traits indicating selection is effective for those traits. However, the values of genetic gain decreased over generations due to the fact that variation decreased due to selection of few superior plants from a heterogenous population. Similar results were reported by Monpara *et al*. (2010) [16], Thirupathi *et al*. (2012) [32] and Meenakshi *et al*. (2023) [15].

Plate 1: Promising line LOK-21(Lam okra-21) selected in F_5 generation of cross VRO-6 x TCR-1674.

Table 1: Mean, variability and heritability parameters for different characters in F_3, F_4 and F_5 generation of cross VRO-6 x TCR-1674

Characters	Generation	Mean	Range	PCV	GCV	Heritability (%)	GA at 5%	GAM at 5%	GG %
Plant height (cm)	F_3	117.26	101-137	8.36	7.28	75.78	15.30	13.05	
	F_4	111.17	93-132	8.55	4.94	33.31	6.52	5.87	-5.19
	F_5	103.96	85-122	7.72	6.09	62.12	10.28	9.88	-6.48
Days to first flowering	F_3	44.69	41-48	4.12	3.18	59.71	2.26	5.07	
	F_4	42.85	38-47	4.85	2.57	28.20	1.21	2.81	-4.11
	F_5	41.09	37-46	4.21	3.23	59.05	2.10	5.12	-4.10
Internodal length (cm)	F_3	6.23	4.5-7.8	13.46	10.00	55.22	0.95	15.31	
	F_4	5.33	4.0-7.0	12.47	8.43	45.68	0.63	11.74	-14.44
	F_5	5.07	3.6-6.7	12.46	8.47	46.18	0.60	11.86	-4.87
Days to 50 % flowering	F_3	55.94	49-61	5.57	4.23	57.70	3.70	6.62	
	F_4	53.36	48-58	4.81	3.34	48.08	2.54	4.77	-4.61
	F_5	51.48	47-57	4.39	2.79	40.30	1.87	3.64	-3.52
First flowering node	F_3	3.94	2-5	21.89	14.44	43.54	0.77	19.63	
	F_4	3.58	2-5	25.79	18.57	51.88	0.99	27.56	-9.13
	F_5	3.50	2-5	27.09	15.75	33.81	0.66	18.87	-2.23
Days to first picking	F_3	64.44	59-70	4.76	2.70	32.22	2.04	3.16	
	F_4	62.56	59-68	3.51	2.31	43.33	1.96	3.14	-2.91
	F_5	60.60	57-67	3.36	1.94	33.48	1.40	2.32	-3.13
Days to last picking	F_3	85.52	77-93	4.99	2.40	23.13	2.03	2.38	
	F_4	82.70	76-89	3.25	2.11	42.10	2.33	2.81	-3.29
	F_5	80.77	75-86	3.13	1.78	32.38	1.68	2.09	-2.33
Number of fruits per plant	F_3	18.14	14-25	12.68	8.03	40.11	1.90	10.48	
	F_4	19.52	15-27	15.69	8.86	31.90	2.01	10.31	7.60
	F_5	23.11	17-29	12.16	6.51	28.68	1.66	7.19	18.39
Fruit length (cm)	F_3	16.75	11.8-21.2	13.75	10.40	57.21	2.71	16.21	
	F_4	17.77	12.9-22.0	12.55	8.83	49.45	2.27	12.78	6.08
	F_5	18.20	13.0-22.6	10.67	7.47	48.96	1.96	10.76	2.41
Fruit girth (cm)	F_3	5.19	3.6-7.0	16.64	12.41	55.65	0.99	19.07	
	F_4	5.55	3.9-7.3	17.18	10.93	40.49	0.79	14.33	6.93
	F_5	5.74	4.0-7.5	16.36	12.75	60.80	1.18	20.48	3.42
Fruit weight (g)	F_3	19.03	14.0-25.3	12.52	8.11	42.01	2.06	10.83	
	F_4	20.71	15.8-27.4	11.46	8.83	59.33	2.90	14.01	8.82
	F_5	22.79	16.0-28.0	10.47	7.90	56.83	2.79	12.26	10.04
Fruit yield per plant (g)	F_3	227.55	182-256	7.67	6.85	79.84	28.70	12.61	
	F_4	237.71	185-274	10.34	9.88	91.26	46.45	19.44	4.46
	F_5	243.95	190-280	9.09	8.58	89.04	40.69	16.68	2.62
Number of seeds per fruit	F_3	48.99	35-58	12.61	8.67	47.21	6.01	12.27	
	F_4	50.96	38-62	12.35	8.49	47.25	6.13	12.02	4.02
	F_5	51.11	39-65	12.70	9.14	51.84	6.93	13.56	0.29
Test weight of seeds (g)	F_3	6.01	4.9-6.9	9.15	6.81	55.39	0.63	10.44	
	F_4	6.18	5.1-7.2	8.20	5.75	49.30	0.51	8.32	2.82
	F_5	6.41	5.5-7.2	7.26	4.02	30.70	0.29	4.59	3.72
YVMV incidence (%)	F_3	7.39	6.5-8.1	6.09	4.01	43.29	0.40	5.43	
	F_4	5.98	4.2-7.1	12.20	8.23	45.56	0.68	11.45	-19.07
	F_5	5.86	4.0-7.0	11.54	7.95	47.51	0.66	11.29	-2.00
Fibre content (g)	F_3	2.10	1.5-3.0	22.71	15.98	49.53	0.49	23.17	
	F_4	2.09	1.4-2.9	16.09	11.51	51.15	0.35	16.96	-0.47
	F_5	2.07	1.3-2.8	13.46	8.71	41.85	0.24	11.60	-0.95
Ascorbic acid (mg)	F_3	13.28	10-16	12.58	9.08	52.14	1.79	13.51	
	F_4	14.27	11-17	12.03	8.70	52.29	1.85	12.96	7.45
	F_5	14.45	11-18	10.84	8.30	58.61	1.89	13.08	1.26
Shelf-life (Days)	F_3	2.59	2-4	22.69	14.97	43.54	0.53	20.35	
	F_4	2.95	2-4	24.74	18.03	53.08	0.80	27.06	13.89
	F_5	3.32	2-5	20.92	15.28	53.36	0.76	23.00	12.54

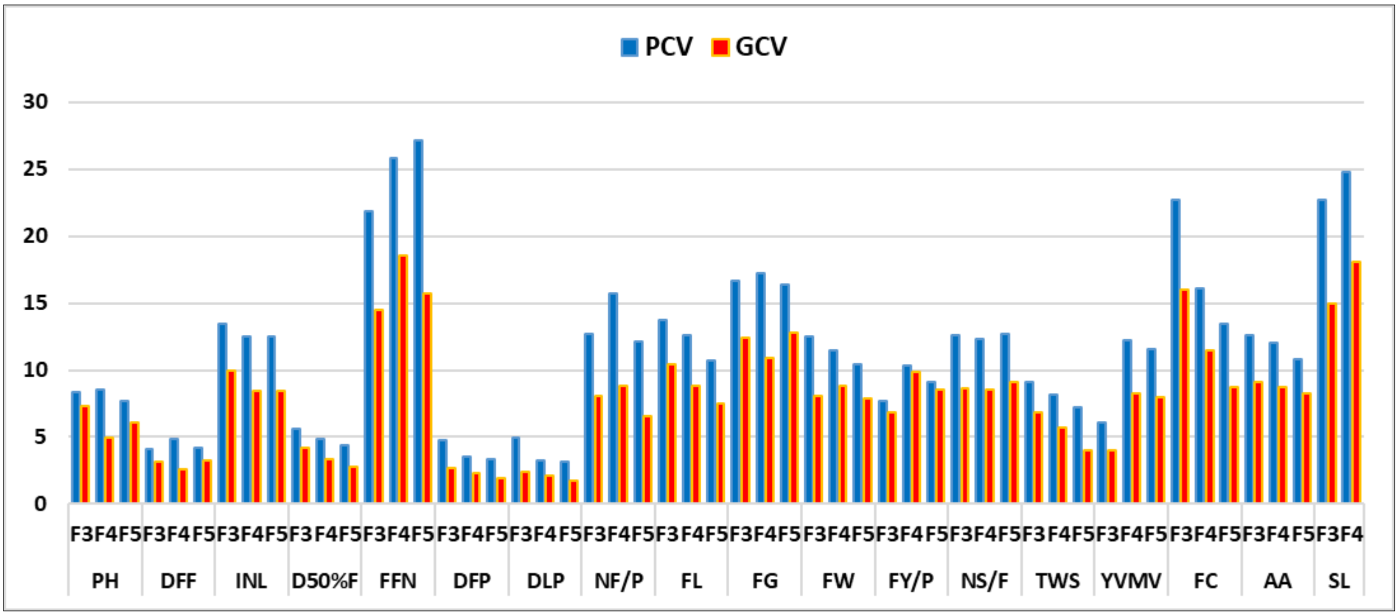
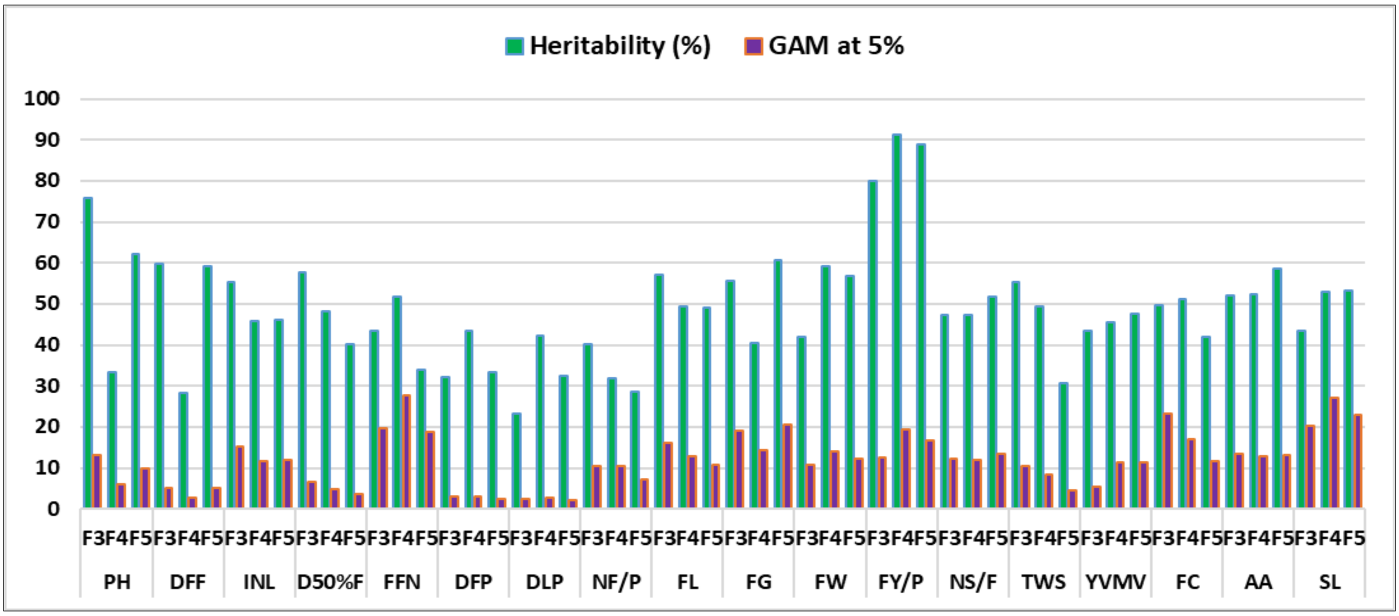


Fig 1: Phenotypic and genotypic coefficient of variation in F_3, F_4 and F_5 generations of cross VRO-6 x TCR-1674



PH - Plant height (cm)	**DFP** - Days to first picking	**FW** - Fruit weight (g)	**FC** - Fibre content (g)
DFF - Days to first flowering	**DLP** - Days to last picking	**FY/P** - Fruit yield per plant (g)	**AA** - Ascorbic acid content (mg)
INL - Internodal length (cm)	**NF/P** - Number of fruits per plant	**NS/F** - Number of seeds per fruit	**SL** - Shelf-life of fruits (days)
D50%F - Days to 50% flowering	**FL** - Fruit length (cm)	**TWS** - Test weight of seeds (g)	
FFN - First flowering node	**FG** - Fruit girth (cm)	**YVMV** - YVMV incidence (%)	

Fig 2: Heritability and genetic advance as per cent mean in F_3, F_4 and F_5 generations of cross VRO-6 x TCR-1674

Conclusion

Twenty Superior progenies in F_5 generation were selected based on their yield and its attributing traits for further evaluation in the further generations. Out of twenty superior selections in LOK-25 [(VRO-6 x TCR-1674)-25-14-3-25] and LOK-21[(VRO-6 x TCR-1674)-14-9-28-21] in VRO-6 x TCR-1674 cross are selected for taking up the small seed production. These six superior lines out of three crosses are going test their yield performance and adaptability in multi environments in *Kharif* 2024 onwards across Andhra Pradesh. Plants are medium to tall with light to dark green fruits had seven ridges lobed medium sized and tolerant to YVMV incidence. The more number of fruits per plant with glossiness and quality products are gives abundance yielding for commercial scale. Long and big sized light green fruits with prominent five ridges pods are borne in stem. Best promising plants were selected in F_5 generation as given below and selfed for further preliminary yield trials.

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