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Assessment of genetic variability, correlation and traits association in sesame (*Sesamum indicum* (L.). using F_4 families under summer rice fallow conditions

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Abstract
The 104 F_4 families of the cross OCT 15 X Thirukkattupalli local were used for evaluation of genetic parameters *viz.,* PCV, GCV, Heritability and Genetic advance in summer rice fallow sesame for the seed yield and attributing traits *viz.,* days to 50% flowering, days to maturity, Plant height, number of branches per plant, number of capsules per plant, number of seeds per capsules, and 1000-seed weight. Low PCV and GCV were observed for days to 50% flowering and days to maturity. Moderate PCV and GCV were observed for plant height and number of seeds per capsule. Higher PCV and GCV were observed for number of branches, number of capsules per plant, 1000-seed weight and seed yield. All the traits exhibited higher percentages of heritability. Days to flowering and maturity showed moderate genetic advance, whereas all other traits exhibited higher percentages of genetic advance. Days to maturity and plant height were recorded positive and significant correlation with seed yield. Number of seeds per capsule had a negative correlation with seed yield. Days to maturity and plant height had a positive direct effect on seed yield. It is assumed that traits with higher heritability and genetic advance *viz.,* plant height, number of branches, 1000- seed weight and seed yield were contributed by additive gene action and selection will be effective for fixing the stable lines under summer rice fallow sesame from the cross OCT15 x Thirukkattupalli local.

Keywords: Summer rice fallow, capsules, heritability, genetic advance, additive gene action

Introduction
Sesame is considered to be the most important oil seed crops of ancient and present day Indian sub-continent with its purposes as healthy edible oil, as a component in ayurvedic preparations and main item in after death rituals (Sanskrit name pitutharpana meaning offerings to the forefathers). India is considered to be the centre of origin for the cultivated sesame crop with greater genetic diversity (De candolle, 1885) [4]. Few references have shown that the African centre may be the primary centre of origin for sesame, but those evidences are not proven scientifically (Bedigian, 2003) [3]. Sesame is commonly cultivated in Asian, European and American countries for its healthy oil quality and flavour. In countries *viz.,* China, Korea and Japan, the sesame oil is an important component in salads and fried rice. In America, it is becoming popular due to its health benefits and many non- shattering mutant varieties have been developed along with synchronous maturity which favours mechanical harvesting. Mechanical harvesting of sesame is only done in USA with the cultivation of non-shattering mutant derived varieties (Langham and Wiemers, 2002) [19]. In India, it is being cultivated in almost all the states for its wider uses in culinary and health purposes. Sesame is cultivated in all three major seasons *viz., Kharif* (June-July), *rabi* (Sept-Oct) as rainfed conditions during monsoon periods and during summer as irrigated crop. Sesame is cultivated in an area of 19.47 lakh ha in India with annual production of 8.66 lakh tonnes and productivity of 431 kg/ha. It is lower than the world average productivity of 535 kg/ha. The national average of India is lower than countries like China and the USA. India ranks first in production and area under production. India is the largest exporter of sesame seeds and it mainly exports to the USA, Vietnam and Russia with worth of more than 35 million USD annually. In Tamil Nadu, Sesame is cultivated in an area of 52686 ha with production of 34,449.00 tonnes with productivity of 530 kg/ha (Season and crop report, TN govt 2021) [23]. The average productivity of Tamil Nadu state is higher than national average, still there is scope to increase the productivity under optimum management practices combined with high yielding varieties

(Jeevamathi and Srinivasan, 2021) [7]. The delta region of Tamil Nadu cultivates sesame in an area of 12457 ha with production of 6590 tonnes with productivity of 529 kg/ha (Tiruchirappalli, Thanjavur, Thiruvarur, Nagapattinam, Mayiladurai and Pudukottai). Rice production is the major contribution from cauvery delta zone (CDZ) and it is cultivated in an area of 14.76 lakh ha annually. After the second rice crop, sesame can be cultivated as rice fallow sesame to increase the area under cultivation and diversify the crops in CDZ. Rice fallow sesame can be a suitable method to utilize the larger rice production area to increase the sesame production (Indian oil Seed Mission, 2021; Javeeda and Dhandapani, 2022) [6]. Rice fallow cultivation of crops has a whole lot of advantages of conservation of soil resources, low inputs use, crop diversification and additional income. Sesame cultivation is highly remunerative with its stable price over years (Kumarasamy and Sekar, 2017) [11]. Rice fallow sesame cultivation needs specifically adapted varieties with low input responses and higher yield. In Tamil Nadu, rice fallow sesame cultivation is having huge potential in Cauvery delta zone with minimum tillage practices. Lack of suitable high yielding varieties of sesame under rice fallow cultivation is a major limiting factor. Attempts were made to identify rice fallow responsive genotypes in sesame and among 95 genotypes tested under rice fallow conditions, the popular variety of the Tiruchirappalli and Thanjavur districts (region starting from Kumbakonam and pattukottai from thanjavur dt to Thirukkattupalli, samayapuram, Lalgudi in Trichy dt) *viz.*, Thirukkattupalli local performed better with higher yield (Dhandapani *et al.*, 2023) [5]. It is highly adapted to summer sesame cultivation in this region, after the rice crop cultivation during Oct-Nov. The variety is the most popular local variety grown for its low input responses, higher yield, with consumer preference of light brown seeds, bold seeds (1000- seed weight: 8.0 g) and higher crude oil recovery of 52.5% (Dhandapani *et al.*, 2022) [5]. Based on the PCA analysis, the identified extreme poor performing line *viz.*, OCT15 was crossed with Thirukkattupalli local and the from F_2 onwards to F_4 selection was made under rice fallow conditions with low input application (Dhandapani *et al.*, 2023) [6]. The present study aimed to learn the inheritance pattern of traits associated with seed yield through genetic variability followed by correlation and path analysis. High PCV, GCV with moderate heritability and genetic advance was observed for traits like plant height number of branches, capsules per plant, 1000 seed weight and seed yield of summer rice fallow sesame screened under coconut gardens in Malappuram region of Kerala. It is important to study the gene action to select and stabilize the better performing families in F_4 suited to summer rice fallow conditions of CDZ from the cross, OCT15 x Thirukkattupalli local.

Materials and methods

Crossing work and development of segregating populations

Based on the diversity analysis (Dhandapani *et al.*, 2023) [6], the extreme lines of better and poor performance under summer rice fallow conditions were selected for crossing program *viz.*, OCT15 and Thirukkattupalli. The lines were crossed during *Kharif* 2019 and F_1 seeds were raised during *rabi* 2019. The true F_1s were forwarded to summer rice fallow 2020. F_2 progenies were stringently selected under summer rice fallow conditions with limited irrigations and no input application as described in the previously published report (Dhandapani *et al.*, 2023) [6]. The progenies were selected based on yield performance under rice fallow conditions and F_2 progenies reconstituted as individual F_3 families during summer 2022 as rice fallow. Better performing families were forwarded to F_4 during *rabi* 2022 as an irrigated crop. Observations on yield and yield attributing traits were taken.

Statistical analysis

The selected F4 families (102 families) were raised in augmented design with four checks *viz.*, Thirukkattupalli local, VRI 2, OCT 15 and Thilothama in 8 blocks with 14 entries and 4 checks. The total of 18 entries per block. Eighth block had 12 entries and 4 checks. Checks were repeated in all the blocks. R statistical analysis was performed to study the variability parameters and Association studies.

Results and Discussion

Variability analysis helps to identify the significant variation present among genotypes for a trait. Phenotypic Coefficient of Variation, Genotypic Coefficient of Variation, Heritability and Genetic Advance as percent of mean of the F_4 population of the cross OCT 15 X Thirukkattupalli Local presented in Table 1 & Fig 1. The trait *viz.*, number of branches per plant (PCV=40.16; GCV= 37.62), number of capsules per plant (PCV=33.03; GCV=32.80), 1000- seed weight (PCV=30.32; GCV=30.32) and seed yield per plant (PCV=47.23; GCV=46.50) had recorded high PCV and GCV and the values are close indicating the PCV is contributed mostly by genotype with less environmental interactions. Similarly, Sahu *et al.* (2022) [20] and Kadvani *et al.* (2020) [8] recorded higher PCV and GCV for number of branches per plant. Sultana *et al.* (2019) [26] recorded higher PCV and GCV for number of capsules per plant. Similarly, Kehie *et al.* (2020) [9] observed higher PCV and GCV for 1000-seed weight. Singh *et al.* (2022) [24] observed higher PCV and GCV for seed yield per plant. Moderate PCV and GCV was recorded for the trait plant height (PCV= 15.22; GCV= 15.06) and number of seeds per capsule (PCV = 15.59; GCV = 13.30). Similar results of Moderate PCV and GCV for plant height and number of seeds per capsule reported by Patidar *et al.* (2020) [15]; Bharathi *et al.* (2019) [2] and Sasipriya *et al.* (2021) [22]. Low PCV and GCV was recorded for the trait days to 50% flowering (PCV = 8.06; GCV = 8.04) and days to maturity (PCV = 5.50; GCV = 5.49). Similar results were reported by Sultana *et al.* (2019) [26]; Paditar *et al.* (2020) [15] and Ranjithkumar *et al.* (2022) [18].

High heritability coupled with low genetic advance indicates the presence of non-additive gene action and selection for such traits may not be efficient in selection of stable performing lines. High heritability and high genetic advance indicate the presence of additive gene effect. Selection may be effective in such cases (Nadarajan *et al.*, 2018) [12]. The results were presented in the Fig 2. Low heritability with low genetic advance suggests that the environment highly affects the trait. In such instances, selection would be ineffective. The traits *viz.*, plant height (cm), number of branches per plant, number of capsules per plant, number of seeds per capsules, 1000-seed weight and seed yield per plant recorded high heritability along with high genetic advance as percent of mean. The similar result for plant height was reported by Sasipriya *et al.*

(2021) [22]. Pohekar *et al.* (2022) [17] reported similar results of higher heritability and GAM for number of branches per plant. Bharath and Reddy (2019) [2] reported similar results of higher heritability and GAM for number of capsules per plant. Patidar *et al.* (2020) [15]; Sirisha *et al.* (2020) [25]; Patel *et al.* (2022) [14] & Sundari *et al.* (2022) [27] reported the higher heritability and GAM for number of seeds per capsule, 1000-seed weight and seed yield per plant. The remaining two traits days to 50% flowering and days to maturity recorded high heritability with moderate GAM. Similarly Patidar *et al.* (2020) [15]; Pavani *et al.* (2020) [16] and Parihar *et al.* (2022) [13] reported the same results in Sesame.

Table 1: Variability parameters of yield components on yield per plant in F_4 generations

Character	PCV (%)	GCV (%)	Heritability (%)	GAM (%)
Days to 50% flowering	8.06	8.04	99.46	16.52
Days to maturity	5.50	5.49	99.67	11.29
Plant height (cm)	15.22	15.06	97.91	30.70
Number of branches per plant	40.16	37.62	87.74	72.59
Number of capsules per plant	33.03	32.80	98.59	67.09
Number of seeds per capsules	15.59	13.30	72.76	23.37
1000-seed weight (g)	30.32	30.32	100.00	62.46
Seed yield per plant (g)	47.23	46.50	96.93	94.31

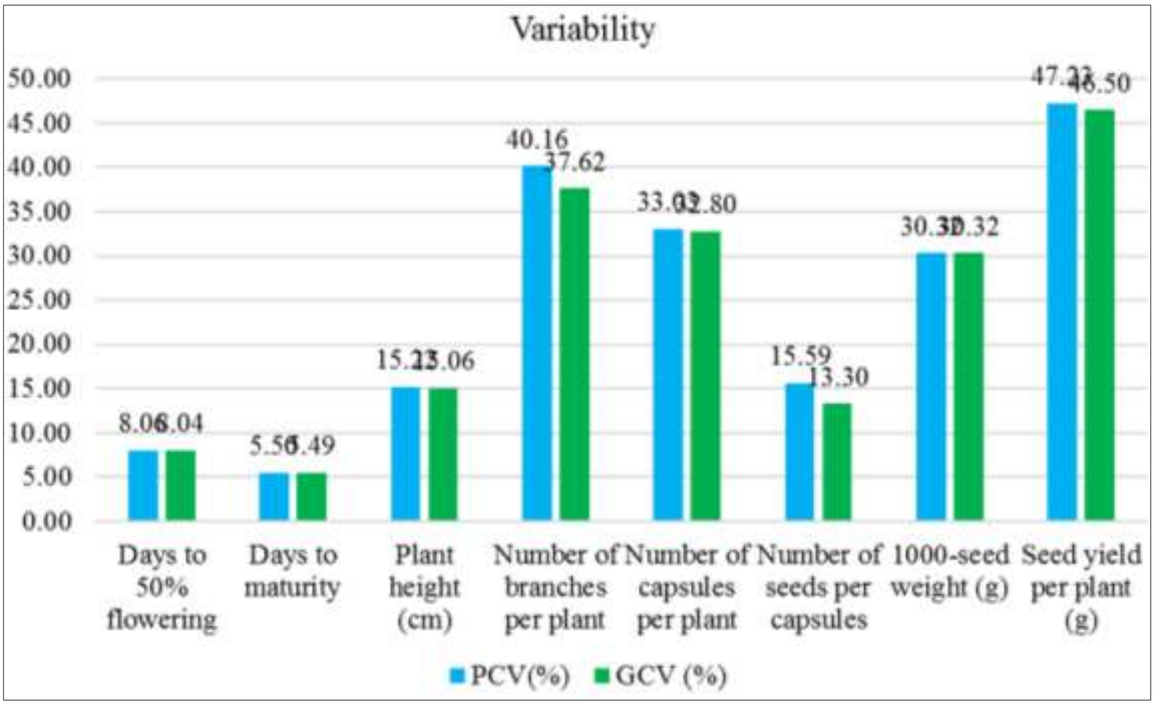

Fig 1: Phenotypic and Genotypic coefficient of variation estimates in F_4 populations of the cross OCT15 X Thirukkattupalli Local under summer rice fallow conditions

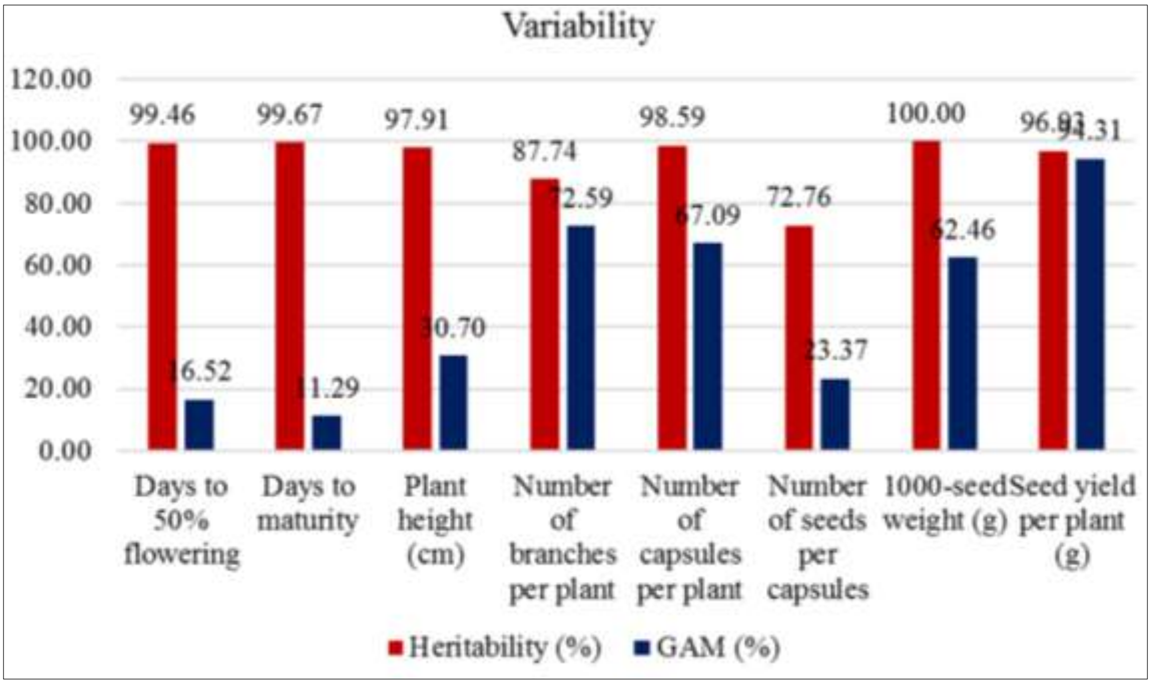

Fig 2: Estimate of heritability and GAM of F_4 populations of the cross OCT15 X Thirukkattupalli Local under summer rice fallow conditions

Association studies used to select the desirable yield attributing traits to improve the seed yield. In this study, the traits *viz.*, days to 50% flowering, days to maturity, plant height (cm), number of capsules per plant and 1000-seed weight recorded significant and positive correlation with seed yield per plant (Table 2 & Fig 3). Days to 50% flowering recorded significant and positive correlation with days to maturity, plant height, number of capsules per plant & 1000-seed weight. The same results found by Sultana *et al.* (2019) [26] & Sasipriya *et al.* (2021) [22]. The trait days to maturity recorded significant and positive correlation with plant height, number of branches per plant, number of capsules per plant & 1000-seed weight. These results are in close agreement with Ahmed *et al.* (2022) [29] for plant height, 1000-seed weight and seed yield per plant, Sultana *et al.* (2019) [26] for number of branches per plant, Saravanan *et al.* (2020) [21] for number of capsules per plant. The trait plant height recorded significant and positive correlation with number of capsules per plant and 1000-seed weight. Similar results were reported by Singh *et al.* (2022) [24] for number of capsules per plant, Saravanan *et al.* (2020) [21] for 1000-seed weight and seed yield per plant. Number of branches per plant recorded significant and positive correlation with number of capsules per plant. Similar result was reported by Singh *et al.* (2022) [24]. Number of capsules per plant recorded significant and positive correlation with 1000-seed weight & seed yield per plant. These results are in close agreement with Sasipriya *et al.* (2021) [22] for 1000-seed weight and Saravanan *et al.* (2020) [21] for seed yield per plant. The trait number of seeds per capsule recorded significant and negative correlation with 1000-seed weight. Similar result was reported by Sultana *et al.* (2019) [26]. The trait 1000-seed weight recorded significant and positive correlation with seed yield per plant in the present results of path analysis. Aboelkassem *et al.* (2021) [1] and Patel *et al.* (2022) [14] reported the same result.

Table 2: Simple correlation coefficient between yield and yield attributes in F_4 generation of Sesame under summer rice fallow conditions

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Number of seeds per capsules	1000-seed weight (g)
Days to maturity	0.72**						
Plant height (cm)	0.19*	0.19*					
Number of branches per plant	0.18	0.21*	0.17				
Number of capsules per plant	0.47**	0.49**	0.22*	0.23**			
Number of seeds per capsules	0.18	0.02	-0.08	0.15	-0.15		
1000-seed weight (g)	0.30**	0.46**	0.22*	-0.06	0.41**	-0.54**	
Seed yield per plant (g)	0.65**	0.74**	0.29**	0.09	0.67**	-0.18	0.74**

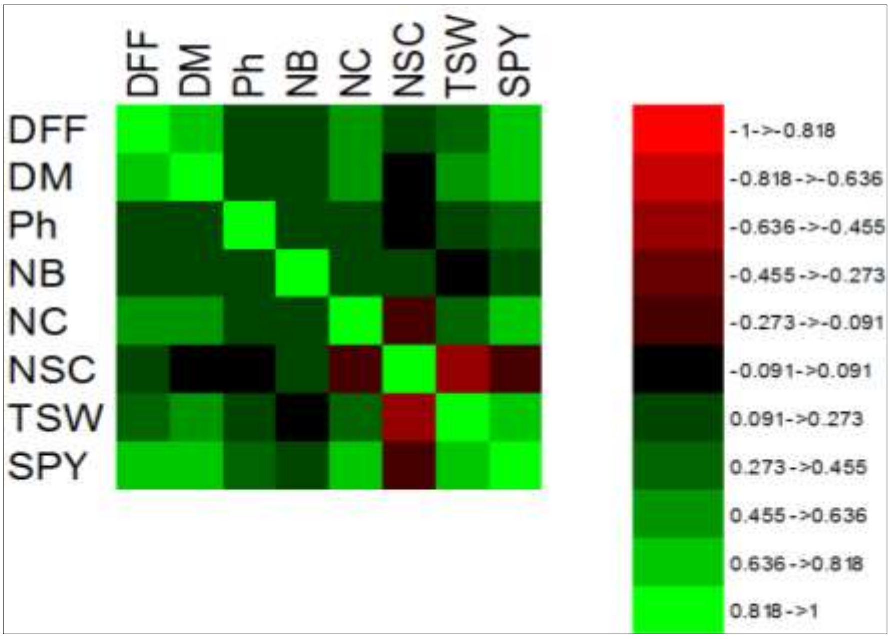

Fig 3: Simple correlation heat map

Path coefficient analysis helps partition the correlation coefficient into its direct and indirect effects (Table 3). In the present study, 1000-seed weight had a high and positive direct effect on seed yield per plant. The trait days to maturity and number of capsules per plant recorded moderate and positive direct effect on seed yield per plant. The similar results reported by Saravanan *et al.* (2020) [21] and Kumar *et al.* (2022) [10]. The residual effect of population was 0.38. It clearly explains the observed characters were more appropriate for the path analysis on seed yield per plant.

Table 3: Direct and indirect effect of yield components on yield per plant in F_4 generation

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Number of seeds per capsules	1000-seed weight (g)	Simple correlation coefficient with seed yield per plant (g)
Days to 50% flowering	0.18	0.17	0.01	-0.01	0.13	0.02	0.15	0.65
Days to maturity	0.13	0.24	0.01	-0.01	0.14	0.00	0.23	0.74
Plant height (cm)	0.03	0.05	0.05	-0.01	0.06	-0.01	0.11	0.29
Number of branches per plant	0.03	0.05	0.01	-0.05	0.06	0.02	-0.03	0.09
Number of capsules per plant	0.08	0.12	0.01	-0.01	0.28	-0.02	0.21	0.67
Number of seeds per capsules	0.03	0.01	0.00	-0.01	-0.04	0.11	-0.28	-0.18
1000-seed weight (g)	0.05	0.11	0.01	0.00	0.11	-0.06	0.51	0.74

Residue effect: 0.38

Conclusion

Summer rice fallow sesame cultivation can be a better alternative cropping system and highly recommended for Cauvery Delta Zone of Tamil Nadu. Mono cropping of rice is becoming order of the day due to various socio-economic factors. Hence, crop diversification with assured remunerative income will alleviate the issues of mono cropping of rice in CDZ. Summer rice fallow sesame cultivation is limited due to lack of well adapted varieties in sesame, as the adaptive features are specific. Hence the present study aimed to develop better performing lines in summer rice fallow sesame from the cross OCT15 X Thirukkattupalli local. The traits *viz.*, number of branches per plant, number of capsules per plant, 1000-seed weight and seed yield per plant indicated high heritability along with high genetic advance as per cent of mean. Hence, the environment influenced these traits and possessed high genetic variability. Hence, selection can be practiced for these traits in these populations. Association studies revealed the Days to 50% flowering, days to maturity, plant height, number of capsules per plant, and 1000 seed weight were positive and significant association with seed yield per plant. Number of seeds per capsule recorded negative correlation with 1000 seed weight. It indicates the increased number of seeds per capsules may have reduced seed size. The path analysis indicated that number of capsules per plant and 1000-seed weight had positive and high direct effects. Hence, based on correlation and path analyses, it can be concluded that the number of capsules per plant and 1000-seed weight can be considered as selection index for the seed yield improvement programme in sesame from the advanced generations of the cross OCT15 X Thirukkattupalli Local under summer rice fallow conditions. However, population specific selection indices are preferred as the association of traits varies with the populations with different donors and recipient parents of varying genetic background identified from the different ecosystems.

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