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GENETIC VARIABILITY AND ASSOCIATION STUDIES FOR POD YIELD AND KERNEL TRAITS IN M3 GENERATION OF GROUNDNUT (*ARACHIS HYPOGAEA* L.)

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ABSTRACT

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop with a narrow genetic base that limits its improvement. Induced mutagenesis provides an effective strategy to generate novel variability for yield enhancement. The present study was carried out during *Kharif* 2024 at Zonal Agricultural Research Station (ZARS), Kalaburagi, in the M_3 generation derived from seven mutagenic treatments, including gamma rays (150, 200, 250 and 300 Gy) and sodium azide (0.02 %, 0.03 %, 0.04 %) along with an untreated control. A total of 171 M_3 families were evaluated for agronomic traits including plant height, primary branches per plant, pods per plant, 100-kernel weight, pod yield per plant, kernel yield per plant and oil content. High phenotypic and genotypic coefficients of variation were recorded for pod yield, kernel yield and pods per plant. High heritability with substantial genetic advance suggested predominance of additive gene action, while positive correlations among yield traits indicated scope for simultaneous selection. The study demonstrates the potential of induced mutagenesis in broadening genetic variability and improving groundnut yield and quality traits.

***Keywords* :** Groundnut, Gamma rays, Sodium azide, variability, Heritability

Introduction

Groundnut (*Arachis hypogaea* L.) belongs to the family Leguminosae and genus *Arachis*. It is a highly self-pollinated, allotetraploid annual legume with a somatic chromosome number of 40 and a basic chromosome number of 10 (Stalker, 1997). Cultivated widely across the tropics and subtropics between 40°S and 40°N, groundnut thrives under annual rainfall of 500–1200 mm and average temperatures above 20°C (Mastewal 2017). In India, groundnut occupies a prominent position in the oilseed economy, ranking first in area and second in production globally after China. India and China are the leading producers, together contributing the majority of global output, with India cultivating nearly 5-6 million hectares annually, producing over 10 million tonnes (Anonymous, 2024), with Gujarat, Rajasthan, Madhya Pradesh, Tamil Nadu, Karnataka, Andhra Pradesh, Telangana and Odisha being major contributors. Groundnut oil and its by-products are widely used for food, industrial and feed purposes.

Despite its economic importance, the narrow genetic base of cultivated groundnut limits improvement through conventional breeding (Kshirsagar 2012). Induced mutagenesis has emerged as a powerful approach to generate novel genetic variability and improve agronomic traits (Rai *et al.* 2021). Physical mutagens, such as gamma rays and chemical mutagens, like sodium azide, induce chromosomal alterations and point mutations, resulting in variability in yield, kernel traits and stress tolerance (Khan *et al*. 2010). The variety 'Vijetha' (R-2001-2) possesses desirable traits, including high pod yield, oil content and (SMK), along with resistance to peanut bud necrosis. However, poor shelling percentage (56-60 %) and irregular kernel size restrict its adoption by farmers. Therefore, the seeds of 'Vijetha' has been treated with mutagen such as gamma rays and sodium azide to improve kernel traits.

Data on the magnitudes of different genetic parameters, including PCV, GCV, broad sense heritability and GAM is necessary to enhance the production of the crop with a high kernel yield. The most essential aspect to take into consideration during selection is genetic variability. Heritability leads to the determination of transmissibility of a trait onto future generation (Satheeshkumar and Saravanan 2012). High genetic advance and high heritability helps to predict genetic gain (Johnson *et al*. 1955). Often the exclusive use of direct selection by only considering these parameters is not helpful. Hence, correlation analysis is required to determine the associationship between yield and its components in order to understand the complex relationship between them (Akhtar *et al*. 2011). Path coefficient analysis determines the level of contribution that a given trait of yield component has to the overall yield in both direct and indirect effects (Ahmadizadeh *et al*. 2011). Considering this, the present study was planned to collect important data on genetic variations, heritability, GAM, character association and path coefficient analysis in M_3 generation of mutagen treated Vijetha variety. This study will contribute towards selection of high pod yielding lines from mutated Vijetha variety.

Material and Methods

The present study was conducted at Zonal Agricultural Research Station (ZARS), Kalaburagi (15°29′ N, 78°29′ E; 211.76 m amsl) during *Kharif* 2024. The experimental material comprised M_3 generations derived from M_2 plants, which in turn originated from seeds of the groundnut variety 'Vijetha' (R-2001-2) treated with gamma rays and sodium azide.

Mutagen Treatments: Gamma rays (150, 200, 250 and 300 Gy) were used to irradiate 200 uniform dry seeds in the gamma chamber at ZARS. Chemical mutagen treatment involved presoaking 200 seeds in distilled water for 2 hr, followed by treatment with 0.02 %, 0.03 % and 0.04 % sodium azide for 6 h. Seeds were thoroughly washed in distilled and running water to remove residual chemicals.

Generation Advancement: Treated seeds were sown during *Kharif* 2022 to raise the M_1 generation with a spacing of 30 × 15 cm. Individual M_1 plants were harvested separately to obtain M_2 progeny rows in *Kharif* 2023. Superior M_2 plants were advanced to M_3 in *Kharif* 2024.

Observations: In M_3, data were recorded on yield and component traits including plant height, days to flowering and maturity, primary branches per plant, pods per plant, pod yield, 100-kernel weight, kernel yield, shelling percentage and oil content (NMR method).

Statistical Analysis: Data were analyzed using R 4.4.1. Mean, range, phenotypic (PCV) and genotypic (GCV) coefficients of variation, broad-sense heritability and genetic advance as percent of mean (GAM) were computed (Burton and DeVane 1953; Johnson *et al*. 1955; Hanson *et al*. 1956). Correlation coefficients were estimated at phenotypic and genotypic levels (Panse and Sukhatme 1964) and path coefficient analysis was conducted to partition direct and indirect effects on pod yield (Dewey and Lu 1959; Wright 1960). Residual effects were calculated to estimate contributions of unmeasured factors.

Results and Discussion

The estimates of genetic variability parameters including GCV and PCV, heritability (h^2) and GAM for different quantitative traits in the M_3 generation of groundnut treated with gamma rays and sodium azide are presented in Tables 1 and 2. In all the characters studied, the PCV was higher than the GCV under both mutagenic treatments, indicating the influence of the environment on trait expression. The estimation of GCV and PCV reflects the extent of genetic and non-genetic variability present among the genotypes for different yield-related traits.

High GCV and PCV were observed for plant height (34.78 % and 25.67 %),pods per plant (54.33 % and 48.35 %), pod yield per plant (58.99 % and 48.35 %) and kernel yield per plant (58.47 % and 48.21 %) at 300 Gy gamma rays (Table 1). Similarly, at 0.02 % sodium azide, higher GCV and PCV were recorded for pods per plant (59.26 % and 54.55 %), pod yield per plant (57.16 % and 48.88 %), kernel yield per plant (59.52 % and 51.31 %) and primary branches per plant (29.19 % and 24.42 %) (Table 2). These results indicate that both mutagens were effective in generating substantial genetic variability for yield and its component traits, providing ample scope for selection. Comparable findings were also reported by Parameshwarappa *et al*. (2005); John *et al*. (2008); Zaman *et al.* (2011); Mukesh *et al*. (2014); Salih *et al*.

(2014); Yadav *et al.* (2014) in mutagenized groundnut populations. Conversely, low GCV and PCV were recorded for days to 50 % flowering and days to maturity under both treatments and moderate GCV and PCV were recorded for shelling percentage under both treatments indicating low genetic variability and greater environmental influence on these traits. These results are consistent with those of Jayalakshmi (1997); Khangura and Sandhu (1973).

High heritability coupled with high GAM was recorded for pods per plant (84.80 % and 88.65 %), pod yield per plant (71.56 % and 84.01 %) and kernel yield per plant (71.56 % and 84.01 %) at 300 Gy gamma rays and for pods per plant (84.73 % and 89.65 %), pod yield per plant (73.12 % and 86.11 %), kernel yield per plant (74.30 % and 91.11 %) and 100-kernel weight (93.08 % and 42.90 %) at 0.02 % sodium azide. This combination of high heritability and high GAM suggests predominance of additive gene action, which allows effective selection for genetic improvement. Similar results were reported by Gopalakrishna *et al.* (2018); Dhanasekar *et al.* (2021) in groundnut mutants.

Moderate heritability with moderate GAM was observed for plant height, primary branches per plant and haulm yield per plant in both treatments, implying the involvement of both additive and non-additive gene effects. Traits like days to flowering, days to maturity and shelling percentage exhibited moderate to low heritability with low GAM, suggesting limited potential for improvement through direct selection alone. Overall, the results indicate that both mutagens gamma rays and sodium azide were effective in generating significant genetic variability in groundnut, with 300 Gy gamma rays and 0.02 % sodium azide being the most promising doses. High heritability coupled with high genetic advance observed for yield and its contributing traits reflects the predominance of additive gene effects and suggests that simple phenotypic selection would be effective in the improvement of these traits.

The phenotypic correlation coefficients among growth, yield and its attributing traits in the M_3 generation of groundnut are presented in Table 3 and Figure 1. Treats such as plant height, primary branches per plant and pods per plant showed significant positive interrelationships and were strongly correlated with kernel yield per plant and pod yield per plant, emphasizing their importance in yield determination. Among all traits, pods per plant recorded the highest positive correlation with pod yield per plant (0.9079), followed by kernel yield per plant (0.8509), highlighting these traits as major yield contributing factors. In contrast, shelling percentage showed a significant negative correlation with pod yield per plant, while hundred kernel weight had a weak positive relationship, indicating limited direct contribution to yield. These findings suggest that selection based on pods per plant, primary branches per plant, plant height and kernel yield per plant would be most effective for yield improvement in groundnut under mutagenic treatments. Similar positive associations between yield and its component traits were reported by Reddy *et al.* (2019); Shinde *et al.* (2020); Meena *et al.* (2022), confirming the consistency of these traits as reliable selection criteria for groundnut yield enhancement.

Path coefficient analysis (Table 4) revealed that pods per plant exhibited the highest positive direct effect (0.9305) on pod yield per plant, followed by kernel yield per plant (0.8194) and plant height (0.1008), indicating their predominant influence on yield. In contrast, days to flowering, days to maturity, primary branches per plant, hundred kernel weight and shelling percentage showed negative direct effects, suggesting their limited direct contribution to yield. However, these traits exerted positive indirect effects through pods per plant and kernel yield per plant, thereby enhancing overall yield expression. The highest positive correlations of pods per plant (0.9079) and kernel yield per plant (0.8509) with pod yield per plant further confirmed their strong direct influence. The low residual effect (0.00788) indicated that most of the variability in pod yield was explained by the traits studied. Hence, selection based on pods per plant, kernel yield per plant and plant height would be most effective for improving yield potential in groundnut. These findings are in agreement with the results of Venkataravan *et al.* (2000); Vijayasekhar (2002).

Conclusion

The present investigation demonstrated that induced mutagenesis using gamma rays and sodium azide effectively created substantial genetic variability in the groundnut variety *Vijetha* (R-2001-2). Among the treatments, 300 Gy gamma rays and 0.02 % sodium azide proved most effective in enhancing variability for yield and its component traits. High heritability coupled with high genetic advance for pods per plant, pod yield per plant and kernel yield per plant, indicated the predominance of additive gene action, suggesting that simple phenotypic selection would be effective for improvement. Correlation and path analyses further revealed that pods per plant, kernel yield per plant, and plant height exerted strong positive associations and direct effects on pod yield per plant, identifying them as key selection traits for yield enhancement. The low residual effect confirmed that the majority of yield variation was accounted for by these traits. Overall, the study concludes that mutagenic treatments, particularly 300 Gy gamma rays and 0.02 % sodium azide, are promising for generating beneficial genetic variability in groundnut, and selection based on pods per plant, kernel yield per plant, and plant height would be most effective for developing high-yielding mutant lines.

Table 1: Genetic variability parameters for various traits in the gamma-irradiated M_3 population of groundnut

Treatment		DF	DM	PH	PBP	PPP	PYP	KYP	HKW	SH
150 Gy (Gamma rays) T_1	PCV (%)	5.72	1.92	18.00	22.62	52.7	55.36	58.35	22.01	16.47
	GCV (%)	4.86	1.88	15.21	18.64	48.00	46.64	48.64	19.82	15.22
	h^2 (BS) (%)	72.17	76.22	80.77	67.93	82.00	70.00	69.00	81.34	85.32
	GAM (%)	8.49	3.98	29.49	31.65	90.10	80.90	82.00	36.84	28.96
200 Gy (Gamma rays) T_2	PCV (%)	6.56	2.05	16.22	24.04	51.52	58.04	61.80	18.74	18.96
	GCV (%)	6.19	1.83	12.36	21.33	47.32	49.70	52.22	17.63	17.56
	h^2 (BS) (%)	88.26	79.79	58.06	78.74	84.00	73.50	71.32	88.18	88.35
	GAM (%)	11.99	3.37	19.41	39.00	89.63	87.95	85.93	34.05	33.96
250 Gy (Gamma rays) T_3	PCV (%)	5.72	2.56	26.61	25.62	54.88	54.88	53.00	14.47	14.47
	GCV (%)	5.29	2.39	19.79	20.22	48.42	48.42	42.82	13.19	13.19
	h^2 (BS) (%)	85.39	87.42	78.37	62.29	77.84	77.84	65.28	83.12	83.08
	GAM (%)	10.75	4.61	40.74	32.88	88.01	88.01	71.28	24.78	24.77
300 Gy (Gamma rays) T_4	PCV (%)	7.52	2.75	34.78	26.13	54.33	58.99	58.47	12.00	12.01
	GCV (%)	6.73	2.63	32.65	16.36	48.35	48.35	48.21	10.47	10.47
	h^2 (BS) (%)	91.23	89.23	89.75	29.89	79.20	71.56	71.56	76.06	76.02
	GAM (%)	13.10	5.36	60.05	16.99	88.65	84.01	84.01	18.18	18.81

Where, **PH**-Plant height (cm), **DF**- Days to flowering, **DM**- Days to maturity, **PBP**-Primary branches per plant **PPP**- Pods per plant, **PYP**- Pod yield per plant (g), **KYP**- Kernel yield per plant (g), **HKW**- 100 Kernel weight (g), **SH-**helling percentage
GCV=Genotypic Co-efficient of Variation, PCV=Phenotypic Co-efficient of Variation, h^2 (BS) =broad sense heritability, GAM=Genetic Advance as per cent of Mean

Table 2: Genetic variability parameters for various traits in the Sodium azide-treated population of groundnut

Treatment		DF	DM	PH	PBP	PPP	PYP	KYP	HKW	SH
0.02% (Sodium azide) T_5	PCV (%)	5.70	1.70	21.00	29.19	59.26	57.16	59.52	22.37	14.33
	GCV (%)	5.24	1.46	19.21	24.42	54.55	48.88	51.31	21.56	13.05
	h^2 (BS) (%)	84.48	70.83	74.77	69.73	84.73	73.12	74.30	93.08	83.02
	GAM (%)	9.93	2.79	30.49	42.08	89.65	86.11	91.11	42.90	24.53
0.03% (Sodium azide) T_6	PCV (%)	5.59	2.28	19.00	28.59	45.64	46.50	49.10	16.74	13.31
	GCV (%)	5.12	2.09	16.21	23.67	39.10	36.76	39.64	15.50	11.93
	h^2 (BS) (%)	84.05	84.86	72.77	68.52	73.41	62.05	65.27	88.57	80.29
	GAM (%)	9.68	3.96	28.40	40.36	69.02	59.88	66.03	30.06	22.05
0.04% (Sodium azide) T_7	PCV (%)	5.94	2.49	19.28	26.79	49.31	50.91	50.63	14.52	16.54
	GCV (%)	5.54	2.32	16.48	15.64	40.22	36.02	32.58	13.21	15.34
	h^2 (BS) (%)	86.17	87.02	73.01	34.10	66.54	50.05	41.58	82.76	85.97
	GAM (%)	10.61	4.47	29.00	18.82	67.60	52.50	43.14	24.77	29.30

Where, **PH** - Plant height (cm), **DFF**- Days to flowering, **DM**- Days to maturity, **PBP**-Primary branches per plant, **PPP**- Pods per plant, **PYP**- Pod yield per plant (g), **KYP**- Kernel yield per plant (g), **HKW**- 100 Kernel weight (g), **SH**- Shelling percentage (%)

Table 3: Estimates of Phenotypic correlation coefficients for growth, yield and its attributing traits in the M_3 generation of Groundnut.

Traits	DF	DM	PH	PBP	PPP	KYP	HKW	SH	PYP
DF	1	0.6277**	-0.7431**	-0.6380**	-0.7097**	-0.4458**	-0.0889	0.4518**	-0.6515**
DM		1	0.8002**	0.7417**	0.7317**	0.5723**	0.2073*	-0.4032**	0.714**
PH			1	0.7215**	0.7242**	0.5656**	0.1489	-0.3786**	0.7107**
PBP				1	0.7712**	0.6753**	0.2674*	-0.2831**	0.7521**
PPP					1	0.7100**	0.1832*	-0.5199**	0.9079**
KYP						1	0.4815**	0.0386	0.8509**
HKW							1	0.1616	0.2906**
SH								1	-0.4764**
PYP									1

*: Significant @ 5% and ** @1% level of significance, respectively.
Where, DF= Days to flowering, DM= Days to maturity, PH= Plant height, PBP-Primary branches per plant PPP= Pods per plant, KYP= Kernal yield per plant(g), HKW= Hundred kernel weight (g), SH= Shelling percentage (%), PYP= Pod yield per plant (g)

Table 4 : Path Coefficient analysis showing direct (diagonal) and indirect effects of different traits on pod yield per plant in M_3 generation of Groundnut

Traits	DF	DM	PH	PBP	PPP	KYP	HKW	SH	rp (PYP)
DF	**-0.0189**	0.0092	-0.0074	0.0035	-0.0660	-0.3687	0.0043	-0.2026	-0.6515**
DM	0.0119	**-0.0147**	0.0080	-0.0041	0.0679	0.4670	-0.0103	0.1801	0.714**
PH	0.0140	-0.0117	**0.1008**	-0.0039	0.0676	0.4760	-0.0072	0.1711	0.7107**
PBP	0.0121	-0.0108	0.0074	**-0.0005**	0.0716	0.5572	-0.0129	0.1261	0.7521**
PPP	0.0134	-0.0004	0.0072	-0.0042	**0.9305**	0.5818	-0.0086	0.2341	0.910**
KYP	0.0085	-0.0085	0.0057	-0.0037	0.0660	**0.8194**	-0.0230	-0.0180	0.8509**
HKW	0.0017	-0.0030	0.0015	-0.0015	0.0167	0.3933	**-0.0480**	-0.0720	0.2906**
SH	-0.0085	0.0058	-0.0038	0.0001	-0.0483	0.0327	-0.0076	**-0.4503**	-0.4764**

Residual value: 0.00788

Where, DF= Days to flowering, DM= Days to maturity, PH= Plant height, PBP-Primary branches per plant, PPP= Pods per plant, KYP= Kernel yield per plant (g), HKW= Hundred kernel weight (g), SH= Shelling percentage (%) and PYP= Pod yield per plant (g)

rp = Correlation Coefficient

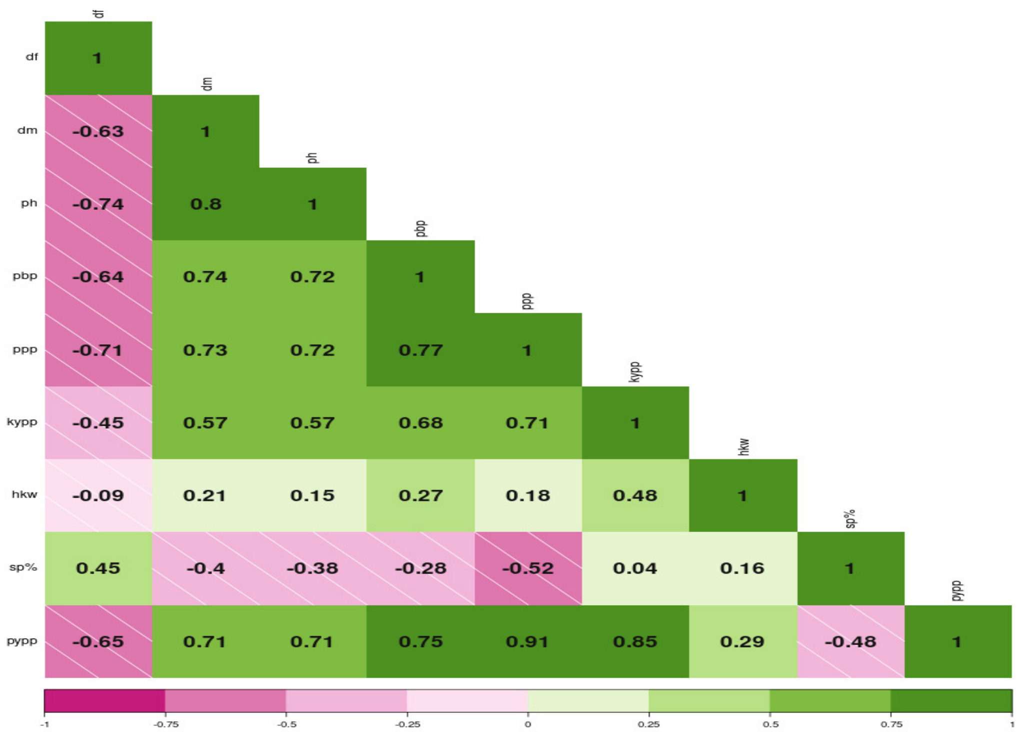

Fig. 1 : Diagrammatic representation of phenotypic correlation of quantitative traits in the M_3 generation of Groundnut

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