

STANDARDIZATION OF CROP GEOMETRY AND FERTILITY LEVELS FOR GROWTH AND YIELD MAXIMIZATION OF HIGH-OLEIC GROUNDNUT VARIETY GIRNAR 4 UNDER TELANGANA CONDITIONS: AN AGRONOMIC EVALUATION TRIAL

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ABSTRACT

A field experiment was conducted during Kharif, 2025 at the AICRP on Groundnut, Regional Agricultural Research Station, Palem, Professor Jayashankar Telangana Agricultural University (PJTAU) to optimize crop geometry and fertility levels for growth and yield maximization of high-oleic groundnut variety Girnar 4 (ICGV 15083). The experiment was laid out in Randomised Block Design with three replications, comprising of seven treatments: T₁ (30 x 10 cm + 75% RDF), T₂ (30 x 10 cm + 100% RDF), T₃ (30 x 10 cm + 125% RDF), T₄ (45 x 10 cm + 75% RDF), T₅ (45 x 10 cm + 100% RDF), T₆ (45 x 10 cm + 125% RDF) and T₇ (local popular check variety Visishta at 30 x 10 cm + 100% RDF). Closer spacing (30 x 10 cm) maintained significantly higher plant population (3,13,333-3,20,000 plants ha⁻¹) over wider spacing (45 x 10 cm, 2,00,000 plants ha⁻¹), while T₆ (45 x 10 cm + 125% RDF) recorded tallest plants (42.4 cm). Yield and yield attributes were significantly influenced by spacing and fertility. T₃ recorded significantly higher pod yield (2499.7 kg ha⁻¹), kernel yield (1687.0 kg ha⁻¹), haulm yield (5017.5 kg ha⁻¹) and biological yield (7517.1 kg ha⁻¹), followed by T₂ and T₇, while lowest yields were recorded in T₄ (1593.3, 1065.5, 3498.0 and 5091.3 kg ha⁻¹ respectively). Hundred-seed weight and sound mature kernels (SMK %) were also highest in T₃ and T₂ and lowest under T₄. Shelling percentage and harvest index (kernel and pod basis) were non-significant, indicating that spacing and fertility altered total dry-matter production without changing partitioning efficiency. Pearson correlation revealed pod yield was strongly and positively correlated with kernel yield, haulm yield, biological yield, 100-seed weight and sound maturing kernels percentage (SMK%) ($r = 0.81-0.98$, $P < 0.01$) but non-significantly correlated with shelling percent. It is concluded that planting high-oleic variety Girnar 4 at 30x10 cm with 125% RDF (50:50:62.5 kg N, P₂O₅, K₂O ha⁻¹) is the most productive agronomic combination for semi-arid conditions of Southern Telangana, significantly outyielding wider spacing and the local check.

KEYWORDS: Groundnut, Girnar 4, High-oleic, Crop geometry, Fertility levels, RDF, Yield attributes

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is the second most important oilseed crop of India after soybean in terms of area and production (AMIC-PJTAU, 2025). Globally, India ranks second after China, contributing 10.30 million tonnes (19%) to the world production of 54.31 million tonnes. As per third advance estimates, Indian groundnut production increased from 10.18 million tonnes in 2023-24 to 11.89 million tonnes in 2024-25 (AMIC-PJTAU, 2025). In Telangana, Regional Agricultural Research Station (RARS), Palem functions as a supporting centre of All India Coordinated Research Project (AICRP) on Groundnut under Professor Jayashankar Telangana Agricultural University (PJTAU) for testing new varieties and standardizing location-specific agronomic practices. Girnar 4 (ICGV 15083) is a virginia bunch, semi-spreading, high-oleic groundnut variety developed through marker-assisted breeding jointly by ICAR-Directorate of Groundnut Research (DGR), Junagadh and ICRISAT, Hyderabad and identified for release in 2019 (ICAR, 2019) and notified in 2020. It contains 78.5% oleic acid as against 40-50% in conventional varieties, with 51% oil, 63% shelling and tolerance to late leaf spot and rust. High oleic acid (>78%) doubles the shelf-life of oil and confectionery products and fetches premium in export markets. However, a newly released variety rarely expresses its genetic potential without agronomic optimization tailored to local conditions, as mandated under AICRP's agronomic evaluation of AVT entries, before large-scale recommendation.

Among agronomic factors, plant geometry and fertility are most manipulable and cost-effective. Crop geometry determines plant population, light interception, leaf area index and dry matter production. Closer spacing (30 × 10 cm) increases plant stand and pod yield per unit area, whereas wider spacing (45 × 10 cm) reduces inter-plant competition and favours individual plant vigour and branching (Saini et al., 2025). Joshi et al. (2019) in a kharif trial with three geometries and three fertility levels reported 30 × 10 cm produced 7.3% and 4.3% higher pod yield over 25 × 10 cm and 20 × 10 cm, while 125% RDF yielded 3.0% and 9.3% higher over 100% and 75% RDF, with

30 × 10 cm + 125% RDF being most remunerative. Similarly, balanced NPK, particularly P and K, is critical for peg penetration, pod development and kernel filling (Singh et al., 2021).

Despite these reports, the optimum spacing × fertility interaction for Girnar 4 has not been standardized for semi-arid Southern Telangana Zone. Hence, a location-specific agronomic recommendation is imperative before popularizing it in place of existing varieties like K6, TAG 24 etc. Therefore, the present investigation entitled "Agronomic Optimization of Crop Geometry and Fertility Levels to Enhance Growth, Yield and Oil Quality of High-Oleic Groundnut (*Arachis hypogaea* L.) cv. Girnar 4 under Semi-Arid Telangana Conditions" was undertaken with objectives: (i) to study the effect of plant spacing and fertility levels on growth, yield attributes and yield of Girnar 4, and (ii) to identify the best agronomic combination vis-à-vis local check for Southern Telangana.

MATERIALS AND METHODS

Experimental Site and Season

The experiment was conducted during kharif (Vanakalam) 2025 at the Regional Agricultural Research Station, Palem(16°31'04" N, 78°14'52" E, 642 m AMSL), Professor Jayashankar Telangana Agricultural University, under the All India Coordinated Research Project (AICRP) on Groundnut (Supporting Centre), as an Agronomic Trial for Variety (AVT) for Girnar 4. The soil was sandy loam, slightly alkaline (pH 7.8), low in available N (158 kg ha⁻¹), medium in P₂O₅ (32 kg ha⁻¹) and high in K₂O (398 kg ha⁻¹).

Experimental Design and Treatments

The experiment was laid out in Randomised Block Design (RBD) with seven treatments and three replications. Crop was sown on 31st July 2025 in gross plot of 4.0 m × 3.0 m (net plot 3.6 m × 2.6 m). The recommended dose of fertiliser (RDF) was 40:40:50 kg N, P₂O₅, K₂O ha⁻¹.

Treatments:

T₁: Girnar 4 + 30x10 cm spacing + 75% RDF

T₂: Girnar 4 + 30x10 cm spacing + 100% RDF

T₃: Girnar 4 + 30x10 cm spacing + 125% RDF

T₄: Girnar 4 + 45x10 cm spacing + 75% RDF

T₅: Girnar 4 + 45x10 cm spacing + 100% RDF

T₆: Girnar 4 + 45x10 cm spacing + 125% RDF

T₇: Popular check variety of the location (Visishta) + 30x10 cm spacing + 100% RDF

Table 1. Fertiliser dose applied under each treatment

Treatment	Spacing / variety	RDF level	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O (kg ha ⁻¹)
T ₁	30x10 cm	75%	30.0	30.0	37.5
T ₂	30x10 cm	100%	40.0	40.0	50.0
T ₃	30x10 cm	125%	50.0	50.0	62.5
T ₄	45x10 cm	75%	30.0	30.0	37.5
T ₅	45x10 cm	100%	40.0	40.0	50.0
T ₆	45x10 cm	125%	50.0	50.0	62.5
T ₇	Check (Visishta), 30x10 cm	100%	40.0	40.0	50.0

RDF = Recommended dose of fertiliser (100% = 40:40:50 kg N, P₂O₅, K₂O ha⁻¹).

Observations Recorded

Plant height (cm) was recorded at harvest from five randomly tagged plants per plot. Plant population (plants ha⁻¹) was recorded by counting established plants in the net plot area at harvest and expressing it on a per-hectare basis. Number of pods per plant was recorded from five randomly selected plants. Pod yield, kernel yield and haulm yield (kg ha⁻¹) were recorded from the net plot area after sun-drying, and biological yield (kg ha⁻¹) was computed as the sum of pod yield and haulm yield. Shelling percentage was computed as the ratio of kernel weight to pod weight, expressed as a percentage, on a sample basis. Hundred-seed weight (g) was recorded from a random sample of 100 sound kernels. Sound maturing kernels (%) were recorded from a random kernel sample by visual grading. Harvest index was computed on both a kernel-yield basis (kernel yield / biological yield × 100) and a pod-yield basis (pod yield / biological yield × 100).

Statistical Analysis

The data recorded on all the growth, yield and quality parameters were statistically analysed following the analysis of variance (ANOVA) technique applicable to a Randomised Block Design with seven treatments and three replications (Panse and Sukhatme, 1985). Treatment means were compared using Fisher's Least Significant Difference (LSD)/Critical Difference (CD) at P = 0.05, wherever the F-test was significant. Pearson correlation coefficients were also worked out among all the growth, yield and quality attributes on a plot-wise basis (n=21) to examine their inter-relationship, and tested for significance at P=0.05 and P=0.01 (df=19).

RESULTS AND DISCUSSION

Growth Parameters

Plant Height

Plant height shown in Fig. 1 differed significantly among the treatments ($P < 0.001$), being tallest under T_6 - 45x10 cm spacing with 125% RDF (42.40 cm), followed by T_7 , the check variety (41.17 cm), and shortest under T_1 - 30x10 cm spacing with 75% RDF (35.93 cm). Within each spacing, plant height increased consistently with increasing fertility level ($T_1 < T_2 < T_3$ and $T_4 < T_5 < T_6$), and at a given fertility level, the wider 45x10 cm spacing produced taller plants than the closer 30x10 cm spacing (e.g. $T_6 > T_3$, $T_5 > T_2$, $T_4 > T_1$).

The taller plants recorded under wider spacing agree with reports that reduced intra-specific competition for light and nutrients under wider plant geometry favours vegetative elongation and individual plant vigour, whereas closer spacing, while raising the total plant population, constrains the growth of individual plants (Saini et al., 2025). The consistent increase in height with fertility level within each spacing further reflects the general growth-promoting effect of an adequate nitrogen and potassium supply on vegetative development in groundnut.

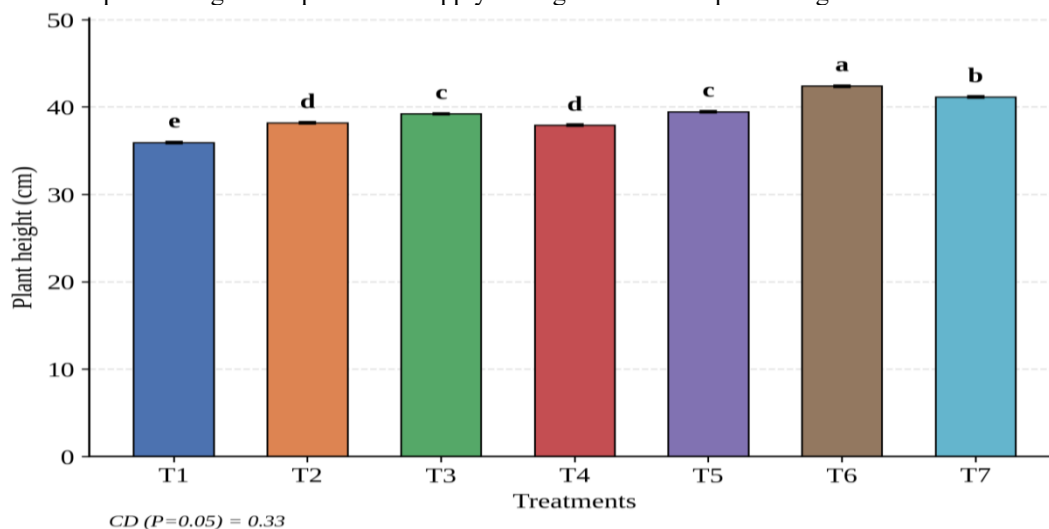


Fig. 1. Effect of plant spacing and fertility levels on plant height of groundnut (Girnar 4).

Plant Population

Plant population shown in Fig. 2 was significantly higher under the closer 30x10 cm spacing - T_1 (3,20,000 plants ha^{-1}), T_2 , T_3 and T_7 (3,13,333 plants ha^{-1} each) - than under the wider 45x10 cm spacing, T_4 , T_5 and T_6 (2,00,000 plants ha^{-1} each) ($P < 0.001$). Fertility level had no bearing on plant population, as expected, since population is determined entirely by the sowing geometry rather than by nutrient supply.

Roughly 1.5-1.6-fold higher plant population recorded under 30x10 cm relative to 45x10 cm spacing is the direct arithmetic consequence of the smaller inter-row spacing at an identical intra-row spacing of 10 cm, and forms the geometric basis for the higher pod and kernel yield recorded under the closer-spaced treatments discussed below, since total yield in groundnut is a product of both per-plant productivity and the number of plants established per unit area.

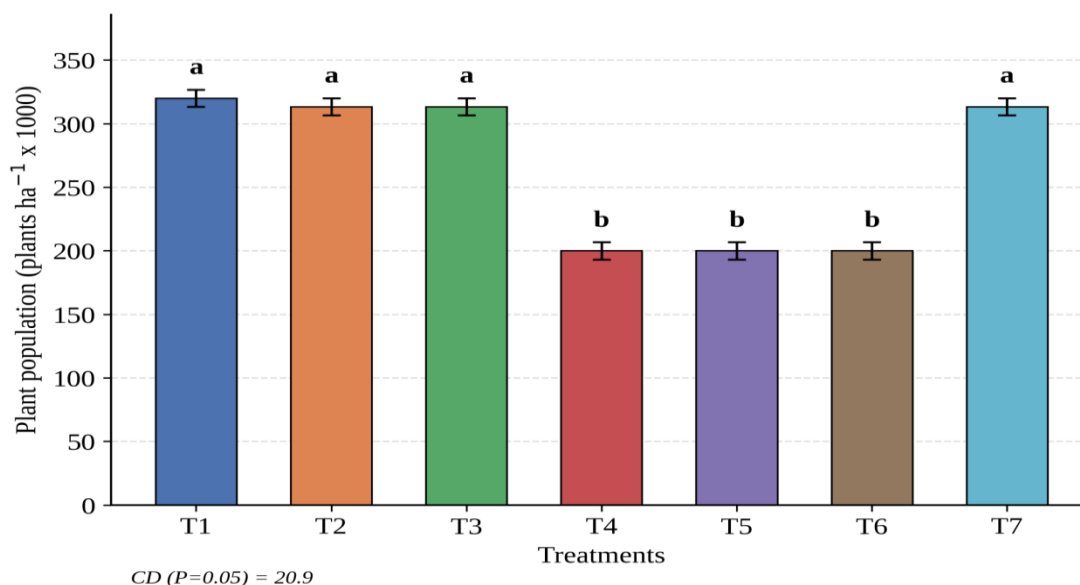


Fig. 2. Effect of plant spacing and fertility levels on plant population of groundnut (Girnar 4).

Yield

Pod yield, kernel yield, haulm yield and biological yield (Table 2) were all significantly influenced by the treatments ($P < 0.01$ for all four parameters). Pod yield, kernel yield, haulm yield and biological yield were each significantly highest under T_3 (2,499.7, 1,687.0, 5,017.5 and 7,517.1 kg ha⁻¹, respectively), statistically at par with T_2 and the check T_7 , and significantly lowest under T_4 (1,593.3, 1,065.5, 3,498.0 and 5,091.3 kg ha⁻¹, respectively) - T_3 exceeded T_4 by 56.9, 58.3, 43.4 and 47.7% for pod, kernel, haulm and biological yield, respectively.

Table 2. Effect of plant spacing and fertility levels on pod, kernel, haulm and biological yield of groundnut (Girnar 4)

Treatment	Pod yield (kg/ha)	Kernel yield (kg/ha)	Haulm yield (kg/ha)	Biological yield (kg/ha)
T_1	1858.1 b	1244.5 b	3957.0 b	5815.2 b
T_2	2465.9 a	1661.7 a	4927.2 a	7393.1 a
T_3	2499.7 a	1687.0 a	5017.5 a	7517.1 a
T_4	1593.3 c	1065.5 c	3498.0 c	5091.3 c
T_5	1972.9 b	1323.4 b	4231.1 b	6204.0 b
T_6	2048.8 b	1376.4 b	4331.3 b	6380.1 b
T_7	2320.7 a	1623.5 a	4685.0 a	7005.7 a
CD (0.05)	242.9	237.2	426.6	609.6

Means followed by the same letter within a column are not significantly different by Fisher's LSD at $P = 0.05$. T_1 : 30x10 cm + 75% RDF; T_2 : 30x10 cm + 100% RDF; T_3 : 30x10 cm + 125% RDF; T_4 : 45x10 cm + 75% RDF; T_5 : 45x10 cm + 100% RDF; T_6 : 45x10 cm + 125% RDF; T_7 : check variety Visishta, 30x10 cm + 100% RDF.

The superiority of T_3 (30x10 cm + 125% RDF) for pod, kernel, haulm and biological yield, closely followed by T_2 (30x10 cm + 100% RDF) and the check T_7 (30x10 cm + 100% RDF, Visishta), closely parallels the findings of Joshi et al., (2019), who reported that in kharif groundnut a closer spacing of 30x10 cm produced 7.3 and 4.3% higher pod yield than 25x10 cm and 20x10 cm respectively, and that 125% RDF produced 3.0 and 9.3% higher pod yield than 100% and 75% RDF respectively, with 30x10 cm combined with 125% RDF giving the best overall performance - an outcome this study reproduces almost exactly for Girnar 4 under Southern Telangana conditions. The consistently lowest yield under T_4 (45x10 cm + 75% RDF) reflects the compounding disadvantage of both a lower plant population (from the wider spacing) and a sub-optimal nutrient supply (from the lower fertility level) acting together, whereas the closer spacing compensated for its narrower per-plant resource share with a substantially higher plant stand, and the higher fertility level ensured adequate nitrogen, phosphorus and potassium for pod and kernel development, phosphorus and potassium in particular being critical for peg penetration and pod filling in groundnut (Singh et al., 2021). The close parallel movement of haulm and biological yield with pod and kernel yield across all seven treatments further indicates that the higher-yielding treatments accumulated more total dry matter overall rather than merely redirecting a fixed quantity of assimilate from vegetative to reproductive parts, an interpretation reinforced by the very strong positive correlation among these four traits reported in the correlation analysis below (Kiranmai Sandhya et al., 2016).

Yield Attributes

Number of pods per plant and 100-seed weight (Table 3) were significantly influenced by the treatments ($P < 0.01$), whereas shelling percentage and harvest index, computed on both a kernel-yield and a pod-yield basis, did not differ significantly among treatments. The number of pods per plant was highest under T_3 (22.87) and lowest under T_4 (18.50). Hundred-seed weight was likewise highest under T_3 and T_2 (41.47 and 41.20 g) and lowest under T_4 (33.07 g). Shelling percentage ranged narrowly from 66.77 to 70.15% and harvest index from 20.95 to 23.22% (kernel basis) and 31.39 to 33.36% (pod basis) across all seven treatments, none of these differences reaching statistical significance.

Table 3. Effect of plant spacing and fertility levels on yield attributes of groundnut (Girnar 4)

Treatment	No. of pods/plant	Shelling (%)	100-seed weight (g)	HI - kernel basis (%)	HI - pod basis (%)
T_1	19.93 b	67.91	34.50 c	21.46	31.83
T_2	22.33 a	67.34	41.20 a	22.45	33.36
T_3	22.87 a	67.45	41.47 a	22.43	33.25
T_4	18.50 b	66.81	33.07 d	20.95	31.39
T_5	21.33 a	66.77	39.67 b	21.25	31.79
T_6	21.77 a	67.18	39.93 b	21.58	32.12
T_7	20.50 b	70.15	40.13 b	23.22	33.11
CD (0.05)	2.05	NS	0.68	NS	NS

Means followed by the same letter within a column are not significantly different by Fisher's LSD at $P = 0.05$. NS = non-significant.

Number of Pods per Plant and 100-Seed Weight

Number of pods per plant and 100-seed weight, the two principal yield-determining components measured in this study, followed the same treatment ranking as final pod and kernel yield, being highest under the 30x10 cm + 100%

¹25% RDF combinations (T₂, T₃) and lowest under the under-fertilised, wide-spaced T₄. This agrees with the well-documented role of pod number and kernel size as primary determinants of pod yield in groundnut: Babariya and Dobariya (2012) reported that pod yield per plant was significantly and positively correlated with number of pods per plant and 100-kernel weight among other components, and Kiranmai Sandhya et al., (2016) similarly found strong positive associations of pod yield with 100-kernel weight and related yield components across environments. The higher 100-seed weight recorded under T₂ and T₃ further indicates that the closer spacing, when adequately fertilised, did not compromise individual kernel filling despite the higher plant density, in contrast to the reduced kernel weight recorded under the under-fertilised, lower-yielding T₄, where both a smaller pod number and lighter kernels combined to depress final yield.

Shelling Percentage and Harvest Index

The absence of a significant treatment effect on shelling percentage and harvest index indicates that, although spacing and fertility level altered the total quantity of pods, kernels and haulm produced, they did not materially change the proportion of kernel recovered from the pod or the proportion of total biomass partitioned into economic yield. These partitioning traits therefore appear to be governed more strongly by the genetic characteristics of the variety than by the agronomic management imposed in this study, an interpretation consistent with the generally narrow range of shelling percentage (66.8-70.1%) and harvest index (21.0-23.2%) recorded across all seven treatments including the check variety, and with reports that shelling percentage and harvest index, while important selection criteria in groundnut breeding, tend to be comparatively stable ratio traits with moderate heritability that respond more to genotype than to management practices of the kind evaluated here (Babariya and Dobariya, 2012).

Quality Parameter

Sound Maturing Kernels (%)

Sound maturing kernels (SMK%) (Fig. 3) were significantly influenced by the treatments ($P < 0.001$), being highest under T₃ (88.07%) and T₂ (87.33%), followed by the check T₇ (85.67%), and significantly lowest under T₄ (78.37%) and T₁ (79.77%).

The higher proportion of sound, well-filled kernels under T₂ and T₃ mirrors the higher 100-seed weight recorded under the same treatments, and both are consistent with the adequate nutrient supply and favourable plant density of the 30x10 cm + 100⁻¹25% RDF combinations having supported fuller pod and kernel development, whereas the combination of wider spacing and the lowest fertility level in T₄ evidently constrained kernel filling and increased the proportion of shrivelled or immature kernels.

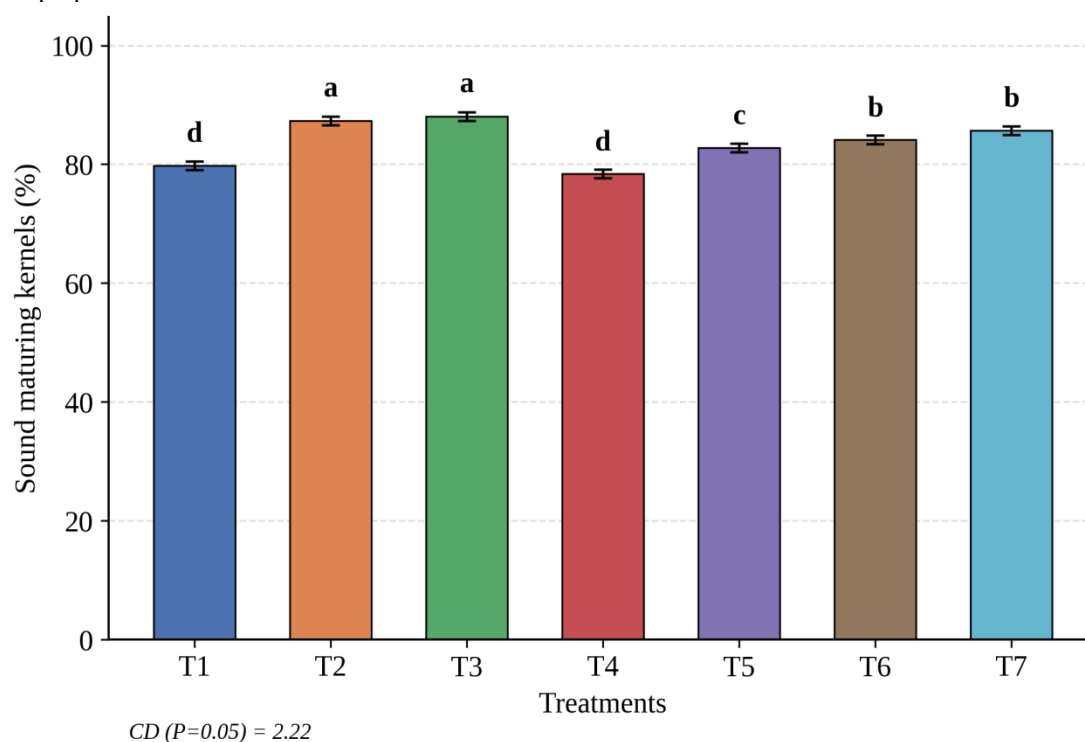
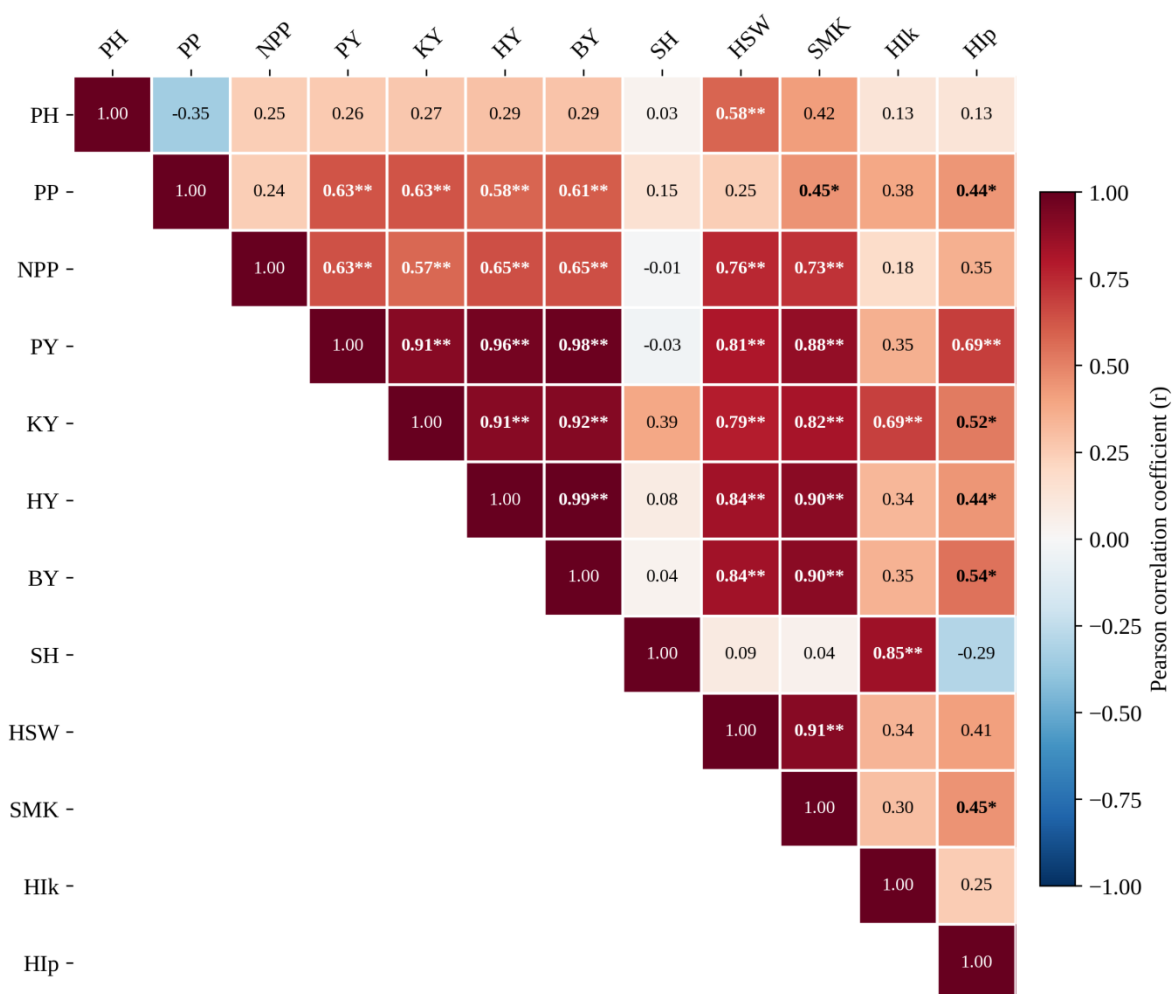


Fig. 3. Effect of plant spacing and fertility levels on sound maturing kernels (%) of groundnut (Girnar 4).

Correlation among Growth, Yield and Quality Attributes

To understand the inter-relationship among the growth, yield and quality attributes recorded, simple Pearson correlation coefficients were worked out on a plot-wise basis ($n=21$) among plant height, plant population, number of pods per plant, pod yield, kernel yield, haulm yield, biological yield, shelling percentage, 100-seed weight, sound maturing kernels percentage and harvest index on both kernel and pod-yield bases shown in Fig. 4.



* Significant at $P=0.05$ ($r \geq 0.433$) ** Significant at $P=0.01$ ($r \geq 0.549$), $df=19$

Fig. 4. Correlation heatmap among growth, yield and quality attributes of groundnut (Girnar 4). Colour intensity and shade indicate the strength and direction of the Pearson correlation coefficient; bold, starred values are significant at $P=0.05$ (*) or $P=0.01$ (**).

Pod yield showed a highly significant and strong positive correlation with kernel yield ($r=0.908^{**}$), haulm yield ($r=0.955^{**}$), biological yield ($r=0.983^{**}$), 100-seed weight ($r=0.808^{**}$) and sound maturing kernels percentage ($r=0.877^{**}$), and a moderately significant positive correlation with number of pods per plant ($r=0.635^{**}$) and plant population ($r=0.632^{**}$), but was not significantly correlated with shelling percentage ($r=-0.033$, NS). Kernel yield showed an essentially identical pattern, being most strongly correlated with haulm yield ($r=0.911^{**}$) and biological yield ($r=0.919^{**}$). These results agree closely with the correlation studies of Kiranmai Sandhya et al., (2016), that reported strong positive association of pod yield with kernel yield, 100-kernel weight and related yield components across environments, and of Babariya and Dobariya (2012), found pod yield per plant significantly and positively correlated with number of pods per plant, kernel yield, 100-kernel weight and biological yield in groundnut. The very strong correlation between haulm and biological yield ($r=0.993^{**}$) is expected algebraically, since biological yield is their arithmetic sum with pod yield, but its magnitude confirms that haulm yield tracked pod and kernel yield closely across treatments rather than varying independently of them.

The essentially negligible and non-significant correlation of shelling percentage with pod yield ($r=-0.033$) and kernel yield (r not significant either) is consistent with the non-significant treatment effect on shelling percentage reported above, and confirms that variation in total yield among the seven treatments arose from differences in pod number, pod filling and plant population rather than from any change in the proportion of kernel recovered per unit weight of pod. Shelling percentage was, however, strongly correlated with harvest index on a kernel basis ($r=0.849^{**}$), both being kernel-centred ratio traits that moved together independently of the treatments. Plant height was significantly correlated only with 100-seed weight ($r=0.584^{**}$) and remained weakly and non-significantly associated with pod yield ($r=0.263$) and other yield traits, indicating that, unlike plant population, the additional vegetative growth recorded under wider spacing and higher fertility did not translate into a proportional yield advantage. Overall, the correlation analysis reinforces the treatment-mean results discussed above: number of pods per plant, 100-seed weight and sound maturing kernels percentage can be regarded as reliable indirect indicators of pod and kernel yield potential in this trial, whereas shelling percentage and harvest index behaved as comparatively independent, treatment-insensitive traits.

CONCLUSION

Based on the growth, yield and quality parameters recorded in this study, it can be concluded that among the spacing and fertility combinations evaluated, T₃ (30x10 cm spacing with 125% RDF, i.e. 50:50:62.5 kg N, P₂O₅, K₂O ha⁻¹) was the most productive treatment for the high-oleic groundnut variety Girnar 4 under the semi-arid conditions of Southern Telangana, recording the highest pod, kernel, haulm and biological yield, 100-seed weight and sound maturing kernels percentage, and was statistically at par with T₂ (30x10 cm + 100% RDF) and superior to the locally popular check variety Visishta (T₇) for most yield attributes. The combination of wider spacing with the lowest fertility level (T₄: 45x10 cm + 75% RDF) consistently gave the poorest performance, underscoring that neither spacing nor fertility level alone, but their combined effect on plant population and nutrient availability, determines the productivity of this variety. Shelling percentage and harvest index were not significantly affected by spacing or fertility level, indicating that yield gains under the better treatments arose from greater total pod and kernel production rather than improved partitioning efficiency. The Pearson correlation analysis reinforced this conclusion, showing that pod yield was very strongly and positively associated with kernel, haulm and biological yield, number of pods per plant, 100-seed weight and sound maturing kernels percentage, but essentially unrelated to shelling percentage, so that number of pods per plant, 100-seed weight and sound maturing kernels percentage can be used as reliable indirect indicators of pod yield potential in future evaluation of this variety.

For farmers of Southern Telangana region intending to cultivate Girnar 4, therefore, a spacing of 30x10 cm combined with 125% of the recommended dose of fertiliser can be recommended for realising the highest pod and kernel yield; where fertiliser cost is a constraint, the same spacing with 100% RDF offers a statistically comparable alternative. Wider spacing (45x10 cm) cannot be recommended for this variety under the tested fertility range, since it consistently reduced plant population and yield relative to the closer 30x10 cm spacing despite producing taller, more vigorously growing individual plants.

Future studies may evaluate this variety under irrigation levels and gypsum × fertility interaction to further refine oil quality (oleic acid %) under Telangana conditions.

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