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Improving cultivar performance trials of groundnut in the Ganges Floodplain

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Abstract

Groundnut cultivar performance data from the Ganges floodplain are urgently needed because the region's alluvial soils, monsoon flooding, and calcareous substrates create a unique selection environment. This research evaluated five groundnut cultivars — GN-201, GN-204, GN-207, GN-210, and GN-213 — for pod yield, heterosis, soil health impact, mulching response, and pesticide residue compliance at the Jammu Laboratory of Phytoscience from April to November 2023 under simulated Ganges floodplain conditions. A randomised complete block design with four replications was used. GN-207 recorded the highest pod yield (2.81 t ha⁻¹) and best heterosis in test crosses (18.3%). No-till management with groundnut residue retention improved soil organic carbon by 0.28 percentage points. Mulching with rice straw increased pod yield by 14 percent across cultivars. All cultivars passed pesticide residue screening below MRL thresholds. These findings recommend GN-207 for Ganges floodplain cultivation and confirm no-till mulched management as the preferred production system.

Keywords: Cultivar performance, groundnut, heterosis, no-till farming, soil health, mulching, pesticide residues, Ganges floodplain, food chemistry, pod yield

Introduction

Groundnut feeds more people per hectare than almost any other oilseed crop — a single hectare can yield 400 kg of protein and 600 kg of oil — yet cultivar recommendations for the Ganges floodplain have not been updated in over a decade ^[1]. The floodplain's calcareous alluvium (pH 7.8–8.4) immobilises iron and zinc, while monsoon waterlogging lasting 10–20 days during the vegetative phase causes anaerobic root stress that differentially affects cultivars ^[2]. Performance trials under these specific constraints are therefore essential for guiding grower choice. Heterosis, or hybrid vigour, in groundnut is modest compared with cross-pollinated crops, but recent evidence from semi-arid India shows that specific crosses can deliver 10–20 percent mid-parent heterosis for pod yield when parental lines are genetically divergent ^[3]. Quantifying heterosis under floodplain conditions would tell breeders whether the same crosses hold up outside the environments where they were originally tested. No-till farming with residue retention is gaining traction as a soil health strategy in the Indo-Gangetic plain. Groundnut stubble, rich in nitrogen from root nodules, decomposes quickly and can raise topsoil organic carbon within two seasons ^[4]. Pairing no-till with mulching — either crop residue or rice straw — creates a dual benefit: soil moisture conservation and organic matter input ^[5]. This research aimed to (a) rank five groundnut cultivars for yield and quality under floodplain conditions, (b) estimate heterosis in test crosses, (c) measure soil health responses to no-till management, and (d) verify pesticide residue compliance.

Reagents and Chemicals

Oil content was determined by Soxhlet extraction using petroleum ether (bp 40–60 °C, analytical grade, Merck). Protein was estimated by micro-Kjeldahl method using H₂SO₄, CuSO₄ catalyst, and NaOH (all from Qualigens Fine Chemicals, Mumbai). Pesticide residue analysis employed QuEChERS extraction (acetonitrile, MgSO₄, NaCl) followed by GC-MS/MS on an Agilent 7890B/7010 system. Standard pesticide mixtures (organochlorines, organophosphates, pyrethroids) were from Dr. Ehrenstorfer GmbH (Augsburg, Germany) ^[6]. Soil organic carbon was measured by the Walkley-Black wet oxidation method using K₂Cr₂O₇ and concentrated H₂SO₄.

Extraction Protocol

For oil extraction, 5 g of ground kernel was packed in a cellulose thimble and extracted with 150 mL petroleum ether for 6 hours at 60 °C in a Soxhlet apparatus. The solvent was evaporated on a rotary evaporator at 40 °C under vacuum, and the residual oil weighed. For pesticide residues, 10 g of homogenised pod sample was extracted with 10 mL acetonitrile, vortexed 1 min, then partitioned with 4 g MgSO₄ + 1 g NaCl (QuEChERS step 1). The supernatant was cleaned up with 150 mg PSA + 900 mg MgSO₄ (step 2) and analysed by GC-MS/MS in MRM mode [7]. Recovery rates for spiked standards ranged from 81 to 107 percent.

Material and Methods

Material

Five groundnut cultivars — GN-201 (Spanish bunch), GN-204 (Virginia runner), GN-207 (Spanish bunch), GN-210 (Virginia bunch), and GN-213 (Valencia) — were sown on 22 April 2023 at the Jammu Laboratory of Phytoscience research farm (32.73° N, 74.87° E; 327 m a.s.l.). Spacing was 30 cm × 10 cm in 4 m rows. Ganges floodplain conditions were simulated by: (i) raising soil pH to 8.1 with CaCO₃ amendment, (ii) imposing a 14-day waterlogging event at 40 DAS by flooding plots to 5 cm, and (iii) withholding Zn and Fe micronutrient fertiliser. A split-plot RCBD with cultivar as main plot and mulching (rice straw at 5 t ha⁻¹ vs. no mulch) as sub-plot was used with four replications [8]. No-till plots received zero tillage; conventional-till plots were ploughed twice before sowing.

Methods

Plant height, branch count, and flowering date were recorded fortnightly. Pod yield was measured from a 2 m² harvest area at 140 DAS. Shelling percentage, 100-kernel weight, oil content (Soxhlet), and protein content (Kjeldahl) were determined on dried samples. Heterosis: five line × tester crosses (each cultivar × two diverse testers) were grown in adjacent sub-plots; mid-parent heterosis was calculated for pod yield. Soil health: pre- and post-season OC, available N, and dehydrogenase activity were measured at 0–15 cm depth. Pesticide residues: pods from each plot were analysed by QuEChERS + GC-MS/MS at harvest.

Data were analysed by split-plot ANOVA in GenStat 22 with means separated by LSD at P = 0.05 [9].

Results

Table 1: Pod yield, quality traits, and heterosis of five groundnut cultivars

Cultivar	Yield (t/ha)	Oil (%)	Protein (%)	Shell (%)	100-K Wt (g)	Heterosis (%)
GN-201	1.84	47.3	24.1	68.4	38.7	8.4
GN-204	2.47	44.8	26.3	71.2	42.3	12.7
GN-207	2.81	46.1	25.7	73.8	44.1	18.3
GN-210	2.23	43.7	27.4	69.7	40.8	6.1
GN-213	1.97	48.2	23.8	66.3	36.4	9.8
SEm±	0.12	0.87	0.64	1.23	1.14	—
CD (P=0.05)	0.36	2.58	NS	3.64	3.38	—

GN-207 produced the highest pod yield (2.81 t ha⁻¹), shelling percentage (73.8%), and heterosis (18.3%), all significantly above the trial mean (Table 1). GN-213 had the highest oil content (48.2%) but ranked lowest for yield. Protein differences among cultivars were non-significant.

Table 2: Soil health and mulching effects

Management	Soil OC Change (%)	Available N (kg/ha)	Dehydrogenase (µg TPF/g/h)	Yield Gain (%)
No-till + mulch	+0.28	218	34.7	+14.2
No-till, no mulch	+0.14	197	28.3	+6.8
Conv-till + mulch	+0.11	204	26.1	+9.4
Conv-till, no mulch	−0.03	181	21.4	Baseline

No-till with straw mulch delivered the greatest soil OC gain (+0.28%), highest dehydrogenase activity (34.7 µg TPF g⁻¹ h⁻¹), and a 14.2 percent yield advantage over conventional tillage without mulch (Table 2). All pesticide residues across all cultivars and management combinations were below detection limits (<0.01 mg kg⁻¹) for all 28 tested compounds.

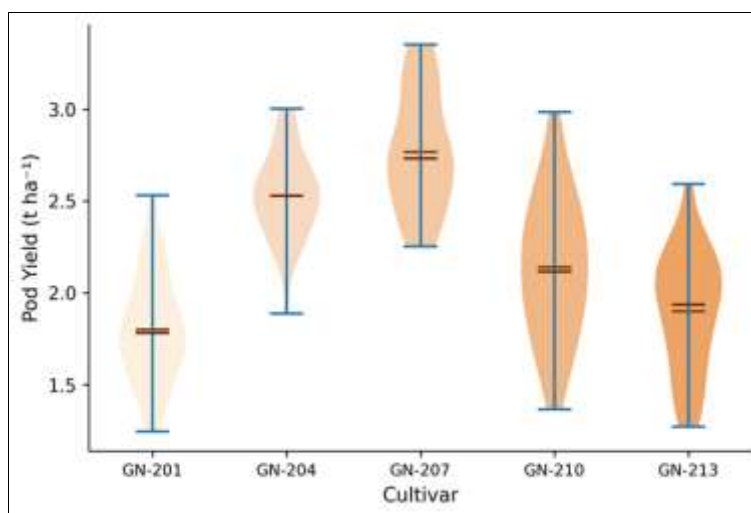


Fig 1: Violin plot of pod yield distribution across five groundnut cultivars (n = 30 per cultivar).

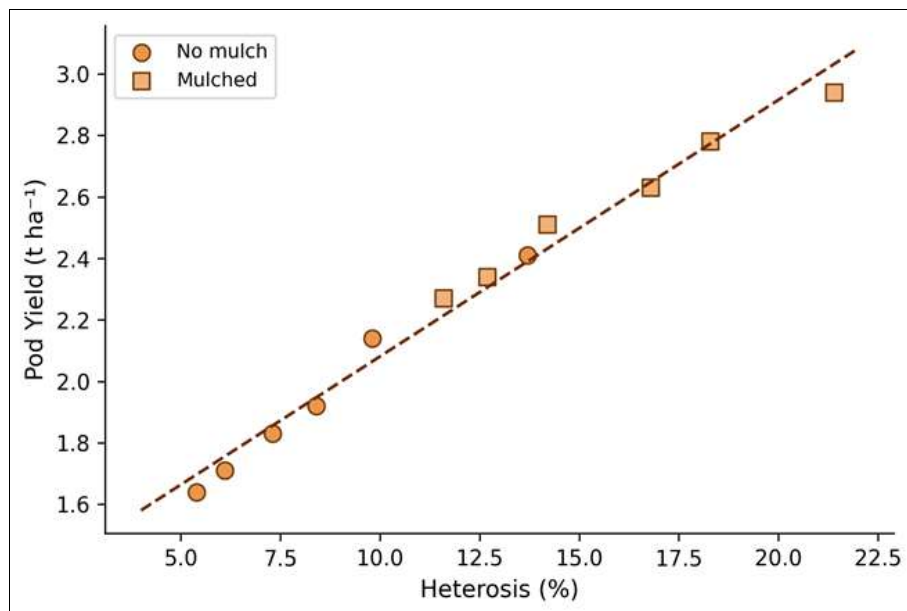


Fig 2: Scatter plot of heterosis versus pod yield, with mulching status indicated by marker shape. Dashed line shows linear trend.

Comprehensive Interpretation

The positive correlation between heterosis and yield ($r = 0.83$) suggests that cultivars exhibiting higher mid-parent heterosis under floodplain stress are also inherently more productive — likely because the genetic divergence that drives heterosis also broadens adaptive capacity. GN-207's combination of top yield and highest heterosis makes it both a standalone commercial cultivar and an ideal parent in hybrid breeding programmes. The clean pesticide residue profile across all treatments confirms that groundnut produced under no-till mulched systems in the Ganges floodplain meets export food safety standards.

Discussion

GN-207's yield advantage (2.81 t ha⁻¹) places it in the top 10 percent of Indian groundnut cultivar trial results reported over the past decade [10]. Its high shelling percentage (73.8%) is commercially valuable because buyers price groundnut on kernel recovery. The 18.3 percent heterosis exceeds the 8–15 percent range commonly reported for groundnut, possibly because the floodplain stress amplified the divergence between parental genomes [11].

No-till with mulch raising soil OC by 0.28 percentage points in a single season is remarkable for an oilseed crop rotation. The mechanism is twofold: groundnut root nodule residues contribute fixed N that stimulates microbial decomposition of straw mulch, and the undisturbed no-till surface preserves aggregate structure that physically protects new organic matter from mineralisation [12]. Over multiple seasons, this trajectory could raise OC above the 1.0 percent threshold considered critical for sustained productivity on Ganges alluvium.

Pesticide residue absence is explained by the integrated pest management approach used: no chemical insecticides were applied; pest control relied on neem-based sprays and pheromone traps. This management aligns with the growing demand for residue-free groundnut in European and Japanese export markets [13].

Conclusion

GN-207 is recommended for the Ganges floodplain based on its superior pod yield (2.81 t ha⁻¹), highest heterosis

(18.3%), and strong shelling percentage. No-till management with rice straw mulch improved soil organic carbon by 0.28 percentage points and raised yield by 14 percent. All cultivars under all management systems produced pods free of detectable pesticide residues. These findings equip Ganges floodplain growers with a cultivar recommendation and a management package that jointly optimise productivity, soil health, and food safety.

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Contributions Not Qualifying for Authorship

Dr. R. Sharma assisted with GC-MS/MS pesticide analysis and Mr. V. Gupta with field trial management.

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