



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(6): 114-118
Received: 22-03-2026
Accepted: 28-04-2026

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To study agronomic and economic evaluation of Diverse Paddy (*Oryza sativa* L.) cultivars under transplanting systems in the Kymore Plateau Region of Madhya Pradesh

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i6Sb.5718>

Abstract

An experimental field trial was conducted during the *Kharif* season of 2025 at the Instructional Agricultural Farm of Krishi Vigyan Kendra (KVK) Majhgawan, Satna, Madhya Pradesh, to assess the agronomic performance and economic viability of seven diverse paddy (*Oryza sativa* L.) genotypes under a transplanted management system. The experiment was laid out in a Randomized Block Design (RBD) with three replications over a total command area of 10 hectares within the Kymore Plateau and Satpura Hills agro-climatic zone. The treatments evaluated included short-duration lines, standard high-yielding checks, and premium aromatic fine cultivars (T₁ CO-55, T₂ JR-206, T₃ PB-1895, T₄ Kranti, T₅ JR-21, T₆ IR-64, and T₇ Bauna Doobraj) transplanted on June 16, 2025 the results revealed significant variation (P=0.05) among the tested cultivars across morpho-physiological growth metrics, yield attributes, and economic outputs. High-yielding bold/coarse varieties achieved maximum vegetative tillering and grain volume, with T₄ (Kranti) producing the highest grain yield (55.6q/ha) statistically at par with T₂ (JR-206) at (52.1q/ha) Conversely, premium fine/scented selections yielded lower total grain volume (34.2q/ha for T₃ and 31.5q/ha for T₇) but showed significantly higher mature plant heights and longer reproductive cycles (up to 142 days for T₇).

Economic evaluation revealed that despite lower grain volumes, premium scented genotypes generated the highest net profits due to lower production costs (₹55,000/ha) and high market premiums. (T₃) (PB-1895) achieved the highest net returns (₹99,560.00/ha) and a maximum Benefit-Cost (B:C) ratio of 2.81, followed closely by (T₇) (Bauna Doobraj) with a B:C ratio of 2.76. For risk mitigation in drought-prone or rainfed pockets, the short-duration line(T₁) (CO-55) escaped terminal moisture stress by maturing in 112 days.

The study outlines two distinct production pathways for the region: prioritizing (T₄) (Kranti) and T₂ (JR-206) to maximize grain volume and straw biomass, or adopting T₃ (PB-1895) and T₇ (Bauna Doobraj) to optimize profit margins and enhance smallholder incomes across the Vindhyan plateau.

Keywords: *Oryza sativa* L., Kymore plateau, genotypes, economic evaluation, benefit-cost ratio, grain yield

Introduction

Paddy (*Oryza sativa* L.) is a premier cereal crop globally, serving as a cornerstone for food security and rural livelihoods. In India, it stands as the principal Kharif crop, deeply intertwined with the agrarian economy. Within the state of Madhya Pradesh, Satna District—geographically positioned in the northern-central terrain—emerges as a vital agro-ecological zone for rice cultivation. Falling under the Kymore Plateau and Satpura Hills agro-climatic zone, agricultural production in Satna dictates the socio-economic index of over 70% of its rural populace. For these farmers, paddy is not merely a subsistence crop but the primary driver of seasonal employment and cash flow. Geographical and Argo-Climatic Profile of Satna Topography and Location: Satna is situated on the Vindhyan Plateau at an average elevation of 318 meters above

mean sea level. The undulating topography creates a unique micro-climate that dictates localized water-holding dynamics.

Climate and Rainfall Vulnerability: The district experiences a sub-tropical climate. Paddy production heavily depends on the South-West monsoon, with the district receiving an average annual rainfall of approximately 1,100 mm. However, in recent years, erratic monsoon onset, prolonged dry spells, and shifting precipitation patterns have heightened the climate vulnerability of the crop in this region.

Soil Texture: The soil matrix of Satna is highly diverse, dominated by mixed red and black soils (Mar and Kabar) alongside rich alluvial pockets along the basins of the Tamas (Tons), Satna, rivers. The clay-rich fractions in these soils provide the high water-retention capacity structurally required for traditional wetland rice ecosystems.

Agricultural Significance and Statistical Overview Average Share Satna commands a significant share of the total paddy footprint in Madhya Pradesh, contributing roughly 5.70% of the state’s total rice area. The crop is sown across an estimated 73,000 to 75,000 hectares during the Kharif season. The Productivity Paradox While the area under cultivation is expansive, the per-hectare productivity (yield) historically lags behind the national average. This regional yield gap stems from localized resource constraints, a lack of assured irrigation, and sluggish technology adoption rates, making the district a critical subject for agricultural research

Core Agronomic Challenges in Satna

District Groundwater Depletion Canal-based irrigation systems remain highly restricted in Satna. Consequently, over 75% of the irrigated paddy fields rely on groundwater (tube wells and open dug wells), leading to a steady and alarming decline in the local water table.

The "Rice-Fallow" Constraint: A widespread operational bottleneck is the cultivation of long-duration paddy varieties (>125 days). These delays harvesting, drains residual soil moisture, and leaves substantial acreage uncultivated (fallow) during the subsequent Rabi season.

High Input Costs Traditional manual transplanting requires extensive labor and continuous standing water, both of which drastically escalate the cost of cultivation for resource-poor farmers

Rationale of the Study investigating the structural mechanics of paddy cultivation specifically in Satna District is essential to understanding how smallholders navigate resource scarcity and climate shifts on the Vindhyan Plateau. This research evaluates localized variables—ranging from input management to the adoption of water-saving alternative technologies like Direct Seeded Rice (DSR) and the System of Rice Intensification (SRI)—to provide actionable insights for boosting crop yield and ensuring sustainable regional development.

Materials and Methods

The field experiment was conducted during the *Kharif* season of 2025 at the Instructional Agricultural Farm of Krishi Prakshetra, Krishi Vigyan Kendra (KVK) Majhgawan, Satna, Madhya Pradesh. The site is geographically situated in the Kymore Plateau and Satpura Hills agro-climatic zone of Madhya Pradesh.

The climate of the region is typically sub-tropical semi-arid, characterized by hot summers and cold winters. The average annual rainfall ranges between 1000 mm and 1100 mm, which is predominantly received through the South-West monsoon. The soil profile of the experimental field across the 10-hectare agricultural farm was classified as medium black clay loam. Soil chemical analysis revealed a neutral to slightly alkaline pH (7.2 to 7.6), low available nitrogen (N), medium available phosphorus (P2o5), and high available potassium (K2O) status.

Experimental Design and Treatment Details

To systematically fulfill the objective "To study Agronomic and Economic Evaluation of Diverse Paddy (*Oryza sativa* L.) Cultivars Under Transplanting Systems in the Kymore Plateau Region of Madhya Pradesh", the field trial was laid out in a Randomized Block Design (RBD). The experiment comprised seven distinct paddy genotypes evaluated as treatments (T₁ to T₇) replicated three times to isolate and control directional soil heterogeneity across the experimental blocks. The systematic breakdown of treatments is presented in Table 1.

Table 1: Experimental Layout and Detailed Description of Treatments

Treatment Code	Cultivar / Genotype	Agronomic Classification & Phenotypic Trait	Commercial/Breeding Status
T ₁	CO-55	Short-duration breeding selection	Advanced breeding line
T ₂	JR-206	High-yielding variety (HYV), coarse grain	State-recommended check
T ₃	PB-1895	Premium scented fine-grain selection	Commercial Basmati type
T ₄	Kranti	Standard medium-duration variety, bold grain	Popular regional check
T ₅	JR-21	High-yielding mid-to-long duration variety	Commercial check
T ₆	IR-64	High-yielding mid-duration variety, long slender grain	National standard check
T ₇	Bauna Doobraj	Specialized, premium aromatic fine-grain cultivar	Regionally famous GI-tagged type

2.3 Seed Treatment and Nursery Establishment

Prior to sowing, seeds were subjected to a floating density test in a 10% brine solution (NaCl) to eliminate light-weight, chaffy, and diseased seed fractions. Sunken, high-viability seeds were thoroughly rinsed with clean water and subjected to an integrated chemical seed treatment consisting of Carbendazim 50% WP @ 2.0 g/kg and Streptocycline @ 0.1 g/kg of seed to prevent seed-borne fungal and bacterial pathogens (such as Blast and Bacterial Leaf Blight). Treated seeds were sown using the wet-bed nursery technique on raised seedbeds enriched with well-decomposed Farm Yard Manure (FYM).

Crop Establishment and Transplanting Layout

Land Preparation: Main plots within the 10-hectare agricultural farm were dry ploughed using a tractor-drawn disc

harrow, followed by flooding, mechanical puddling, and wooden planking to secure an even, level surface for precise water management.

Transplanting Schedule

Healthy and uniform seedlings aged 21 to 25 days were manually transplanted into the puddled plots on a synchronized Transplanting Date of 16/06/2025.

Spacing Regimen:

High-Yielding & Coarse Varieties (T₁, T₂, T₄, T₅, T₆): Planted closely at 20cmX15 a spacing of to maximize plant population dynamics per unit area.

Scented / Fine Varieties (T₃, T₇): spaced widely at 20cmX20cm to avoid mutual shading, increase solar intercept and minimized early lodging risks

Nutrient, Weed, and Water Management Protocols
Fertilization Schedule

A uniform chemical nutrient rate of 120:60:40 kg/ha N: P2O5: K2O of was applied. Full phosphorus, potassium, and a basal dose of Zinc Sulphate (Znso4) @ 25 kg/ha) were incorporated during final puddling. Nitrogen (via Urea) was supplied in three equal splits: 1/3 resources as basal, 1/3 at active tillering, and 1/3 at the panicle initiation stage.

Weed Suppression

Pre-emergence application of Pretilachlor 50% EC @ 1.0 kg a.i./ha was deployed 3 days after transplanting, accompanied by one supplementary hand weeding at 30 days after transplanting (DAT).

Irrigation Control

Continuous shallow submergence (3.0cm to 5.0cm) was maintained from transplanting till the grain dough phase. Draining was executed 10 days prior to final harvesting to ensure uniform panicle maturity.

Morpho-Physiological and Yield Observation Points

To evaluate treatment responses accurately within the RBD framework, non-destructive and destructive sampling was performed at regular growth intervals. Five representative plants were randomly tagged from each replication plot to record the parameters outlined in Table 2.

Table 2: Systematic Log of Agronomic Observation Points

Growth Phase	Core Evaluation Parameter	Measurement Unit / Methodology
Growth Parameters	Plant Height	Measured from base to highest leaf tip at 30, 60, 90 DAT, and maturity.
	Number of Tillers	Manual count per hill at active tillering, panicle initiation, and maturity.
	Days to 50% Flowering	Visual log when 50% of panicles fully emerge from the leaf sheath.
Yield Attributes	Days to Maturity	Chronological days from transplanting (16/06/2025) to 90% grain ripening.
	Effective Tillers	Total number of productive panicle-bearing tillers per hill.
	Panicle Length	Linear length (cm) measured from the neck node to the tip of the panicle.
	Filled Grains / Panicle	Count of completely filled grains separated from empty/chaffy spikelet's.
Final Yield Indices	Test Weight	Mass (g) of 1,000 randomly selected, sun-dried grains.
	Grain Yield	Cleaned grain weight per net plot, converted to quintals per hectare (q/ha)
	Straw Yield	Dry straw mass per net plot, converted to quintals per hectare (q/ha)
	Harvest Index (HI%)	Calculated as: $HI\ (%) = \left(\frac{\text{Grain yield}}{\text{grain yield} + \text{straw yield}} \right) \times 100$

Economic Calculations and Benefit-Cost (B:C) Ratio

The total cost of cultivation includes expenses for seed, land preparation, nursery raising, transplanting, fertilizers, plant protection chemicals, labor, and harvesting operations. Cost of cultivation parameters was standardized at Rs 59,000.00 per hectare for high-yielding varieties (T₁, T₂, T₄, T₅, T₆) and adjusted to Rs55,000.00 per hectare for specialized premium fine/scented varieties (T₃, T₇) due to differences in seed and nutrient dynamics. Economic performance and treatment efficiencies were analyzed mathematically using standard agricultural indices:

Gross returns (/ha) = Grain yield X market prize +Straw yield X market prize

Net returns (/ha) = Gross returns -total cost of cultivation

Benefit-cost (B:C) ratio = $\left(\frac{\text{Gross returns (/ha)}}{\text{Total cost of cultivation (/ha)}} \right)$

Results and Discussion

Morpho-Physiological Growth Parameters

The genetic diversity among the seven evaluated paddy cultivars significantly influenced all monitored phenotypic and physiological parameters (Table 3).

Table 3: Growth Performance Dynamics of Paddy Cultivars under a Transplanting System

Treatment Code	Cultivar / Genotype	Plant Height at 60 DAT (cm)	Plant Height at Maturity (cm)	No. of Tillers / Hill at 60 DAT	Days to 50% Flowering	Total Days to Maturity
T ₁	CO-55	74.2	92.5	11.4	78	112
T ₂	JR-206	82.5	104.1	14.8	94	126
T ₃	PB-1895	98.4	128.6	10.2	102	138
T ₄	Kranti	85.1	108.3	15.2	96	131
T ₅	JR-21	88.3	112.4	13.9	99	135
T ₆	IR-64	80.6	101.8	14.5	92	124
T ₇	Bauna Doobraj	91.2	116.5	9.8	105	142
—		2.15	3.10	0.42	1.8	2.2
—	CD ()	6.62	9.55	1.29	5.5	6.8
—	CV (%)	4.35	4.92	5.60	3.2	3.0

Plant Height Trends

Scented fine cultivars (T₃, and T₇) grew significantly taller than standard breeding lines. (T₃) (PB-1895) exhibited the maximum

mature height (128.6cm) driven by genetic configurations common to Basmati selections. The shortest heights were recorded in the early line(T₁) (CO-55)

Tiller Production

High-yielding bold/coarse cultivars achieved significantly higher tiller counts per hill. The absolute maximum was recorded in (T₄) (Kranti) with (15.2) tillers /hill closely followed by(T₂) (JR-206). Fine-grain aromatic cultivars (T₃, T₇) expressed significantly fewer tillers.

Crop Phenology

Sowing cycles showed clear deviations. (T₁) (CO-55) was identified as a highly efficient short-duration line, maturing in just (112days) Conversely, the specialty cultivar (T₇) (Bauna Doobraj) required the longest reproductive window, taking (142days) to reach full maturity.

Yield Attributes and Biological Yield Fractions

Yield parameters and biological harvest allocations differed significantly among cultivars under uniform nutrient regimes (120:60:40 kg/ha N: P₂O₅: K₂O)

Table 4: Yield Attributes and Productivity Matrix of Evaluated Paddy Cultivars

Treatment Code	Cultivar / Genotype	No. of Effective Tillers / Hill	Panicle Length (cm)	No. of Filled Grains / Panicle	1000-Grain Weight (g)	Grain Yield (q/ha)	Straw Yield (q/ha)	Harvest Index (%)
T ₁	CO-55	9.2	21.4	112.5	22.1	38.4	48.2	44.34
T ₂	JR-206	12.4	24.8	134.2	25.4	52.1	63.4	45.11
T ₃	PB-1895	8.1	28.1	96.4	19.5	34.2	54.6	38.51
T ₄	Kranti	13.1	25.2	142.6	26.1	55.6	66.8	45.42
T ₅	JR-21	11.5	25.9	138.1	24.8	50.8	62.1	45.00
T ₆	IR-64	12.1	24.1	130.5	23.2	49.3	58.7	45.65
T ₇	Bauna Doobraj	7.9	23.4	102.8	16.2	31.5	50.4	38.46
—		0.35	0.65	4.20	0.58	1.45	1.82	—
—	CD ()	1.08	2.00	12.94	1.79	4.47	5.61	—
—	CV (%)	6.10	4.75	5.95	4.65	5.80	5.55	—

Yield Attribution Dynamics

High-yielding check (T₄) (Kranti) outperformed other varieties, registering the highest numbers for effective tillers (13.1/hill) and filled grains (142.6/panicle). Long-slender aromatic selections (T₃) produced longer panicles (28.1cm) but logged lower grain fill densities.

Final Yield Output

T₄ (Kranti) produced the highest final grain yield (55.6q/ha), statistical parity with T₂ (JR-206) at (52.1q/ha) Specialty selections like T₇ (Bauna Doobraj) yielded less grain (31.5q/ha) due to lower individual test weights (16.2g)

allocated dry matter efficiently, resulting in stable harvest index values between 45.00% and 45.65% Aromatic cultivars (T₃, T₇) allocated a larger share of dry matter to vegetative straw structures, resulting in lower harvest indices (38.5%)

Economic Evaluation and Monetary Advantage

Economic performance was calculated using current local market rates for the Kymore Plateau region. Standard coarse rice was priced at ₹2,300/q, premium Basmati type (T₃) at ₹4,200/q, and regional aromatic (T₇) at ₹4,500/q. Straw values were standardized at ₹200/q.

Harvest Index (HI%)

Coarse and mid-duration commercial cultivars (T₆, T₄, T₂, T₅)

Economic Analysis and Benefit-Cost Configurations of Paddy Cultivars

Treatment Code	Cultivar / Genotype	Cost of Cultivation (₹/ha)	Estimated Grain Price (₹/q)	Gross Returns (₹/ha)	Net Returns (₹/ha)	Benefit-Cost (B:C) Ratio
T ₁	CO-55	₹59,000.00	₹2,300.00	₹97,960.00	₹38,960.00	1.66
T ₂	JR-206	₹59,000.00	₹2,300.00	₹1,32,510.00	₹73,510.00	2.25
T ₃	PB-1895	₹55,000.00	₹4,200.00	₹1,54,560.00	₹99,560.00	2.81
T ₄	Kranti	₹59,000.00	₹2,300.00	₹1,41,240.00	₹82,240.00	2.39
T ₅	JR-21	₹59,000.00	₹2,300.00	₹1,29,260.00	₹70,260.00	2.19
T ₆	IR-64	₹59,000.00	₹2,300.00	₹1,25,130.00	₹66,130.00	2.12
T ₇	Bauna Doobraj	₹55,000.00	₹4,500.00	₹1,51,830.00	₹96,830.00	2.76
—		—	—	3412.50	3412.50	0.06
—	CD ()	—	—	10514.40	10514.40	0.18
—	CV (%)	—	—	5.42	8.12	5.10

Economic Drivers

High-yielding coarse varieties like T₄ generated high total biomass, but their lower market price limited net profitability. The lower initial input costs (₹55,000/ha) combined with high market prices for premium grains significantly improved net returns for scented selections.

Net Profit and B:C Trends: The highest net returns were recorded for T₃ (PB-1895) at ₹99,560.00/ha, with a maximum

B:C ratio of 2.81. This was followed closely by the regional premium variety T₇ (Bauna Doobraj), which achieved a B:C ratio of 2.76. Among coarse varieties, T₄ (Kranti) remained the most profitable option (2.39).

Summary, Conclusion, and Recommendations

4.1 Summary of Findings

The field experiment conducted at Krishi Vigyan Kendra (KVK)

Majhgawan, Satna, evaluated seven diverse paddy genotypes (T_1 to T_7) to under a uniform transplanting system. The study revealed a clear trade-off between vegetative biomass allocation and economic value per unit of crop harvest

Growth and Phenology

Premium scented genotypes like (T_3) (PB-1895) and (T_7) (Bauna Doobraj) grew significantly taller but required a longer duration to reach full maturity (up to 142 days). In contrast, (T_1) (CO-55) was identified as a highly efficient short-duration line (112 days).

Yield Dynamics

High-yielding coarse varieties like (T_4) (Kranti) and (T_2) (JR-206) produced the highest number of effective tillers per hill, resulting in maximum grain yields (55.6q/ha and 52.1q/ha respectively).

Economic Advantage

Although the aromatic fine-grain selections (T_3 and T_7) yielded less total grain, they incurred lower initial production costs and commanded high market premiums. This combination generated the highest net profits and benefit-cost ratios.

Conclusion

The experiment highlights two distinct pathways for optimizing paddy production on the medium black clay loam soils of the Kymore Plateau:

The Productivity Pathway

Cultivars T_4 (Kranti) and T_2 (JR-206) maximize grain yield per unit area. These genotypes are well-suited for intensive food-production systems, regional food security goals, or farms with high livestock demands requiring large volumes of quality straw.

The Profitability Pathway

Cultivating premium fine/scented genotypes like T_3 (PB-1895) and T_7 (Bauna Doobraj) yields less total grain but generates higher net returns and superior B:C ratios (2.81 and 2.76), respectively). This approach maximizes net profits for smallholder farmers who have access to quality-driven consumer markets.

Summary Discussion and Recommendations

The experiment highlights two distinct pathways for optimizing paddy production in the Kymore Plateau:

- For Volume and Biomass:** Cultivars (T_4) (Kranti) and (T_2) (JR-206) maximize grain yield per unit area. They are well-suited for intensive food-production systems or areas with high straw demand.
- For Profit Optimization:** Cultivating premium fine/scented genotypes like (T_3) (PB-1895) and (T_7) (Bauna Doobraj) yields less total grain but generates higher net returns and B:C ratios. This choice maximizes net profits for smallholder farmers in the region

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