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AGRONOMIC RESEARCH & FIELD CROP EVALUATION — PCP PROJECT REPORT

Field Performance, Weed Dynamics, and Economics of Biofortified Wheat (HD-3406) under Smart Seeder in Eastern Uttar Pradesh

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ABSTRACT: -

A field experiment was conducted during the Rabi season of 2025–26 at the Instructional Farm, College of Agriculture, Kotwa, Azamgarh (U.P.) to assess the morpho-physiological performance, phytosociological weed community structure, and financial returns of biofortified wheat (Triticum aestivum L., cv. HD-3406) direct-drilled using a Smart Seeder under rice residue retention. The trial was established on an allocated plot area of 0.405 ha. Vegetative development progressed steadily, culminating in a mean final plant height of 83.52 cm and 4.8 tillers plant^{-1}. The leaf area index (LAI) peaked at 4.65 during the booting stage (90 DAS). Weed ecological evaluation across five sampling quadrats identified five major weed species, dominated by Vicia sativa (Summed Dominance Ratio, SDR = 28.20), followed by Melilotus indica (SDR = 22.92) and Chenopodium album (SDR = 20.03). Net field biological productivity produced an average grain yield of 16.30 q ha^{-1} alongside an estimated straw yield of 24.45 q ha^{-1}. Total cost of cultivation stood at ₹34,200 ha^{-1} against a gross realization of ₹60,310 ha^{-1}, generating a net return of ₹26,110 ha^{-1} and an operational Benefit-Cost (B:C) ratio of 1.76. Direct drilling via Smart Seeder effectively conserved soil moisture and curbed grassy weed establishment, establishing a sustainable mechanism for wheat intensification in eastern Uttar Pradesh.

Keywords: *Biofortified wheat, HD-3406, Smart Seeder, Residue management, Weed dynamics, Summed Dominance Ratio, Benefit-Cost ratio.*

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INTRODUCTION:

Wheat (Triticum aestivum L.) is one of the world's most vital staple cereal crops belonging to the grass family Poaceae, providing approximately 20% of the total food calories and protein intake for the global human population. In India, wheat was cultivated over an area of 32.8 million hectares with a total national output of 117.94 million tonnes and an average productivity of 3,595 kg ha^{-1} during 2024–25. Hexaploid bread wheat (2n = 6x = 42, AABBDD) constitutes over 95% of national production owing to its exceptional viscoelastic gluten composition suitable for traditional flatbreads and bakery goods.

In the rice-wheat cropping sequence of the eastern Indo-Gangetic Plains (IGP), late harvest of long-duration paddy frequently pushes wheat sowing into late November or December. Delayed sowing exposes the reproductive phase to terminal heat stress, substantially diminishing test weight and photosynthetic efficiency (Sen et al., 2016). Furthermore, intensive multi-pass preparatory tillage destroys soil structure, depletes organic matter, and encourages dense flushes of annual weeds like Phalaris minor (Chhokar et al., 2012).

The introduction of the Smart Seeder—which combines straw management and precision placement of seed and basal fertilizer under surface mulch—presents an eco-friendly alternative to in-situ stubble burning (Kamboj et al., 2020; Mahal et al., 2022). When integrated with zinc- and iron-dense biofortified wheat cultivars such as HD-3406 (40.6 ppm Zn, 39.4 ppm Fe), this intervention addresses both climate vulnerability and micronutrient deficiencies (Yadava et al., 2020). The present study was carried out to evaluate the growth dynamics, weed flora spectrum, and operational economics of HD-3406 under the Smart Seeder system in Azamgarh, eastern Uttar Pradesh.

MATERIALS AND METHODS

Experimental Site, Climate, and Soil

The experiment was executed at the Instructional Farm, College of Agriculture, Kotwa, Azamgarh (U.P.), covering an allocated area of 0.405 ha. Geographically, the location falls under the humid subtropical climatic belt (Köppen Cwa) experiencing hot summers and cool dry winters with an average precipitation of 1,110 mm. Winter nights frequently dip below 5 °C. The experimental soil was sandy loam to clay loam in texture, well-drained, with an organic carbon content in the medium range and a slightly acidic to neutral reaction (pH 6.5–7.2).

Sowing, Agronomic Management, and Crop Protection

Sowing was performed on November 23 using a tractor-operated Smart Seeder at a

seed rate of 100 kg ha^{-1}, maintaining 20 cm inter-row spacing and 5 cm intra-row seed drop. Basal fertilization comprised 50% of the total recommended nitrogen and 100% of phosphorus and potassium supplied via DAP, MOP, and Urea, alongside zinc sulphate. The remainder 50% nitrogen was top-dressed in two equal splits at the Crown Root Initiation (CRI) stage (21–25 DAS) and the jointing stage (45–50 DAS). Protective irrigations were scheduled at physiological checkpoints: CRI, late tillering, jointing, booting, and milking.

Sampling and Data Estimation

Five plants were randomly marked and tagged within a 1.0 m² area to monitor plant height (cm), number of tillers plant^{-1}, and leaf parameters at 30, 60, and 90 Days After Sowing (DAS) and at harvest. Leaf area per plant was computed using length, maximum width, and a correction factor of 0.62 (Watson, 1952), projected over ground area per plant (20 cm × 5 cm = 100 cm²):

Leaf Area Index (LAI) = [Leaf Length (cm) × Leaf Width (cm) × Total Functional Leaves × 0.62] / Ground Area (cm²)

Yield attributes including spike count plant^{-1}, spike length, grain count spike^{-1}, and 1000-grain test weight were recorded at physiological maturity.

Weed floristic composition was evaluated using the quadrat method (1.0 m × 1.0 m) randomly thrown across five spots at 50 DAS. Phytosociological indices were determined as per standard ecological



methodology (Mishra, 1968; Raju, 1998):

- *Absolute Density (AD) = Total individuals recorded across all quadrats*
- *Relative Density (RD, %) = [AD of a species / ∑ AD of all species] × 100*
- *Absolute Frequency (AF, %) = [Quadrats of occurrence / Total quadrats] × 100*
- *Relative Frequency (RF, %) = [AF of a species / ∑ AF of all species] × 100*
- *Importance Value (IV) = RD + RF ; Summed Dominance Ratio (SDR) = IV / 2*

RESULTS AND DISCUSSION

Morphometric Growth and Foliar Canopy

Plant height exhibited continuous elongation throughout the vegetative and reproductive phases (Table 1). Average height increased from 23.52 cm at 30 DAS to 35.72 cm at 60 DAS, accelerating rapidly during stem elongation to 79.18 cm at 90 DAS and reaching 83.52 cm at maturity. Similar developmental trends under direct drill establishment were recorded by Singh et al. (2018).

Tiller formation gained impetus post-CRI stage, reaching 2.8 tillers plant^{-1} at 60 DAS and stabilizing at 4.0 at 90 DAS and 4.8 at harvest (Table 2). Foliar expansion analysis revealed an increase in leaf length from 17.32 cm at 30 DAS to 21.50 cm at 90 DAS, with leaf width broadening from 0.80 cm to 1.60 cm (Table 3). Consequently, canopy LAI expanded progressively from 1.12 at 30 DAS to 2.85 at 60 DAS, peaking at 4.65 at 90 DAS during full flag leaf emergence.

Yield Components and Grain Output

Yield components recorded at maturity demonstrated a mean of 2.33 spikes plant^{-1}, an average spike length of 8.0 cm, and 44.6 grains

Table 1: Plant height (cm) of biofortified wheat (HD-3406) recorded at successive growth stages

Plant Tag No.	30 DAS	60 DAS	90 DAS	At Harvest
Plant 1	23.20	29.30	67.70	73.10
Plant 2	25.80	37.80	83.90	88.10
Plant 3	27.80	35.20	80.20	83.20
Plant 4	18.70	33.90	79.60	84.50
Plant 5	22.10	35.20	84.50	88.70
Mean ± S.E.	**23.52 ± 1.57**	**35.72 ± 1.48**	**79.18 ± 2.97**	**83.52 ± 2.76**

Table 2: Number of tillers plant^{-1} of wheat cv. HD-3406 across phenological intervals

Plant Tag No.	30 DAS	60 DAS	90 DAS	At Harvest
Plant 1	–	4	6	6
Plant 2	–	4	7	8
Plant 3	–	3	3	4
Plant 4	–	1	2	3
Plant 5	–	2	2	3
Mean	**–**	**2.80**	**4.00**	**4.80**

spike^{-1} with a 1000-grain test weight of 32.0 g (Table 4). Net biological realization generated a grain yield of 16.30 q ha^{-1} (1,630.25 kg ha^{-1}). Factoring in an agronomic Harvest Index of ~40%, straw yield was calculated at 24.45 q ha^{-1}.

The observed grain yield (16.30 q ha^{-1}) was largely influenced by terminal high-temperature exposure during the grain-filling period and initial crop establishment dynamics under surface residue in late-sown conditions, in line with trends observed in the Eastern

Table 3: Leaf dimensions and canopy Leaf Area Index (LAI) of wheat cv. HD-3406

Plant Tag No.	30 DAS L (cm)	30 DAS W (cm)	60 DAS L (cm)	60 DAS W (cm)	90 DAS L (cm)	90 DAS W (cm)
Plant 1	18.70	0.70	18.70	1.40	18.90	2.00
Plant 2	16.20	0.80	16.30	1.10	19.10	1.40
Plant 3	17.90	1.10	22.10	1.30	22.20	1.40
Plant 4	15.30	0.50	21.90	1.70	22.70	1.80
Plant 5	18.50	0.90	23.30	1.20	24.60	1.40
Mean	**17.32**	**0.80**	**20.46**	**1.34**	**21.50**	**1.60**
Estimated LAI	**1.12**		**2.85**		**4.65**	

Table 4: Yield-attributing characteristics and estimated harvest yield of wheat cv. HD-3406

Agronomic Character	Observed Parameter	Yield Unit
Effective spikes plant^{-1}	2.33	Numbers
Average spike length	8.00	cm
Grains spike^{-1}	44.60	Numbers
1000-grain weight (Test weight)	32.00	g
Grain yield per hectare	**16.30**	**q ha^{-1}**
Straw yield per hectare	**24.45**	**q ha^{-1}**
Estimated Harvest Index (HI)	**40.00**	**%**



Plain Zone of Uttar Pradesh (Sen et al., 2016).

Weed Community Dynamics

Vegetative weed assessment yielded 104 individual weed specimens across five distinct species in the sampling quadrats (Table 5). The leguminous broadleaf species Vicia sativa established highest dominance with an Absolute Density of 37, Relative Density of 35.57%, Importance Value of 56.40, and the highest SDR of 28.20. It was succeeded by Melilotus indica (SDR = 22.92) and Chenopodium album (SDR = 20.03). Narrow-leaf weeds (Cynodon dactylon, SDR = 15.70) and sedges (Cyperus rotundus, SDR = 13.14) occupied lower dominance levels.

Table 5: Phytosociological attributes and weed dynamics under Smart Seeder establishment

S.N.	Weed Species	Botanical Name	Family	Q1	Q2	Q3	Q4	Q5	AD	RD (%)	AF (%)	RF (%)	IV	SDR
1	*Vicia sativa L.*	*Vicia sativa*	Fabaceae	11	4	8	5	9	37	35.57	100.0	20.83	56.40	28.20
2	*Melilotus indica (L.) All.*	*Melilotus indica*	Fabaceae	7	3	5	9	2	26	25.00	100.0	20.83	45.83	22.92
3	*Chenopodium album L.*	*Chenopodium album*	Amaranthaceae	2	6	6	2	4	20	19.23	100.0	20.83	40.06	20.03
4	*Cynodon dactylon (L.) Pers.*	*Cynodon dactylon*	Poaceae	2	3	3	2	1	11	10.57	100.0	20.83	31.40	15.70
5	*Cyperus rotundus L.*	*Cyperus rotundus*	Cyperaceae	3	1	0	4	2	10	9.61	80.0	16.67	26.28	13.14
Total				**25**	**17**	**22**	**22**	**18**	**104**	**100.00**	–	**100.00**	**200.00**	**100.00**

The thick in-situ residue layer created by the Smart Seeder effectively obstructed solar radiation reaching the soil, inhibiting small-seeded annual grasses such as Phalaris minor, confirming patterns described by Chhokar et al. (2012) and Kumar et al. (2013). Nevertheless, vigorous broadleaf species with larger carbohydrate seed reserves successfully penetrated the mulch blanket, emphasizing the need for targeted post-emergence broadleaf weed management.

Production Economics and B:C Ratio

Financial accounting under prevailing input rates in eastern Uttar Pradesh revealed a total cost of cultivation of ₹34,200 ha^{-1}, encompassing machine operational hiring, biofortified seed, balanced nutrient management, crop protection, and mechanical harvesting (Table 6). Gross revenue accrued was ₹60,310 ha^{-1}, comprising grain sales (16.30 q @ ₹2,500 q^{-1} = ₹40,750) and straw realization (24.45 q @ ₹800 q^{-1} = ₹19,560). The cultivation generated a net profit of ₹26,110 ha^{-1} and an operational Benefit-Cost (B:C) ratio of 1.76. By eliminating repeated

disc plowings, the Smart Seeder saved diesel and operational time, ensuring financial viability as documented by Kamboj et al. (2020) and Das et al. (2014).

Table 6: Itemized cultivation expenditure, gross realizations, and profitability indicators

S.N.	Operational Heads / Inputs	Cost (₹ ha⁻¹)
1	Preparatory tillage & Smart Seeder machine operational hiring	4,800.00
2	Certified biofortified seeds and seed treatment bio-agents	7,200.00
3	Nutrient management (RDF: Urea, DAP, MOP & $ZnSO_4$)	7,200.00
4	After-care, labor, and irrigation scheduling charges	2,700.00
5	Integrated weed management and plant protection inputs	4,500.00
6	Harvesting, threshing, and bagging charges	7,800.00
	Total Cost of Cultivation (A)	**34,200.00**
Item	**Output Volume & Prevailing Farmgate Unit Rate**	**Revenue (₹ ha⁻¹)**
Grain	16.30 quintals @ ₹2,500 q^{-1}	40,750.00
Straw (Bhusa)	24.45 quintals @ ₹800 q^{-1}	19,560.00
	Gross Return (B)	**60,310.00**
	Net Return (B − A)	**26,110.00**
	Benefit-Cost Ratio (Gross Return / Cost)	**1.76**

CONCLUSION

Direct drilling of biofortified wheat (HD-3406) with a tractor-drawn Smart Seeder proved viable for in-situ residue management under eastern Uttar Pradesh conditions. The system avoided residue burning, achieved a grain productivity of 16.30 q ha^{-1}, and delivered viable economic profitability with a B:C ratio of 1.76. Phytosociological analysis demonstrated that surface mulch suppresses grassy annual weeds, although dominant broadleaved species such as Vicia sativa and Melilotus indica require targeted post-emergence weed management.

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