

Profitability of Soybean-Wheat Cropping System under Permanent Broad Bed Furrow System in Madhya Pradesh: Evidence from Farmers' Fields

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ABSTRACT

Soybean productivity has stagnated in recent years, primarily due to abiotic stress, including climatic aberrations such as erratic rainfall patterns that cause both waterlogging and drought stress, as well as biotic stress from weed, disease, and pest infestations. This study assesses the impact of the Permanent Broad Bed Furrow (PBBF) technology, which is helpful in this condition. Data on yield and cost of cultivation were collected from major soybean producing districts in Madhya Pradesh and analysed using a paired t-test. The average soybean yield in demonstration plots was 5.32 quintals per acre, representing a 25.2% increase over the control plots (4.28 q/acre). The PBBF technology led to a 5.3% reduction in the average cost of cultivation. The economic returns of PBBF technology under the soybean-wheat system were substantially higher compared to conventional practices. The findings establish that the PBBF technology is a potent climate-resilient solution that not only mitigates weather-related risks but also significantly enhances the productivity and profitability of the soybean-wheat system. The study advocates for the large-scale promotion of this technology through supportive policies and extension services to achieve sustainable intensification of the soybean-based cropping system.

Keywords: Permanent Broad Bed Furrow (PBBF), Climate Resilience, Yield Economic Return, On-farm Demonstration

1 | INTRODUCTION

The soybean-wheat cropping system covers a significant area (4.5 million ha) in central India (Nargund et al. 2024). Further, Soybean (*Glycine max* L. Merr.), often referred to as the "golden bean," is one of the most vital oilseed crops globally and holds a paramount position in India's agricultural economy. It serves as a primary source of edible oil and high-quality vegetable protein, making it crucial for the nation's nutritional security and for alleviating protein-calorie malnutrition. With approximately 40% protein and 18-20% oil content, along with essential amino acids, vitamins, and minerals, soybean is an indispensable component of the food, feed, and industrial sectors (Sharma, 2015; Dupare et.al., 2016). India is one of the top five soybean producers in the world, and the state of Madhya Pradesh is aptly called the "Soya State," accounting for the largest share of the country's area and production. In 2024-25, the state had 5.87 million hectares under soybean cultivation, producing 5.28 million tonnes. Wheat (*Triticum aestivum* L.) is again the major cereal crop playing vital role in India's food security. In 2024-25, the crop is grown in 32 and 7.76 million hectares (m ha) in India and in Madhya Pradesh, respectively, producing 117.5 and 23.4 million tonnes. However, despite its dominance, the productivity in the region has been hovering around a modest 900 kg/ha in soybean and 3012 kg/ha in wheat, which is

significantly lower than the global average. This stagnation in productivity is a matter of serious concern, attributed to a confluence of biotic, abiotic, and socio-economic constraints (Prashnani et al., 2023). Among the most critical challenges confronting soybean-wheat farmers in Madhya Pradesh is the increasing vulnerability to climate change. The region's agriculture, predominantly rainfed, is highly susceptible to the vagaries of the southwest monsoon, and early cessation of groundwater leads to the non-availability of water to irrigate the wheat crop at critical stages. Recent decades have witnessed a discernible shift in monsoon patterns, characterised by a reduced number of rainy days but an increased frequency of high-intensity rainfall events, interspersed with prolonged dry spells. The prevalent deep black soils (*Vertisols*) in this region, while fertile, have poor drainage capacity. Consequently, intense rainfall leads to transient waterlogging, creating anaerobic conditions in the root zone that severely hamper crop growth and nodulation. Conversely, extended dry spells during critical growth stages cause moisture stress, leading to significant yield reductions. This dual challenge of excess and deficit soil moisture is a primary factor contributing to the wide gap between potential and actual farm yields. The dominant cropping system in the state, soybean followed by wheat, further exacerbates issues related to soil health and resource management. Conventional cultivation practices, involving flatbed sowing, often lead to

poor crop establishment under aberrant weather conditions and contribute to soil degradation over time. Therefore, an urgent need for climate-resilient agricultural technologies that can buffer the crop against weather shocks, conserve natural resources, and ensure sustainable productivity (Bahera et.al. 2007 and Sun et.al. 2023). The Permanent Broad Bed and Furrow (PBBF) system is a direct planting system without any tillage operations in sequence cropping that has emerged as a promising conservation agriculture technology to address these challenges. This in-situ soil and water conservation technique involves creating raised beds for sowing the crop and intervening furrows to manage water. The furrows act as drainage channels during periods of excessive rainfall, safely removing surplus water from the field and preventing waterlogging. During dry spells, these same furrows capture and store rainwater, allowing it to infiltrate the soil profile and become available to the crop roots, thus providing supplemental irrigation (Sharma et.al. 2020; Motwani and Ashish, 2018, Sharma et.al. 2019, and Verma et al. 2024). Besides, the benefits of PBBF technology have been demonstrated at ICAR-National Soybean Research Institute (ICAR-NSRI), Indore; its adoption at the farm level remains limited due to a lack of awareness, technical know-how, and access to appropriate machinery. To bridge this gap, a collaborative project was initiated by the ICAR-NSRI, Indore, and ITC Limited to validate, demonstrate, and popularize the PBBF technology on farmers' fields with the dual objectives to train and demonstrate the use of PBBF in the soybean-wheat cropping system and to see the impact of the intervention on the yield, expenditure, and income.

2 | MATERIALS AND METHODS

2.1 | Study Area

The study was conducted during the *Kharif* (rainy) and *Rabi* (winter) seasons of 2022 in five major soybean-wheat producing districts of Madhya Pradesh, namely Vidisha, Indore, Ujjain, Dewas, and Sehore. These districts were purposively selected as they represent the core soybean-wheat growing region and are priority areas for ITC's agricultural extension programs. The agro-climatic conditions of these districts are broadly similar, characterized by hot summers, cool winters, and monsoon-dependent rainfall, with deep to medium black cotton soils (*Vertisols*) being the predominant soil type. These soils are known for their high water-holding capacity but poor internal drainage, making them susceptible to waterlogging.

2.2 | Selection of Beneficiaries and Demonstration Design

From the project villages across the five districts, a total of 200 soybean and 175 wheat-growing farmers were selected as beneficiaries to participate in the on-farm demonstrations. The same number of farmers without BBF was also selected as a control. For each demonstration plot, a corresponding control plot was identified on an adjacent field of the same farmer with similar soil type and land conditions. Care was taken that the control plot was identical to that of the demo plot in order to realise the true impact of PBBF technology. The demonstrations were conducted on a 1-acre plot for each beneficiary farmer. The district-wise distribution of demonstration and control plots is detailed in Table 1.

Table 1. District-wise distribution of demonstration and control plots.

Sr. No.	District	Soybean		Wheat	
		No. of Demonstration Plots	No. of Control Plots	No. of Demonstration Plots	No. of Control Plots
1	Vidisha	40	40	40	40
2	Ujjain	20	20	20	20
3	Indore	40	40	40	40
4	Dewas	20	20	20	20
5	Sehore	80	80	55	55
	Total	200	200	175	175

2.3 | Capacity Building and Training

To empower farmers with the necessary knowledge and skills, intensive training programs were organized at the ICAR-NSRI, Indore. The 200 beneficiary farmers were trained in five batches of 40 participants each. The beneficiaries were trained during *kharif* and *rabi* 2022-23. Farmers were trained on Permanent Broad Bed Furrow (PBBF) technology and climate resilient management practices for soybean-wheat production, management of insects of soybean, management of major soybean diseases with climate resilient practices, and weed management in soybean under a changing climate scenario.

2.4 | Data

Data on seed and straw yield were collected from both demonstration and control plots. Detailed information on the cost of various cultivation operations (land preparation, seeds, fertilizers, plant protection, labour, etc.) was collected through structured schedules and personal interviews with the participating farmers. The collected data were compiled and analysed to work out the economics of cultivation. The following parameters were calculated:

Cost of Cultivation (₹/acre): Total expenses incurred in production.

Gross Returns (₹/acre): Output (Seed and straw yield) (q/acre) × Market Price (₹/q).

Net Returns (₹/acre): Gross Returns - Cost of Cultivation.

Further, the fixed cost of the PBBF seed drill is not taken into account to show the net return over variable cost only. In order to determine the statistical significance of the differences in yield, cost, and returns between the demonstration and control plots, a paired t-test was employed for each district.

2.5 | Water Productivity

Water productivity for soybean and wheat was calculated by dividing the economic yield by the total water applied (Sarma, 2014). Soybean was cultivated under rainfed conditions; therefore, the total water applied comprised the effective

rainfall at each location. Wheat, grown under irrigated conditions, received both irrigation water and effective rainfall, which together constituted the total water applied at the respective locations.

3 | RESULTS AND DISCUSSION

The on-farm demonstrations effectively showcased the superiority of the PBBF-based technology package over traditional farming practices. The results of crop yield and economics are presented and discussed below.

3.1 | Impact on Soybean Seed Yield

The adoption of the PBBF system, along with the improved package of practices, resulted in a substantial improvement in soybean yield across all five districts. As depicted in Table 2, the average yield in the demonstration plots consistently surpassed that of the control plots.

Table 2. Average yield of soybean (q/acre) in demonstration and control plots.

S. No.	District	Control	Demo	% yield increase over control	Significance (% LoS)
1	Vidisha	3.59	4.83	34.90	1
2	Ujjain	5.17	5.45	5.00	1
3	Indore	3.23	4.10	27.00	1
4	Dewas	4.32	5.10	18.00	1
5	Sehore SIPA	4.02	5.61	39.50	1
6	Sehore NCHSE	5.38	6.86	27.50	1
Mean		4.28	5.32	25.20	10

A detailed analysis (Table 2) reveals that the percentage increase in yield varied across locations, reflecting the influence of local weather conditions during the crop season. The highest yield advantage was recorded in Sehore SIPA (39.5%), followed by Vidisha (34.9%), Sehore NCHSE (27.5%), and Indore (27.0%). Even in Ujjain, where the control plot yields were relatively high, the demonstration plots showed a 5% increase. Overall, the average seed yield across all locations was 25% higher in the PBBF demonstration plots (5.32 q/acre) compared to the control plots (4.28 q/acre). The p-values obtained from the paired t-test were highly significant for all districts except Ujjain (where it was marginally non-significant), confirming that the observed yield differences were statistically robust and attributable to the technological intervention. The significant

yield enhancement can be attributed to several factors inherent to the PBBF system. Primarily, the system provides a robust defence against weather variability. During high-intensity rainfall, the furrows efficiently drained excess water, preventing the critical issue of waterlogging in the heavy black soils. The synergistic effect of other improved practices, such as the use of high-yielding varieties and proper seed treatment, further contributed to this yield advantage.

3.2 | Impact on Wheat Grain Yield

A key advantage of the Permanent Broad Bed Furrow system is its potential for permanence, where the same land configuration is maintained for the subsequent *Rabi* season crop.

Table 3. Average yield of wheat (q/acre) in demonstration and control plots.

S. No.	District	Control	Demo	% yield increase over control	Significance (% LoS)
1	Vidisha	15.23	15.65	2.70	NS
2	Ujjain	21.4	22.5	5.14	1
3	Indore	12.07	15.46	27.00	1
4	Dewas	17.8	22.05	23.80	1
5	Sehore	17.39	19.09	9.70	1
Mean		16.77	18.95	13.0	

The average wheat yield in the demonstration plots was 18.95 q/acre, which is 13.0% higher than the average yield of 16.77

q/acre observed in the conventional flatbed control plots (Table 3). The impact was particularly pronounced in the

districts of Indore and Dewas, which recorded substantial yield advantages of 27.0% and 23.8%, respectively. The yield increase was statistically significant at the 1% level of significance in all districts except Vidisha, where the difference was marginal and not significant.

3.3 | Economic Impact Analysis

The economic viability of any technology is paramount for its adoption by farmers. The analysis of the cost of cultivation, gross returns, and net returns clearly demonstrates the financial benefits of the PBBF-based system.

3.3.1 | Cost of Cultivation in Soybean

Contrary to the perception that advanced technologies might increase costs, the BBF system, on average, resulted in a slightly lower cost of cultivation. The average cost incurred in demonstration plots was ₹10,999 per acre, which was 5.36% lower than the ₹11,622 per acre spent on control plots (Table 4). This reduction can be attributed to more efficient field operations, better weed management due to improved crop canopy, and potentially lower costs for corrective measures against waterlogging or pest/disease outbreaks due to a healthier crop stand. While there was an exception in Vidisha, where demonstration costs were higher, the overall trend indicates economic efficiency.

Table 4. Comparison of average cost of cultivation in soybean (₹/acre).

District	Control (₹/acre)	Demo (₹/acre)	Significance (% LoS)
Vidisha	9051	9298	1
Ujjain	9093	3867	1
Indore	4063	3921	1
Dewas	14739	11900	1
Sehore	15574	11801	1
Mean	10504	8157	

3.3.2 | Cost of Cultivation in Wheat

The economic advantages of the Permanent Broad Bed Furrow (PBBF) system become even more evident when analysing the

cost of cultivation for the subsequent wheat crop. The data reveal a substantial reduction in production expenses for farmers using the PBBF method.

Table 5. Comparison of average cost of cultivation in wheat (₹/acre).

District	Control (₹/acre)	Demo (₹/acre)	Significance (% LoS)
Vidisha	10,551	11,436	1
Ujjain	12,343	12,335	NS
Indore	11,311	11,242	NS
Dewas	7,959	7,686	10
Sehore SIPA	14,798	12,196	1
Sehore NCHSE	12,769	11,099	1
Mean	11,622	10,999	

The cost of cultivation in the demonstration plots was ₹8,157 per acre, a remarkable 22.3% reduction compared to the ₹10,504 per acre incurred in the conventional control plots (table 5). This significant cost saving is primarily attributed to the drastic reduction in tillage operations. Since the beds and furrows are already established, the need for extensive land preparation (ploughing and harrowing) before sowing wheat is eliminated. The cost reduction was exceptionally high in districts like Ujjain, Dewas, and Sehore. While the costs in Indore were comparable. Vidisha reflected a different picture where the demonstration plot cost was slightly higher,

possibly due to localized factors or specific input costs in that season.

3.3.3 | Gross and Net Returns

Soybean: The dual benefit of higher yields and lower cultivation costs translated into significantly higher gross and net returns for the farmers who adopted the demonstrated technology. The average gross returns from demonstration plots were ₹27,092 per acre, substantially higher than the ₹22,156 per acre from control plots (Table 6).

Table 6. Comparison of average gross returns (₹/acre) – Soybean.

District	Control (₹/acre)	Demo (₹/acre)	Significance (% LoS)
Vidisha	20,337	26,859	1
Ujjain	27,868	30,307	5
Indore	16,201	21,413	1
Dewas	20,706	22,883	1
Sehore SIPA	20,338	31,003	1
Sehore NCHSE	27,488	30,087	1
Mean	22,156	27,092	

Table 7. Comparison of average net returns (₹/acre) – Soybean.

District	Control (₹/acre)	Demo (₹/acre)	Significance (% LoS)
Vidisha	9,786	15,423	1
Ujjain	15,525	17,971	5
Indore	4,891	10,171	1
Dewas	12,748	15,196	1
Sehore SIPA	5,539	18,807	1
Sehore NCHSE	14,719	18,988	1
Mean	10,535	16,093	

Table 8. Comparison of average gross returns (₹/acre) – Wheat.

District	Control (₹/acre)	Demo (₹/acre)	Significance (% LoS)
Vidisha	41185	42799	1
Ujjain	61587	61618	NS
Indore	25090	32787	1
Dewas	42145	52226	1
Sehore	42082	48333	1
Mean	42418	47552	

Table 9. Comparison of average net returns (₹/acre) – Wheat.

District	Control (₹/acre)	Demo (₹/acre)	Significance (% LoS)
Vidisha	32134	33430	1
Ujjain	52493	52238	1
Indore	21026	28866	1
Dewas	27405	40325	1
Sehore	26637	36684	1
Mean	31939	38309	

Wheat: The increased yield from the Permanent Broad Bed Furrow (PBBF) system directly translated into higher gross returns for the farmers. The analysis shows a clear financial advantage for the wheat crop grown under the demonstration plots.

The most crucial indicator of profitability, the net return, showed a remarkable improvement. The average net return for farmers using the PBBF technology package was ₹16,093 per acre, which was 52.7% higher than the average net return of ₹10,535 per acre realized from conventional practices (Table 7).

Farmers earned ₹47,552 per acre from the demonstration plots, which is 12.1% more than the ₹42,418 per acre earned from the conventional control plots (Table 8). This increase in revenue was particularly significant in districts like Dewas and Indore, where the gross returns were substantially higher. The

This substantial increase in farm income underscores the economic superiority of the BBF system and serves as a powerful incentive for its wider adoption. The highly significant p-values across all districts for gross and net returns confirm that these economic benefits are statistically valid and directly linked to the intervention.

results were statistically significant across all districts except for Ujjain, where the difference was negligible. This outcome is a direct consequence of the higher crop productivity observed in the PBBF system. As gross return is a function of yield and market price, the yield advantage of 13.0% was the primary driver behind this boost in farm income.

The ultimate measure of a technology's success is its impact on net profitability. The analysis of net returns from wheat cultivation (Table 9) demonstrates the profound economic benefits of the Permanent Broad Bed Furrow (PBBF) system. The results indicate that the average net return from the demonstration plots was ₹38,309 per acre, representing a significant 20.0% increase over the ₹31,939 per acre earned from the control plots. The net financial gains were high in Dewas, Sehore, and Indore. While the net returns in Ujjain were comparable between the two groups.

Water productivity: The highest water productivity (WP) in soybean was observed under permanent broad bed furrow (PBBF, demonstration plot) compared to farmer's practices (Fig. 1). The mean soybean water productivity observed under BBF across locations were 1.46 kg/ha mm. Whereas 1.21 kg/ha mm WP was recorded under farmer practices. The water productivity was increased by 20.7 % under demonstrations plots as compared to farmer's practices. The soybean water productivity ranged from 0.76-2.76 kg/ha mm under demonstration plots across the locations. However, in farmer's practices soybean water productivity ranged from 0.59-2.57 kg/ha mm across the locations.

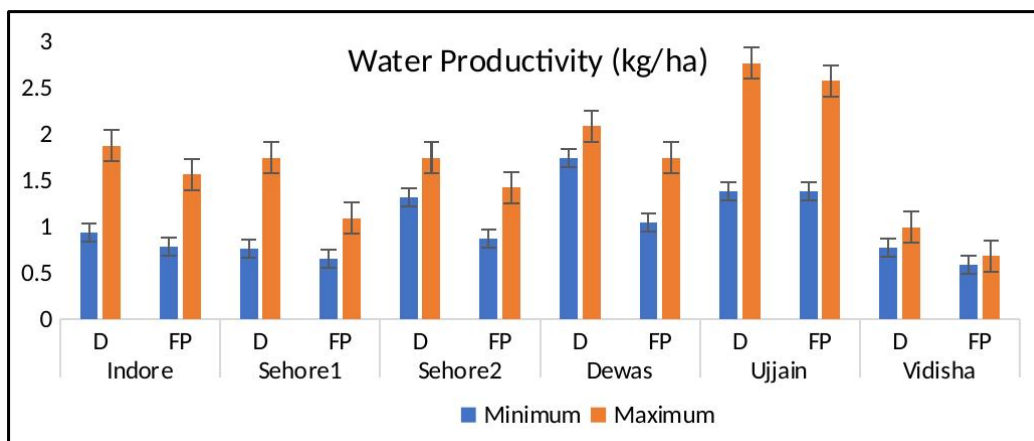


Fig. 1. Water productivity of soybean grown under different crop establishment techniques at a farmer's field in five districts of Madhya Pradesh (D-Demonstration, FP – Farmers' Practice 'SIPA 'NCHSE).

The highest water productivity in wheat was observed under permanent broad bed furrow (PBBF, demonstration plot) compared to farmers' practices (Fig. 2). The wheat water productivity ranged from 2.50 to 7.75 kg ha-mm under PBBF

across locations. However, in farmers' practices, wheat water productivity ranged from 1.65 to 6.15 kg ha-mm across the locations.

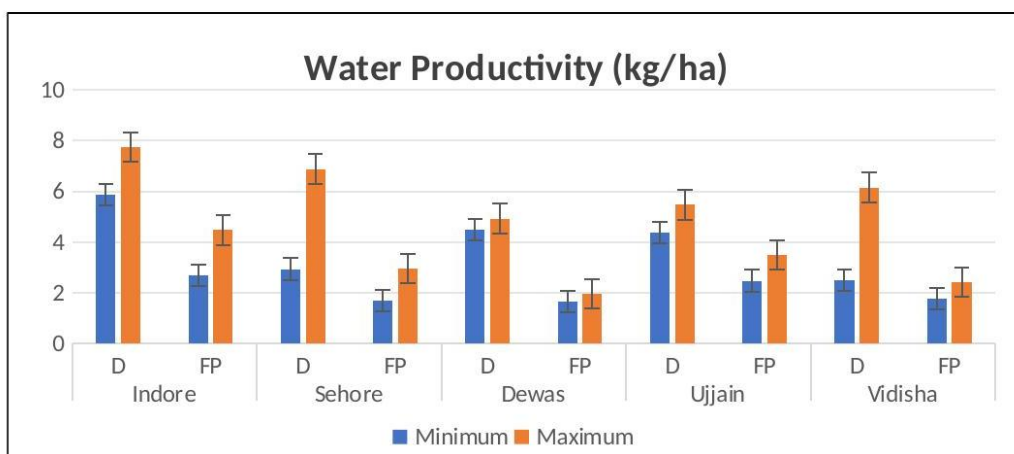


Fig. 2. Water productivity of wheat grown under different crop establishment techniques at the farmer's field in five districts of Madhya Pradesh (D-Demonstration, FP – Farmers' Practice).

4 | CONCLUSION

This study successfully demonstrated the profound impact of the Permanent Broad Bed Furrow (PBBF) technology package

on the productivity and profitability of soybean and wheat cultivation in the major growing regions of Madhya Pradesh. It was proven that the PBBF system, combined with improved agronomic practices, is a highly effective climate-resilient

technology. The technology is economically viable and highly profitable. It not only increased gross returns through higher yields but also reduced the average cost of cultivation, culminating in a 52.7% and 20% increase in average net returns in soybean and wheat, respectively. Government agencies, both at the state and national levels, should formulate policies to promote the large-scale adoption of the PBBF system. This could include providing financial assistance or subsidies for the purchase of BBF seed drills and promoting their availability through custom hiring centres.

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REFERENCES

- Behera U K, Sharma A R and Pandey H N. 2007. Sustaining productivity of wheat-soybean cropping system through integrated nutrient management practices on the Vertisols of central India. *Plant Soil*. **297**, 185–199
- Dupare B U, Billore S D, Sharma P and Verma S K. 2016. Domestic utilization of soybean based food preparations in rural area: an action research. *Soybean Research*, **14**(1), 46-51
- Motwani S and Ashish. 2018. Performance of soybean planted on broad bed furrow system under real farm conditions. *Soybean Research*, **16** (1&2), 113-00
- Nargund, R., Verma, R.K., Ramesh, A., Sharma, M.P., Halli, H.M. and Govindasamy, P., 2024. Short-Term Benefits of Tillage and Agronomic Biofortification for Soybean–Wheat Cropping in Central India. *CLEAN–Soil, Air, Water*, 52(11),p.e202300300.<https://doi.org/10.1002/clen.202300300>
- Prashnani M, Dupare B, Vadrevu K P, Justice C. 2024. Towards food security: exploring the spatio-temporal dynamics of soybean in India. *PLoS ONE*, **19**(5), e0292005
- Sarma, A. 2014. Numerical Agronomy. Kalyani Publishers, New Delhi.
- Sharma P, Dupare B U and Khandekar N. 2020. Economic impact assessment of Broad-Bed Furrow seed drill for soybean. *Agric Res.*, **9**, 392–399
- Sharma P, Patel R M and Dupare B U. 2015. Profitability of soybean vis-à-vis major kharif crops in Madhya Pradesh. *Soybean Research*, **13** (2), 65-77
- Sharma V P. 2015. Soybean economy of India : performance, problems and prospects. *Journal of Oilseeds Research*, **32**(1)
- Sun Q, Zhang P, Zhao Z, Li X, Sun X, Jiang W. 2023. Continuous wheat/soybean cropping influences soybean yield and rhizosphere microbial community structure and function. *Agronomy*, **13**, 28
- Verma R.K., Raghavendra N., and Singh K.H. 2024. Permanent Broad Bed Furrow Technology for soybean-based cropping systems. *Indian Farming* 74 (09): 34-36.