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Yield Gap, Yield Performance and Farmer Economics Analysis of High Yielding Biofortified Wheat Variety DBW-187 with the Special Reference to the Adoption in District Bijnor (U.P.) India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research investigated the yield differences, yield efficacy, economic consequences, technology index and adoption rates of the high-yielding biofortified wheat variety DBW-187 and high-yielding wheat variety enriched with essential nutrients. It addresses crucial aspects of food security and

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nutrition by analyzing the gap between potential and actual farm yields. Being biofortified, DBW-187 contributes to addressing micronutrient deficiencies in populations dependent on wheat as a staple food. Frontline demonstrations were executed in 128 farmers' fields in 11 blocks from 2019-20 to 2023-24, contrasting DBW-187 with conventional farming practices. The study adopted a mixed-methods approach, incorporating field tests, economic analysis, and surveys of farmers. The results indicated that DBW-187 regularly surpassed local varieties, achieving an average yield of 58.74 qt/ha, in contrast to 42.65 qt/ha for conventional farming practices, signifying a 37.72% enhancement. The technological gap averaged 38.10 qt/ha, however the extension gap was 16.09 qt/ha, signifying possibility for enhancement in achieving the varieties complete potential. The average adoption rate of DBW-187 across the district was 54.73%, exhibiting considerable heterogeneity among blocks, ranging from 47.61% to 65.21%.

Keywords: Biofortified variety; yield gap; technology index; adoption.

1. INTRODUCTION

Wheat (Triticum aestivum L.) is an essential food crop for billions of people in world, providing vital nutrients and calories to a significant portion of the population (Shiferaw *et al.,* 2013). According to Sharma *et al.* (2021), wheat is the second most important food crop in India after rice. It is crucial for both agricultural economics and national food security. Despite significant advancements in wheat production, challenges persist about yield discrepancies, nutritional deficiencies, and economic sustainability for farmers, particularly in regions like Uttar Pradesh.

The yield gap, characterised as the difference between potential and actual agricultural output, has been thoroughly examined in agricultural sciences (Lobell *et al.,* 2009). Mitigating the yield gap in wheat production in India is crucial for enhancing food security, increasing farmer incomes, and meeting the nutritional needs of a growing population (Joshi *et al.,* 2016).

Biofortification, or the improvement of crop nutritional value through conventional breeding or genetic modification, has become a practical approach to address micronutrient deficiencies and raise crop yields at the same time (Bouis and Saltzman,2017). The development of high-yield, biofortified wheat varieties represents a significant progress in achieving agricultural productivity and nutritional goals.

The variety DBW-187 has received attention for its ability to address yield disparities and nutritional deficiencies in wheat production. DBW-187, created by Indian agricultural scientists, is notable for its high yield potential, improved nutritional characteristics, and resilience to various agro-climatic conditions (Kumar *et al.,* 2020). However, the adoption and effectiveness of this variation in certain regional contexts, such as Bijnor district in Uttar Pradesh, remain insufficiently studied.Located in western Uttar Pradesh, the Bijnor district is an important agricultural region that places a strong focus on wheat production. The district's diverse agro-ecological conditions and socio-economic factors make it an ideal case study for evaluating the potential impacts of biofortified wheat varieties on crop yield and farmer profitability (Singh *et al.,* 2019).

This research aims to meticulously analyse the yield gap, yield performance, and economic implications of adopting the high-yielding biofortified wheat variety DBW-187 in Bijnor district. Through the examination of these factors, we want to improve the understanding of biofortified crop adoption and its potential to address productivity and nutritional challenges in Indian agriculture.

2. MATERIALS AND METHODS

This study employed a mixed-methods approach to investigate the yield gap, yield performance, and economic implications of adopting the high-yielding biofortified wheat variety DBW-187 in Bijnor district, Uttar Pradesh, India. The research was conducted in the Bijnor district (29.3724° N, 78.1358° E), located in western Uttar Pradesh. Frontline demonstrations were conducted from 2019-20 to 2023-24 in the Kotwali, Afjalgarh, Nehtor, Kiratpur, Haldaur, Dhampur, Budhanpur, Najibabad, Jalilpur, M. Devmal, and Noorpur blocks of Bijnor district, involving 128 farmers' fields to evaluate yield disparities, yield performance, economic analysis for farmers, and the adoption of the wheat variety DBW-187 relative to conventional farming practices. Yield data from frontline demonstrations and agricultural techniques were gathered from representative samples across multiple locations. Randomised complete block design (RCBD) experiments were performed over 30 farms in five tehsils of the Bijnor district. Each farm had plots of DBW-187 in conjunction with the prevalent local variety as a control. The Indian Council of Agricultural Research (ICAR, 2020) recommendations were followed when implementing standard agronomic practices. Grain yield was evaluated at harvest for both DBW-187 and control plots.

Structured questionnaires were administered to 150 farmers (50 adopters of DBW-187 and 100 non-adopters) to gather data on socio-economic factors, agricultural practices, and adoption decisions.Net returns and benefit-cost ratios were calculated using input expenditures and market valuations. The yield gap was calculated by deducting actual farmer yield (Ya) from predicted yield (Yp), using the methodologies outlined by Martin K. van Ittersum et al. (2013).

The subsequent formulas have been employed to estimate the technology gap, extension gap, and technology index, using the methodologies of Samui et al. (2000) and Sagar and Chandra (2004).

Technology gap = Potential yield - Demonstration yield
Extension gap = Demonstration yield - Farmers' yield
Technology index = [(Potential yield - Demonstration yield) / Potential yield] x 100

3. RESULTS AND DISCUSSION

The research conducted throughout 128 demonstrations in 11 blocks of Bijnor district indicated substantial enhancements in wheat productivity and economic returns following the introduction of the biofortified wheat variety DBW-187.

3.1 Yield Performance

The potential and field performance of the Biofortified Wheat Variety DBW-187, in conjunction with the local check, were assessed, and the data are presented in Table-1. The data shown in Table-1 clearly indicates that seed yield greatly increased from 32.23 to 47.26 percent throughout various blocks of Bijnor district, in comparison to the local check. The mean yield of DBW-187 (58.74 qt/ha) consistently surpassed the farmers' practice (42.65 qt/ha) across all blocks, demonstrating an average yield enhancement of 37.72%. The most significant yield increase occurred in the Kiratpur (47.26%) and Najibabad (45.43%) blocks, whilst Budhanpur exhibited the least increase (31.36%). This significant yield enhancement corresponds with the findings of Kumar et al. (2020), who documented the higher performance of biofortified wheat cultivars across various agro-climatic situations. Rana et al. (2002) indicate that field demonstrations are highly helpful in bridging the productivity gaps between enhanced and traditional farming practices. Singh et al. (2011) assert that various cultivars exhibit distinct seed yields and yield disparities between novel and traditional variants. Singh et al. (2023) similarly documented this type of evidence in their research. Mohapatra et al. (2008), Mollah (2011), Saini (2013), Singh (2013), and Venkatasalam (2012) have also corroborated the findings. This notable yield enhancement corresponds with the results of Bhattacharya et al. (2021), who documented comparable yield benefits of biofortified wheat cultivars in several regions of India.

3.2 Economic Analysis

The economic analysis shown in Table 1 revealed that the incremental return of Biofortified Wheat Variety DBW-187 compared to conventional farming practices varied from Rs. 106,528.60 to Rs. 121,367.90 per hectare across different blocks in Bijnor district. The amount was significant in the Jalilpur block (Rs. 121,367.90). Singh et al. (2013) reported on the supplementary net returns in the analysis of promptly sown wheat varieties. In 2019, Singh K. K. and Singh D. P. reported that farmers achieve greater net returns compared to their peers. Singh and Rana (2006) reported a net return of Rs. 13,149.00 per hectare for mustard cultivation. Singh et al. (2018) found a net return of Rs. 54,595.52 per hectare for the wheat cultivar. Bouis and Saltzman (2017) observed that this economic advantage could significantly propel uptake in their analysis of biofortification programs.

The benefit-cost ratio of the biofortified wheat variety DBW-187 surpassed that of the local check in all blocks. The range was from 3.21 to 3.55. In challenging situations, mustard crops can help maintain the stability of a production system since they are naturally resilient and thrive in rainfed environments, according to

Hedge (2006). In the Saharanpur district of Uttar Pradesh, the benefit-cost ratio of HD-2967 was consistently superior across all blocks when compared to the local bill (K K Singh and P K Singh, 2015). Singh et al observed that, in 2018, farmers obtained supplementary advantages at a reduced cost per unit of local cheque.

3.3 Yield Gap Assessment

The technology gap (Table 1) varied from 34.60 to 40.77 quintals per hectare, with an overall mean difference of 38.10 quintals per hectare. The shortest gap of 34.60 was seen in block Kiratpur, while the largest distance of 40.77 was noted in blocks Budhanpur and M. Devmal during the investigation. The disparity between potential and frontline demonstrations is attributable to climatic, edaphic, socio-economic, and management factors. Kadian et al. (1997) assert that only location-specific, technology-driven recommendations can bridge the technological divide. Verma et al. (2017) reported that the technological gap in basmati rice varied from 5.2 to 7.40 qt/ha, with an average difference of 6.41 qt/ha overall. Singh K. K. and Singh D. P. (2019) and K. K. Singh et al. (2023) assert that technical deficiencies can be addressed through the timely provision of high-quality seeds at designated places, together with location-specific, technology-driven recommendations.

3.4 Extension Gap and Technological Index

Table-1 indicated that the extension gap varied from 13.33 to 19.90 quintals per hectare, with an overall mean difference of 16.09 quintals per hectare. The highest extension gap of 19.90 qt. per ha. was seen in block Kiratpur, while the lowest extension gap of 13.33 qt. per ha. was noted in block Budhanpur. This signifies the necessity to educate farmers utilising several extension tools. The findings were corroborated by Gupta and Sharma (2005). K K Singh and P K Singh (2012) indicate a disparity in the varieties of basmati rice. These findings were supported by Singh et al. (2018) and Singh et al. (2022). This highlights the imperative of training farmers via various extension strategies, such as FLD, to promote the adoption of innovative agricultural technologies and mitigate the extensive extension gaps (Seal et al. 2017 and Shubha et al. 2018). A noticeable and substantial yield gap exists between farmers' practices and demonstration fields. The selection of late-sown wheat varieties is a significant determinant of increased net returns. The disparity in extension and technology can be reconciled via the persistent endeavours of extension agencies and the implementation of location-specific technologies. The need for high-quality seeds of promptly sown wheat varieties is rising, resulting in participatory quality seed production on farmers' fields.The average **technological index** of 39.44% in Table 1 signifies the viability of the variety in the region. The reduced results in regions such as Kiratpur (35.81%) and Jalilpur (36.41%) indicate a superior adaptation of DBW-187 in these localities.

3.5 Adoption Rate

The overall adoption rate indicated in Table-2 demonstrates that the adoption of the biofortified wheat variety DBW-187 significantly affects seed yield in relation to the yield gap. Yield improved in the demonstration field as a result of the adoption of a newly released variety. The adoption rate of the biofortified wheat variety DBW-187 varied from 47.61% to 65.21% throughout several blocks in the district, with a mean percentage increase of 54.73% compared to the local check. The significant adoption rate indicates a favourable response from farmers and likely signifies the variety's exceptional performance, as evidenced by yield and economic assessments (Kumar et al., 2020). Rana et al. (2002) assert that the demonstration has proven to be highly beneficial in agricultural practices. The adoption rates of Pusa Basamti-1401 in the district increased, as indicated by the 2011 study conducted by Singh et al. Singh et al. (2018) also corroborated these findings. In 2019, there was a rise in the adoption rates of newly promptly sown wheat varieties in the district, as reported by Singh K. K. and Singh D. P.

The substantial adoption rate of DBW-187 (54.73%) in Bijnor district has considerable implications for regional food security and nutrition. The biofortified characteristics of DBW-187 indicate that a significant proportion of the wheat cultivated in the district now possesses improved nutritional value. This corresponds with the objectives of biofortification initiatives aimed at mitigating micronutrient deficiencies on a population scale (Bouis and Saltzman, 2017).

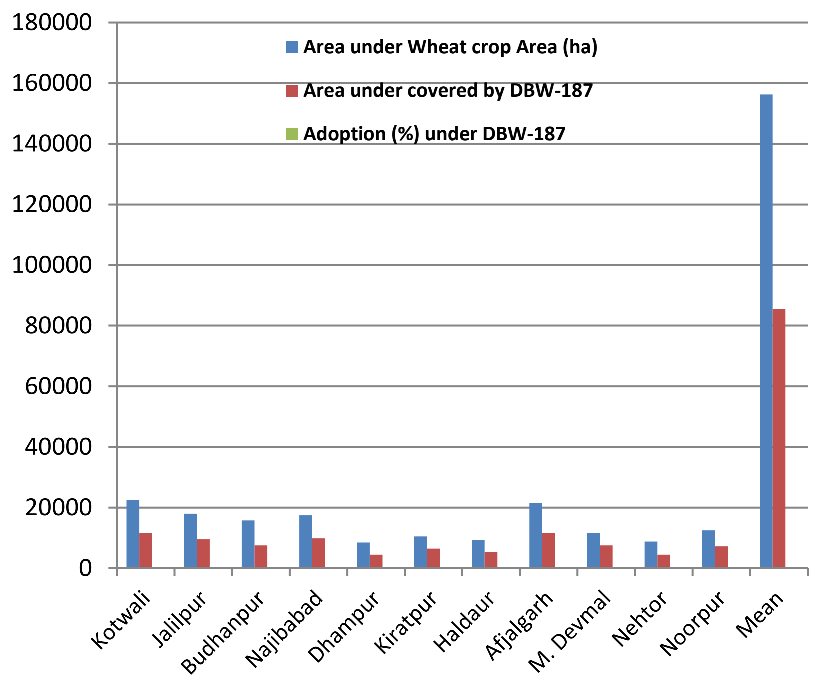
Table 1. Productivity, Economics, yield gap, extension gap of Wheat Variety DBW-187

Name of blocks	No. of demo.	Avg. yield (qt./ha)			% Yield increased	Net Return (Rs/ha)		BCR		Technology gap (qt./ha)	Extension gap (qt./ha)	Technological index
		PY	DY	FY		DY	FY	DY	FY			
Kotwali	38	96.60	60.52	42.86	41.20	112653.90	68594.61	3.34	2.87	36.08	17.66	37.34
Jalilpur	14	96.60	61.42	43.53	41.09	121367.90	73794.64	3.52	2.48	35.18	17.89	36.41
Budhanpur	06	96.60	55.83	42.50	31.36	108708.30	71475.00	3.23	2.44	40.77	13.33	42.20
Najibabad	08	96.60	58.12	42.50	45.43	107106.30	66325.00	3.22	2.33	38.48	15.62	39.83
Dhampur	14	96.60	58.53	42.82	34.28	113133.10	71628.57	3.55	2.44	38.07	15.71	39.40
Kiratpur	05	96.60	62.00	42.10	47.26	114540.00	65205.00	3.38	2.31	34.60	19.90	35.81
Haldaur	07	96.60	60.78	43.42	39.98	106528.60	63982.00	3.21	2.25	35.82	17.36	37.08
Afjalgarh	10	96.60	56.50	42.50	32.94	110545.00	71615.00	3.27	2.44	40.10	14.00	41.51
M. Devmal	09	96.60	55.83	42.22	32.23	109975.00	71966.67	3.25	2.44	40.77	13.61	42.20
Nehtor	05	96.60	56.00	42.00	33.33	109010.00	71910.00	3.24	2.45	40.60	14.00	42.02
Noorpur	12	96.60	57.95	42.70	35.71	112722.00	71793.75	3.32	2.12	38.65	15.25	40.01
Mean	128	--	58.74	42.65	37.72	111480.9	69844.57	3.32	2.41	38.10	16.09	39.44

PY = Potential yield, DY =Demo. Yield), FY = Farmers Yield, BCR= Benefit Cost Ratio

Table 2. Adoption of Biofortified Wheat Variety DBW-187 in district Bijnor

Block	Area under Wheat crop Area (ha)	Area under covered by DBW-187	Adoption (%) under DBW-187
Kotwali	22500	11500	51.11
Jalilpur	18000	9500	52.77
Budhanpur	15750	7500	47.61
Najibabad	17500	9850	56.28
Dhampur	8500	4500	52.94
Kiratpur	10500	6500	61.90
Haldaur	9200	5450	59.23
Afjalgarh	21500	11500	53.48
M. Devmal	11500	7500	65.21
Nehtor	8800	4480	50.90
Noorpur	12500	7250	58.00
Mean	156250	85530	54.73



4. CONCLUSION

By assessing potential and actual farm yields, the study covers important issues related to nutrition and food security. The study gives the scientific community important information about yield performance under actual agricultural circumstances, assisting in identifying limitations and areas for development. The research indicates that the application of appropriate scientific approaches and advanced agricultural technology through extensive front line demonstrations substantially reduced the technological gap, leading to increased productivity. Enhanced and more comprehensive extension programs in the district are necessary to provide farmers with greater technological support through demonstrations, training sessions, and visits to other demonstration fields, and field day programs that augment the horizontal dissemination of technology among the maximum number of farmers in the region. Participatory seed production in farmers' fields arises from the increasing demand for high-quality seeds of various types.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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