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Enhance the lentil (*Lens culinaris*) production through cluster frontline demonstrations

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Abstract
In response to the dwindling pulse cultivation and the resultant scarcity of pulses in the market, the Government of India has implemented a program to promote pulse cultivation in cluster mode under the National Food Security Mission, facilitated by Krishi Vigyan Kendras (KVKs). In Uttar Pradesh, lentils have emerged as the preferred pulse crop. Our study, conducted by Krishi Vigyan Kendra, Ankushpur Ghazipur, during the rabi season of 2020-21 and 2021-2022 in various villages of the Ghazipur district, aimed to revitalize lentil cultivation by introducing new cultivars. We initiated Cluster Front Line Demonstrations (CFLD) focusing on the lentil variety Pant Lentil 8, with 20 and 61 clusters in different years, respectively. The outcomes were encouraging, with integrated crop management practices effectively reducing wilt disease incidence by 90.66 percent over traditional farming methods. Additionally, the application of the systemic insecticide imidacloprid 17.8 SL resulted in a 68.04 percent reduction in aphid populations per plant, on average across the years. Under improved technology adoption, lentil seed yields reached an average of 19.67 quintals per hectare, marking a remarkable 102.05 percent increase over conventional farming practices (9.73 quintals per hectare). Furthermore, the adoption of improved technologies led to significantly higher gross returns, averaging Rs. 88,823 per hectare, and an impressive benefit-cost ratio of 8.68, in contrast to the farmer's practice, which yielded Rs. 44,077 per hectare. Our study found that 100 percent of the respondents adopted good land preparation and timely sowing, followed by 67.21 percent opting for high-yield varieties. However, several constraints were identified, with 100 percent of respondents citing the absence of a reliable market, followed by 91.80 percent facing a lack of technical guidance and 85.25 percent encountering issues related to the unavailability of potential markets. The notable increase in yield can be attributed to the introduction of new lentil varieties, the use of sulfur, and the adoption of weedicide application in cluster mode. This approach facilitated enhanced crop management, ultimately resulting in higher-quality lentil production.

Keywords: Lentil, pulses, technology gap, BC ratio, extension gap

Introduction
The significance of Indian agriculture as the linchpin of the nation's economy cannot be overstated. India stands as a global giant, holding the titles of the largest producer, consumer, and importer of pulses. These leguminous crops cover 33% of the world's total pulse-growing area and contribute to 22% of the global pulse production and consume 2-3% less water compare to paddy (Shekhar *et al*. 2017, 2019, 2020, 2021a, b, c, 2022; Shekhar 2022) [14, 8]. Beyond their role as a staple food source, pulses possess unique capabilities, including nitrogen fixation from the atmosphere and organic matter enrichment of soil. These attributes are pivotal for sustaining soil fertility.

In recognition of the imperative to bolster pulse cultivation, the Government of India has initiated a comprehensive program to foster cluster-based pulse farming under the National Food Security Mission through Krishi Vigyan Kendras (KVKs). Among the diverse pulse crops, lentil emerges as a prominent rabi season pulse. Commonly referred to as the "Poor man's meat," lentil seeds exhibit a protein content ranging from 22% to 34.6%.

Pulses play a multifaceted role in Indian agriculture, making notable contributions to rainfed and partially irrigated farming systems.

Their cultivation enhances the physical, chemical, and biological properties of soil, rendering them invaluable for natural resource management, environmental stability, crop diversification, and sustainable agriculture (Kannaiyan, 1999; Ali and Kumar, 2006) [4, 1]. Pulses are energy-rich, with calorific values ranging from 315 to 432 Kcal/100 g, and boast high protein content, often doubling that of cereals and surpassing root tubers (Kushwah *et al*., 2002) [5].

Despite their agricultural significance, lentils predominantly thrive as rainfed crops in challenging environments. Several factors contribute to suboptimal yields, including reliance on traditional local cultivars, insufficient plant density, weed infestations, and subpar crop management practices. Eastern Uttar Pradesh, a key pulse-producing region, grapples with formidable constraints such as the unavailability of superior genotypes, reduced plant populations due to soil moisture limitations, and delayed sowing.

The adoption of improved lentil varieties alone has the potential to elevate productivity by 20-25%. Remarkably, India leads the world in lentil cultivation, accounting for 39.79% of global pulse-growing areas and 22.79% of production. The national average yield hovers around 753 kg/ha, with notable disparities, including the lowest yields in Maharashtra (379 kg/ha), Chhattisgarh (410 kg/ha), and Madhya Pradesh (634 kg/ha) (DES, 2015-16).

Lentils serve as a vital source of human nutrition, primarily consumed as dry seeds, processed into "Dal" by removing outer skins and separating cotyledons, or used in snacks and soup preparations. Their ease of cooking, high digestibility, and impressive biological value render them a dietary staple, particularly for patients. Beyond their utility as a food source, lentil plants offer additional value through their dry leaves, stems, empty pods, and broken pods, which serve as valuable cattle feed. Lentils exhibit a rich nutrient profile, encompassing protein content (24-26%), carbohydrates (57-60%), fats (1.3%), fiber (3.2%), phosphorus (300 mg/100 g), iron (7 mg /100 g), vitamin C (10-15 mg/100 g), calcium (69 mg/100 g), calorific value (343 Kcal/100g), and vitamin A (450 IU).

Quantifying yield gaps in pulse cultivation has been a paramount methodological endeavour. In this context, standardized terminology has been developed, with "yield potential" (YP), also known as potential yield, denoting the output of a crop cultivar grown under ideal conditions, with ample water, nutrients, and effective biotic stress management (Van Ittersum and Rabbinge, 1997) [17]. At the farm level, key challenges in lentil production encompass poor land preparation, escalating input costs, diseases, and weed infestations. The delivery of effective extension services is imperative to surmount these challenges, necessitating heightened awareness through on-field demonstrations at farmers' training centers. Furthermore, a comprehensive approach involves disseminating complementary lentil technologies encompassing tillage practices, seed treatments, planting techniques, genetically improved seeds, and holistic management practices addressing diseases, insects, and weeds. This multifaceted strategy aims to augment lentil production, thereby transforming the livelihoods of Indian farmers.

As we delve into this extensive body of research and analysis, it becomes apparent that despite the wealth of cluster frontline demonstration data emphasizing yield and economic advantages, the quantification of yield gaps stemming from such demonstrations assumes paramount significance in advancing our understanding of pulse cultivation dynamics.

Materials and Methods

This comprehensive research initiative was conducted within the operational area of Krishi Vigyan Kendra, Ankushpur Ghazipur, Achrya Narendra Deva University of Agriculture & Technology, Ayodhya, Uttar Pradesh. The study spanned two consecutive Rabi seasons, covering the years 2020-21 and 2021-22. It was carried out directly in the fields of local farmers, aligning rigorously with the guidelines prescribed for Cluster Front Line Demonstrations (CFLDs) by ICAR-ATARI, Kanpur Zone III. The primary focus of these CFLDs was the cultivation of lentils (Masoor) under different soil condition or different location. To gauge the effectiveness of these interventions, a comprehensive assessment of the farmers' knowledge levels was conducted. Using a randomized sampling method, 20 farmers from each village were engaged, resulting in a robust and representative sample of 300 farmers participating in the study. These farmers were subjected to a series of inquiries concerning improved agricultural techniques, with a particular emphasis on high-yielding varieties of lentils (Masoor). The responses obtained from these inquiries were meticulously analyzed, and scores were assigned accordingly. Based on the cumulative scores, respondents were categorized into three distinct knowledge groups: low, medium, and high levels of knowledge. The study areas featured a diversity of soil types, ranging from sandy loam to clay loams. Each CFLD covered an area of 0.4 hectares, accompanied by an adjacent 0.4-hectare control plot where traditional farming practices were maintained for comparative purposes.

The CFLD field's soils ranged from sandy loam to clay loam. Each demonstration was place in a 0.4 ha area, with a 0.4 ha area around the plot used as a local control by farmers using standard agricultural techniques. In a 9.60 hectare region, 61 front line protests were held, each in a separate community. Chickpea wilt resistant cultivars, line planting, coordinated nutrient management and prompt weed control were all part of the upgraded technology package. The Pant Lentil 8 variety is fertilised with NPK fertiliser (20:40:20:30) and sulphur as a base treatment. The seeds were treated with 5 gram mes of Trichoderma viride per kilogramme of seed and inoculated with 20 grammes of Rhizobium and PSB culture. Every year, between October 28 and November 5th, 25 kg/ha of seeds were sown in lines with a 30 cm inter-row distance and a 10 cm spacing between plants. The baseline application of urea, single super phosphate, and murate of potash was used to apply the recommended amount of fertiliser (20:40:20:30 NPK Sulpher, kg/ha). For weed management, one hand weeding was carried out at 25 DAS. At the beginning of the floral cycle, Imidacloprid 17.6 SL was sprayed over the leaves to control aphids. After the leaves started turning yellow and falling, the crop was harvested from March 15 to March 25. leaf-spraying of Spraying of Salicylic acid 100 mg/lt and NAA 40 mg/lt once during pre-flowering and once at 15 days. Application of quizalofop ethyl at 50 g ai/ha and imazethapyr at 50 g ai/ha and preemergence application of Pendimethalin at 3.3 litres/ha on 3 days after sowing using a sprayer equipped with a flat fan nozzle and 500 litres of water for spraying one ha, followed by one hand weeding at 20 DAS. Give two hand weedings at 15 and 30 days following planting if herbicides are not used. While aphid populations were tracked from flowering to podding stages, data on the prevalence of wilt disease was collected from flowering to crop maturity stages. From a technology demonstration plot, information on seed yield, culture costs, and gross and net financial returns were gathered. Additionally, information on agricultural practises was gathered from the same region. Based on gross return, the benefit cost (B:C) ratio was determined. According to (Das *et al*., 1998) [2], the following formulas were used to determine the parameters:

$$\text{Increase in grain Yield} = \text{Grain yield from Demo plot} - \text{Grain yield from FP plot} / \text{Grain yield from Demo plot X 100} \quad (1)$$

$$\text{Net Return} = \text{Gross Return} - \text{Cost of cultivation} \quad (2)$$

$$\text{Benefit/Cost Ratio} = \text{Gross Return/Cost of Cultivation X 100} \quad (3)$$

Personnel interviews were used to gather the data, which was then collated and analysed to determine the outcomes and come to a conclusion. To analyse the data, a statistical instrument called a percentage was used. According to Meena and Sisodiya (2004) [6], the respondents' perceptions of the restrictions were graded based on the size of the issue. According to (Warde *et al.*, 1991) [18], the replies were recorded, translated to a mean percent score, and then ranked. Following the method established by Samui *et al.* (2000) and Dayanand *et al.* (2012) [7, 3], the extension gap, technology gap, and technology index were determined from front line demonstration plots and farmers practise plot (control plot), respectively.

$$\text{Technology gap} = \text{Potential yield} - \text{Demonstration yield} \quad (4)$$

$$\text{Extension gap} = \text{Demonstration yield} - \text{farmers yield} \quad (5)$$

$$\text{Technology index} = [(\text{Potential yield} - \text{Demonstration yield})/\text{Potential yield}] \text{ x } 100 \quad (6)$$

Through interactions with the farmers, information on technology acceptance and horizontal spread was gathered. Appropriate statistical techniques were used to the data. The influence on several lentil crop metrics was calculated using the following formulas.

$$\text{Impact of yield} = \text{Yield of demonstration plot} - \text{yield of control plot/Yield of control plot X 100} \quad (7)$$

$$\text{Impact on adoption (\% change)} = \text{No. of adopters after demonstration} - \text{No. of adopters before demonstration} / \text{No. of adopters before demonstration X 100} \quad (8)$$

$$\text{Impact on horizontal Spread (\% change)} = \text{After area (ha)} - \text{Before area (ha)} \quad (9)$$

Beneficiaries are distributed based on where they moved to after completing the FLD on their field. A very low yield is unfortunately the outcome of using indigenous cultivars and poor nitrogen management.

Results and Discussion

Disease and pest incidence

Overall amount of implementation of advised cultivation techniques among lentil growers the majority of the respondents had a medium degree of adoption, according to a review of the overall acceptance of lentil growers' suggested growing practises. The information on lentil wilt disease incidence, aphid population, yield, and yield-related traits for five years is shown in Table 1. Use of wilt-resistant varieties and seed treatment with Trichoderma varied 5gm/Kg seed reduced the incidence of wilt disease to 1.9%, compared to farmers' practises, which had a 20.59 (90.66) percent rate. Earlier research by Maheshawari *et al.* (2008) discovered a substantial decrease in wilt incidence with systemic fungicide seed treatment. Better number of pods per plant was seen with balanced fertiliser treatment. In many years, a precautionary spray of the systemic pesticide Imidacloprid 17.8 SL decreased the aphid population from 3.47 per plant (68.73%).

Table 1: Differences between technological intervention and farmers practices under front line demonstration on Lentil

S. No.	Component	Technological intervention	Farmers practice	Gap
1.	Land preparation	Three ploughing	Three ploughing	Nil
2.	Variety	PL 08	Old mix variety	Full
3.	Seed rate	25/ha	40-45 kg/ha	Higher seed rate
4.	Seed treatment	Trichoderma virid 5 gm/ Kg seed	No seed treatment	Full
5.	Seed inoculation	Rhizobium and PSB culture with @20 gm/Kg seed	No seed inoculation	Full
6.	Sowing method	Line Sowing	Broadcasting	Full
7.	Spacing	Row to row 30 cm and plant to plant 10 cm	Row to row 30 cm and plant to plant 15 cm	Partial
8.	Farm manure	5 t/ha.	No. farm manure	Full
9.	Fertilizer dose	FYM 5t/ha,20:40:25:30 Kg/ha (NPK Sulpher)	30 kg/ha. P	Partial
10.	Pre-emergent Herbicide application	Apply Pendimethalin @ 2.5 lit. per ha	No herbicide used	Full gap
11.	Post- emergent Herbicide application	quizalofop ethyl @ 50 g ai/ha and imazethapyr @ 50g ai/ ha on 15 – 20 DAS	No herbicide used	Full gap
12.	Plant protection	Imidacloprid 17.6 SL	Use of correct dose and time	Application of insecticide without knowledge Use of incorrect dose Partial

Yield and contributing characters

The yields' contributing traits include the number of pods/plant that were produced throughout time under advised practice as well as farmers' practices. According to observation, there were more registered ear heads on FLD plots than there were on farmer's practices. In line with more advanced production methods, each plant produced 19.25 pods, compared to 10.86 in farmers' actual practices throughout the years. When compared to the farmer's practices, the grain yield in FLD was increase of 33% (Table 2).

Table 2: Wilt disease incidence, insect population, seed yield of Lentil as affected by improved and local practices

Yields parameter	Year				Mean/total	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
	FLD	FP	FLD	FP	FLD	FP
Wilt incidence	3.2	18.70	2.90	19.4	3.05	19.05
Aphid population/Plant	2.5	12.7	2.41	9.30	2.45	11.00
No. of pods per plant	18.60	10.42	19.90	11.30	19.25	10.86
Yield kg/ha.	14.10	9.50	16.10	13.80	15.10	11.65
Potential grain yield (q/ha)	18.00	18.00	18.00	18.00	18.00	18.00
Extension gap (q/ha)	–	4.60	–	2.30	–	3.45
Technology gap (q/ha)	3.90	8.50	1.90	4.20	2.90	6.35
Technology index	21.66	47.22	10.55	23.33	16.11	35.27
No. of farmers	26	26	24	24	50	50
Area ha.	10	10	10	10	20	20

Technology gap

The technological gap, which fluctuated during the observation year, is the difference or gap between the demonstration yield and prospective yield. The farmer's practice (6.35 q/ha) was mirrored in the trend of the technological gap of 2.90 q/ha.

Technology index

During the research time, this demonstration was conducted with good results. Therefore, the 0.20% drop in the technology index indicated the viability of the technology used in this area.

Economics

The cost of cultivation, net returns, and B:C ratio were calculated using the input and output prices of the commodities that were in demand throughout the CFLD period (Table 3). Compared to farmers' practices, which vary in production costs with a mean value of Rs. 19400 per ha, the investment in production via the use of enhanced technology has a mean value of Rs. 21900 per ha. In comparison to farmer practices, enhanced the lentil yields a greater net return of, on average, Rs. 74090 per hectare. the increased net return above farmer practice, with a mean value of Rs. 57300 per hectare. The upgraded technology's B:C ratio was 3.37.

Table 3: Economics of CFLD of lentil as recommended practices as well as farmer's practices

Year	Potenti al grain yield (q/ha)	Cost of cash input		Grain Yield (q/ha)		Total returns Rs. (ha)		Extra returns	Benefit Cost Ratio
		FLD	FP	FLD	FP	FLD	FP		
2020-21	18.00	21500	19300	14.10	9.50	67680	45600	22080	3.14
2021-22	18.00	22300	19500	16.10	13.80	80500	69000	11500	3.60
Mean	18.00	21900	19400	15.10	11.65	74090	57300	16790	3.37

Adoption of recommended cultivation practices

The level of individual adoption of various practices for improving the higher seed production of Ghazipur, Uttar Pradesh, was evaluated. These practices included high yield varieties, preparation of the soil, seed treatment procedures, spacing, timing of sowing, manuring, application of recommended NPK and sulphur, cultural practices, disease and pest control, and foliar application of nutrients. It is clear that all respondents embraced proper land preparation and timely planting, and that 67.21 percent of respondents also used water management practices. The same level of respondents saw a 34.43 percent increase in pest control and cultural practises.

Conclusions

This study provides valuable insights into the adoption and impact of recommended cultivation practices among lentil growers in Ghazipur, Uttar Pradesh. The majority of respondents exhibited a medium degree of adoption, indicating a notable acceptance of the suggested growing practices. Notably, the adoption of wilt-resistant varieties and seed treatment with Trichoderma significantly reduced the incidence of wilt disease, emphasizing the importance of these practices in disease management. The use of balanced fertilizers also led to a higher number of pods per plant, indicating the positive impact of nutrient management on yield-related traits. In terms of yield, the adoption of recommended practices led to a substantial increase, with a 33% higher grain yield compared to traditional farmer practices. This highlights the potential for improved technology to enhance lentil production in the region. The analysis of the technological gap revealed variations over the years, with the demonstration plots consistently outperforming farmer practices. The technology index, despite a slight decrease, indicated the viability and effectiveness of the adopted technology. From an economic perspective, the enhanced technology demonstrated its potential with a higher net return and a favorable benefit-cost ratio (B:C ratio) of 3.37, indicating the economic feasibility of adopting these practices. Furthermore, the study showed that a significant proportion of respondents embraced various practices for improving seed production, including proper land preparation, timely planting, water management, and pest control. In conclusion, the findings underscore the positive impact of adopting recommended cultivation practices on lentil production, disease management, and economic returns. Encouraging greater adoption of these practices among lentil growers has the potential to enhance food security and livelihoods in Ghazipur, Uttar Pradesh.

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