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Impact of Different Technology Interventions on Agronomical Traits of Chickpea (*Cicer arietinum* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The study conducted over three consecutive Rabi seasons (2020-21, 2021-22, and 2022-23) in the Lalburra block of Balaghat sought to promote advanced chickpea production techniques among farmers. A total of 15 demonstrations spanning 6.0 hectares showcased the benefits of adopting improved agricultural practices. This included the use of the high-yielding chickpea variety JG-16, soil test-based nutrient management, and targeted pest and disease control measures. Over the past three years, the demonstration plots achieved an average yield of 11.98 q ha^{-1}, while traditional farming methods produced only 8.01 q ha^{-1}. This leads to a remarkable yield enhancement of 47.48%. Additionally, the study recorded an average technology gap of 6.07 q ha^{-1}, an extension gap of 3.86 q ha^{-1}, and a technology index of 33.36%. The study underscores the effectiveness of advanced chickpea production techniques, increased yield while highlighting the need to bridge technology and extension gaps for enhanced productivity in the Lalburra block.

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Keywords: Front line demonstrations; chickpea yield; economics; technology gap; extension gap; technology index.

1. INTRODUCTION

Pulses are cultivated on approximately 85.40 million hectares globally, producing around 87.40 million tonnes, with an average yield of 1023 kg ha^{-1}. India leads the world in both area (29.3 million hectares) and production (24.5 million tonnes), contributing 34% to global pulse acreage and 26% to total production [1-4]. Among pulses, chickpea (*Cicer arietinum*) holds historical significance, having been cultivated for over 8,000 years [5]. Chickpea, plays a pivotal role in ensuring food and nutritional security for millions of the people [6-10]. As a rich source of protein, essential amino acids, fiber, and micronutrients like iron and zinc, chickpea serves as a staple in the diet, particularly for low-income households where access to diverse protein sources may be limited. Its resilience to semi-arid conditions, along with its nitrogen-fixing ability, makes it an essential crop in sustainable farming systems, contributing to soil fertility and reducing the need for synthetic fertilizers [3]. In the face of climate change and growing population pressures, promoting chickpea cultivation can help enhance food security by providing a nutritious, drought-resistant crop that supports both human health and environmental sustainability [4,11].

Chickpea is primarily a cool-season legume crop, recognized globally for its nutritional and economic value. It is commonly known as garbanzo or Bengal gram, it ranks third among food legumes worldwide, following beans and peas [12]. Over 50 countries are involved in chickpea cultivation, with 22 countries farming it on more than 20,000 hectares and 19 countries growing it on areas between 10,000 to 20,000 hectares. Leading chickpea producers include India (responsible for 65% of global production), followed by Pakistan (10%), Turkey (7%), Iran (3%), Myanmar (2%), Mexico (1.5%), and Australia (1.5%) [3,12]. Chickpea plays a critical role in nutrition, offering a cost-effective protein source for those who cannot afford animal proteins or adhere to vegetarian diets. Additionally, it is a rich source of essential minerals like calcium, phosphorus, magnesium, zinc, and iron, as well as unsaturated fatty acids, fibre, and beta-carotene. Its agronomic value is equally important: chickpea enhances soil fertility by fixing nitrogen, contributing up to 140 kg N ha^{-1} yr^{-1} [13]. This legume meets 70% of its nitrogen needs through symbiotic nitrogen fixation, reducing the need for external nitrogen inputs and benefiting subsequent cereal crops [14]. The residual nitrogen and organic matter from chickpea cultivation greatly improve soil health and fertility, making it a vital crop for sustainable agriculture.

The typical sowing season for chickpea falls between November and December, with harvesting occurring from March to April. A promising approach in chickpea cultivation is the Cluster Front Line Demonstration (CFLD), which creates a vital link between researchers and farmers, facilitating the transfer of advanced technologies while offering farmers a platform to provide direct feedback [15-20]. Therefore, the present investigation was carried out to study the technology gap, extension gap, technology index and economic utility of the intervened package of practices of chick pea on farmers practices.

2. MATERIALS AND METHODS

The present study was carried out over three consecutive *Rabi* seasons - 2020-21, 2021-22, and 2022-23 in the Lalburra block of Balaghat district, Madhya Pradesh. The soil at the demonstration sites was loamy, with a pH ranging from 5.9 to 6.8, providing a suitable environment for crop growth. Soil analysis revealed variations in nutrient levels, with available nitrogen ranging from 180-260 kg ha^{-1}, phosphorus between 15-24 kg ha^{-1}, and potassium from 280-330 kg ha^{-1}. The purposive sampling technique is used to select the chick pea growing farmers from the study area. The selection of demonstration sites and the layout of the trials, followed the guidelines provided by [1]. The 15 farmers having the good source of irrigation were identified for the study. Spanning an area of 6.0 hectares, the study involved Front-Line Demonstrations with plot sizes of 0.4 hectares each. Following this, a series of group meetings and specialized training sessions were conducted to equip the participating farmers with the necessary skills and knowledge on the chick pea cultivation package of practices.

The demonstration plots emphasized several key practices, including the use of high-quality chickpea seeds, proper seed treatment, timely sowing, effective weed management, the application of recommended fertilizer doses, and the implementation of pest and disease management strategies based on need. These plots were compared to traditional farmer practices, which were used as the local check (refer to Table 1 for comparative data).

Farmers' feedback on the technologies used in the demonstrations was collected to inform future research and improve extension efforts, ensuring that practices are fine-tuned to the needs of the farming community. This approach not only demonstrated improved farming techniques but also provided valuable insights for refining agricultural extension activities moving forward. The data collected from front line demonstration's fields as well as from control field (farmers practices) and finally the technology gap, extension gap, technology index were calculated as formula given by [21-23] as follows:

Technology Gap = Potential yield – Demonstration yield
Extension Gap = Demonstration yield – Farmer's yield
Additional Return = Demonstration Return-Farmer practices return
Technology index = Potential Yield-Demonstrated Yield/Potential Yield

The economic yield of chickpea is calculated by first determining the production cost, followed by assessing the gross return from the market value of the harvested crop. The net return is then obtained by subtracting the input costs from the gross revenue, providing a clear measure of profitability. The benefit-cost ratio was determined by dividing the net returns by the cultivation costs associated with each treatment combination [24]. Study was conducted in statistical RBD method with 3 replications. The results were analyzed statistically using analysis of variance (p = 0.05) ANOVA [25] by using SPSS software version 23.0 [26].

3. RESULTS AND DISCUSSION

3.1 Yield

The technologies implemented in the demonstration fields and the traditional practices followed by farmers in the control plots are detailed in Table 1. Over the study period, chickpea (variety JG-16) in the front-line demonstration plots achieved seed yields of 11.24 q ha^{-1}, 12.01 q ha^{-1}, and 12.61 q ha^{-1} for the 2020-21, 2021-22, and 2022-23 seasons, respectively (p > 0.05). In comparison, the yields from the farmers' practice plots were 7.90 q ha^{-1}, 8.10 q ha^{-1}, and 8.35 q ha^{-1} for the same years. The data reveals a significant improvement in yield, with the intervention plots averaging 11.95 q ha^{-1}, markedly higher than the farmers' average of 8.11 q ha^{-1} (as shown in Table 2). The increase in seed yield for chickpea JG-16 under the recommended package of practices was striking, with gains of 42.06%, 49.38%, and 51.01% over the farmers' traditional methods in the years 2020-21, 2021-22, and 2022-23, respectively. These results clearly demonstrate the yield-enhancing potential of adopting improved agricultural techniques [11,27]. In Madhya Pradesh, where the demonstrations were conducted, the improved practices led to an overall yield increase of 47.34% compared to conventional farming methods. The findings from Table 2 further underscore the consistent superiority of productivity in the demonstration plots using modern interventions. This suggests that Madhya Pradesh has substantial potential to boost chickpea production (JG-16) through the widespread adoption of recent technological advancements and improved agronomic practices. The increase in chickpea yield observed in Front Line Demonstrations (FLD) is typically attributed to the adoption of improved cultivation practices and the use of high-yielding varieties [17, 19, 28]. FLDs focus on showcasing advanced agronomic techniques such as optimized sowing times, precision in seed spacing, efficient water management, and integrated nutrient and pest management strategies. These demonstrations often employ superior chickpea varieties that are more resistant to diseases, pests, [29] and abiotic stresses like drought or salinity, which contribute to greater yield stability. Moreover, the timely application of biofertilizers and the adoption of mechanized sowing and harvesting methods further enhance productivity. By facilitating farmer education and providing access to these innovations, FLDs play a crucial role in improving chickpea yields, leading to greater food security and economic returns for farmers [6, 11, 21, 27]. Sharma and Singh [30] reported that implementing improved agricultural practices such as utilizing high-yielding varieties, optimizing seed rates, applying balanced fertilizers, practicing line sowing, and ensuring timely control of weeds, pests, and diseases, resulted in grain yields of 13.2 q ha^{-1} and 13.1 q ha^{-1} during the *Rabi* seasons of 2021-22 and 2022-23, respectively. This represented a substantial 53.8% increase in yield compared to traditional farming methods, underscoring the significant impact of adopting these enhanced techniques on productivity.

Table 1. Difference between technological intervention and farmers practices for chickpea (JG 16)

Particular	Technology Interventions	Farmers Practice
Variety	JG 16	Local variety
Seed rate	75 kg ha^{-1}	85 kg ha^{-1}
Seed treatment	Trichoderma @ 5 g kg^{-1} of seed	Not applied
Rhizobium culture	10g kg^{-1} seed	Not treated
Time of transplanting	15th to 20th November	25th November to 05th December
Weed management	Pendimethalin @ 1.5 kg ha^{-1}	Not applied
Fertilizer dose	20:60:50 kg NPK ha^{-1} (on soil test basis)	Irrational use of nitrogenous fertilizers and no application of DAP
Insect-pest management	Need based spray of insecticide at Economic threshold level (ETL)	Overdoses/ non recommended brands of insecticide

Table 2. Grain yield and gap analysis of demonstration intervention in chickpea (JG 16)

Year	Area (ha)	No. of farmers	Yield (q ha^{-1})			Increase over farmer practices (%)	Technology gap (q ha^{-1})	Extension gap (q ha^{-1})	Technology index (%)
			Farmers Practice	Demonstration	Potential				
2020-21	2	5	7.90	11.24	18	42.06	6.76	3.34	37.55
2021-22	2	5	8.10	12.10	18	49.38	5.90	4.00	32.77
2022-23	2	5	8.35	12.61	18	51.01	5.39	4.26	29.99
Mean	**6**	**15**	**8.11**	**11.98**	**18**	**47.48**	**6.01**	**3.86**	**33.36**
***p*-Value**	**-**	**-**	**0.365**	**0.043***	**-**	**0.026***	**0.042***	**0.044***	**0.026***

Table 3. Economics of demonstrated intervention in chickpea (JG 16)

Year	Cost of cultivation (Rs ha^{-1})		Gross Return (Rs ha^{-1})		Net return (Rs ha^{-1})		Benefit cost (B:C) ratio	
	Farmers Practice	Demonstration	Farmers Practice	Demonstration	Farmers Practice	Demonstration	Farmers Practice	Demonstration
2020-21	28,400	30,500	38,512	54,795	10,112	24,295	1.35	1.79
2021-22	29,100	33,200	41,310	61,710	12,210	28,510	1.41	1.85
2022-23	30,300	34,580	43,670	65,950	13,370	31,370	1.44	1.90
Mean	**29,266**	**32,760**	**41,164**	**60,818**	**11,897**	**28,058**	**1.40**	**1.84**
***p*-Value**	**0.092**	**0.048***	**0.056**	**0.031***	**0.058**	**0.032***	**0.052**	**0.045***

MSP of chickpea is Rs. 4875 (2020-21), Rs. 5100 (2021-22) and Rs. 5230 (2022-23)

3.2 Technology and Extension Gap

The study revealed a mean technology gap of 6.07 q ha^{-1} and an extension gap of 3.86 q ha^{-1}, indicating a considerable difference between potential and actual yields (p > 0.05) in both demonstration and control plots. Additionally, the technology index was recorded at 33.33%, highlighting the scope for improving chickpea (JG-16) production through modern agricultural practices. These results underscore the need for greater efforts in encouraging farmers to adopt the recommended technologies, which have demonstrated their potential to significantly boost yield. Similar findings have been reported in previous studies on chickpea (29.17% yield gap, 33.19% technology gap) and wheat (15.71% yield gap, 21.40% technology gap) under front-line demonstration programs, further supporting the effectiveness of these interventions in bridging the yield gap [24, 25]. Over the course of three years, the average extension gap, technology gap, and technology index were recorded as 277 kg/ha, 614 kg ha^{-1}, and 31.40%, respectively [31]. These figures highlight the disparities in achieving optimal crop performance, with the extension gap reflecting the difference between farmers' yields and demonstration trials, while the technology gap indicates the shortfall in attaining full potential yields. The technology index, at 31.40%, quantifies the room for improvement in adopting innovations to bridge these gaps and enhance overall productivity. The results emphasize the importance of continued outreach and education to convince farmers of the benefits of adopting these innovative practices, leading to enhanced productivity and sustainable farming outcomes.

3.3 Economic Returns

The cost of cultivation under traditional farmer practices showed a steady and significant (p > 0.05) rise over the three years, increasing from Rs. 28,400 ha^{-1} in 2020-21 to Rs. 29,100 in 2021-22 and Rs. 30,300 in 2022-23. In comparison, the demonstrated interventions recorded notable percentage increase in cultivation costs: 7.39% in 2020-21, 14.09% in 2021-22, and 14.12% in 2022-23. However, despite the increased investment, the gross and net returns from farmer practices also grew across the same years - from Rs. 38,512 and Rs. 10,112 per hectare in 2020-21 to Rs. 41,310 and Rs. 12,210 in 2021-22, and finally Rs. 43,670 and Rs. 13,370 in 2022-23. The results from the demonstrated plots, however, painted a much brighter picture. Gross returns in the intervention fields surged by 42.28% in 2020-21, 49.38% in 2021-22, and an impressive 51.01% in 2022-23, all over the control plots. The benefit-cost (B:C) ratio consistently improved across the three years of experimentation under the demonstration, with the highest B:C ratio recorded in 2022-23, showing the clear financial advantages of adopting improved practices. These findings align with earlier studies, which also reported that front-line demonstrations led to significantly higher gross and net returns compared to traditional practices [22, 23, 27]. Sharma et al. [32] revealed an impressive input-output ratio of 1:81 in chickpea cultivation, demonstrating a highly efficient return on investment. On average, farmers realized a net profit of ₹26,574.80 per hectare, reflecting the economic viability and profitability of chickpea farming under the conditions studied. This substantial financial gain underscores the potential for chickpea cultivation to contribute to both agrarian sustainability and rural livelihoods.

4. CONCLUSION

The findings of this study underscore the significant improvements in chickpea (JG-16) seed yields achieved through the application of advanced agricultural technologies. While efforts were made to disseminate knowledge of these practices to farmers, a notable gap in full adoption persists, posing a challenge for farming communities. Nevertheless, the demonstrated plots consistently surpassed traditional farming methods, resulting in substantial increases in both gross (42.28, 49.38 & 51.01 %) and net returns (41.62, 42.83 & 42.62 %) over the three consecutive years (2020-21, 2021-22, and 2022-23). This study highlights the untapped potential of modern farming techniques and emphasize the critical need to address the adoption gap. By focusing on bridging this divide, the study aims to facilitate broader benefits for the agricultural sector, ultimately enhancing productivity and sustainability for farmers.

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 the writing or editing of this manuscript.

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COMPETING INTERESTS DISCLAIMER

Authors have declared that no competing interests exist.

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