Research Article

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Yield gap analysis and economics of onion (*Allium cepa* L.) cultivation in western Arid Kachchh of Gujarat

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ABSTRACT

Thirty-seven demonstrations on onion cultivation were executed to assess the impact of improved farming practices on yield outcomes. Results indicated that onions grown under the enhanced agricultural practices produced yields ranging from 254.62 to 275.50 q/ha, significantly surpassing the yields under traditional farmer practices, which varied from 205 to 216 q/ha. The yield increase under the improved practices ranged from 24.20% to 27.55%. Economic assessments revealed that the benefit-cost ratio in demonstration plots varied from 2.23 to 4.26, compared to 2.02 to 3.80 in farmer-managed plots. The study emphasizes that adopting these improved practices not only increases onion yield but also enhances the profitability of onion farming.

Introduction

The onion (*Allium cepa* L.) is one of the earliest bulbous vegetable crops cultivated by humans and belongs to the monocotyledonous plant family Amaryllidaceae. It has been domesticated for its culinary, medicinal, and religious uses since prehistoric times, earning it the title of the "Queen of the kitchen" is another name of onion. The distinct flavor and aroma of onions are primarily attributed to their sulfur compounds, which are also responsible for their medicinal properties (Robinowitch and Currah, 2002). Historical references, such as the Charak Samhita (3rd–4th century A.D.), highlight the therapeutic uses of onions (Ray *et al.*, 1980a, 1980b). Furthermore, the Sanskrit term "Palandu," used in the Vedic era, further illustrates its cultural and historical significance (Aiyar and Vaganarayana, 1956).

Onions are known for their high nutritional value, surpassing several common vegetables in terms of beneficial compounds (Ngomle *et al.,* 2020). Rich in sulfites, allicin, ajoene, thiosulfinates of allixin, and other bioactive components, onions are recognized as both a food and a medicinal herb. Regular consumption has been associated with the prevention of various health conditions, including cancer, rheumatoid arthritis, digestive disorders, hypertension, and diabetes (Corzo-Martinez *et al*., 2007). Additionally, onions exhibit antifungal properties and, to a lesser degree, insecticidal capabilities (Block, 2010). While Central Asia is considered the primary region of origin for onions, the Near East also plays a significant role in its cultivation (McCollum, 1976).

Onions are not only an important vegetable crop but also a key contributor to the global economy. In the fiscal year 2017–18, India exported over 1.58 million metric tons of onions, valued at Rs. 308882.23 lac (Anonymous, 2018). India

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ranks as the second-largest producer of onions worldwide, following China. In 2021, the country produced 26.64 million tons of onions across 1.62 million hectares, with an average yield of 16.40 t/ha. Notably, Gujarat is a leading onion-producing state, contributing 2.46 million metric tons from 99,413 hectares with a productivity rate of 247.9 q/ha (Anonymous, 2021-22). Other major onion-producing states in India include Maharashtra, Karnataka, Madhya Pradesh, Rajasthan, Andhra Pradesh, and Tamil Nadu.

Despite the substantial production of onions, challenges such as the use of low-yielding traditional varieties and a lack of hybrid development hinder the potential for improving productivity. Several factors, including variety selection, integrated nutrient management (INM), integrated weed management (IWM), water management, and plant protection, influence the overall productivity of onion crops. Among these, the selection of appropriate varieties plays a critical role in enhancing crop yield. The poor availability of quality seeds and the slow replacement rate of conventional varieties are additional obstacles to increasing onion production.

To address these challenges, Front Line Demonstrations (FLDs) have been initiated to promote the adoption of high-yielding varieties and advanced crop management practices. FLDs offer a platform to introduce the latest agricultural technologies and improve the management of onion fields under diverse agro-climatic conditions (Singh and Varshney, 2010; Verma *et al*., 2010). The adoption of improved seed varieties, proper seed treatment, appropriate planting techniques, balanced nutrition, effective weed control, and an integrated pest and disease management approach has been shown to significantly enhance crop yields. Furthermore, FLD programs facilitate the dissemination of research-based technologies from ICAR and Agricultural Universities (AUs), helping to bridge the yield gap, technological gap, and extension gap between demonstrated practices and farmers' conventional methods (Nagarajan et al., 2001).

In response to these limitations, Krishi Vigyan Kendra (KVK) has initiated FLD programs aimed at increasing the adoption of high-yielding onion varieties such as Hybrid Rosy, coupled with improved cultivation practices and packaging methods to boost productivity and financial returns. This study also explores the economic aspects of onion cultivation, including yield gaps, technological gaps, and the extension gaps between farmers' practices and demonstration plots.

Method and Materials

The ICAR-CAZRI, Krishi Vigyan Kendra, Bhuj-Kachchh-II (Gujarat), undertook Front Line Demonstrations (FLDs) in farmer's fields spanning the *rabi* seasons from 2013-14 to 2015-16. A total of 37 farmers participated in this study, which was conducted across several selected villages, including Jambudi, Khambra, KotdaChakar, Kukma, Lohariya, Pantiya, Ratnal, ReldiNani, and Tharawada, situated within the Anjar and Bhuj Talukas. The cumulative area of these selected villages amounted to 14.8 acres. Soil samples were collected from the farmers' fields prior to the commencement of the study, and subsequent analysis revealed that the soils were predominantly saline to alkaline in nature. The pH values of the soils ranged between 7.5 and 8.5, indicating a moderately alkaline to alkaline character. The electrical conductivity (EC) values varied between 0.9 to 2.2 dSm-1, further confirming the saline-alkaline status of the soils. Additionally, the organic carbon content was found to be low to medium, with values ranging from 0.12% to 0.5%. These soil characteristics played a crucial role in influencing the crop growth and performance during the demonstration trials.

The Hybrid Rosy onion seeds were supplied by the National Seeds Corporation Limited and distributed to selected farmers for the successful implementation of Front-Line Demonstrations (FLDs). Prior to the FLDs, a series of training workshops were organized for the beneficiary farmers, encompassing all aspects of onion cultivation, ranging from nursery management to successful crop harvest techniques. The specific technology employed for the FLDs, as compared to the traditional methods used by the farmers, is summarized in Table 1 and detailed in the subsequent sections. Throughout the demonstration process, a horticulture scientist provided consistent supervision by visiting the farmers' fields to ensure the proper implementation of the technology, covering all stages from nursery preparation to harvesting. This regular monitoring was crucial to guarantee adherence to the recommended practices and ensure optimal crop management.

Farmer selection, site identification, the efficient application of inputs, and the overall demonstration process followed the methodologies outlined by Choudhary (1999). These methods ensured the successful execution of the FLDs, enabling the accurate assessment of technology adoption. Data were systematically collected from both demonstration and control plots, capturing key parameters such as cultivation costs, gross returns, net returns, and benefit-cost ratios. These data were then tabulated for comparative analysis to assess the economic viability of the introduced technology in contrast to conventional farming practices.

To identify the yield gaps - specifically the extension and technology gaps - the yields from the demonstration plots were compared with those from the farmers' traditional check plots. The yield gap was quantified using the equations proposed by Sagar and Chandra (2004) and Samui *et al*. (2000), which also facilitated the calculation of the technology gap and technology index. These analyses provided insights into the effectiveness of the demonstrated technology in bridging the gap between traditional and improved onion cultivation practices.

Technology gap = [Potential yield - Demonstration yield]
Extension gap = [Demonstration yield – Farmer's practice yield]
Additional return = [Demonstration return- Farmer's practice return]
Technology index = [(Potential yield - Demonstration yield)/ Potential yield] x 100

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return (Rs. ha}^{-1}\text{)}}{\text{(Total cost of cultivation (Rs. ha}^{-1}\text{)}}$$

Table 1. A comparison study between applied technology intervention and farmer's practice under FLD of onion crop in the study area

Cultivation operations	Practices used by farmer	Intervention applied under demonstrated plot	Indication of gap
Soil and water testing	Not in practice	Have done in all locations	Full gap
Variety	Local	Hybrid Rosy	Full gap
Treatment of seed	None	Trichoderma @ 10 g/ kg seed	Full gap
Rate of seed applied	14 kg/ha	7 kg/ ha	Partial gap
Methods of sowing	Flat bed	Raised Bed	Partial gap
Nutrition Management	Without recommendation	Farm yard Manure: 20-25 ton/ ha Recommended dose of 100:50:50 NPK ha^{-1}. Half dose of nitrogen & full dose of phosphorus and Potash applied at the time of transplanting and half dose of N 1 month after transplanting.	Partial gap
Weeding	One Hand weeding	A Pre-emergence weedicide application of oxyflurofen 23.5% @ EC 0.10-0.15 kg a.i./ha + One hand weeding at 45 DAT	Partial gap
Micronutrient Spray	Not practiced of micronutrient spray	2 foliar spray of micro mix @ 0.25%	Full gap
Plant Protection measures	Only chemical spray without recommendation	Integrated pest and disease management practices applied	Partial gap

Results and Discussion

Bulb yield: The results from the demonstration practices have shown a significant improvement in onion bulb yield due to the adoption of advanced agricultural technologies. These outcomes suggest that the farmers benefited from the new techniques encouraged in the demonstration region. As detailed in Table 2, the onion bulb production exhibited a consistent increase over the years of the demonstration. The data indicated that the onion bulb yield from the demonstration plots was superior to that from the local check, with an average increase of 26.06%. The maximum average onion bulb yield recorded was 266.04 q/ha, highlighting the effectiveness of the demonstrated practices.

These findings are in line with the results of several studies in onion production. Similar increases in yield have been reported by Hiremath and Nagraj (2010); Hiremath *et al.* (2011); Gaharwar *et al.* (2017); Gaharwar and Ughade (2018), Gupta *et al.* (2015), Kumar (2014), and Warade *et al.* (2006), supporting the positive impact of modern agricultural practices on onion yields. Additionally, yield improvements in various other crops have been observed in similar contexts. For instance, Balai *et al.* (2013) reported enhanced yields in vegetables, Kumar *et al.* (2010) in bajra, Mishra *et al.* (2009) in potatoes, Ramniwas *et al.* (2022a) in drumsticks, Singh *et al.* (2011) in solanaceous vegetables, and Tandel *et al.* (2014) in brinjal, further emphasizing the broader applicability of these practices. The increase in onion bulb yield in the demonstration plots also suggests the suitability of the onion hybrid variety Rosy for the climatic conditions of Kachchh. This observation corroborates the findings of Modi *et al.* (2023), who attributed that introduction of high yielding varieties, created awareness among beneficiaries for scientific cultivation practices like timely owing, recommended spacing, balanced use of manure, fertilizers and weed management as well as integrated pest and disease management. Thus, the success of the demonstration plots not only supports the viability of the adopted technologies but also underscores the potential for their widespread adoption in similar agro-ecological regions.

Table 2. Year wise details and yield performance of onion under front-line demonstrations

Year	No. of Demo	Area (ha)	Yield (q ha^{-1})			Increased yield over local check (%)
			Potential yield (PY)	Demo yield (IP)*	Check yield (FP)	
2013-14	17	6.8	300	254.62	205	24.20
2014-15	10	4.0	300	268.00	212	26.42
2015-16	10	4.0	300	275.50	216	27.55
Average			300	266.04	210	26.06

*IP=Improved practice; FP= Farmer's practice

Table 3. Extension gap, technology gap and technology index of onion under FLDs

Year	Technology gap (q ha^{-1})	Extension gap (q ha^{-1})	Technology index (%)
2013-14	45.38	49.62	15.13
2014-15	32.00	56.00	10.67
2015-16	24.50	59.50	08.17
Average	33.96	55.04	11.32

Technology gap analysis: The technology gap, in comparison to other cultivation criteria, assumes a critical role as it underscores the challenges faced when attempting to implement a comprehensive package of methods. This gap reflects the limitations encountered in the face of environmental and varietal changes. The technology gap is defined as the difference between potential yields and demonstration yields under actual field conditions. Based on the data presented in Table 3, the technology gap observed during the study period ranged from 24.50 to 45.38 q/ha, with an average value of 33.96 q/ha. This indicates a considerable discrepancy between the potential yields that could theoretically be achieved under ideal conditions and the yields observed during the demonstration phase. The significant gap suggests the existence of constraints that hinder the realization of potential yields in practice. The fluctuation in the technology gap across different years of demonstration can be attributed to multiple factors, including variations in soil fertility, local meteorological conditions, and differing farming practices across the study sites. These environmental and agronomic factors may have led to a disparity in performance, as crop productivity is highly sensitive to such variations. To address this gap, it is essential to reduce the yield gap between demonstrated yields and potential yields through focused interventions such as the conduct of Front Line Demonstrations (FLDs). These demonstrations serve as an important tool for showcasing optimal practices and bridging the gap between research and real-world implementation. Furthermore, tailored recommendations based on local conditions are critical to closing the technology gap. It is, therefore, recommended to employ site-specific technologies and implement precision-based farming techniques, as highlighted by Ghosh *et al.* (2024), Kumar *et al.* (2021), and Singh *et al.* (2011).

Extension gap analysis: Prior to the study period, a significant extension gap was identified among farmers, as the majority were not utilizing high-yielding onion varieties or optimized agronomic practices. This resulted in a noticeable disparity between the potential technological advancements in onion cultivation and the practices employed by farmers. To bridge this gap, Krishi Vigyan Kendra (KVK) initiated Front-Line Demonstrations (FLDs) on various farmers' fields, showcasing improved onion cultivation techniques. The implementation of these enhanced practices resulted in an increase in bulb yield when compared to traditional methods previously employed by the farmers. Table 3 presents data that clearly illustrate a large extension gap, with yield differences between the demonstration plots and the local control plots ranging from 49.62 to 59.50 q ha^{-1}. This discrepancy underscores the underutilization of high-yielding cultivars and modern farming techniques, which were not widely adopted by the farming community. The adoption of these technologies remains limited, thereby contributing to the substantial extension gap observed between the demonstrated technologies and the locally practiced methods. The persistence of this extension gap emphasizes the urgent need for widespread awareness and adoption of high-yielding onion varieties and an improved set of agronomic practices. These results are consistent with findings reported by Teggelli *et al.* (2015), who suggested that the gradual introduction and adoption of superior crop production technologies, including high-yielding varieties, can effectively reverse the trend of expanding extension gaps. Moreover, the successful closing of such gaps necessitates focused extension efforts through educational outreach and technology demonstration, which encourage farmers to embrace scientifically validated practices. The findings from this study are also in alignment with earlier research on other crops. For instance, Ramniwas *et al.* (2022b) demonstrated similar extension gap phenomena in Isabgol, while Bhoraniya *et al.* (2017) and Lal *et al.* (2013) reported similar challenges in coriander cultivation. Furthermore, Mukharjee (2003) highlighted the importance of context-specific problem identification and the development of targeted solutions to significantly enhance crop productivity.

Technology index analysis: The technology index is a critical measure of the applicability and practicality of a specific agricultural technology for farmers. As demonstrated in Table 3, the technology index values exhibited a declining trend, ranging from 15.13% at the beginning to 8.17% by the conclusion of the demonstration period. This indicates a growing feasibility and relevance of the technology under field conditions over time. The reduction in technology index values suggests that farmers were increasingly able to adopt and apply the demonstrated technologies with greater success as the demonstration progressed. The overall average technology index of 11.32% further supports this trend, reflecting the efficacy of the demonstrated technologies in real-world conditions. A key factor contributing to this outcome could be the accurate application of the technologies during the demonstration period, combined with favorable weather conditions, which likely enhanced the demonstration's success. As highlighted by Jeengar *et al.* (2006), Hiremath and Nagraj (2010), and Sagar and Chandra (2004), a lower technology index indicates a closer alignment between research farm technologies and their practical application on farmer fields, thereby making them more accessible and usable for agricultural practitioners. The current results are consistent with previous studies on the impact of Frontline Demonstrations (FLDs) in various crops. Research by Choudhary *et al.* (2018), Chauhan *et al.* (2020), Dayanand *et al.* (2012), Mishra *et al.* (2009), and Raj *et al.* (2013) also observed similar trends in the successful adaptation and adoption of demonstrated technologies, underscoring the importance of technology transfer and its impact on enhancing agricultural practices.

Economic analysis: The economic viability of the demonstration technologies was evaluated using several key economic variables, including the cost of cultivation, net return, and the benefit-cost (B:C) ratio. The net return exhibited significant year-to-year variability, primarily driven by fluctuations in the market price of onion bulbs. This price variability had a direct impact on the financial returns observed in the study. Over the course of the demonstration period, it was evident that both the production cost and the market price of the produce played substantial roles in determining the profitability of the farming systems. Analysis of the data revealed that the demonstrated technologies consistently outperformed the local farmer's practices in terms of all key economic indicators, including benefit-cost ratio, net financial returns, and gross financial return. The demonstrated technology produced a higher average net monetary return (NMR) of Rs. 170,280, alongside a B:C ratio of 2.94, compared to the farmer's checks, which achieved an NMR of Rs. 126,226.67 and a B:C ratio of 2.61. This improvement can largely be attributed to the higher bulb yields obtained through the demonstrated technology, which resulted in more favorable economic outcomes compared to the control plots. The findings of this economic analysis suggest that the demonstrated technology offers superior profitability and is economically viable for adoption. These results align with similar findings reported by Ghosh *et al.* (2024), Hiremath and Nagraj (2010) and Hiremath and Hilli (2012), who noted comparable economic benefits with advanced agricultural technologies. Additionally, the results are consistent with those reported by Bhargav *et al.* (2015), Dhaka *et al.* (2010), and Ramniwas *et al.* (2022c) for other crops such as chickpea, maize, and fennel, where the adoption of improved practices led to enhanced financial returns.

Table 4. Economic analysis of front-line demonstrations in onion

Year	Cost of cultivation (Rs./ ha)		Gross return (Rs./ ha)		Net return (Rs./ ha)		Additional return (Rs./ ha)	B:C Ratio	
	IP*	FP	IP	FP	IP	FP		IP	FP
2013-14	80000	70920	178234	143500	98234	72580	25654	2.23	2.02
2014-15	88000	78000	375200	296800	287200	218800	68400	4.26	3.80
2015-16	95000	85500	220400	172800	125400	87300	38100	2.32	2.02
Average	87666.67	78140.00	257944.67	204366.67	170278.00	126226.67	44051.33	2.94	2.61

*IP=Improved Practice; FP= Farmers Practice

Conclusion

In conclusion, the Front-line Demonstration (FLD) of the Hybrid Rosy onion variety, conducted over three years (2013–14 to 2015–16) in a farmer's field using improved technology, clearly indicates the potential to enhance onion bulb yield, resulting in higher financial returns and improved benefit-to-cost (B:C) ratios. Furthermore, the adoption of the demonstrated technology contributed to a reduction in both the technology gap and technology index values. These findings underscore the superiority of locally tested technologies when implemented in real-world farming conditions, specifically in Kachchh. The FLD approach not only enhanced productivity and quality but also positively impacted farmers' attitudes, skills, knowledge, and competence. Additionally, it fostered stronger interactions between scientists and farmers, thus contributing to the dissemination of contemporary agricultural technologies. FLDs play a critical role in encouraging the adoption of innovative practices, thereby increasing agricultural output and income. Overall, this study affirms that FLDs are an effective extension strategy for introducing validated technologies at the village level, narrowing the extension gap, and empowering the agricultural community with sustainable growth prospects.

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Conflict of Interest

The authors have no conflict of interest.

Data Sharing

All relevant data are within the manuscript.

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