



Demonstrating the impact of improved fennel production technologies on yield and income in arid Kachchh

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Summary

It is customary in India to offer fennel seeds after a meal and eating fennel seeds after a meal is considered a healthy practice, primarily because of its ability to keep the digestive system healthy. Frontline demonstrations (FLDs) on Fennel were organized by ICAR-CAZRI, Krishi Vigyan Kendra, Kukma, Bhuj in different villages of Anjar and Bhuj Talukas of Kachchh from 2019-20 to 2021-22. The high-yielding variety Gujarat Fennel-12 was evaluated at the farmer's field under the frontline demonstration programme (FLDs). A total of 60 demonstrations were conducted in 24 ha area at farmers' fields against farmer's practice in arid Kachchh of Gujarat. The average seed yield under improved practice was 2160 kg ha⁻¹ compared to the farmer's practice (1770 kg ha⁻¹) and increased significantly by 22.08% on average over farmer's practice output. The average extension gap, technology gap and technology index were 390.00 kg ha⁻¹, 240.00 kg ha⁻¹ and 10.00%, respectively. Through the adoption of improved practices, farmers get additional average returns of Rs.22562 ha⁻¹. During this period to strengthen technology dissemination and promote wider adoption, KVK Kukma, Bhuj also formed fennel growers in collaboration with the Department of Agriculture (DoA) and ATMA. During the period, four training programmes and field days were organized, through which more than 550 farmers were educated about improved fennel production technologies, including the use of improved varieties and recommended agronomic practices. Frontline demonstrations programme created greater awareness, attitude and skill to adopt improved practices of Fennel and therefore, increased their production and economics.

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Introduction

India is the largest producer, consumer, as well as exporter of spices and spice products in the world. Gujarat is a leading producer of seed spices particularly Fennel, Coriander, Cumin, Isabgol and Dill. Fennel (*Foeniculum vulgare* Mill.), commonly known as 'Saunf' belongs to the family Apiaceae (Umbelliferae) and is believed to be native of Southern Europe and the Mediterranean region. It is one of the most seed spices in India mainly grown in Gujarat and Rajasthan, which is mainly used in culinary and pharmaceutical preparations. Fennel is used in various traditional systems of medicine like in Ayurveda, Unani, and Siddha in the Indian and Iranian traditional systems of alternative and balancing medicine. The seeds are rich in protein (9.5%), minerals and vitamins (Samadia & Haldhar 2019; Haldhar et al. 2018). The seeds contain essential oil, which is used as a flavouring agent in the manufacturing of pickles, cakes perfumes, soap, liquors and cough drops. Its seeds contain 0.7 to 1.9% volatile oil in which the chief constituent is an ethole (50-70%). The volatile oil is used for manufacturing cordials and fennel water which is given to infants as medicine. Fennel seeds have been used as an ingredient for removing any foul smell from

the mouth. Dried fennel seeds are often used in various digestive problems, including heartburn, bloating, loss of appetite and colic in infants. India is the largest producer of fennel, which is cultivated in a 78.976 thousand-hectare area with a production of 127.160 thousand tonnes and productivity of 1610 kg ha⁻¹ (Anonymous 2021a; Haldhar & Meena 2026). The fennel seeds were exported to the tune of 33741.50 tonnes values worth Rs. 29396.40 lakh from India during 2020-21 (Anonymous, 2021b). Gujarat is the largest producer of fennel in the country producing 75540 tonnes from 41970 hectares of area with the productivity of 1799.91 kg ha⁻¹ (Anonymous, 2020-21c). In Gujarat state, it is mainly cultivated in Surendranagar, Banaskantha, Mehsana, Aravali, Patan and Kachchh districts. The main objective of FLDs is to demonstrate newly released crop production and protection technologies and their management in the farmers' field under different agro-climatic regions Frontline demonstration (FLD) is one of these programmes, which focuses on increasing productivity by providing vital inputs as well as improved packages of practices that have been tested by scientists from ICAR Institutes and State Agricultural Universities (SAUs). The yields are higher when high-yielding variety seed, recommended seed rate, seed treatment, planting time, appropriate fertiliser dose, weed control, and integrated pest and disease management

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are used, as opposed to farmer's practices. Other key aspects of this initiative include promoting the farming of improved varieties, receiving feedback from farmers concerning barriers to the adoption of recommended improved technologies for further research, and maximising the technology diffusion process among farmers.

Keeping in mind these considerations, KVK conducted FLDs in farmers' fields to encourage the adoption of the high-yielding variety Gujarat Fennel-12 as well as an improved package of practices in the arid Kachchh, with the goal of increasing productivity and increasing net profit from this crop. The current study seeks to investigate the Yield Gap, Technological Gap, Extension Gap, Technology Index, and Yield Gap between FLD plots and farmers' practices, as well as the level of technology adoption and economics of the technology.

Materials and Methods

The current study was conducted by the ICAR-CAZRI, Krishi Vigyan Kendra, Bhuj-Kachchh-II (Gujarat) during the rabi, 2019-20 to 2021-22 at farmer's fields. A total of 60 frontline demonstrations were held throughout a 24.0 ha area in various villages namely Bhujodi, Chapredi, Dhaneti, Dhori, Kukma, Khambra, Kotda Chakar, Chubdak, Jawaharnagar, Modsar, Nana Reha and Reldi of Anjar and Bhuj Talukas of the Kachchh district. The Kachchh district is bounded by 23°24' to 23°46' North latitudes and 69°38' to 73°58' East longitudes. The total geographical area of Kachchh district is 45652 sq. km divided into ten talukas which is the largest district in Gujarat as well as in India. The average annual rainfall is registered at 250-340 mm and about 95 per cent of the total rainfall occurs during June-September. A number of rainy days are very few; the annual average is only 13 days. The variations in the timing and quantity of rainfall are very high having a co-efficient of the variability of about 60 per cent. This unreliability and uncertainty of rainfall have made Kachchh susceptible to droughts. Winds are generally moderate to high with an annual wind speed of 11.3 km per hour. Winter and summer temperatures range from 7- 48°C with an average humidity of 63 per cent annually and increase to 80 per cent during the south-west monsoon. The soils in the study area were primarily saline and alkaline in nature with pH values 7.8 to 9.0, EC ranging from 0.9 to 2.6 dSm⁻¹ and low to medium in organic carbon (0.12-0.70%). Nitrogen and potassium in the soil varied from 169-301 and 134 to 470 kg/ha, with low to medium quantities of phosphorus. The practices adopted for the current study comprised high yielding variety of Gujarat Fennel-12 (Released by SDAU, Dantiwada, Gujarat) with an improved package of practices, where existing farming techniques were viewed as a local check or farmer's practice (FP). Line sowing of the crop was done in the third and fourth week of October with a recommended spacing of 45x15 cm. Seed treatment was done with *Trichoderma viridae* @ 10 g per kg seed. The crop was fertilized with recommended dose of fertilizers i.e. 90 kg N and 30 kg P₂O₅ per hectare. Full dose of phosphorus and half dose of nitrogen were applied as basal doses and the remaining half dose of nitrogen was applied at

35 and 65 DAS. In addition to this, one foliar spray of chelated EDTA-Zn and EDTA-Fe @ 0.3% was given during the flowering stage. For weed control applied soil application of pendimethalin @ 1.0 kg/ha as pre-emergence and followed by one-hand weeding at 35 DAS. During the life cycle of the crop, there is not any serious disease or insect-pest observed, however, some places aphid is observed and controlled by two foliar sprays of neem oil as a precautionary measure in the field. The FLDs were used to look at the differences in potential yield and demonstration yield, as well as the extension gap and technology index. In this impact study, yield data was obtained from FLD plots along with local farming practices widely used by farmers in this region, for comparative analysis. During this period to strengthen technology dissemination and promote wider adoption, KVK Kukma, Bhuj also formed a Farmers Interest Group (FIG) on fennel in collaboration with the Department of Agriculture (DoA) and ATMA. During the period, four training programmes and field days were organized, through which more than 550 farmers were educated about improved fennel production technologies, including the use of improved varieties and recommended agronomic practices. The extension gap, technology gap, and technology index were calculated using the Samui *et al.* (2000) equations.

Technology gap = Potential yield - Demonstration yield
Extension gap = Demonstration yield - Farmers practice yield

Additional return = Demonstration return- Farmers practice return

Technology index = [(Potential yield - Demonstration yield)/Potential yield] x 100

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

Results and Discussion

Seed Yield Performance

The frontline demonstrations (FLDs) on fennel demonstrated the effectiveness of improved production technologies in enhancing seed yield under farmers' field conditions. As presented in Table 1, the improved practice (IP) recorded an average seed yield of 2,160 kg ha⁻¹, compared with 1,770 kg ha⁻¹ under farmers' practice (FP), representing an average yield increase of 22.03% over three years (2019-20 to 2021-22). The potential yield of Gujarat Fennel-12 (GF-12) was 2,400 kg ha⁻¹. Year-wise, the yield advantage under FLDs ranged from 17.68% to 24.32%, indicating the consistent performance of improved production practices across the study period. The higher seed yield in the demonstration plots may be attributed to the adoption of an improved package of practices, including the use of high-yielding GF-12 seed, optimum sowing time and seed rate, seed treatment, appropriate sowing methods and spacing, effective weed management, irrigation scheduling, and need-based plant protection measures. The yield gap between the demonstrated and farmers' practices highlights the scope for improving fennel productivity through the systematic dissemination and adoption of recommended technologies. These findings

are consistent with earlier studies reporting yield enhancement through frontline demonstrations in fennel and other seed spices (Choudhary et al. 2018; Garwal &

Arora 2013; Lal et al. 2016; Meena et al. 2016; Poonia et al. 2017; Tamboli et al. 2020).

Table 1. Year-wise details and yield performance of frontline demonstrations (Average of three years)

Year	No. of Demo	Area (ha)	Yield (kg ha ⁻¹)			Increased yield over local check (%)
			Potential Yield (PY)	Demo Yield (IP)*	Check Yield (FP)	
2019-20	10	4.0	2400	2300	1850	24.32
2020-21	30	12.0	2400	2050	1650	24.24
2021-22	20	8.0	2400	2130	1810	17.68
Average			2400	2160	1770	22.08

*IP=Improved Practice; FP= Farmers Practice

Technology Gap Analysis

According to the Table 2, the technology gap represents the difference between the potential yield of a variety and the yield achieved under frontline demonstrations (FLDs). It indicates the extent to which the potential productivity of a recommended technology is realized under farmers' field conditions. During the study period (2019–20 to 2021–22), the technology gap ranged from 100 to 350 kg ha⁻¹, with an average of 240 kg ha⁻¹. The lowest technology gap (100 kg ha⁻¹) was recorded in 2019–20, whereas the highest (350 kg ha⁻¹) occurred in 2020–21.

Variations in the technology gap may be associated with differences in soil fertility, irrigation-water quality, climatic conditions, pest and disease incidence, and the level of crop management across farmers' fields. These findings highlight the importance of location-specific crop management and timely technical guidance to minimize yield gaps and improve the realization of potential productivity. Similar observations regarding technology gaps in frontline demonstrations have been reported by Kumar et al. (2021) and Mukherjee (2003).

Table 2. Extension gap, technology gap and technology index of Fennel under FLDs

Year	Technology Gap (Kg ha ⁻¹)	Extension Gap (Kg ha ⁻¹)	Technology Index (%)
2019-20	100	450	4.17
2020-21	350	400	14.58
2021-22	270	320	11.25
Average	240	390	10

Extension Gap Analysis

The extension gap, defined as the difference between the seed yield obtained under improved practices and that under farmers' practices, reflects the potential yield improvement achievable through the dissemination and adoption of recommended agricultural technologies. As per the table 2, the present study, the extension gap ranged from 320 to 450 kg ha⁻¹, with an average of 390 kg ha⁻¹. The maximum extension gap (450 kg ha⁻¹) was observed in 2019–20, while the minimum (320 kg ha⁻¹) was recorded in 2021–22. The observed extension gap indicates the scope for enhancing fennel productivity through improved varieties and recommended production practices. The lower extension gap in the final year may reflect changes in the relative performance of demonstration and farmers' practice plots; however, it cannot independently establish increased technology adoption without supporting adoption data. Strengthening farmer training, field demonstrations, and follow-up advisory services could help promote the adoption of improved fennel production technologies. Similar findings have been reported by Borhaniya et al. (2017), Lal et al. (2013), and Singh et al. (2011).

Technology Index Analysis

The technology index indicates the extent to which the demonstrated yield falls short of the potential yield and is expressed as a percentage of the potential yield. A lower technology index generally indicates that the

demonstrated technology has achieved a yield closer to its potential under prevailing field conditions. In the present study, as per Table 2, the technology index ranged from 4.17% in 2019–20 to 14.58% in 2020–21, with an average of 10.00%. The lowest index in 2019–20 corresponded to the smallest technology gap and the highest demonstration yield (2,300 kg ha⁻¹), which was close to the potential yield of 2,400 kg ha⁻¹. Conversely, the highest index in 2020–21 reflected a larger technology gap and a lower demonstration yield of 2,050 kg ha⁻¹.

The results indicate that the improved fennel production technology achieved a relatively high proportion of its potential yield under the conditions prevailing during the demonstration period. Nevertheless, annual variations suggest that field conditions and crop management may influence the extent to which potential yields are realized. The findings are broadly consistent with studies on frontline demonstrations in different crops reported by Choudhary et al. (2018), Dayanand et al. (2012), and Mishra et al. (2009).

Conclusions

The frontline demonstrations conducted by ICAR–CAZRI, Krishi Vigyan Kendra, Kukma, Bhuj (2019–20 to 2021–22), substantiate the agronomic efficacy and economic viability of improved fennel production technologies under the hyper-arid agro-climatic conditions of Kachchh, Gujarat. The optimized management practices yielded a

mean seed productivity of 2,160 kg ha⁻¹, surpassing the prevailing farmers' practice (1,770 kg ha⁻¹) and achieving a substantial yield augmentation of 22.03%. Quantitative yield gap analysis revealed an average technology gap of 240 kg ha⁻¹ and an extension gap of 390 kg ha⁻¹, emphasizing the imperative to accelerate knowledge dissemination and bridge the transfer of technology. Furthermore, the favourable mean technology index of 10.00% reflects close proximity to the genetic yield ceiling of the cultivar Gujarat Fennel-12 (2,400 kg ha⁻¹), though inter-annual variability underscores the influence of environmental fluctuations under rainfed/limited irrigation conditions. Collectively, these findings validate the efficacy of structured front-line demonstrations, systematic capacity building, and targeted advisory frameworks in optimizing resource-use efficiency. Future research must prioritize multi-location validation across diverse agro-ecological zones, longitudinal assessment of yield stability, and holistic analyses of water-use dynamics and economic returns under variable input and climatic regimes.

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