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RESEARCH PAPER

Impact of frontline demonstrations (FLD) in maize across diverse agro-ecologies of India

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Abstract Frontline Demonstrations (FLD) of improve package of practices of maize was undertaken across 30 centres/locations of 11 diverse agro-climatic zones of India to explore the efficacy of FLD in improving maize yield across different seasons and regions. Meticulous research conducted at multiple research centres revealed significant advancements in crop productivity achieved through FLD implementation when compared to conventional Farmers' Practices (FP). The study displayed an ardent enhancement of maize grain yield in Western Himalayan (48.0–58.6%), Eastern Himalayan (29.8–132.7%), Lower Gangetic plain (14.2%), Middle Gangetic plain (5.5–41.3%), Upper Gangetic plain (54.6%), Trans Gangetic plain (6.2–92.8%), Eastern plateau and hills (85.0%), Central plateau and hills (39.5–46.0%), Western plateau and hills (29.6–46.0%), Southern plateau and hills (5.1–21.4%), Gujarat plains and hills (28.1%) through FLD over FP. The cumulative findings from all agroclimatic zones indicated that FLD contributed to a significant 37.2 per cent increase in maize productivity across India. Although FP consistently outperformed FLD in most scenarios, the study highlighted the significance of FLD in enhancing maize yield, especially during the spring season. These results underscore the immense potential of FLD in revolutionizing agricultural productivity and offer valuable insights for policymakers and stakeholders to adopt evidence-based interventions, ultimately benefiting farmers and ensuring food security and agricultural resilience across the country.

Keywords: Agroclimatic zones · Frontline demonstrations · Farmers' practices · Maize, Season

Introduction

Maize (*Zea mays*), the most versatile food crop, is cultivated across the globe, covering an extensive area of approximately 197 million hectares in over 180 countries. Its global production stands at an impressive 1148 million metric tons, with a remarkable productivity of 5.82 tons per hectare. It is a staple food crop for millions of people worldwide, especially in many developing countries (Jat *et al*., 2019a; Erenstein *et al*., 2022). It serves as a primary source of calories and nutrition, contributing to food security and addressing hunger challenges. In India, maize holds a significant position as the third most important crop, following wheat and rice. It is cultivated throughout the year in most of its states for various purposes that include grain, feed, fodder, green cobs, sweet corn, baby corn, popcorn, starch and industrial products. The past few years have seen dramatic changes in the production and productivity of maize with more area under single cross hybrids. These improved varieties along with natural resources management technologies are largely promoted to improve productivity, meet the various demands of its multiple uses and the livelihood of the maize farmers. As per the advance estimates for 2020-21, a new record has been set for maize in India, the crop

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was being grown on 9.7 m ha land with a production of 30.2 mt and productivity of 3.1 t/ha (Agricultural Statistics Division, Directorate of Economics & Statistics). However, the productivity of the *kharif* season representing over 80% acreage is still low (2.7 t/ha) compared to *rabi* (5.2 t/ha) (IIMR, 2023). The majority, over 70 per cent, of *kharif* maize cultivation takes place under rainfed conditions, leading to the prevalence of various biotic and abiotic stresses (IIMR, 2023). The stark contrast in productivity between these two seasons can be attributed to the differing stress levels and the varied degree of assurance in the ecological conditions under which they are grown. Moreover, the contention over the extent of adoption of improved technologies and their impact is in question given the national average maize yield remains very low (3.1 t/ha) compare to developed countries (5.75 t/ha).

The improved hybrids of Quality Protein Maize (QPM), enriched with tryptophan and lysine, have also contributed to the food and nutritional security of the country. The demand for maize is ever increasing due to its multifarious uses and burgeoning population, and this is to be achieved under the scenario of changing climate and depleting availability of arable land and water (Rakshit *et al.,* 2014). Front-line demonstrations (FLD) are crucial field-level activities where new agricultural technologies and practices are demonstrated on the farmers' fields to showcase their effectiveness and benefits (Dubey *et al*., 2010). It holds a critical need in agriculture as it serves as an effective extension approach to promoting the adoption of innovative maize technologies and practices among farmers (Dhaka *et al*., 2010). FLD allows for the validation of new and improved maize varieties, hybrids, and cultivation practices under real farm conditions as well as assesses the performance and suitability of these technologies (Samant and Satpathy, 2016). Various location-specific issues in maize production can be addressed by FLD which will serve as an effective extension strategy to promote the adoption of improved technologies and practices among farmers.

There are growing concerns, about the equitable benefits of these improved technologies across the states, agro-ecologies and farmers categories. Therefore, a study has been frame to assess the impact of FLDs to better understand the yield gap across different regions.

Material and methods

The study is based on the Frontline Demonstrations (FLD) data from 2016 to 2021, gathered at farmers' fields as part of the National Food Security Mission (NFSM) project. The FLDs involve location-specific maize technology packages comprising improved agricultural practices, with a primary emphasis on enhanced hybrid varieties, disease and pest management practices, and improved agronomic techniques across diverse locations. The data were obtained from thirty (30) centers situated in 13 diverse agro-climatic zones across India (Table 1), ensuring comprehensive representation of various ecological conditions. Maize yield data of beneficiary and non-beneficiary farmers were collected for three season *viz., kharif, rabi* and *spring*. The collected data were subjected to statistical analysis, including ANOVA to determine the impact of improve maize technology under FLD on maize productivity across different regions and season.

Results

A comprehensive assessment of data across the research centres revealed the considerable superiority of FLD over farmer practices in terms of grain yield, with the former attaining a significant average increase of 37.2 per cent (Figure 1).

Table 1. Locations of FLD in different agroclimatic zones

Agro-climatic zone	Centres/locations taken for study
Western Himalayan region	Kangra, Almora, Srinagar
Eastern Himalayan region	Gossaingaon, Imphal, Umiam
Lower Gangetic plain region	Kalyani
Middle Gangetic plain region	Sabour, Varansi, Dholi, Begusarai
Upper Gangetic plain region	Bahraich
Trans Gangetic plain region	Hisar, Pantnagar, IIMR, New Delhi, PAU
Eastern plateau and hills region	Ambikapur, Bhubaneswar
Central plateau and hills region	Chhindwara, Udaipur, Banswada
Western plateau and hills region	Kolhapur, Jhabua
Southern plateau and hills region	Hyderabad, Coimbatore, Dharwad, Mandya, WNC
Gujarat plains and hills region	Godhra

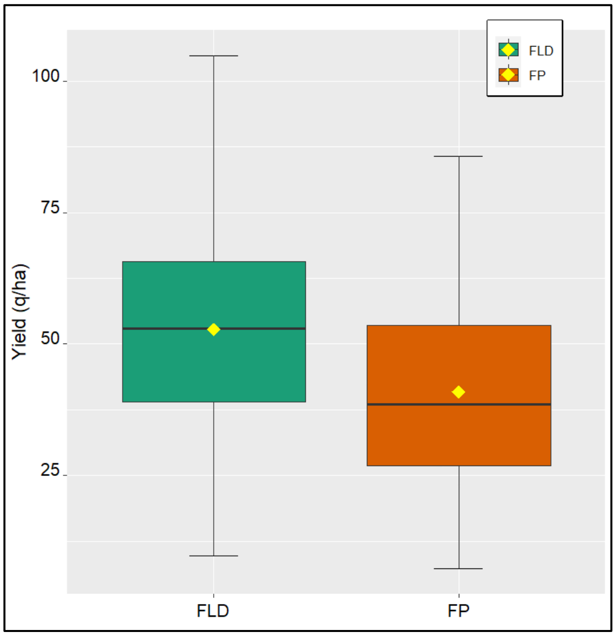

Figure 1. Mean grain yield of maize in FLD and FP across different agro-climatic zones of India

In the context of the Western Himalayan region, meticulous research endeavours have elucidated notable strides in maize yield through the application of Frontline Demonstrations (FLD) in comparison to conventional Farmers' Practices (FP) at the Kangra, Almora, and Srinagar research centres. Evidently, the Kangra centre exhibited a remarkable yield increase of 50.6 per cent, while the Almora and Srinagar centres equally displayed substantial enhancements, with impressive rises of 49.5 and 48.5 per cent, respectively (Figure 2 & 3). This impressive margin signifies the consistent and substantial benefits garnered through the implementation of Frontline Demonstrations in this particular region. Within the Eastern Himalayan region, the study revealed a noteworthy advancements in crop yield through the application of FLD in comparison to FP at the Gossaingaon, Imphal, and Umiam research centres. Impressively, the Gossaingaon centre demonstrated a substantial yield increase of 36.1 per cent, while the Imphal and Umiam centres displayed even more remarkable enhancements, with astounding rises of 132.7 and 29.8 per cent, respectively (Figure 2).

FLD recorded an increase in yield by 14.2 per cent over FP in the Kalyani centre that was only obtained from the rabi season in the Lower Gangetic Plain region. In the Sabour, Varanasi, Dholi, and Begusarai centres of the Middle Gangetic plain region, FLD recorded an increase in yield over FP by 5.5, 41.3, 20.7, and 15.9 per cent,

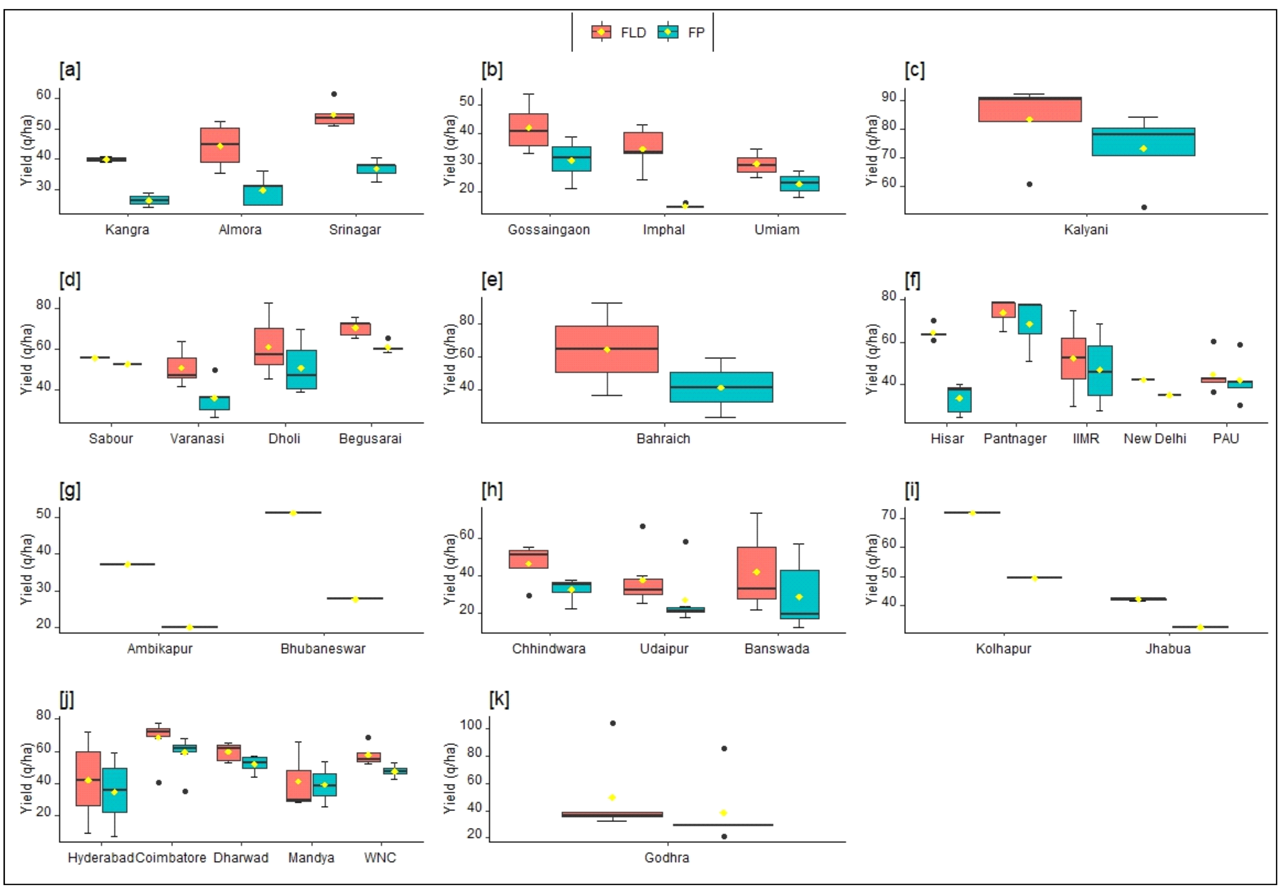

Figure 2. Grain yield of maize in FLD and FP within different locations across different agro-climatic zone of India

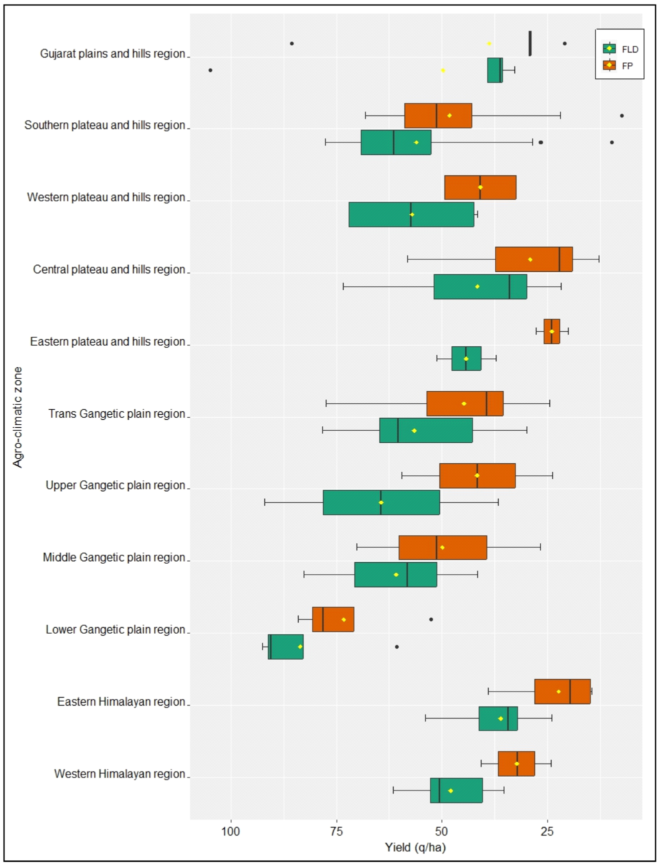

Figure 3. Grain yield of maize in FLD and FP across different agro-climatic zones of India

respectively. Moreover, a meticulous analysis of grain yield data throughout the kharif and rabi seasons has unveiled the consistent superiority of FLD over FP within this zone. On average, FLD demonstrated a remarkable 21.9 per cent increase in yield compared to FP. Notably, during the kharif season, FLD exhibited a substantial 28.3 per cent higher yield, while during the rabi season, this advantage remained significant at 16.9 per cent. In the Upper Gangetic Plain region, FLD recorded a yield increase of 54.6 per cent above FP in the Bahraich centre. This gain was attained equally throughout both the rabi and spring seasons. In the context of the Trans Gangetic Plain region, significant improvements in crop yield were observed with the adoption of FLD compared to FP at various research centres. Notably, Hisar centre recorded the most substantial increase, with a remarkable 92.8 per cent rise in yield. Similarly, Pantnagar, IIMR, New Delhi, and PAU centres also experienced notable improvements of 7.9, 11.3, 20.0 and 6.2 per cent, respectively. Furthermore, the aggregated data across all research centres demonstrated that FLD consistently outperformed FP, resulting in a mean increase of 26.4 per cent in grain yield. This noteworthy achievement was observed consistently across both the *kharif* and spring seasons.

In the Eastern plateau and hills region, FLD recorded an increase yield by 85.1 and 84.8 per cent over FP in the Ambikapur and Bhubaneswar centre, respectively (Figure 2). The average gain in performance of FLD in terms of grain yield was in equally came out from *kharif* and *rabi* season in this zone (Figure 2 & 3). In the Central plateau and hills region, FLD recorded an increase yield by 42.2, 39.5 and 46.0 per cent over FP in the Chhindwara, Udaipur and Banswada centre, respectively (Figure 2). The mean performance of FLD in terms of grain yield was 53.3 and 29.5 per cent higher than the FP in *kharif* and *rabi* season, respectively making it an average of 43.1 per cent higher yield in FLD over FP in this zone (Figure 3). In the Central plateau and hills region, FLD exhibited remarkable improvements in crop yield when compared to FP at various research centres. Specifically, at the Chhindwara, Udaipur, and Banswada centres, FLD demonstrated impressive increases in yield by 42.2, 39.5 and 46.0 per cent, respectively (Figure 2). Furthermore, a comprehensive assessment of grain yield data across the region revealed the consistent superiority of FLD over FP. During the *kharif* season, FLD achieved a substantial 53.3 per cent higher yield than FP, and in the *rabi* season, this advantage remained significant at 29.5 per cent. On average, FLD displayed an impressive 43.1 per cent higher yield than FP within this particular zone. In the Western plateau and hills region, FLD recorded an increase yield by 46.0 and 29.6 per cent over FP in the Kolhapur and Jhabua centre, respectively (Figure 2). Moreover, a comprehensive analysis of grain yield data across the region has revealed a consistent and noteworthy advantage of FLD over FP. Both the *kharif* and *rabi* seasons showed comparable performance gains, with FLD achieving an average yield improvement of 39.6 per cent. In the Southern plateau and hills region, FLD recorded an increase yield by 21.3, 15.9, 14.6, 5.1 and 21.4 per cent over FP in the Hyderabad, Coimbatore, Dharwad, Mandya and WNC centre, respectively. The average gain of 16.3 per cent in performance of FLD in terms of grain yield was recorded to the extent of 14.7 and 17.6 per cent from *kharif* and *rabi* season, respectively in this zone. Moreover, at the Godhra centre in the Gujarat plains and hills region, FLD yielded an impressive 28.1 per cent increase in yield compared to FP. This noteworthy gain was attributed to the combined

Table 2. Performance of FLD and FP in terms of maize yield (q/ha) across the different agroclimatic zones

Agro-climatic zone	*Kharif*		*Rabi*		*Spring*		Mean	
	FLD	FP	FLD	FP	FLD	FP	FLD	FP
Western Himalayan region	47.87	32.18	–	–	–	–	47.87	32.18
Eastern Himalayan region	34.77	19.21	42.23	30.96	29.84	15.77	36.03	22.27
Lower Gangetic plain region	–	–	83.57	73.25	–	–	83.57	73.25
Middle Gangetic plain region	51.69	40.28	71.73	61.36	0.00	0.00	60.80	49.86
Upper Gangetic plain region	–	–	92.08	59.52	36.60	23.70	64.34	41.61
Trans Gangetic plain region	45.25	35.61	–	–	60.87	48.25	56.53	44.74
Eastern plateau and hills region	37.17	20.11	51.20	27.70	–	–	44.19	23.91
Central plateau and hills region	35.15	22.93	58.24	44.97	–	–	41.57	29.05
Western plateau and hills region	56.76	40.84	57.30	40.85	–	–	57.03	40.85
Southern plateau and hills region	52.35	45.64	59.12	50.28	–	–	56.00	48.13
Gujarat plains and hills region	52.35	41.20	39.18	28.96	–	–	49.71	38.75

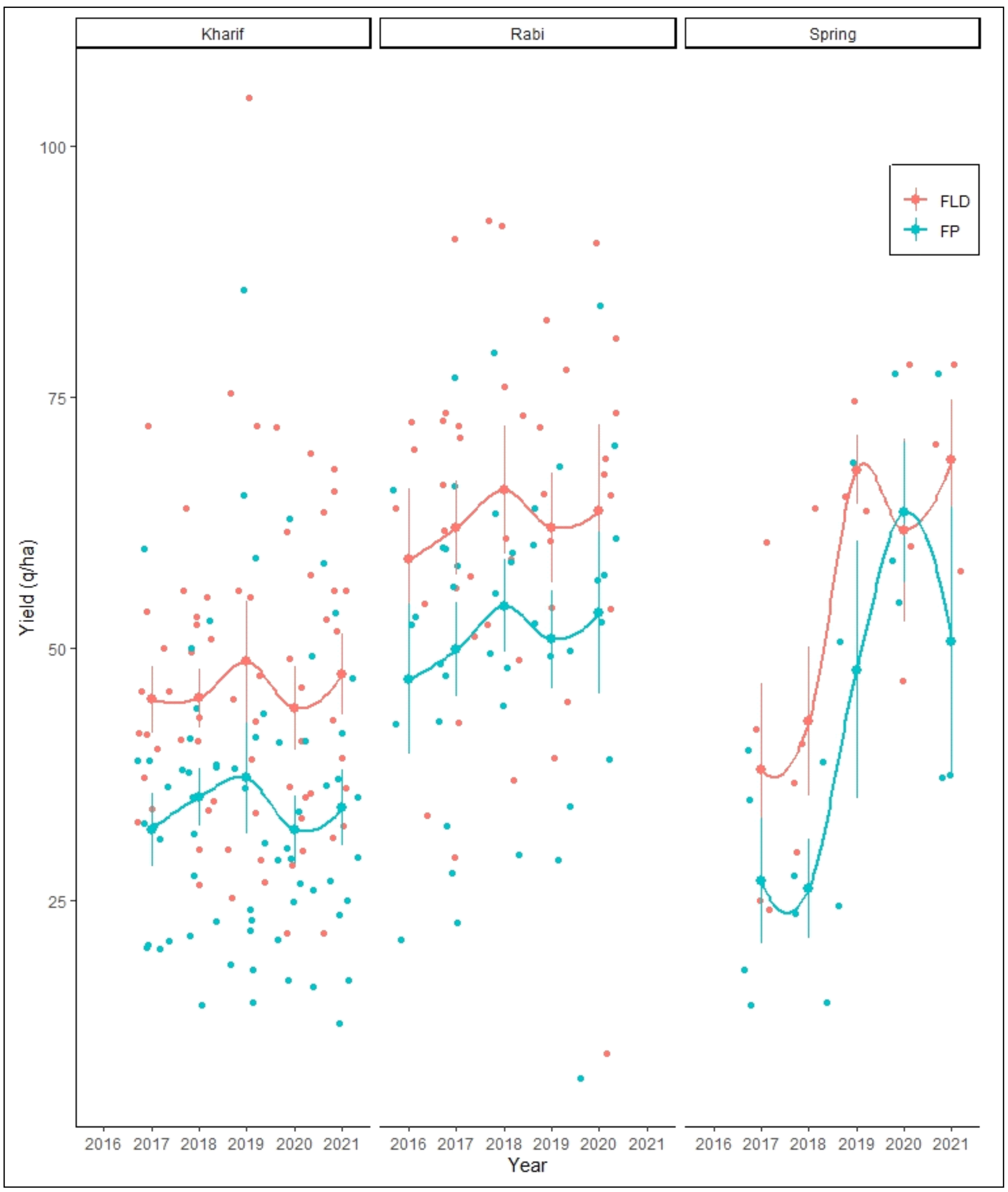

Figure 4. Grain yield of maize in FLD and FP in different seasons across the years (2016–2021)

impact of both the *kharif* and *rabi* seasons, with the former contributing to a significant 27.0 per cent improvement and the latter achieving an even higher increase of 35.3 per cent.

A comprehensive seasonal analysis of FLD and FP spanning the years from 2016 to 2021 revealed intriguing insights. While FP consistently outperformed FLD in all scenarios, a notable contrast emerged during the spring season, where FLD exhibited a significant increase in yield, as depicted by the steep slope in the graph (Figure 4). Pooling together data from diverse agroclimatic zones, the cumulative findings indicated that FLD contributed substantially to boosting India's maize productivity, recording an impressive 37.2 per cent increase over FP. These results underscore the pivotal role played by Frontline Demonstrations in enhancing agricultural productivity and present valuable opportunities for further research and interventions to improve maize cultivation practices across the country.

Moreover, comprehensive analysis of the data across the various seasons demonstrated the significant superiority of FLD over FP in terms of grain yield. Specifically, in the *kharif* season, FLD resulted in a remarkable 81.0 per cent higher yield compared to FP. In the *rabi* season, this margin was equally impressive, with FLD showing a 36.4 per cent increase in yield. Not to be outdone, during the spring season, FLD showcased exceptional performance, achieving an astonishing 89.2 per cent higher yield than FP. Collectively, these findings culminated in an average of 61.8 per cent higher yield for FLD over FP within this particular zone.

Field demonstrations (FLDs) actively introduce farmers to innovative maize technologies, providing first hand exposure and fostering motivation for adoption. These demonstrations actively showcase improved maize varieties and agronomic practices, significantly augmenting maize yields, enhancing food security, and bolstering farm profitability. Improved varieties, designed to yield higher outputs through genetic enhancements such as disease and pest resistance, drought tolerance, and agronomic traits, are central to these efforts. There exists a pressing need to strengthen the local seed systems, particularly for public hybrids, to ensure easy and timely access to improved hybrids. Strengthening the extension system is crucial for

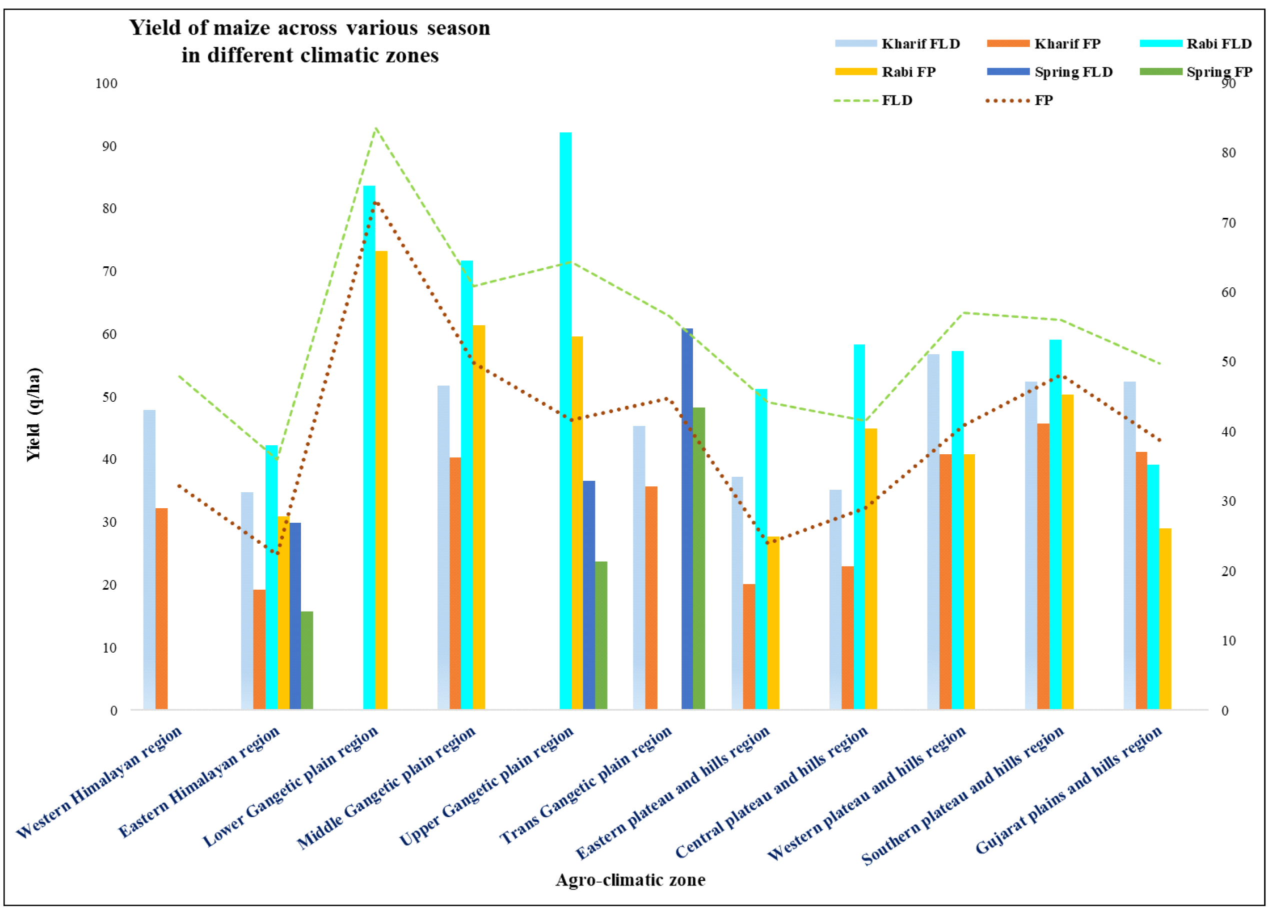

Figure 5. Performance of FLD and FP in terms of maize yield (kg/ha) across the seasons (*kharif, rabi, spring*) different agro-climatic zones

facilitating the widespread dissemination of technologies in farmers' fields.

Conclusion

It is evident from these findings that the adoption of improved technologies of maize holds immense promise in enhancing maize productivity throughout the country across diverse agroclimatic zones. These results not only highlight the regional variability in yield improvement but also emphasize the overall superiority of FLD over conventional Farmers' Practices (FPs). Such advancements offer valuable insights and encouragement for the broader agricultural community to adopt and implement more effective and sustainable farming practices. Nonetheless, it is paramount to acknowledge the dynamic nature of agricultural systems and the multifaceted factors that contribute to crop productivity. As such, further in-depth analyses and rigorous evaluations are indispensable to ascertain the long-term impact and scalability of FLD in this region. Moreover, these findings lay the groundwork for informed policy decisions and targeted interventions to optimize agricultural practices, ultimately benefitting farmers and ensuring the resilience of the agrarian sector. The continuous pursuit of research and scientific inquiry will undoubtedly facilitate the dissemination of best practices, fostering sustainable and enhanced agricultural practices in the Eastern Himalayan region and beyond.

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