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Bridging the Yield Gap in Chilli Cultivation: Performance of Arka Harita Hybrid in Farmer's Field

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Abstract

Front Line Demonstrations (FLDs) were conducted during 2022-23 and 2023-24 in Mandya district of Karnataka to evaluate the performance of the Arka Harita chilli hybrid under real farm conditions. Compared to the local varieties commonly grown by farmers, Arka Harita showed a significant yield advantage, producing 187.65 q/ha of green chilli-an increase of 34.2 per cent over the farmers' practice (139.80 q/ha). The hybrid also performed better in terms of plant height, branching, fruit length and fruit count per plant. Economically, it proved more profitable, offering a higher net return (Rs.2,07,975/ha) and benefit-cost ratio (3.83) than the traditional approach. Incidence of key pests and diseases such as murda complex and powdery mildew was notably lower in the FLD plots, thanks to hybrid resistance and adoption of integrated pest management practices. The technology and extension gaps were 32.35 q/ha and 47.85 q/ha respectively, while the technology index stood at 14.70 per cent indicating strong field-level adaptability. Farmer feedback showed high satisfaction with the hybrid's market appeal and performance, with most expressing interest in continued use. The study highlights the role of FLDs in bridging yield gaps and promoting improved varieties for sustainable chilli production.

Keywords : Arka Harita, Front line demonstration, Chilli hybrid, Yield gap, Murda complex, Farmer adoption

Chilli (*Capsicum annuum* L.), a prominent member of the Solanaceae family, is one of the most widely cultivated spice crops across India. Believed to have originated in Mexico or Central America (Salvador, 2002), it has since become an integral part of Indian cuisine due to its pungency, flavor, aroma and color. India stands as the largest producer, consumer and exporter of chillies, contributing nearly 25 per cent to global production. Chilli alone accounts for approximately 33 per cent of Indian spice exports and constitutes about 16 per cent of global spice trade (Kumar & Lal, 2021).

The genus *Capsicum* comprises over 30 species, of which five-*C. annuum*, *C. frutescens*, *C. chinense*, *C. pubescens* and *C. baccatum*-are extensively cultivated and economically significant (Bosland and Votava, 2003). The crop thrives in warm and humid climates and is cultivated under both irrigated and rainfed conditions. Chilli fruits are rich in vitamins A, C and E and are widely used in culinary, pharmaceutical and cosmetic industries. Products such as chilli pickles and dried powders are highly valued, and compounds like capsaicin are employed for their medicinal, antimicrobial, antioxidant and anticancer properties (Parthasarathy *et al*., 2008; Lahbib *et al*., 2015 and Khan *et al*., 2014).

Despite the expanding demand for both fresh and processed chilli, its productivity remains constrained due to several challenges. These include limited adoption of improved production technologies, biotic

stresses such as the murda complex and powdery mildew and restricted access to high-yielding hybrids (Indira *et al.,* 2001). Although research institutions have developed promising technologies, their limited adoption by farmers reflects a gap in extension and technology dissemination (Kiresur, 2001).

Demonstrations have proven to be one of the most effective extension methodologies to bridge this gap. Front Line Demonstrations (FLDs), in particular, play a crucial role in showcasing the practical viability and economic benefits of improved technologies under farmers' field conditions. Demonstrations encourage technology adoption through experiential learning, observation and participation (Pathak, 1999). Previous national demonstration programs have successfully shown the yield-enhancing potential of modern crop production techniques (Anonymous, 2012).

Mandya district of Karnataka, despite having substantial area under chilli cultivation, suffers from low productivity due to poor technology adoption and vulnerability to pest and disease outbreaks. This not only affects the income of small and marginal farmers but also threatens India's competitive edge in global chilli markets. Against this backdrop, FLDs were conducted on the high-yielding hybrid 'Arka Harita' chilli to evaluate its field-level performance and demonstrate its advantages over local varieties, particularly in the management of the murda complex and enhancement of economic returns.

Material and Methods

The Front Line Demonstration (FLD) on Arka Harita chilli hybrid was conducted during the *kharif* season of 2023-24 in Mandya district of Karnataka, covering selected villages (Lakshmisagara, Menagra, Maradipura and bramhadevarahalli) of Pandavapura and Nagamangala taluks. The region falls under the Southern Dry Zone (Zone-6) of Karnataka, characterized by an average annual rainfall of 750-900 mm, red sandy loam to clay loam soils and a temperature range of 18-34°C.

Villages were purposively selected based on the following criteria: area under chilli cultivation, conducting PRA, previous exposure to extension activities of KVK, willingness of local farmer groups to participate and accessibility for regular monitoring. Priority was given to villages facing consistent yield gaps due to pest/disease pressure and suboptimal agronomic practices.

A total of 20 progressive farmers were selected in collaboration with the KrishiVigyan Kendra (KVK) and the Department of Horticulture. Selection criteria included willingness to adopt improved technologies, availability of land, irrigation facilities and prior experience in chilli cultivation. Each demonstration plot covered an area of 0.4 ha (1 acre), with adjacent control plots (farmers' practice) maintained under similar conditions for direct comparison.

The experimental layout followed a comparative, non-replicated design under real-farm conditions. The treatment (T1) comprised Arka Harita chilli hybrid with Integrated Crop Management (ICM) practices, while the control (T2) included the local variety with traditional farmer practices.

To assess performance, yield and agronomic data for the local varieties were recorded from adjacent control plots managed by the same farmer using their regular practices. Uniform sampling procedures were adopted in both FLD and control plots by randomly selecting 10 representative plants per plot to measure plant height, number of branches, fruit count per plant and fruit weight. The total green chilli yield was computed by harvesting the entire plot and converting it to q/ha, ensuring consistency in comparison.

The Arka Harita hybrid, developed by ICAR-IIHR, Bengaluru, is known for its dark green fruits, high pungency, resistance to leaf curl virus and market-preferred traits. Seeds were sourced from ICAR-IIHR.

Land was prepared with two deep ploughings followed by harrowing. Raised beds (1.2 m width, 30 cm height) were prepared and 30-day-old seedlings raised in pro-trays under protected conditions were transplanted at a spacing of 60 cm x 45 cm.

Well-decomposed FYM at 20 t/ha was incorporated before transplanting. The FLD plots received ICM practices including biofertilizers (Azospirillum and PSB @ 2 kg/acre), recommended fertilizer dose (150:75:75 NPK kg/ha), drip irrigation, manual weeding and mulching and integrated pest and disease management using neem-based products, Emamectin benzoate, Trichoderma and Pseudomonas fluorescens. The control plots were managed as per local farmer practices.

Annexure : **Summary of FLD and control practices**

The following observations were recorded :

Agronomic Parameters : Plant height (cm), number of primary branches, days to flowering and fruiting, fruit length and girth (cm), fruit weight (g), number of fruits per plant and green chilli yield (t/ha).

Quality Parameters : Capsaicin content (mg/g using HPLC), pungency (Scoville Heat Units), dry matter content (%) and shelf life (days).

Pest and Disease Incidence : Percentage incidence of thrips and leaf curl virus and mite population per leaf.

Resource and Economic Efficiency : Input use (fertilizers, pesticides, labour), cost of cultivation, gross and net returns and benefit-cost (B:C) ratio.

Market Performance : Market price (Rs./kg), time to marketable maturity (days) and post-harvest losses (%).

Farmer Feedback and Adoption Indicators : structured interviews and Likert-scale feedback for yield, pest resistance and marketability; post-FLD adoption rate (%).

Extension Impact : pre and post-training knowledge tests, knowledge gain (%) and field day participation.

Yield parameters were recorded by selecting 10 healthy, representative plants at random from each demonstration and control plot. Key traits such as plant height, number of branches, fruit length and number of fruits per plant were measured manually at peak flowering and fruiting stages.

Green chilli yield was obtained by harvesting the entire 0.4 ha plot, weighing the marketable produce using a digital balance and converting it to q/ha. Sub-samples of fruits were used to measure average fruit weight and size. Care was taken to ensure uniform methods across FLD and local plots to allow fair comparison.

Data collected were analyzed using standard statistical methods. Paired t-tests were applied to compare the means between T1 and T2. Descriptive statistics were used for adoption, satisfaction and feedback data. Results were interpreted at 5 per cent significance level.

Annexure : Summary of FLD and control practices

Component	FLD Treatment (T1)	Control (T2)
Variety	ArkaHarita	Local (Byadgi, Guntur, Mandya local)
Nursery	Pro-tray, polyhouse	Open field nursery
Fertilizer	150:75:75 NPK kg/ha (split) + micronutrients	Blanket 100:50:50
Biofertilizer	Azospirillum + PSB @ 2 kg/acre	Not applied
Irrigation	Drip (3-day interval)	Flood (weekly)
Weed control	Manual + mulching	Manual
Pest management	Need-based IPM (Neem, Emamectin benzoate, etc.)	Calendar pesticide sprays
Disease management	Copper oxychloride, Trichoderma, Pseudomonas sprays	Fungicide mixtures

Results and Discussion

Enhanced Performance of Arka Harita Chilli through Front Line Demonstrations (2022–24)

Front Line Demonstrations (FLDs) carried out during 2022-23 and 2023-24 in Mandya district yielded compelling evidence in favor of Arka Harita chilli hybrid. The hybrid consistently outperformed local varieties not just in yield but also in economic returns, input efficiency and disease tolerance. The findings underscore the significance of introducing well-bred hybrids supported by scientific agronomy.

Yield Performance and Agronomic Superiority

Across the two-year study, Arka Harita demonstrated clear agronomic superiority. The hybrid attained a mean plant height of 55.4 cm and fruit length of 11.6 cm, compared to 49.2 cm and 9.2 cm, respectively, under local practices. Fruit count per plant was notably higher (160 in FLD vs. 125 in Farmers' Practice), resulting in a substantial 34.2 per cent increase in green chilli yield (187.65 q/ha vs. 139.80 q/ha). Notably, disease incidence from murda complex was 57.24 per cent lower in Arka Harita (Table 1) . These results are in line with Bosland and Votava (2003) and Basavaraj *et al.* (2010), who highlighted hybrid vigor as a major factor in improved yield and resilience in Capsicum species.

Economic Viability and Profitability

The profitability of Arka Harita was significantly higher. FLD plots recorded a net return of Rs.207,975/ ha, substantially more than Rs.141,500/ha under Farmers' Practice. The benefit-cost ratio was also more favorable (3.83 vs. 3.07), underscoring the economic appeal of the hybrid. Singh *et al.* (2014) and Shivakumar *et al.* (2018) similarly observed that scientific demonstrations with improved varieties led to enhanced farm incomes (Table 2).

Table 2

Economic analysis of Arka Harita chilli hybrid under FLD and Farmers' Practice

Particulars	FLD (Rs/ha)	Farmers' Practice (Rs/ha)
Cost of cultivation	73,500	68,200
Gross returns	281,475	209,700
Net returns	207,975	141,500
Benefit-Cost ratio (B:C)	3.83	3.07

Bridging Yield Gaps: Technology and Extension Indices

Despite the impressive yield of 187.65 q/ha, a technology gap of 32.35 q/ha from the potential yield (220 q/ha) was noted. The extension gap-difference between FLD and local practice yields-stood at 47.85 q/ha (Table 3). A technology

Table 1

Performance of Arka Harita chilli hybrid under Front Line Demonstration (FLD) and farmers' practice (FP)

Particulars	FLD (Arka Harita)	Farmers' Practice	% Increase Over FP
Plant height (cm)	55.4	49.2	12.60
Number of branches per plant	7.2	6.1	18.03
Fruit length (cm)	11.6	9.2	26.09
Number of fruits per plant	160	125	28.00
Green chilli yield (q/ha)	187.65	139.80	34.20
Disease incidence (Murda complex)	6.5%	15.2%	-57.24

TABLE 3

Technology gap, extension gap and technology index in chilli production

Particulars	Potential yield (q/ha)	Demonstration yield (q/ha)	Farmer's yield (q/ha)	Technology Gap (q/ha)	Extension Gap (q/ha)	Technology Index (%)
Arka Harita Chilli	220	187.65	139.80	32.35	47.85	14.70

index of 14.70 per cent indicates promising adaptability under field conditions. These indicators are crucial to gauging the real-world performance of new technologies (Indira *et al.,* 2001).

Extent of Adoption of Recommended Technologies

One of the more encouraging outcomes of the FLDs was the improvement in technology adoption. Use of certified hybrid seed surged from 20 to 95 per cent, pest management adoption increased from 22 to 78 per cent and significant gains were recorded in nutrient and disease management practices. This pattern highlights the FLD's role as a catalyst for capacity building, echoing the findings of Kiresur *et al.* (2001) (Table 4).

Farmers' Perception of Arka Harita Hybrid

Farmer feedback was overwhelmingly positive. On a 5-point scale, Arka Harita scored 4.6 for market demand and pungency, 4.4 for disease tolerance and 4.2 for fruit size. Such favorable perception is vital for long-term adoption and it aligns with consumer preferences described by Bosland and Votava (2003) Table 5.

TABLE 5

Farmers' perception on Arka Harita chilli hybrid (n = 30)

Parameter	Mean Score (1–5 scale)	Ranking
Pungency and market demand	4.6	I
Tolerance to Murda complex	4.4	II
Fruit size and length	4.2	III
Yield potential	4.1	IV
Suitability for pickles and processing	3.9	V
Overall satisfaction	4.3	-

Constraints in Chilli Cultivation

Challenges faced by farmers included murda complex (90%), seed access (75%), rising input costs (70%) and volatile market prices (68%). These constraints require institutional support-timely seed availability, IPM adoption and regulated market interventions-as also suggested by Lahbib (2015) Table 6.

TABLE 4

Extent of adoption of recommended chilli production technologies by farmers

Recommended Practice	% Adoption Before FLD	% Adoption After FLD	% Change
Use of certified hybrid seed (Arka Harita)	20	95	+75
Raised nursery and seed treatment	30	85	+55
Integrated nutrient management	25	80	+55
Soil test-based fertilizer application	18	70	+52
Pest and disease management (Murda Complex)	22	78	+56
Use of organic inputs and bio-agents	15	62	+47

Table 6

Constraints perceived by farmers in chilli cultivation

(n = 30)

Constraints Identified	% of Respondents
Murda complex and powdery mildew incidence	90
Lack of availability of quality hybrid seed	75
High cost of pesticides and inputs	70
Market price fluctuations	68
Lack of awareness about scientific production methods	65

Soil Properties of Demonstration Fields

Soils across FLD sites were slightly acidic (pH 6.4-6.9), with medium organic carbon (0.49%) and balanced NPK levels-conditions conducive to chilli cultivation (Table 7). Regular organic amendments also enriched microbial activity and soil health, consistent with Parthasarathy *et al.* (2008).

Fertilizer Schedule and Nutrient Management

FLDs followed the recommended NPK schedule (150:75:75 kg/ha), supplemented by FYM (15 t/ha) and micronutrients (Zn, B). In contrast, farmers' plots often lacked these inputs or applied them imprecisely (Table 8). The resulting vigor and uniformity in FLD plots reiterate the importance of nutrient management (Bosland and Votava, 2003).

Pest and Disease Incidence

FLD plots recorded significantly lower pest and disease levels: murda complex (6.5% vs. 15.2%), powdery mildew (4.8% vs. 11.6%), and fruit borer (3.2% vs. 7.5%). The integration of IPM strategies and resistant varieties was instrumental in this reduction. Khan (2014) also observed similar benefits from IPM in chilli (Table 9).

Table 7

Soil properties of demonstration fields before sowing

Soil Parameter	Observed Range	Mean ± SE	Soil Category
Soil texture	Sandy loam	-	Sandy loam
pH	6.4 - 6.9	6.65 ± 0.05	Slightly acidic
EC (dS/m)	0.12 - 0.22	0.17 ± 0.03	Normal
Organic carbon (%)	0.42 - 0.58	0.49 ± 0.04	Medium
Available N (kg/ha)	230 - 280	255 ± 10.2	Medium
Available P_2O_5 (kg/ha)	18 - 25	21.8 ± 2.1	Medium
Available K_2O (kg/ha)	180 - 210	195 ± 8.6	Medium

Table 8

Fertilizer schedule followed under FLD and farmers' practice

Nutrient	Recommended Dose (kg/ha)	FLD Application	Farmer's Practice
Nitrogen (N)	150	150 in 3 splits	100 in 2 splits
Phosphorus (P_2O_5)	75	Basal full dose	Partial applied
Potassium (K_2O)	75	Full in 2 splits	Not properly used
Micronutrients (Zn/B)	As per soil test	Applied	Not used
FYM (t/ha)	15	Applied	Less than 5 t/ha

TABLE 9

Pest and disease incidence recorded under FLD vs Farmers' Practice

Pest/ Disease	FLD Incidence (%)	FP Incidence (%)	% Reduction
Murda Complex	6.5	15.2	57.24
Powdery Mildew	4.8	11.6	58.62
Fruit borer	3.2	7.5	57.33
Thrips and mites	5.6	12.3	54.47

Extension Activities and Farmer Training

The FLD program included on- and off-campus training, field days and distribution of educational materials. Over 250 farmers participated. Satisfaction scores averaged 4.7, reflecting strong knowledge transfer and engagement. These efforts validated Pathak's (1999) view that effective demonstrations require robust extension interfaces (Table 10).

Comparative Performance with Local Varieties

Compared with traditional varieties like Byadagi and Guntur, ArkaHarita stood out in yield (187.65 q/ha vs. 122.5-135.3 q/ha), disease resistance and market attributes. Its uniform fruit size and deeper green color were appreciated by traders and consumers alike. These benefits support the need for focused hybrid development as emphasized by Bosland and Votava (2003) Table 11.

TABLE 10

Training and awareness activities conducted for FLD farmers

Activity	No. of Events	No. of Participants	Average Satisfaction (1–5)
On-campus training	2	35	4.8
Off-campus training	3	62	4.7
Field day	1	110	4.9
Farmer-scientist interaction	2	47	4.6
Distribution of literature	150 copies	100% of participants	4.5

Post-FLD Adoption and Sustainability

Nearly all farmers (93.3%) expressed intent to continue with ArkaHarita and 96.6 per cent would recommend it to peers. Such wide acceptance highlights both the adaptability of the hybrid and the trust fostered through FLDs (Table 12). This

TABLE 12

Post-FLD farmer satisfaction and willingness to adopt Arka Harita

(n=30)

Response Category	% of Respondents
Will continue Arka Harita in next season	93.3%
Will recommend to other farmers	96.6%
Found FLD training useful	100%
Satisfied with input support and guidance	90.0%
Reported improvement in income	86.7%

TABLE 11

Comparative performance of Arka Harita with local varieties

Parameter	Arka Harita	Byadagi (Local)	Guntur Local	Mandya Local
Yield (q/ha)	187.65	122.50	135.30	110.40
Avg. fruit length (cm)	11.6	8.9	10.2	9.1
Murda resistance	High	Low	Moderate	Low
Market acceptance	Very High	High	Moderate	Low
Colour & pungency	Deep green, medium	Dull red, high	Red, very hot	Pale red, mild

supports the long-term sustainability principles described by Kiresur *et al.* (2001).

The two-year Front Line Demonstration programme on Arka Harita chilli hybrid in Mandya district clearly established its agronomic and economic superiority over traditional varieties. The hybrid recorded a notable 34.2 per cent yield increase, a higher benefit-cost ratio (3.83) and significantly reduced pest and disease incidence. These improvements underscore the hybrid's suitability for enhancing chilli productivity under farmers' field conditions.

Equally important was the rise in adoption of scientific practices such as certified seed use, integrated nutrient management and IPM, facilitated through targeted training and extension activities. Farmers expressed high satisfaction with Arka Harita's marketability, fruit quality and resilience, reflecting its practical utility.

The results validate the effectiveness of FLDs in bridging yield gaps, promoting new technologies and fostering sustainable farming practices. Scaling up such demonstrations, along with ensuring input availability and continuous farmer engagement, can accelerate chilli sector growth in Karnataka and similar agro-ecological regions.

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