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Farmers' Participatory Extension Research for Dissemination of *Pennisetum glaucum* (L.) R.Br. Variety-*Sulkhaniya Bajra* in India

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ABSTRACT

Background: Drawing from the different farmer participatory and farmer-managed trials, morphological characterization of farmer's pearl millet variety-*Sulkhaniya Bajra* was investigated for facilitating registration under PPV and FR Act with performance and suitability evaluation under different agro-climatic zones of the country for its wide-scale dissemination.

Methods: Researcher managed and farmer implemented trails (RMFITs) constituted under randomized block design having five treatments with four replications were conducted at two farmers' fields under Jaipur conditions. During 2016-2019, Farmer-Managed and Farmer Implemented Trials (FMFITs) in Gujarat and Rajasthan with Farmer-Managed Trials (FMTs) in Haryana, Tamil Nadu, Telangana, and Maharashtra were also conducted.

Result: *Sulkhania Bajra* was superior in both grain (30.6 q/ha) and fodder (63.q/ha) yield as compared to the checks and was characterized by distinct long earheads (64.95 cm), higher plant height (193.13 cm) with early maturity which took 46 days for 50% spike emergence. The unique characteristics coupled with adaptability to harsh environments also enable the variety to serve as suitable breeding material. Multiple drivers influence new technology adoption decisions, the present study reiterates using evidence-backed knowledge for designing and implementing the trials with the farmers' involvement, taking into account the possible drawbacks for wider acceptance.

Key words: Climate-resilient, Dissemination, Extension, Farmer's Variety, Pearl millet.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.), an important grain, forage, and stover crop (Rao *et al*., 2017) is also one of the major climate-resilient crops for food security and income for small-scale farmers in the arid and semi-arid regions of Africa and Asia (Shweta, 2015). India leads in the area and production of pearl millet making it the largest producer in the Asian continent; Rajasthan, Maharashtra and Gujarat states cover nearly 80% of the total pearl millet cultivation in India (Chandra *et al*., 2021).

Rao *et al*. (1986) reported the *Sulkhaniya Bajra* landrace from Churu, Rajasthan, and advocated its conservation and role in the development of climate-resilient varieties, but a steep decline in the cultivation of variety was reported. For the last four decades, a single grassroots innovator from Churu was involved in its conservation and improvement through mass selection. The efforts of such farmers engaged in conservation and varietal improvement need recognition for the large-scale proliferation of the local varieties for the benefit of the farming communities. In order to protect the variety, National Innovation Foundation (NIF)-India recognized and rewarded the farmer, provided incubation support for *in situ* seed multiplication and intellectual property rights protection under the PPV and FR, Act 2001. Characterized by early maturity, long compact earheads, and superior performance under rainfed conditions, coupled with 18.5% protein, 40.6 ppm iron, 137.8 ppm calcium and 33.4 ppm zinc content (NIF, 2017), the variety was selected for dissemination through farmers' involvement.

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Small-scale farmers in adverse environmental conditions with limited external inputs have benefitted immensely from on-field evaluation trials and participatory research trials. Such trials offer an increase in the amalgamation of modern and traditional plant breeding methods, thereby enhancing the benefits of newly introduced crop varieties to the farming communities (Angarawai *et al*., 2016). The objectives of the present study include

morphological characterization of *Sulkhaniya Bajra* and evaluation of its performance and suitability using on-farm trials in different agro-climatic regions under rainfed conditions for dissemination.

MATERIALS AND METHODS

The criteria defined by Norman *et al*. (1995) and Witcombe *et al*. (1996) with slight modifications were adopted for performance, suitability assessment and morphological characterization of the variety. Seeds of the test variety-*Sulkhaniya Bajra* procured by NIF-India from the innovator were provided to the farmers for the trials.

Researcher Managed and Farmer Implemented Trials (RMFITs)

The performance and morphological characterization trials of the variety with standard (RHB 173, RHB 177 and MPMH -17) and local checks, laid in RCBD with five treatments and four replications were carried out at two farmers' fields in Jaipur (Zone XIII), Rajasthan during July-October 2016. The net plot size was 3.15 m × 3.15 m with RxP spacing of 45 cm × 15 cm; standard package of practices recommended for Jaipur condition were used for a good crop stand.

Farmer managed and farmer implemented trials (FMFITs)

In order to check the suitability and adaptability of the claimed traits (Plant height, Earhead length, and Grain yield) of the test variety, FMFITs were undertaken in Gujarat (Zone XIII) and Rajasthan state (Zone VIII and XIV) at 6 and 10 locations respectively during 2016-2019.

Farmer-managed trials (FMTs)

The volunteer farmers provided with test variety seeds to conduct trials in Maharashtra (Zone IX), Haryana (Zone VI), Tamil Nadu (Zone X) and Telangana (Zone X) states for introducing the variety in different agro-climatic zones under rainfed conditions during 2017-2019.

Observations and statistical analysis

The morphological characterization was done based on DUS descriptors of pearl millet (PPV and FRA, 2015). Data for yield and yield-attributing traits from the RMFITs were pooled and subjected to standard analysis of variance while the FMFITs and FMT claimed traits data were pooled to calculate means and presented in tables and figures using MS Excel 2010.

RESULTS AND DISCUSSIONS

Morphological characterization

The morphological characterization of *Sulkhaniya Bajra* was completed from the RMFITs based on the DUS descriptors for pearl millet (PPVFRA, 2015) (Table 1). *Sulkhaniya Bajra* was tall and erect growth habits with early maturity. It is a short-duration variety with long spikes and small grains. The short-duration crop variety is the most preferred trait to

Table 1: Morphological characterization of *Sulkhaniya bajra* recorded from researcher managed farmer implemented trials conducted during July-October 2016.

Plant descriptors	Expressions (Range)
Plant: Growth habit	Erect
Time of spike emergence (50% plants with at least one spike emerged fully)	Early
Plant: Height (excluding spike)	Tall (181-216 cm)
Plant: Number of nodes	Low (8-10)
Plant: Node pigmentation	Green
Plant: Number of tillers	Medium (3-8)
Plant: Number of productive tillers	Low (2-3)
Leaf: Blade length	Medium (50-60 cm)
Leaf: Blade width (at widest point)	Medium (3-4 cm)
Spike: Anther colour	Yellow
Spike exertion	Complete
Spike: Length	Very long (50-81 cm)
Spike: Width at maximum point (excluding bristles)	Medium (1.5-3 cm)
Spike: Bristle	Present
Spike: Bristle Appearance	Prominent (Bristle length> 2 mm from the ear head)
Spike shape	Cylindrical
Spike: Tip sterility	Present
Spike: Density	Compact
Seed: Colour	Yellow brown
Seed: Shape	Globular
Seed: Weight of 1000 grains	Small (5-7.5 g)
Forage characters	Stay Green
Forage: Stalk juiciness	Juicy

overcome drought as the main constraint in semi-arid zones (Hassan *et al*., 2014).

The plant height ranged between 181-216 cm and categorized it under tall variety with erect growth habit. The green nodes were 8-10 in number while three to eight total tillers and 2-3 productive tillers were recorded. The stay-green stalk of the variety was juicy, increasing the palatability of the fodder. The varieties having such traits can serve dual purposes for both grain and fodder purposes.

The spike exertion was complete with yellow anthers. The distinct compact and cylindrical very long spikes (50-81 cm) were bristled prominently and were marked with curved tips, a feature commonly observed among the local landraces and varieties with very long spikes where spike compactness and presence of bristles vary considerably among different genotypes as reported by Satyavathi *et al.* (2018).

The small, globular and yellow-brown coloured seeds of the variety is a dominant trait preferred by farmers during selection. The yellow and orange colour of seeds is associated with the presence of carotenoids in different crops including pearl millet (Sathya *et al*., 2014).

Researcher managed and farmer implemented trials (RMFITs)

The performance of *Sulkhaniya Bajra* in comparison with local and standard checks at two locations in Jaipur (Zone VIII) reported a significant difference among the various treatments for yield and yield attributing traits. Among all the varieties tested, *Sulkhaniya Bajra* recorded superior plant height at both locations (Table 2). *Sulkhaniya Bajra* recorded 2.76% superiority in plant height than the at par variety RHB-173. The distinct earheads of *Sulkhaniya Bajra* reported 59.58% increase in the earhead length over the best check RHB-173 in the pooled data of both locations. The earhead girth of RHB-173 was significantly superior to all checks and test variety at both locations while *Sulkhaniya Bajra* recorded the lowest earhead girth (Table 2).

The grain yield of *Sulkhaniya Bajra* was significantly superior over all the tested checks at both locations with a pooled overall increase of 12.09% over the best check RHB-173. Based on DUS characters, *Sulkhaniya Bajra* recorded as early maturing which can contribute to its yield; a trait also considered as a good drought escape mechanism and enables escape from bird and pest damages ensures better yield; it is the most preferred trait over the late-maturing varieties by the farmers (Andrews and Kumar, 1996). *Sulkhaniya Bajra* also recorded superior earhead length and higher yield among checks. The earlier finding of Gupta (2015) that ear length have a significant and positive correlation with grain yield is corroborating the present experimental results (Table 2).

The maximum dry fodder yield was recorded in RHB-173 at both locations with a 3.85% overall higher fodder yield over *Sulkhaniya Bajra*. Gupta (2015) recorded the higher stover yield of both RHB-173 and RHB-177 which is in corroboration with the present result obtained (Table 2). *Sulkhaniya Bajra* characteristics like high yield, long compact

Table 2: Performance evaluation of *Sulkhaniya Bajra*-pearl millet variety in comparison with standard and local checks under researcher managed farmer implemented trials at two locations under Jaipur conditions during *Kharif* 2016.

Tr. No.	Treatment details	Plant height (cm)			Earhead length (cm)			Earhead girth (cm)			Grain yield (q/ha)			Dry fodder yield (q/ha)		
		Location 1	Location 2	Pooled Mean	Location 1	Location 2	Pooled Mean	Location 1	Location 2	Pooled Mean	Location 1	Location 2	Pooled Mean	Location 1	Location 2	Pooled Mean
T_1	Sulkhaniya	197.30	188.95	193.13	66.50	63.40	64.95	6.90	6.65	6.78	31.84	29.36	30.60	65.12	61.68	63.40
T_2	RHB 173	190.95	184.65	187.80	27.10	25.40	26.25	9.05	8.50	8.77	27.13	26.68	26.90	67.71	64.17	65.94
T_3	RHB 177	151.80	141.45	146.63	24.85	22.60	23.73	7.98	7.45	7.71	19.86	18.92	19.39	61.76	57.01	59.39
T_4	MPMH-17	183.00	144.15	163.58	25.35	26.90	26.13	7.80	7.40	7.60	25.18	24.80	24.99	58.11	53.04	55.58
T_5	Local check	138.70	121.40	130.05	23.95	22.55	23.25	7.50	7.20	7.35	17.51	17.04	17.27	39.17	36.32	37.75
	SEm± (L)		4.35			0.60			0.11			0.46			0.53	
	CD 5% (L)		12.67			1.76			0.32			1.33			1.55	
	SEm± (T)	5.02	12.80	6.88	1.69	0.88	0.95	0.22	0.27	0.18	0.79	1.21	0.72	0.79	1.49	0.84
	CD 5% (T)	15.49	39.47	20.04	5.22	2.72	2.78	0.68	0.85	0.51	2.43	3.73	2.10	2.43	4.58	2.45
	SEm± (T × L)			9.73			1.35			0.25			1.02			1.19
	CD 5% (T × L)			28.33			3.93			0.73			2.97			3.47
	CV %	5.83	16.40	11.84	10.09	5.49	8.22	5.62	7.38	6.51	6.48	10.35	8.56	2.70	5.46	4.22

ear heads, and better fodder quality have been reported (NIF, 2017).

Farmer managed and farmer implemented trials (FMFITs)

The performance and adaptability trials of *Sulkhaniya Bajra* in comparison to local checks were done under FMFITs in Rajasthan (10-locations) and Gujarat (6-locations) states during 2016-2019. The performance of *Sulkhaniya Bajra* was superior in all the traits recorded as compared to local checks at all the locations of Gujarat and Rajasthan. An increase of 12.13% and 32.17% in plant height over local check was observed in Gujarat and Rajasthan respectively (Table 3). The earhead length of *Sulkhaniya Bajra* was significantly superior to local check with an increase of 61.88% in Gujarat and 64.03% in Rajasthan. As compared to local checks, *Sulkhaniya Bajra* recorded with a 10.88% higher grain yield at Rajasthan, however, only 1.11% higher grain yield was recorded at Gujarat which did not reflect much difference between the local check and *Sulkhaniya bajra* (Table 3). The combined average increase of 5.99 per cent in grain yield was reported across both states. Plant height, earhead length, and grain yield of *Sulkhaniya Bajra* were maximum under Gujarat conditions in comparison to Rajasthan. The better performance of the variety in Gujarat may be attributed to the nutrient-rich soil and relative higher rainwater use efficiency resulting in better capture and use of nutrients in comparison to the xeric conditions in Rajasthan. This is in corroboration with the previous studies of Rao *et al.* (1986) where he reported a significant difference in the length of earheads of *Sulkhaniya Bajra* between two locations in different zones. Despite the differences between states, an interesting observation to note was that the *Sulkhaniya Bajra* performed superior to local check in both states and was preferred by the farmers due to better performance under rainfed conditions with minimum inputs.

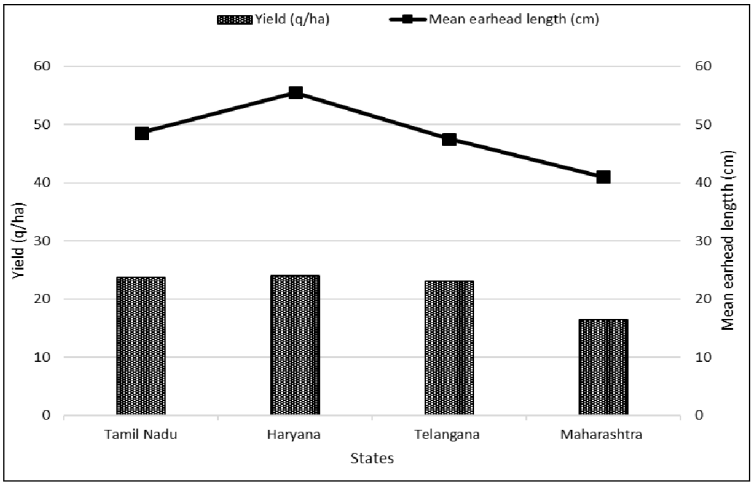
Farmer managed trials (FMTs)

The pooled earhead length and grain yield data of *Sulkhaniya Bajra* for the farmer-managed trials (Fig 1) shows considerable differences in the traits between the states. Maximum earhead length and grain yield was reported from the state of Haryana (Zone VI) followed by Tamil Nadu (Zone X), Telangana (Zone X) and Maharashtra (Zone IX and XIII). The fluctuation in the pearl millet productivity is affected by the amount and distribution of rainfall along with the change in temperature and relative humidity in different years

Table 3: Comparative performance of farmer's developed *Sulkhaniya Bajra* pearl millet variety in comparison with local checks under farmer managed farmer implemented trails in the states of Rajasthan and Gujarat.

State (No. of locations)	Districts covered	Plant height (cm)			Earhead length (cm)			Grain yield (q/ha)		
		Sulkhaniya bajra	Local check	PIOC	*Sulkhaniya bajra*	Local check	PIOC	*Sulkhaniya bajra*	Local check	PIOC
Gujarat (6)	Rajkot and Banaskantha	206.09	181.10	12.13	64.54	24.60	61.88	26.20	25.91	1.11
Rajasthan (10)	Jaipur and Barmer	193.43	131.20	32.17	60.05	21.60	64.03	24.91	22.20	10.88
Mean		199.76	156.15	21.83	21.83	23.10	62.92	25.55	24.05	5.87
SD		8.95	35.28		3.17	2.12		0.91	2.62	
SEm ±		6.33	24.95		2.25	1.50		0.64	1.85	
CV%		4.48	22.60		5.10	9.18		3.56	10.90	

*PIOC= Percent increase over check.



Fg 1: Performance of innovator's pearl millet variety-*Sulkhaniya Bajra* in different states under farmer-managed trials (FMT).

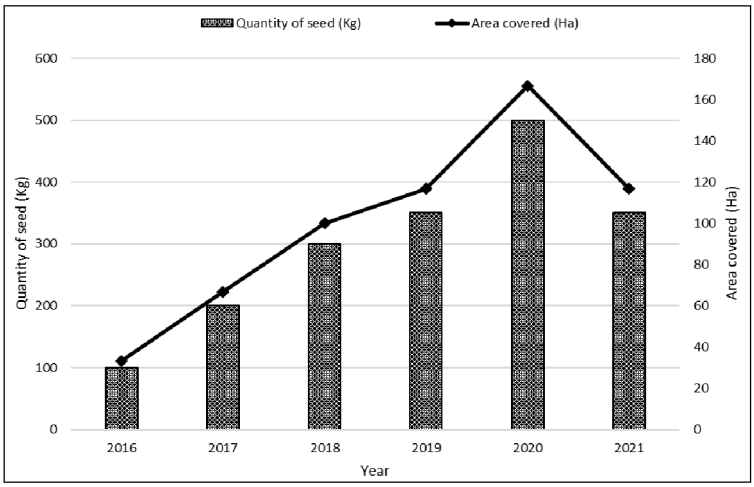


Fig 2: Quantity of seeds sold and area under cultivation of Sulkhaniya bajra-pearl millet variety during 2016-2021.

(Sharma, 2014). Moreover, the existence of a suboptimal and multifold gap in attainable yield between the farmer practice and researcher-managed trials is evidenced (Wani *et al*., 2009). The farmers' feedback on the fodder quality of *Sulkhaniya Bajra* reported a preference for both green and dry fodder. As compared to landraces, the commercial varieties and hybrids are characterized by shorter plant height and smaller thicker spikes (Satyavathi *et al*., 2018); moreover, landraces have performed better in yields than modern cultivars due to better adaptations (Witcombe *et al*., 1996) supports the present feedback recorded.

The popularity of the variety gradually increased based on the farmer's participatory on-farm trials in different states. The sale of seeds by the innovator and the area covered increased near around five times during the period 2016 to 2020 (Fig 2) through the incubation support of NIF. Crop varietal innovations and the management of crop genetic resources directly involve the farmers, especially in the small and marginal farming systems of arid and semi-arid regions (Bellon and van Etten, 2014). As evidenced in the present study, given a choice, the farmers will choose the varieties that are better adapted to climatic and biotic stressors providing nutritional and economic security. In the arid agroecosystems, crop and livestock production is interdependent. Farmers across the globe have shown a preference for the crop varieties with better grain and fodder yield potential under stressed and unfavourable conditions similar to *Sulkhaniya Bajra* as reported previously (Kumari *et al*., 2016).

CONCLUSION

The present study clearly demonstrates that in order to make sure the availability of climate-resilient, nutritionally efficient, and sustainable germplasms for future cultivation, sourcing seeds outside the conventional geographic boundaries is a prerequisite. *Sulkhaniya Bajra* performed well across regions and was preferred due to its grain and fodder yield potential under minimum inputs over the popular hybrids and local checks. As evidenced, the variety was sturdy in its performance and showed better adaptability to different edaphic and climatic conditions.

The nutritional advantage, as reported earlier about higher iron, zinc and calcium makes the variety suitable for inclusion in the midday meal and public distribution system for nutritional security, especially for poor sections of societies that are prone to iron deficiency predominantly among women and children. *Sulkhaniya bajra* is a unique complete package for both the growers, consumers and can be a potential breeding material, requires both in-situ conservation and *ex-situ* propagation. However, the biochemical analysis for ascertaining the presence and quantification of minerals and vitamins, particularly carotenes will strengthen the nutritional profile of the variety and warrants further investigations.

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Competing Interests

The authors declare no competing interests.

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