Project Coordinator Review

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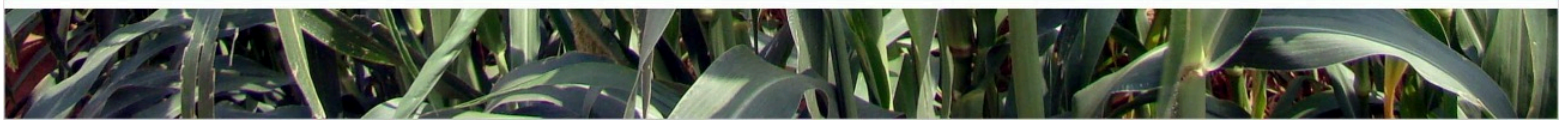

REVIEW OF PEARL MILLET RESEARCH

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the fourth most widely cultivated food crop after rice, wheat and maize in India. It is a climate resilient nutricereal that grows rapidly with fewer inputs and has high photosynthetic efficiency, good and balanced nutritional profile, tolerant to adverse climatic conditions and biotic stresses. It is mainly grown under the most adverse agro-climatic conditions where other staple cereal crop like rice and wheat are not able to survive. It can very well grow in the harshest conditions including low soil fertility, high soil pH, high soil Al^{3+} saturation, low soil moisture, high temperature, high soil salinity and scanty rainfall. It is the 6th major cereal crop globally followed by maize, rice, wheat, barley and sorghum and stands as a crucial climate-resilient crop, offering sustenance, fodder and nutritional stability in some of the most arid and impoverished regions worldwide, especially across sub-Saharan Africa (SSA) and Asia, with a particular focus on India. It is being cultivated over 30 million ha worldwide, with the major crop area in Africa (>18 million ha) and Asia (>10 million ha). It is also used in industries such as - alcohol and fuel, starch and processed food sectors.

During 2023-24, pearl millet area in India was 7.36 million ha with an average production of 10.67 million tons and 1449 kg/ha productivity (Source: DA&FW).The major pearl millet growing states are Rajasthan, Maharashtra, Uttar Pradesh, Gujrat and Haryana contributing to 90% of total production in the country. Rajasthan contributes nearly 45% followed by Uttar Pradesh (19%), Haryana (9%), Gujarat (9%), Maharashtra (6%) and Tamil Nadu (2%). Most of pearl millet in India is grown in rainy (*kharif*) season (June/July-September/October). Pearl millet is also cultivated during summer season (February-May) in parts of Gujarat, Rajasthan and Uttar Pradesh; and during the post-rainy (*rabi*) season (November-February) at a small scale in Maharashtra and Gujarat. Pearl millet is more nutritious than commonly consumed staple crops such as wheat, rice, maize and sorghum. The grain is rich in carbohydrates, proteins, fats, fibres, resistant starch, vitamins, antioxidants, essential micronutrients such as iron and zinc and has a more balanced essential amino acid profile than maize or sorghum. Lipids are dominated with omega-3 and omega-6 fatty acids (polyunsaturated fatty acids) that contribute to good health of heart and brain. Pearl millet is not expensive like pearl but it's definitely has pearl like quality which is beneficial to the body. 100 grams of bajra contains- energy 360 calories, moisture 12 g, protein 12 g, fat 5 g, mineral 2 g, fiber 1 g, carbohydrate 67 g, Calcium 42 mg, phosphorus 242 mg, and iron 8 mg. It offers gluten-free grains with high and better protein in terms of quality and quantity making it ideal for people with gluten allergy. It is the only cereal which retains alkaline nature even after cooking with a low glycemic index thus making it a diabetic friendly food. It acts as a probiotic food for microflora in our inner ecosystem and hydrates our colon to keep us from being constipated. Its consumption has been associated with protection against certain types of cancer and cardiovascular diseases. It has high proportions of slowly digestible starch (SDS) and resistant starch (RS) which contribute to low glycemic index (GI) and is much sought after in the recent times of transforming diets, food habits and the food industry. Hence, pearl millet is gaining lot of popularity among

health conscious people all over the world. It can play a vital role in overcoming malnutrition to ensure food and nutritional security. Due to its excellent nutritional properties, pearl millet is designated as ***nutri-cereal*** (Gazette of India, No. 133 dtd 13th April, 2018) for production, consumption, trade and was included in Public Distribution System (PDS). In 2023, Hon'ble prime minister of India rebranded millets as **'*Shree Anna*'** for their climate resilience and nutritional superiority and declared ICAR-IIMR, Hyderabad as **"*Global Centre of Excellence for Millets*".** In order to mainstream and exploit nutritionally superiority of millets and promote their cultivation, Govt. of India declared **Year 2018** as the **"Year of Millets"** and after declaration of FAO Committee on Agriculture (COAG) forum in 2021, **Year 2023** was celebrated as **"International Year of Millets".**

Research on Pearl millet improvement in India is carried through the All India Coordinated Research Project on Pearl Millet (AICRP-PM) administered by Indian Council of Agricultural Research (ICAR) through a network of 12 AICRP centers in Rajasthan, Gujarat, Maharashtra, Uttar Pradesh, Karnataka, Andhra Pradesh, Madhya Pradesh, Punjab, Haryana and Tamil Nadu. The AICRP-PM centers located in 12 State Agricultural Universities (SAU's) and University of Mysore pursue mandated activities and strategic research on pearl millet in the areas of germplasm utilization, improvement, production, protection and value addition etc.

Through ICAR- All India Coordinated Research Project on Pearl millet, a total of **206 hybrids and 66 varieties** were identified and released for cultivation in different agro-ecological zones of the country. Pearl millet is the **first crop to establish first global minimum standards for micronutrient content in promotion criteria in the cultivar release policy.** *Pearl millet is the first crop in the world to introduce bench mark levels for Fe (42 ppm) and Zn (32 ppm) in cultivar promotion and release since 2018 ensuring nutritional security in the country falling in line with the vision of nutrionallly secure India.* A number of production and protection technologies specific to different agro-ecological regions which will prove useful in enhancing the productivity of improved cultivars to commercial farming scales and increase the profitability of pearl millet growers were developed through this system.

Development of high yielding, dual purpose disease resistant cultivars for low rainfall areas i.e. A_1 zone is of utmost priority for increasing pearl millet productivity at national level. Refinement of technologies for processing of grain, development of value added products along with development of sound extension support for popularization of these technologies and products, spread of pearl millet cultivation in non-traditional areas and pearl millet hybrid seed production in North - Western part of the country is the need of the hour.

CROP IMPROVEMENT

1. Hybrids/ varieties notified

Pearl millet hybrids/varieties were notified and released for cultivation in various agro-ecologies of the country *viz.*

i. Two hybrids viz., GHB 1294 (MH 2555) and MPMH 42 (MH 2553) were released for cultivation in A_1 zone i.e. western Rajasthan and drier parts of Gujarat and Haryana.

ii. GHB 538 Improved (MH 2561) was released as EDV for cultivation in A_1 zone i.e. western Rajasthan and drier parts of Gujarat and Haryana.

iii. HBH 191294 (MH 2577) was released for cultivation in A zone for the states Rajasthan, Gujarat, Haryana, Madhya Pradesh, Uttar Pradesh, Punjab and Delhi in late maturity group.

iv. Two hybrids viz., 86M22 (MSH 377) and PB 1879 (MSH 371) were released for cultivation in summer growing areas of Gujarat, Rajasthan, Uttar Pradesh, Maharashtra and Tamilnadu.

v. Three hybrids viz., GHB 1351 (MSH 370) (BanasNayan), Proagro 9001 (MH 2440) and PBH-1625 (MH 2323) (Palem Sajja-1625) were released for cultivation in Gujarat, Haryana and Telangana, respectively.

The following seven hybrids were identified for cultivation in various agro-ecologies of the country during Varietal Identification Committee Meeting (Virtual) held on 10-11, July, 2023during Combined AGM of Millets, hosted by ICAR-IIMR, Hyderabad viz., MH 2553 (MPMH 42),MH 2555 (GHB 1294), MH 2661 (GHB 538 Improved), MH 2577 (HBH 191294), MSH 371 (PB 1879) and MSH 377 (86M22).

Genetic enhancement

A significant progress was made during the year 2023-24 in genetic enhancement of crop. A total of 125new experimental cultivars and 35 released hybrids/varieties were evaluated in 14trials during *kharif* and *summer* 2023 at 62 test locations in the four agro-climatic zones of the country. These genotypes expressed a wide range of grain and stover productivity (Table1).

2. Utilization of male-sterile (A) and restorers (R) lines

A wide range of A and R lines were used in order to develop new experimental hybrids for evaluation. The hybrids evaluated during 2023 were based on 71 A-lines (by name) and 77R-lines (by name). This is contributing significantly towards genetic diversification of parental lines and ultimately pearl millet hybrids for different agro ecologies in the country.

3. Assessment of grain quality- Fe, Zn, Protein and Fat

During the 52nd AGM of ICAR-AICRP on Pearl millet at PAU, Ludhiana a landmark decision of including minimum Fe (42 ppm) & Zn (32 ppm) in promotion criteria was taken.

In Coordinated experimental trials, 156 entries with high grain yield along with the checks were analysed for grain iron and zinc content across the locations. The iron and zinc content ranged from (41-99ppm) and (27-60 ppm) respectively over different trials and locations.

A total of 64 entries were assessed for quality parameters like protein and fat. The values ranged from 8.5–13.0% in protein content and ranged from 4.8-6.2% in fat content. (This demonstrates that there existsenough opportunity to select for protein content in addition to high grain and stover yields).

Table 1: Details of coordinated trials on Pearl millet conducted during 2023

Zone	Trials	No. of test entries& Checks	Range	
			Grain Yield (kg/ha)	Stover Yield (kg/ha)
A_1	IHT Early	31	1606-2552	4113-5483
	AHPTEarly	09	1952-2443	4342-5172
A	IHT Medium	27	2151-3662	6078-10300
	IHT Late	25	2321-4499	8167-13613
	AHT Late	17	2784-4181	7729-11810
	PT	16	1644-2923	6455-8965
B	IHT Medium	27	1776-4040	5080-8429
	AHT Medium	06	2582-3564	6007-7739
	IHT Late	25	2497-4233	7748-11992
	AHT Late	07	3290-4049	6630-8697
	PT	16	1318-2584	3602-6037
Summer	SHT	17	4145-5500	6973-10991

4. Breeder seed Production

During 2023-24, breeder seed production of 54 parental lines (A, B & R) of hybrids and 07 OPVs was undertaken. A total of 26.953q of breeder seed was produced which was higher than the indented quantity of breeder seed (10.978q) from Department of Agriculture and Cooperation, Ministry of Agriculture and Farmer Welfare (GOI).

5. DUS test and registration of cultivars with PPV & FRA

A total of 14candidate/reference varieties and 2local checks were tested at ICAR-AICRP on Pearl Millet, Jodhpur and ICAR-AICRP on Pearl Millet, BRS, Dhule. Observations on candidate and reference varieties for twentyeight characters were recorded as per general and specific DUS guidelines of pearl millet. One DUS Character Study Trial was also conducted with 34 parental lines (18 B & 16R lines) and 20 hybrids at ICAR-AICRP on Pearl Millet, Jodhpur and ICAR-AICRP on Pearl Millet, BRS, Dhule.

6. ICAR-ICRISAT partnership research

A total of 126 R lines and 90 B lines were assessed by breeders in five trials at 12 locations on AICRP centers and cooperating centers and superior entries were selected for utilization in their breeding programme. In elite inbred joint biofortification trial a total of 50 entries including checks were evaluated across 7 locations. High Fe and Zn amongst B lines were recorded in entry no. 28,31,38,25,29,36,40 and 42 in comparison to the best check ICMB 96666 (Fe 87 ppm). For Zn content entry no. 47,46,38,25,32,36,28,42,29 and 31in comparison to the best check ICMB 96666 (Zn53 ppm). High Fe and Zn amongst R lines were recorded in entry no. 12,18,19,1,13,16,17,11 and 14 in comparison to the best check ICMR1503 (Fe 100 ppm). For Zn content entry no. 12,1,16,6,11,19 and 13 in comparison to the best check ICMR1503 (Zn56 ppm). In Marker Assisted Breeding Trial (Bi- parental QTL mapping population for blast resistance) a total 290 entries along with one check (ICMB 95444) evaluated. On the basis of agronomic and blast score 288 entries were found superior in comparison to the check ICMB 95444.

7. CRP Biofortification (Pearl millet) Parental Line Trial (CRPB PLT)

The trial was conducted using 33 entries including two checks across 6 locations viz., Mandor, Jaipur, Hisar, New Delhi, Jamnagar and Dhule. The performance for days to 50% flowering, plant height (cm), Effective tillers /plant, head length (cm), head girth (cm), seed set (%), and agronomic score. The days to 50% flowering ranged from 44 (Dhanshakti) to 64 (PPMI 1275). The plant height ranged from 111 cm (JMSB 20227) to 179 cm (DHLB 1708). Effective tillers per plant was 2.4 (DHLB 1806) to 3.6 (G 73-107). Head length ranged from 13 cm (H77/833-2) to 26 cm (RIB/S-23/423-426). Head girth ranged from 1.5 cm (H 77/833-2) to 3.3 (DHLB 1609, DHLB 1806, JMSB 222211and S-21/13). The seed set (%) under open pollination condition ranged from 62 (MIR 710) to 88 (DHLB 1603PPMI 1274). Agronomic score ranged from 2.6 (PPMI 1273) to 3.8 (252-SB-23). Grain sample of all test location collected and analyzed for grain nutrient content at ICRISAT. Grain iron content ranged (47 -88 ppm) none of the entry recorded higher in iron content. Grain zinc content ranged (30-57 ppm) none of the entry recorded higher in zinc content compared to best check Dhanshakti (Fe 88 & Zn 57 ppm).

Effect of different processing methods like Blanching, Malting and Fermentation of sprouts on nutritional composition of pearl millet on dry weight basis. A significant decrease was observed in crude protein content of malted flour (72 h) from 10.46 percent to 10.21 percent in HHB 299 and 11.48 percent to 11.24 per cent in HHB 311. The crude protein content of all other types of processed flours increased by 3.70 to 7.30 per cent, compared to control in both the hybrids. Ash content of unprocessed pearl millet flour was 2.57 (HHB 299) and 2.39 (HHB 311) per cent. Malting (48, 60 and 72 hours of germination) resulted in 4.82 to 7.78 per cent reduction of ash in HHB 299 and 4.60 to 7.53 per cent reduction in HHB 311. The ash content of blanched pearl millet flour was 2.69 (HHB 299) and 2.48 (HHB 311) per cent and that of fermented pearl millet flour was 2.85 (HHB 299) and 2.61 (HHB 311) per cent. Compared to control, ash content of blanched and fermented flour was significantly higher and it was observed that the ash content of malted flours decreased by 4.60 to 7.78 per cent. On overall mean (variety)

basis, ash content of fermented flour (2.73%) was significantly higher, followed by blanched (2.59%), unprocessed (2.48%) and malted flour (2.29 to 2.36%).

Trainings imparted to rural womens on nutri-garden, preparation of value added products like biscuit, ladoo and other bakery products. Various technologies of pearl millet were displayed and public was educated to increase intake of pearl millet based products.

PLANT BIOTECHNOLOGY

PMMB 1: VALIDATION OF MARKERS IN PEARL MILLET

Experiment 1: Validation of drought tolerance markers in pearl millet drought/heat tolerant genotypes suitable for A_1 zone.

- A total of 15 SSR primers specifically reported for drought were used for PCR amplification and molecular characterization among 19 pearl millet genotypes. All the 15 SSRs amplified products of varying sizes ranging between 100-500 bp with PIC value ranging from 0.38 to 0.73.

Experiment 2: Validation and molecular characterization of disease tolerant genotypes

- A total of 48 SSR primers were used for PCR amplification with 38 entries of downy mildew nursery trial. Out of 48 SSRs, 39 primers amplified products of varying sizes ranging from 100 to 500 bp. Similarly, a total of 53 SSR primers were used for PCR amplification with 44 entries of blast nursery trial. Out of 53 SSRs, 43 primers amplified products of varying sizes ranging from 120 to 450 bp.

Experiment 3: Validation of already reported high Fe/Zn markers among pearl millet lines rich in Fe and Zn content

- A total of 92 SSR primers were used for PCR amplification and validation among 38 pearl millet genotypes. Out of 92 SSRs, 71 primers amplified products of varying sizes ranging from 90 to 750 bp.

PMMB 2: MOLECULAR CHARACTERIZATION OF GERMPLASM OF PEARL MILLET

Experiment 1: DNA profiling of identified/advanced hybrid entries of third year testing

- Analysis of MH 2626 and MH 2631 using 36 primers displayed a unique profile. Out of the 36 primers used, 26 SSR primers (72.2%) were found polymorphic for MH 2626 and 29 SSR primers (80.6%) were found polymorphic for MH 2631.

Experiment 2: Molecular characterization of high/low rancidity genotypes (landraces) in pearl millet.

- A total of 95 SSR primers were used for PCR amplification and characterization among 24 pearl millet genotypes. Out of 95 SSRs, 83 primers amplified products of varying

sizes ranging from 100 to 600 bp and 10 (10.5 %) were monomorphic and 73 (76.8%) were polymorphic. (Table 2.2 and Fig. 2.3). PIC values varied from 0.37 to 0.81.

- Cluster analysis was carried out among the genotypes using NTSYS and SSR markers discriminated well between the genotypes and gave 4 major clusters viz., I, II, III and IV the similarity coefficient ranged between 0.59 to 0.77. The genetic relationships among the genotypes were consistent and the information revealed through this study is very useful and can be further used in breeding programmes.

Details of Molecular Breeding experiments conducted during 2023-24

S. No.	Name of experiment	No. of genotypes	No. of markers used	No. of amplified markers	No. of polymorphic markers	Polymorphism %
PMMB 1: VALIDATION OF MARKERS IN PEARL MILLET						
1	**Experiment 1:** Validation of drought tolerance markers in pearl millet drought/heat tolerant genotypes suitable for A_1 zone	19	15	15	15	100%
2.	**Experiment 2:** Validation and molecular characterization of disease tolerant genotypes	38 entries of DM	48	39	27	56.3 %
		44 entries of blast	53	43	30	56.6 %
3.	**Experiment 3:** Validation of already reported high Fe/Zn markers among pearl millet lines rich in Fe and Zn content	38	92	71	58	71.8%
PMMB 2: MOLECULAR CHARACTERIZATION OF GERMPLASM OF PEARL MILLET						
4.	**Experiment 1:** DNA profiling of identified/advanced hybrid entries of third year testing	4 (2 genotypes and 2 checks)	36	36	26 (for MH2626) & 29 (for MH 2631)	72.2% (for MH2626)& 80.5% (for (MH2631)
5.	**Experiment 2:** characterization of high/low rancidity genotypes (landraces) in pearl millet	24	95	83	73	76.8%

AGRONOMY

Resource management:

Five agronomical trials on the aspects of Nitrogen management among advance pearl millet hybrid entries during *Kharif* season; Enhancing biofortified/non- biofortified pearl millet hybrids productivity and quality through micronutrients, Quantification of contribution of production factors towards the yield and economics of pearl millet, Improving nitrogen use efficiency by split application of nitrogen at different growth stages under irrigated condition and Productivity of pearl millet [*Pennisetum glaucum* (L.) R.Br. Emend. Stuntz]-Mustard/Chickpea cropping sequence as influenced by organic and natural farming were conducted during *Kharif* season of 2023among different agro climatic zones (Zone A1, Zone A and Zone B) (Table 3).

Table 3: The list of the experiments along with treatments are as under:

S. N.	Title	Treatment
1	**PMAT1**:Response of pearl millet advance hybrid entries to nitrogen levels **Kharif Season** Zone A(1b)	20 (Hybrid Entry 1; Checks 4) & N level: 4 (0, 30, 60 & 90 kg/ha)
2	**PMAT3:**Enhancing biofortified/non-biofortified pearl millet hybrids productivity and quality through micronutrients under irrigated situation	Total Treatments : 18 **Main Plots: Hybrids (2):** MPMH 17 (Non Biofortified) and HHB 299 (biofortified) **Sub Plots :Micronutrient management practices:** T_1 : Control, T_2 : Soil application $ZnSO_4$ @ 25 kg/ha, T_3 : 0.5% $ZnSO_4$ Foliar spray at 20-25 DAS, T_4 : Soil application $FeSO_4$ @ 20 kg/ha, T_5 : 0.5% $FeSO_4$ Foliar spray at tillering stage (20-25 DAS), T_6 : 0.5% $MnSO_4$ Foliar spray at tillering stage (20-25 DAS), T_7 : 0.2% $CuSO_4$ Foliar spray at tillering stage (20-25 DAS), T_8 : 0.2% Borax Foliar spray at tillering stage (20-25 DAS) and T_9 : $ZnSO_4$ (25 kg/ha) + $FeSO_4$ (20 kg/ha) + 0.2 % Borax.
3	**PMAT4:**Contribution of production factors to the yield and economics of pearl millet	Total Treatments : 8 T_1: Full package & practices of the location [(RDF+ ZnSO4 @ 25 kg/ha+ $FeSO_4$ @ 0.5-0.75% at 20-25 DAS + bioinoculant seed treatment (Azoteeka/as per availability) + thinning & gap filling + weeding & hoeing (3 & 5 Weeks after sowing)+ Irrigation], T_2 : T_1- RDF, T_3 : T_1- $ZnSO_4$ @ 25 kg/ha, T_4 : T_1- $FeSO_4$ @ 0.5-0.75% at 20-25 DAS, T_5 : T_1- bioinoculant seed treatment (Azoteeka), T_6 : T_1- thinning & gap filling, T_7 : T_1-

S. N.	Title	Treatment
		weeding & hoeing (3 & 5 Weeks after sowing) and T_8 : T_1- Irrigation.
4	**PMAT 6:** Response of pearl millet to split application of nitrogen at different growth stages under irrigated condition	Total Treatments : 12 **Main Plots : Three nitrogen levels** N_1 – 100 % RDN, N_2 – 112.5% RDN &N_3 – 125 % RDN **Sub Plots: Nitrogen split applications (4)** S_1: Entire dose of N at sowing, S_2: 50% N at sowing + 50% N at tillering (20-25 DAS), S_3: 50% N at sowing + 50% N at boot stage (35-40 DAS), S_4: N will be applied in three splits (25% basal), 50% at tillering (20-25 DAS) and 25% at boot stage (35-40 DAS) as sub plot.
5	**PMAT 7:** Productivity of pearl millet [*Pennisetum glaucum* (L.) R.Br. Emend. Stuntz]-Mustard/Chick pea cropping sequence as influenced by organic and natural farming	T_1: Control (RDF), T_2: RDN* through Farm yard manure (FYM), T_3: RDN through Vermicompost (VC), T_4: DN through Poultry manure (PM) for Zone A&B / *Sheep or Goat manure for ZoneA_1, T_5: DN through Poultry manure(PM) for Zone A&B / *Sheep or Goat manure for ZoneA_1, T_6: RDN through Poultry manure (PM)for Zone A&B / *Sheep or Goat manure for ZoneA_1, T_7: RDN through Poultry manure + Biofertilizer T_8 : Cow based bio formulation and T_9: RDF

The salient achievements are as below:

- The advance hybrid entries MH 2626 (30.47 q/ha) and MH 2631 (29.17 q/ha) were found higher grain yielder than the check 86M86 (28.65 q/ha) but lower than the checks KBH 108 (31.97 q/ha) and MP 7878 (30.66 q/ha). The dry stover yield was found superior in the advance entry MH 2626 (75.79 q/ha) comparable with the check KBH 108 (74.08 q/ha) but superior over the checks 86M86 (67.61 q/ha) and MP 7878 (68.63 q/ha). Maximum grain (34.52 q/ha) and stover (78.37 q/ha) yields were recorded with the application of 90 kg N/ha and it produced 40.2, 18.3 and 6.4% more grain yield whereas, stover yield was 26.2, 12.2 and 4.2% higher over application of 0, 30 kg and 60 kg N/ha, respectively.
- The experiment conducted to find out the effect of micronutrients on the crop growth, productivity, quality and economics of biofortified/non-biofortified pearl millet hybrids under irrigated conditionin Zone A_1 revealed the superior performance of hybrid HHB 299 (24.73 q/ha) compared to MPMH 17 (21.31 q/ha) in terms of grain yield. Among the basal and foliar application of the micronutrients, the grain yield (26.52 q/ha) was found 32.2% superior in the treatment T_9 : $ZnSO_4$ (25 kg/ha) + $FeSO_4$ (20 kg/ha) + 0.2 % Borax over the control whereas, the stover yield was higher by 21.7%. The gross returns (Rs. 85241/ha) and net returns (Rs. 59643/ha) were found highest in the treatment T_9 whereas, BC ratio (3.65) in the T_5 treatment compared to the control (Rs. 65776/ha, Rs. 44443/ha and 3.11, respectively).

In Zone A, the treatment T_9: $ZnSO_4$ (25 kg/ha) + $FeSO_4$ (20 kg/ha) + 0.2 % Borax improved the grain and stover yield by 29.5% and 13.3% over the control. The application of $ZnSO_4$ as basal application and $FeSO_4$ as foliar application improved the grain yield by 20.6 and 12.9% as compared to the control. The application of Mn, Cu and B did not bring out significant improvement in the grain yield over the control. The hybrid HHB 299 had significantly higher Fe, Zn and B content in grain as compared to MPMH 17 whereas, Mn content was found more in MPMH 17. The Fe and Zn content were also found higher in both grain and stover where these were applied in comparison to without their application. The gross returns (Rs. 91633/ha), net returns (Rs. 53414/ha) and BC ratio (2.64) in the treatment T_9 were noticed highest compared to all the treatments including control (Rs. 71096/ha, Rs. 35798/ha and 2.18, respectively).

In Zone B, The mean grain yield was higher by 9.6% in the biofortified hybrid HHB 299 (27.14 q/ha) in comparison to MPMH 17 (24.77 q/ha). Similar pattern was also observed for dry stover yield and it was higher by 10.1% in this hybrid. Among the basal and foliar application of the micronutrients, the grain yield (30.43 q/ha) was found highest in the treatment T_9 : $ZnSO_4$ (25 kg/ha) + $FeSO_4$ (20 kg/ha) + 0.2 % Borax over all the treatments which was 34.1% superior over the control (22.70 q/ha). The application of different micronutrients bring out between 2.50 to 7.73 q/ha more grain yield over the control. The gross returns (Rs. 72324/ha) and net returns (Rs. 43520/ha) in the treatment T_9 whereas, BC ratio (2.53) in the T_2 treatment were noticed highest compared to all the treatments including control (Rs. 53166/ha, Rs. 27217/ha and 2.10, respectively).

- The studies carried out during 2021to 2023 for the quantification of the role of individual production factors towards productivity and economics in the pearl millet crop revealed that in Zone A_1,the maximum reduction of 64.1% was observed when irrigation was not applied and it was followed by without weeding (38.0%), without RDF (35.7%) and without thinning and gap filling (35.0%). The grain yield reduction among other treatments was between 12.8-19.3%.

  In Zone A, the maximum reduction of 45.3% was observed when RDF was not applied. The reduction was 36.1% when weeding was not carried out. The grain yield reduction among other treatments was between 8.5-43.7%) and net returns (15.3-92.5%) across the treatments.

  In Zone B, the maximum reduction of grain yield of 48.3% was observed when RDF was not applied which was followed by without weeding and hoeing (46.2%) and without thinning & gap filling (29.5%). The gross returns reduced from Rs. 7550 to Rs. 23357/ha among different treatments as compared to Rs. 73029/ha in the full package and practices treatments. The respective value of net returns was between Rs. 7296 to Rs. 19632/ha and Rs. 44044/ha, respectively.
- The experiment was conducted with an objective to study the optimum dose and time of split application of nitrogen and see its effect on pearl millet crop growth, productivity and economics. In Zone A_1, three time split application of N (S_4) i.e1/4 as Basal+50%at tillering + ¼ at boot stage recorded 14.8, 8.7 and 3.8%higher grain yield over S_1 (Entire dose of N at sowing), S_2 (50% N at sowing and 50% N at tillering) and S_3 (50% N at sowing and 50% N at boot) The BC ratio was also highest in the S_4 treatment (4.02).

In Zone A, The three times split N applications (S_4) had higher grain yield by 24.4, 6.2 and 10.6% over S_1, S_2 and S_3 treatments. The net returns were lower by Rs. 18200, Rs. 6489 and Rs. 9841/ha, respectively in S_1, S_2 and S_3 treatments as compared to S_4 treatment. At Hisar, the three split application had also the highest uptake of N (145.5 kg/ha), P (46.0 kg/ha) and K (234.4 kg/ha) as compared to the range of 121.3-135.6, 37.4-42.9 and 204.7-222.7 kg/ha, respectively in the treatments from S_1 to S_3.

In Zone B, the mean data of four locations exhibited that among the split application of nitrogen, the grain (25.29 q/ha) as well as stover yield (50.49 q/ha) were lowest in S_1 whereas, the grain yield was in the range of 27.26 to 27.67 q/ha in the S_2 to S_4 treatments. At Vijayapur, the NPK content and their uptake studies in grain was also carried out and it was found the three split application of N had highest uptake of N (50.1 kg/ha), P (17.4 kg/ha) and K (20.9 kg/ha) in grain as compared to the range of 41.7-46.2, 14.6-16.2 and 17.8-19.8 kg/ha, respectively in the treatments from S_1 to S_3.

- The field experiment aimed to evaluate the effect of organic and natural farming on productivity, quality, soil properties and microbial counts of pearl millet and mustard/chickpea crops was started during *Kharif*, 2022.

In Zone A_1, The grain yield was improved by 50.9 and 55.0% in the RDF treatment over the control and by 14.8 and 18.7% over the cow based formulation treatment (T_8). The T_9 treatment resulted in Rs. 22919/ha and Rs. 6863/ha more net returns over the control and cow based treatments. During Rabi 2022-23 at Mandor maximum chickpea seed yield (26.43 q/ha) was recorded by RDF treatment which was significantly higher than all other organic treatments except cow based bio formulation treatment (24.27 q/ha seed; 33.17 straw). The RDF treatment resulted in Rs. 93452 and Rs. 17028/ha more net returns over control and cow based bio formulations treatment.

In Zone A, The grain and stover yields were higher by 67.5 and 51.1% in the RDF treatment over cow based formulation treatment (T_8). The RDF treatment resulted in Rs. 38626/ha and Rs. 28435/ha more net returns over the control and cow based treatments. The protein content was observed maximum in the Poultry manure (9.9%) treatment as compared to 9.4% in RDF and cow based treatments whereas, lowest in the control (8.7%). At Hisar, cow based bio formulations notably recorded more bacterial population (6.13×10^9cfu count g-¹ soil) over control (4.91×10^9 cfu count g^{-1} soil) and RDF treatment (4.91×10^5cfu count g-¹ soil) however, it was maximum in vermicompost + biofertilizers treatment (6.66×10^9cfu count g-¹ soil).

The mustard seed and straw yield were higher by 66.3 and 42.9% over the cow based formulation treatment. At Hisar, the pearl millet equivalent yield was highest in RDF treatment (86.07 q/ha) whereas it was 40.10 in control and 47.98 q/ha in Cow based bio formulations treatment. The range was between 52.89 to 62.11 q/ha in organic manure treatments.

In Zone B, the grain and stover yield were higher by 34.3 and 23.9% over the cow based formulation treatment. The RDF treatment resulted in Rs. 33295/ha and Rs. 21237/ha more net returns over the control and cow based treatments. The protein content was observed maximum in vermicompost + biofertilizers (12.9%) whereas, it was 12.4% in RDF and 12.2% in cow based treatments and 10.5% in the control. At Vijyapur, the treatment cow based bio formulation notably recorded higher bacterial population (46.3 ×

10^6cfu count g^{-1} soil) over control (38.7 × 10^6 cfu count g^{-1} soil) and RDF treatment (40.3 × 10^6 cfu count g^{-1} soil). At Peruvullum, cow based bio formulations notably recorded highest bacterial population (11.7 × 10^6cfu count g^{-1} soil) over control (7.0 × 10^6 cfu count g^{-1} soil) and RDF treatment (8.7×10^6 cfu count g^{-1} soil).

The seed and straw yields in chickpea were higher by 68.6 and 52.1% in the RDF treatment over the control and by 9.3 and 10.3% over the cow based formulation treatment (T_8). At Coimbatore, maximum gross returns (Rs. 78362/ha), net returns (Rs. 40040/ha) and BC ratio (2.0) were recorded by RDF treatment and this treatment resulted in Rs. 14594 and Rs. 2442/ha more net returns over control and cow based bio formulations treatment.

FRONT LINE DEMONSTRATIONS

During *Kharif* & *Summer* 2023 crop seasons, various Front Line Demonstrations (FLD's) on different production aspects [Improved hybrid/variety, Use of biofortified hybrid/variety, Use of improved hybrid HHB 299, Recommended dose of Nitrogen & Phosphorus along with Zn, biomix and herbicide Atrazine +1 HW) *v/s* Farmer's Practices (Use of Pvt. Hybrid, Suboptimal use of N (40-60 kg/ha] were conducted on 666.8 ha area against the target plan of 1000 ha on pearl millet crop in the states Rajasthan, Haryana, Gujarat, Madhya Pradesh, Punjab, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. Adoption of improved production technologies recorded 19.8 to 45.8% higher grain yield compared to the yield recorded with the farmer's practice in Zone A_1, 10.4 to 24.7% in Zone A and the increase was 13.7 to 28.1% in Zone B. During *summer* season recorded 6.7 to 23.6% higher grain yield compared to the yield recorded with the farmer's practice. The FLD's on Biofortified hybrid/variety was conducted in 586.8 ha area (88.0%) in the state of Rajasthan (340 ha.), Haryana (16.8 ha.), Gujarat (50 ha.), Madhya Pradesh (20 ha.), Andhra Pradesh (90 ha.), Punjab (20 ha.), Tamil Nadu (20 ha.), Karnataka (10 ha.) and Maharashtra (20 ha.). In zone-wise FLD's on Biofortified hybrid/variety 290, 156.8 and 140 ha. in zone A_1, A and zone B, respectively.

PLANT PATHOLOGY

Screening for diseases: During *kharif* and *summer* 2023, Nine trials were conducted on various aspects of pathology at Mandor, Jaipur, Hisar in Zone A_1, and Mandor, Jaipur, Hisar, Gwalior, Jamnagar in Zone A and Mysore, Aurangabad, Dhule, Coimbatore, and Patancheru in Zone B. Total of 259 (+17) entries were screened against downy mildew, blast, rust, smut and ergot diseases. Out of these, 195(+17) entries were found resistant against downy mildew at 60 DAS however, 193 entries against blast, and all the entries found resistant to rust, smut and ergot disease at 60 DAS.

The mean downy mildew incidence 3.0% in Zone A1, 3.0% in Zone A and 3.1% in Zone B was observed at 60 DAS in initial trial, whereas in advanced trial, mean downy mildew incidence is 2.1% in Zone A 1, 1.4% in Zone A and 1.3% in Zone B was observed at 60 DAS. It was also observed that rust and blast continued to be the main diseases of pearl

millet. In Initial trials, the mean blast incidence ranges from 3.9% in Zone A 1, 4.1% in Zone A and 4.5% in Zone B was observed at 60 DAS. Whereas, In Advance trials, the mean blast incidence ranges from 5.1% in Zone A 1, 3.8% in Zone A and 4.3% in Zone B was observed at 60 DAS. The range of downy mildew in the farmer field varied from 0 to 10%. It was observed that blast (up to 80%) and rust (up to 50%) were becoming more severe in the states of Maharashtra and Karnataka was around 10-50%. Blast was recorded 1-80% in majority of the farmers' fields of Maharashtra, Rajasthan, Gujarat, and Karnataka while high rust incidence (50%) was observed in Maharashtra. However, smut and ergot incidence was very low in the most of the surveyed states.

Table 3: Details of highly resistant entries against downy mildew, blast, rust, smut and ergot.

Trial	Total number of entries	Highly resistant entries (No.)				
		Downy Mildew	Blast	Rust	Smut	Ergot
PMPT I	106	95	00	R	R	R
PMPT II	32	32	00	R	R	R
PMPT III	35	33	00	R	R	R
PMPT IV	41	35	-	-	-	-
PMPT V	45	-	00	-	-	-

ENTOMOLOGY

Seven trials in *Kharif* and one in summer (total 8 trials) were allotted to entomology discipline. All the allotted experiments were conducted successfully.

Trial	No. of entries/ treatments	Major insect-pests	Achivements/findings.
PMET-1A (Jamnagar, and Fatehpur-Shekhawati). **The data of Jaipur centre was not received.**	106 initial lines/ populations were screened against major insect-pests.	Shoot fly	**This pest was observed at Jamnagar and Fatehpur Shekhwati.** **At vegetative stage**, none of the entry was found resistant. Nineteen entries were moderate resistant, 62 entries were tolerant, 23 were susceptible and two were highly susceptible. The overall range of incidence was 2.78% (MH 2742) to 23.36% (MH 2772). The overall average incidence was 8.25%. **At ear head stage**, one entry was found free from damage (Resistant, MP 632), nine were moderate resistant, 39 were tolerant, 51 were susceptible and six were highly susceptible. The overall range of incidence was 0.0% (MP

Trial	No. of entries/ treatments	Major insect-pests	Achivements/findings.
			632) to 23.17% (MH 2799). The overall average incidence was 11.29%.
		Stem borer	**<u>This pest was observed at Jamnagar and Fatehpur Shekhwati.</u>** **<u>At vegetative stage</u>**, 13 entries were found resistant, 35 were moderate resistant, 38 were tolerant and 20 were susceptible.The range of incidence was 0.0 to 18.22%. **<u>At ear head stage</u>**, 55 entries were found resistant and 51 were moderate resistant and the range of incidence was 0.0-3.71%. The overall incidence was higher at vegetative stage (5.81%) as compared to ear head stage (0.72%).
		Helicoverpa armigera	**<u>This pest was observed at Jamnagar and Fatehpur Shekhwati.</u>** The larval population of *H. armigera* recorded at ear head stage revealed that five entries were found free. The range of population was 0.0 to 5.75 larvae/5 ear heads and the average population was 0.84 larvae/5 ear heads.
		Grey weevil	**<u>This pest was observed only at Fatehpur Shekhwati.</u>** Seventeen entries were found free. The range was 0.0-2.50 damage score and the mean score was 0.88.
		Leaf roller.	**<u>This pest was observed only at Fatehpur Shekhwati.</u>** Five entries were found free. The range was 0.0-5.50 damage score and the mean score was 1.64.
PMET-1B (Jamnagar, FPS & Jodhpur) **The data of Jaipur centre was not received.**	32 Advance lines were screened against major insect-pests.	Shoot fly	**<u>This pest was observed at Jamnagar and Fatehpur Shekhwati.</u>** **<u>At vegetative stage</u>**, none of the entry was found resistant (0.0%) or moderate resistant. Eleven entries were found tolerant and the range of incidence was 6.18% to 23.19% and the mean incidence was 12.34%. **<u>At ear head stage</u>**, one entry (MH 2723) was found Resistant, 19 were moderate resistant

Trial	No. of entries/ treatments	Major insect-pests	Achivements/findings.
			and 10 were tolerant and the range of incidence was 0.0 to 14.93%. The overall incidence was higher at vegetative stage (12.34%) as compared to ear head stage (4.70%).
		Stem borer	**<u>This pest was observed at Jamnagar and Fatehpur Shekhwati.</u>** At vegetative stage, none of the entry was found resistant, 16 were moderate resistant and 15 were tolerant and the range of incidence was 1.23-16.06%. At ear head stage, 23 entries were found free-resistant and the range of incidence was 0.0% to 5.56%. The overall incidence was higher at vegetative stage (5.34%) as compared to ear head stage (0.67%).
		Helicoverpa armigera	**<u>This pest was observed at Jamnagar and Fatehpur Shekhwati.</u>** The larval population of *H. armigera* recorded at ear head stage revealed that none of the entry was found free. The range of population was 0.17 to 3.33 larvae/5 ear heads and the average population was 1.40 larvae/5 ear heads
		Grey weevil	**<u>This pest was observed only at Fatehpur Shekhwati.</u>** None of the entry was found free. The range was 1.0-3.67 damage score and the mean score was 1.29.
		Leaf roller.	**<u>This pest was observed only at Fatehpur Shekhwati.</u>** One entry (MH 2715) was found free. The range was 0.0-4.33 damage score and the mean score was 1.45.
PMET-2 (Jamnagar, Anand, Fatehpur-shekhawati, Jaipur,	Monitoring on insect-pest on Research Station	**Incidence:** At Jamnagar (Gujarat), *Helicoverpa* larvae (8.91/5 ear heads), chaffer beetle (2.18/5 EH), *Eublema* larvae (12.82/5 EH) and hairy cater pillar larvae (8.36/5 EH) were found to be highest. At Jaipur, white grub damage per cent was high (3.99%). At Mandor-Jodhpur, grass hopper (6.15%) and leaf roller (5.77%) was high. At Fatehpur-	

Trial	No. of entries/ treatments	Major insect-pests	Achivements/findings.
Jodhpur, Aurangabad & Hisar), *Total- 7 locations		Shekhawati, shoot fly (25.00%), stem borer (11.67%), termite (8.75%), blister beetles (3.67/5 EH) and grey weevil damage score (3.08) was high. At Aurangabad FAW (8.00%) was high. At Anand and Hisar the insect-pest incidence was low to moderate. **Losses:** The average losses in grain and fodder were 18.10% and 18.87%, respectively.	
PMET-3 (Jamnagar, Anand, Jaipur, FPS, Aurangabad & Hisar) *Total- 6 locations.	Survey of insect-pests at farmer's fields	147 fields in Gujarat (Jamnagar & Anand centres), 141 fields in Rajasthan (Jaipur & Fatehpur-Shekhawati centres), 54 Fields in Haryana (Hisar centre) & 27 fields in Maharashtra (Aurangabad centre) were surveyed for insect-pest infestations at farmer's fields. **Grass hopper** (5.48%), **grey weevil** damage score (1.82) and leaf **roller damage** per cent (1.78%) was highest in Gujarat farmer's fields surveyed. Whereas, **Shoot fly** (16.86%), **stem borer** (5.89%), **white grub** (4.60%), **termite** (3.89%), ***Helicoverpa*** (10.44 larvae/ 5 ear heads) and **blister beetles** (3.55/5 ear heads) were highest in Rajasthan surveyed fields.**FAW** was recorded only in Maharashtra (8.89%) farmer's fields. **Chaffer beetle** (1.1/5 ear heads) was highest in Haryana fields surveyed.	
PMET-5 (Jamnagar, Jodhpur & FPS) *Total- 3locations	Nine chemicals were tested for *Helicoverpa armigera* management in pearl millet.	The spray of emamectin benzoate 0.002% recorded lowest larval population after 24hrs, 3 days and 7 days of spray as well as recorded the highest grain and fodder yield along with ICBR.	
PMET-7 (Jamnagar and Anand in Gujarat)	Survey of insect-pests of summer pearl millet on farmers' field.	Survey was carried out in pearl millet at farmer's fields (138 fields) during summer by Jamnagar and Anand centre in Gujarat. The overall pest incidence was low. **Shoot fly** (av.1.57%) and **stem borer** (av.2.12%), were the major pest followed by ***Helicoverpa armigera*** (0.88 larvae/ 5 ear heads) in surveyed fields. **Grey weevil** (0.86 damage score) and **FAW** (0.14%) was very low. The natural enemy **lady bird beetle** (av. 0.19 beetles/5 plants) and **chrysopa** (av. 0.16 adults/ 5 plants) were also observed in very low numbers in surveyed fields.	

Trial	No. of entries/ treatments	Major insect-pests	Achivements/findings.
PMET-8 (Jamnagar, Anand, Jodhpur, Jaipur and Anatapur) *Total-5 locations	Storage trial-34 advance entries were screened against *Tribolium* and *Rhizopertha*		**Jamnagar:** On the basis of per cent grain damage (up to 1.0%), adult emergence (up to 50 adults/100g seeds), per cent weight loss (up to 5.0%) and germination percentage (above 95.00%) at 6 months storage period PB 1705 and MPMH 21 were found to be most promising against ***Tribolium sp***.
			Anand: On the basis of per cent grain damage, adult emergence and per cent weight loss at 6 months storage period the entries viz., HHB 67 imp., Pusa 383, GHB 1294, PB 2118621, Pusa comp-728, Pusa 2103, PB 1939, AHB 1269 and KBH 108 were found to be most promising against ***Rhyzopertha dominica***.
			Anantapur: On the basis of per cent grain damage, adult emergence, per cent weight loss and germination percentage at 6 months storage period the entries *viz.*, MH 2553-MPMH 42, MH 2555-GHB 1294, MH 2661-EDV 538 Imp-4, MH 2619PB 2118621, MH 2577-HBH 191294, MH 2580-86M93, MP 613-GBL-6, MPMH 21 , RHB 177, AHB 1200 , HHB 272 , MPMH 17 , PB 1705 , 86M01 , Pratap, AHB 1269 , NBH 5767 , KBH 108 , 86M86 and MP-7792 performed better against ***Rhizopertha dominica***.
			Mandor-Jodhpur: The entry MP 612 recorded lowest per cent grain damage, adult population of ***Rhizopertha*** and weight loss and highest germination percentage.
			Jaipur: Not Reported.
PMET-9 (Jamnagar, Anand & Jaipur, Jodhpur & Aurangabad) *Total- 5 locations.	Monitoring of **Fall Army worm** (*Spodoptera frugiperda*) in *Kharif* pearl millet The moth catches were low and it was observed only at Jamnagar (0-0.82 adults/ pheromone trap) and Aurangabad (0-0.6 adults/ pheromone trap). Whereas, at rest of the locations no catches were observed.		

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