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REVIEW OF PEARL MILLET RESEARCH

Pearl millet (*Pennisetum glaucum* (L). R. Br.) is cultivated on about 30m ha in more than 30 countries of five continents viz. Asia, Africa, North America and Australia. At individual country level, India has the largest area (7 million ha) with 9.25 million tons of production, Pearl millet is ranked third after wheat and rice and is grown in Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, Haryana, Tamil Nadu, Andhra Pradesh and Karnataka.

Most of pearl millet in India is grown in rainy (*kharif*) season (June-September) but is also cultivated during summer (February-May) in Gujarat, Rajasthan and Uttar Pradesh and during post-rainy (*rabi*) season (November-February) at a small scale in Maharashtra and Gujarat. During *kharif* season, pearl millet is largely grown as rainfed crop except in some areas in eastern Rajasthan, southern Haryana and western Uttar Pradesh where supplemental irrigation is provided in case of shortage of rainfall during the crop season. Summer season pearl millet is cultivated as an irrigated crop under high levels of agronomic management.

Pearl millet is primarily grown for food and dry fodder. The latter is major component of livestock ration during the dry period of year. Pearl millet is also an excellent forage crop because of its lower hydrocyanic acid content than sorghum. Its green fodder is rich in protein, calcium, phosphorous and other minerals with oxallic acid within safe limits.

Its grain are mainly used for human consumption in the form of food but mostly as leavened and unleavened flat breads and porridges. Several bakery product and extruded and weaning food products are also prepared. Besides, pearl millet grain is a highly nutritious with high levels of metabolizable energy and protein and more balanced amino acid profile than maize or sorghum. Its grains have high densities of iron and zinc the two most important micro-nutrients for which widespread deficiency in human population had been reported worldwide, including India. A significant portion of pearl millet grain is also used for non-food purpose such as poultry feed, cattle feed and alcohol extraction.

Enormous accomplishments have been made in pearl millet improvement during the last 25 years. Genetically diverse germplasm and breeding materials with adequate disease resistance have been strategically utilized in the breeding of hybrid parental lines resulting in development of hybrids with good adaptation to diverse production environments. High productivity combined with appropriate maturity duration (mostly 75-85 days) as per the agro-ecological requirements, and downy mildew resistance have been given the highest priority in the cultivar development programme using both conventional and molecular breeding techniques. A total of 115 improved cultivars were released during the last 30 years, which provided a wider cultivar choice to farmers in various agro-ecological regions.

Agronomic research conducted through AICRP on pearl millet included both research station experiments and on-farm extension trials that led to the establishment of detailed recommendations for individual pearl millet growing zone with respect to time of sowing, seed rate, weed management, fertilizer application (including bio-fertilization), cropping

systems and moisture conservation. Proper agronomic recommendations made it possible to harness the yield potential of high-yielding hybrids and varieties.

High-yielding hybrids and open-pollinated varieties (OPVs) have been widely adopted by Indian farmers. Currently, nearly 65% of pearl millet area is under improved cultivars, mainly hybrids. Following the adoption of high-yielding and disease resistant cultivars, pearl millet productivity has gone up from 539 kg/ha during 1986-90 to 1186 kg/ha during 2010-15 registering a 73% improvement, which is highest among all food crops. The rate of improvement in pearl millet productivity during 1986-2014 has been 20 kg/ha/year as compared to 6.3 kg/ha/year during 1960-1985.

Pearl millet improvement research in India is carried out through the All India Coordinated Research Project on Pearl Millet (AICRP-PM) administered by Indian Council of Agricultural Research (ICAR). The AICRP-PM has a network of 14 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 (SAUs) and University of Mysore pursue mandated activities and strategic research on pearl millet in the area of germplasm utilization, improvement, production, protection, value addition etc. The growing conditions for pearl millet vary from near-optimum with high external inputs to highly drought-prone environments. This led to the prioritization of research in cognizance of production constraints and differential requirement of various crop growing regions. Hence, the whole pearl millet area has been divided into zones viz., A1, A and B. Zone A1 is comprised of parts of Rajasthan, Gujarat and Haryana receiving less than 400 mm annual rainfall. Zone A is comprised of the remaining parts of the states of Rajasthan, Gujarat and Haryana and the entire pearl millet growing areas of Uttar Pradesh, Madhya Pradesh, Punjab and Delhi. This zone has sandy loam soils and an annual rainfall of greater than 400 mm. Zone B is comprised of the states of Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh with rainfall greater than 400 mm, heavy soils and mild temperature conditions. The B zone has shorter days compared to A1 and A zones.

MANDATE

- Plan and execute applied and adaptive research of different centers so as to improve pearl millet productivity
- Strengthen research facilities and programmes on drought tolerance in relation to development of restorers, male-sterile lines, hybrids and populations
- Develop efficient production strategy involving response to low inputs, cropping systems, unconventional areas (summer season), and contingency planning
- Strengthen research on downy mildew disease management – basic studies on the causal organism, disease resistance breeding and disease management
- Strengthen research on value addition to the crop to increase income of the farmers
- Collect, introduce, evaluate and distribute the important germplasm to the cooperating centers

The results of the research conducted during 2014-15 are summarized below:

CROP IMPROVEMENT

1. Release of new hybrids

Two hybrids and one variety were released and notified in 2014-15 for different growing regions and seasons. For *kharif* season hybrids NBH 5767 (MH 1785) and NBH 5061 (MH 1812) were released and notified for zone B (South - Central zone) comprising the states of Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. Variety Dhanshakti (ICTP 8203 Fe 10-2) was released and notified across the zones of the country comprising states of Karnataka, Andhra Pradesh, Tamil Nadu, Rajasthan, Haryana, MP, Gujarat, UP and Punjab.

2. Genetic enhancement

A significant progress was made during the year 2014-15 in genetic enhancement of crop. A total of 158 new experimental cultivars were evaluated in 14 trials during *kharif* and *summer* 2014 at 68 test location in the four agro-climatic zones of the country. These genotypes expressed a wide range of grain and stover productivity (Table 1).

Table 1: Details of trials conducted in 2014

Zone	Trials	No. of test entries	Range	
			Grain yield (kg/ha)	Stover yield (q/ha)
A1	IHT Early	14	2370-3086	44-63
	AHPT Early	8	2036-2645	42-62
A	IHT Medium	29	2456-3717	63-93
	IHT Late	35	2622-3948	74-101
	AHT Medium	2	2964-3974	66-89
	AHT Late	7	3274-4314	69-103
	PT	14	1414-2521	41-72
B	IHT Medium	29	2142-3478	36-60
	IHT Late	35	3240-4733	72-107
	AHT Medium	4	2812-3761	44-52
	AHT Late	14	2880-4045	54-75
	PT	14	1256-2583	30-51
A1, A and B	IHT (Fe & Zn)	14	2328-3319	59-87
Summer	SHT	21	4186-5295	71-89

3. 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 2014 were based on 101 A-lines (by name) and 122 R-lines (by name). This is contributing significantly towards genetic diversification of parental lines and ultimately of hybrids in the country.

4. Assessment of grain quality

- A total of 71 test entries were assessed for quality parameters like protein and fat. A wide range in protein content (8.01 - 12.86%) was observed in the test material demonstrating that there exists enough opportunity to select for protein content in addition to high grain and stover yields.
- A special trial for development of high iron and zinc hybrids was carried out in which hybrids MH 2072, MH 2068, MH 2075, MH 2077, MH 2078 and MH 2079 were identified having high iron (71-75 ppm) and zinc (35-42 ppm) content along with high grain yield.
- Iron and zinc content of hybrids tested in advance trials in zone A1, A and B during *kharif* 2014 were also estimated. Range of iron and zinc along with superior hybrids are presented in table 2.

Table 2: Zone-wise details of superior pearl millet test hybrids and varieties containing high iron and zinc

Trial	Hybrid	Iron (ppm)	Zinc (ppm)
AHT (M)-A	MH 1928	51	33
AHT (M)-B	MH 1852	65	36
	Pratap	63	37
	MH 1930	57	34
AHT (L)-A	MH 1939	54	35
	MH 1888	57	39
	86M86	56	40
AHT (L)-B	MH 1888	55	33
	86M64	60	41
	MH 1964	55	31
	B 2301	57	38

5. Breeder seed Production

During the current year breeder seed production of 13 parental lines (A, B & R) of hybrids and of 12 OPVs was organized. A total of 36.29 q of breeder seed was produced which was much higher than the indented quantity of breeder seed (9.04 q) from Department of Agriculture and Cooperation, Ministry of Agriculture.

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

- The DUS testing was undertaken as per approved guidelines of PPV & FRA during *kharif* 2014. A total of 59 candidate varieties including 25 for second year and 34 for first year along with 18 reference/example varieties were tested at AICRP on Pearl Millet, Jodhpur and MPKV, Rahuri. Observations on candidate and reference varieties for twenty six characters were recorded as per general and specific DUS guidelines. During the year under report seven cultivars and parental lines namely KBR 780, JKBH 768, MP-7872 (MH-1610), JKBH 778, AKASH (VBBH 350) and KBR 870 were registered with PPV and FRA and several are in the process of registration. So far 81 cultivars and parental lines (33 Public and 48 Private) have been registered with PPV and FRA.
- The monitoring team led by Dr. H.P. Yadav at AICRP on Pearl Millet, Jodhpur on October 11, 2014 and members of monitoring team at Rahuri on October 14, 2014 visited the DUS experiments.
- One-day training programme for awareness on Protection of Plant Varieties and Farmers' Right and DUS testing at AICRP on Pearl Millet was organized at Jodhpur on October 07, 2014 in which 14 scientists/technical persons at AICRP on Pearl Millet participated.
- One day awareness programme on provisions for farmers rights under Protection of Plant Varieties and Farmers' Rights Act-2001 on February 21, 2014 was organized at MPKV, Rahuri and 160 participants including tribal farmers participated.

7. ICAR-ICRISAT partnership research

A total of 146 R lines and 106 B lines were assessed by breeders at 18 locations on AICRP centers and cooperating centers. Superior entries were selected for utilization in their breeding programme. Selected 75 advance genetic material from various centers were also assessed for high iron and zinc content. Phenotyping of selected material was accomplished for mapping QTL for downy mildew and drought tolerance. High forage population lines (23) were evaluated during summer 2014 for green fodder yield, leaf stem ratio and dry matter percent. Heat tolerance nursery comprising of 90 breeding lines (80 B- and 10 R-lines) and a Heat Tolerant B-Composite was evaluated at 3 locations along with 5 checks (2 heat tolerant checks: 86M11, 86M64; and 3 heat susceptible checks: ICMB 04555, ICMB 10999, and ICMR 08666) for flowering period heat stress during Summer- 2014. Data were considered only for those plants which got exposed to air temperatures of $\geq 42^{\circ}\text{C}$ during flowering time. Amongst identified designated parents, ICMB 02333, 04888, 04999, 05666, 06666, and ICMR 09222 had seed setting (SS) of $> 50\%$, and 5 other B-lines had SS of $\geq 50\%$. Seed set in Heat Tolerant B-Composite varied from 55-90%.

RESOURCE MANAGEMENT

Five different agronomy trials on the aspects of nitrogen management in advance hybrid & population entries (early, medium and late) during *kharif* season and in the newly released hybrids during summer season, integrated nutrient Management (INM) for pearl millet hybrids under optimum management, nutrient management through major and trace elements in the pearl millet under rainfed situations, integrated weed management in pearl

millet and to evaluate the comparative performance of advance entries during *kharif* & summer seasons of 2014 were conducted in different agro climatic zones (Zone A1, A and B).

The salient achievements are as below:

- Response of advance entries to different nitrogen levels study showed that in Zone A1, the performance of advance test hybrid entries MH 1777, MH 1837 and MH 1831 in terms of grain yield was found significantly better than the check HHB 67 Imp.; in Zone A, the advance entry MH 1890 was the highest grain yielder and it produced 4.7% higher grain yield than the check Nandi 61 and in Zone B, entries MH 1904 (3590 kg/ha) and MH 1901 (3692 kg/ha) produced quite higher grain yield over both the checks Pratap (3028 kg/ha) and 86M64 (3033 kg/ha). There was significant increase in the grain and fodder yield up to 40 kg N/ha in Zone A1, whereas, the increase was up to 90 kg N/ha in Zone A & B.
- During the summer season in Zone A & B, the grain and fodder yield of pearl millet increased significantly up to 120 kg N/ha and both the advance entries MSH 276 and MSH 278 produced more mean grain yield (5545 & 5599 kg/ha) than check 86M64 (5336 kg/ha).
- INM studies carried out among three different hybrids in each zone showed the superiority of treatment 75% of RDF + PSB + *Azospirillum* + 5.0 t FYM/ha over RDF alone in Zone A1 & Zone B. In Zone A, seed treatment with bio inoculants *Azospirillum* and PSB in addition to RDF was the best one & it improved the grain and dry fodder yield to the tune of 8.2 and 12.3% over the RDF alone. Among the hybrids, HHB 67 Imp. in Zone A1, RHB 173 in Zone A & 86M86 in Zone B were the best grain yielder.
- Integrated weed management (IWM) studies under rainfed situation revealed that post emergence application of Atrazine @ 0.4 kg/ha followed by one hand weeding at 35 DAS was found better than the already recommended pre-emergence application of Atrazine @ 0.5 kg/ha followed by one hand weeding at 35 DAS practice in Zone A1, whereas, both these treatments were found at par in other two Zones A & B.
- Nutrient management studies revealed that application of 5.0 t FYM/ha improved the grain yield by 9.9, 12.6 and 12.5% over no FYM in Zone A1, A & B, respectively. The application of ZnSO₄ in combination with RDF produced higher grain yield compared to RDF alone in Zone A1 & A and use of other micro & trace nutrients (FeSO₄, Borex and Gypsum) along with RDF did not result in much improvement in the yield. Application of ZnSO₄, FeSO₄, Borex and Gypsum in addition to the RDF recorded 13.2, 12.0, 11.2 and 9.3% higher grain yield than recorded with RDF alone in Zone B.
- There was a decrease of 5.3 and 107.4% in Zone A1; 11.1 and 82.7% in Zone A and 11.5 and 61.8% in Zone B in the grain yield in D2 (July 25-30) and the D3 (August 10-15) sowings compared to the D1 (July 10-15). The interaction effect between dates of sowing and advance entries was found significant in Zone A1 & A, thereby, indicating differential behavior of the pearl millet entries with delayed sowing.

TECHNOLOGY DEMONSTRATED

During *kharif* 2014 crop season, various Front Line Demonstrations (FLD's) on different production aspects (Chemical weed management through Atrazine, use of micro nutrient $ZnSO_4$, moisture conservation practices, use of recommended dose of NPK, improved hybrid/ variety, opening of furrows in between two rows at 30-35 DAS and sowing of pearl millet at wider row spacing of 90-120 cm.) were conducted on 186 ha area against the target plan of 200 ha on pearl millet crop in the states of Rajasthan, Gujarat, Haryana, Madhya Pradesh, Tamil Nadu, Karnataka, Maharashtra and Andhra Pradesh. Adoption of improved production technologies recorded 21.1 to 30.2% higher grain yield compared to the yield recorded with the farmer's practice in Zone A1, 10.1 to 23.8% in Zone A whereas, this increase was between 13.2 to 63.0% in Zone B. During summer season in Gujarat state, the grain yield of 2944 kg/ha was obtained with improved cultivation practices as against 2710 kg/ha recorded with farmer's practices and improving the grain yield by 8.6%.

PLANT PHYSIOLOGY

Five physiological trials were conducted at Mandor, Jaipur and Jamnagar during summer and *kharif* 2014.

Table 3: Summary of Physiology trials conducted in 2014

Trial	No. of treatments	Title
PMPHY I	24	Screening of advance summer hybrids against terminal stress
PMPHY II	13	Characterization for drought tolerance in pearl millet genotype
PMPHY III	7	Effect of foliar spray on agronomic parameters
PMPHY IV	5	Varietal characterization in pearl millet on the basis of root shoot traits
PMPHY V	5	Physiological mechanism of drought tolerance in pearl millet at early seedling stage

PMPHY-1: At Jamnagar under terminal stress condition MSH 278, MSH 276 and MSH 284 were the highest yielder among advance summer hybrids.

PMPHY-2: B-lines (109SB13, 106SB13, 98222B and 99222B) and inbred line (J 2290, J 2532 and J 2580) were high yielder under terminal stress condition

PMPHY-3: Among various growth substances potassium chloride (1.50%) improved grain yield and fodder yield (2071 kg/ha and 3833 kg/ha) followed by the Benzyl adenine applied @ 50ppm (1875 kg/ha and 3792 kg/ha) at Mandor and at Jamnagar 3450 kg/ha, 4869 kg/ha, respectively. Whereas, at Jaipur, benzyl adenine applied @ 50ppm gave highest

grain yield (1537 kg/ha) and the stover yield was found highest (5425 kg/ha) in potassium chloride.

PMPHY-4: Five genotypes namely, HHB 67 Improved, RHB 177, HHB 256, RHB 173 and GHB 558 were studied for drought tolerant parameters, viz; shoot length, root length, shoot fresh weight, root fresh weight, shoot dry weight and root dry weight at three location (Mandor, Jaipur and Jamnagar). The genotype RHB 173 exhibited maximum shoot length, shoot dry weight and GHB 558 exhibited maximum root length, shoot fresh weight, root fresh weight, and root dry weigh. Thus, these two hybrids can perform better under water stress conditions.

PMPHY-5: Application of PEG at 5% and 10% adversely affected all the drought tolerating parameters namely, shoot length, seedling dry weight, relative water content, membrane stability index, chlorophyll content decreased significantly with PEG induced water stress in all the hybrids while root length and catalase activity increased significantly under water stress. The hybrids MH 1969 and MH 1970 performed better both under non stress and water stress conditions owing to maintain higher RWC, MSI Chlorophyll content and catalase activity at 10 and 20 days after sowing at Jaipur. Only one hybrid (MH 1970) performed better under PEG induced water stress condition in 10 and 20 days old seedling at Mandor as well as Jamnagar.

PLANT PATHOLOGY

Screening for diseases: During *kharif* and Summer 2014 a total of 353 entries were screened against downy mildew, smut, rust, blast and ergot. Eight pathological trials were conducted at Mandor, Jaipur, Hisar, Gwalior, Jamnagar and Anand in zone A; and at Mysore, Aurangabad, Dhule, Coimbatore and Patancheru in zone B. Out of these, 157 entries were highly resistant showing $\leq 5\%$ downy mildew incidence at 60 days after sowing at all India level. In addition, surveys were conducted at farmer's field to assess overall disease scenario during the crop season. The diversity in downy mildew pathogen was also characterized. The mean downy mildew incidence at 60 days after sowing was 4.87% in zone A and 5.51% in zone B, indicating good resistance to downy mildew in test entries evaluated in Initial Trial. Similarly, mean downy mildew incidence in genotypes evaluated in Advance Trial was 6.98% in zone A and 5.06% in zone B at 60 days after sowing. During field surveys, it was observed that downy mildew and blast continued to be the main diseases of pearl millet. The range of downy mildew in the farmers' field varied according to the cultivar. It was observed that blast was becoming more severe in the states like Rajasthan, Maharashtra and Madhya Pradesh. Fields in Tamil Nadu and Karnataka were free from blast incidence. High rust incidence was observed in Maharashtra where up to 30% rust was recorded during the field survey. Ergot incidence was observed in Rajasthan, Tamil Nadu and Karnataka and smut incidence was very low in the most of the fields surveyed.

Table 4: Details of highly resistant ($\leq 5\%$) entries at All India level at 60 DAS

Trial	Total number of entries	Highly resistant entries (No.)	Range (%)
PMPT I	124	78	0.38 (MH 2040) – 23.93 (MH 2058)
PMPT II	55	26	1.29 (GHB 744) – 24.24 (B 2301)
PMPT III	30	15	1.18 (KBH 108) – 21.78 (B 2301)
PMPT IVa	65	17	2.20 (HHB 67-2 Imp) – 91.50 (7042 S)
PMPT VII	24	21	0-11.89 (86M64)

ENTOMOLOGY

Screening for insect-pests: Trials were conducted at Jaipur and Jamnagar in which 55 genotypes were tested against key pests of pearl millet as per detail given below. There was a wide range in insect infestation in various treatments.

Table 5: Summary of entomology trials conducted in 2014

Trial	No. of entries/treatments	Major insect-pests
PMET- I	55	Shoot fly, stem borer, grey weevil, leaf roller and <i>Helicoverpa armigera</i>
PMET- II	Monitoring on Research Farm	Shoot fly, stem borer, leaf binder, grass hopper, jassid, thrips, Flea beetle, Coccinelid beetle, Chrysopa, Blister beetle, earhead beetle, Termite and <i>Helicoverpa armigera</i>
PMET- III	Survey on Farmers' field	Shoot fly, stem borer, leaf binder, grass hopper, Termite, <i>Helicoverpa armigera</i> , jassid, thrips and White grub
PMET- IV	8	Shoot fly and stem borer
PMET- V	4	Shoot fly, stem borer, and <i>Helicoverpa armigera</i> and White grub
PMET -VI	7	Storage grain pest of pearl millet
PMET -VII	11	White grub

WORK DONE AT COE PEARL MILLET CCS HAU, HISAR

Training camps organized in Villages: In villages preparation of pearl millet traditional products viz; laddoo and sev, baked products and cake was demonstrated. Information regarding nutritional importance of pearl millet and setting up of enterprise of Pearl Millet products was also given.

Table 6: Details of training camps organized in villages by CCS HAU Hisar

S. No.	Village	Date
1	Lehroda (Sonipat)	October 27, 2014
2	Nallod (Rohtak)	November 25, 2014
3	Rewarikhera (Jhajjar)	December 10, 2014
4.	Sirdhaan (Fatehabad)	January 17, 2015
4.	Gurgaon Village (Gurgaon)	February 02, 2015
5.	Pali (Rewari)	March 02, 2015
6.	Gothra (Rewari)	March 03, 2015

Training Course for DES: Refresher course was organized for all the DES (Home Science) from various KVK on January 28-29, 2015. They were given information on nutritional importance processing of pearl millet, entrepreneurial scope and demonstration on various bajra based value added products.

Training Organized By DES: All DES (Home Science) trained under COE Pearl Millet organized trainings for ladies in areas of different districts of Haryana under KVK's where they are working. Forty trainings were organized.

Awareness campaigns: Awareness campaigns were organized to create awareness about nutritional importance and value addition of pearl millet and to increase its consumption among rural and urban masses. Four awareness campaign were organized during 2014-15. During campaigns, participants were given information on the nutritional importance of pearl millet and value added products which can be prepared from pearl millet. The participants were also given information on entrepreneurial potential of Pearl millet products on small and large scale. The Samples of pearl millet products were distributed among masses for creating awareness on alternative uses of pearl millet.

Product Development:

- Development of laddoo, sev and Dhokla, cake, biscuits, noodles, pasta already complete.
- Gluten free biscuits have also been developed.
- Convenience products/Kulcha is under process for standardization.



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