Proceedings of the International Millets Conference 2023

Promoting Millets through Interdisciplinary Research: New Varieties and New Markets for a better Tomorrow!

Eds.: Dipak Santra and Sanjib Bhuyan

August 1 - 3, Gering Civic Center
Gering, Nebraska, USA

Organized by: University of Nebraska-Lincoln, Rutgers University, and North American Millets Alliance

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PROGRAM of the International Millets Conference 2023 (https://preec.unl.edu/international-millets-conference-2023)

August 1-3, 2023, Gering, Nebraska, USA[1]

Organizing Committee Chairs: Dr. Dipak Santra (University of Nebraska – Lincoln, USA) AND Dr. Sanjib Bhuyan (Rutgers University – New Jersey, USA).

Members: Dr. Kishor Goswami (IIT Kharagpur), Mr. Dipanjan Kashyap (IIT Kharagpur), Ms. Dwiti Baruah Thapa (IIT Kharagpur), Mr. Partha Pratim Saikia (IIT Kharagpur), Dr. Rituraj Khound (UNL), Mrs. Kayla Smith (UNL), Ms. Chabela Guzman (UNL), Mrs. Deidra McCarthy (UNL).

DAILY PROGRAM

DAY 1	**Tuesday, August 1, 2023**
12:00 – 12:30 PM	Registration at the Gering Civic Center, Gering, Nebraska
12:30 – 12:45 PM	Meet in front of Gering Civic Center, Gering, Nebraska
12:45 - 1:00 PM	Travel to Legacy Plain Museum (Field tour)
1:00 - 2:30 PM	Field tour-1: Legacy Plains Museum (https://legacyoftheplains.org/)
2:30 - 3:00 PM	Travel to UNL- Panhandle Research and Extension Center (UNL-PREEC)
3:00 - 3:15 PM	Break at the UNL-PREEC
3:15 - 4:45 PM	Field tour-2: UNL-Panhandle Research and Extension Center (https://preec.unl.edu/)
4:45 - 5:00 PM	Return to Hotel and End of the day (Dinner on your own)
DAY 2	**Wednesday, August 2, 2023**
8:00 - 8:30 AM	Registration; Load the bus at the Gering Civic Center for the Field Tour to Sidney
8:30 - 10:00 AM	Travel to Sidney, NE (Field tour)
10:00 - 11:00 AM	Touring the High Plains Ag. Lab (UNL's Dryland Research Farm), Sidney, NE
11:00 - 11:30 AM	Travel to Kriesel Certified Seed, Gurley, NE
11:30 - 12:30 PM	Certified seed (wheat, millets, barley, oat) production, processing, and marketing
12:30 - 1:30 PM	Lunch (provided, courtesy Kriesel Certified Seed, Gurley, NE)
1:30 - 3:00 PM	Returning to Gering Civic Center, NE

[1] We gratefully acknowledge funding from the FAS/USDA under its competitive EMP Agreement (USDA-FAS-EMP-2021-18-831243) with Rutgers University, New Jersey to host this conference event. Additional support was received from the following entities: Dryland Genetics, LLC. IA; Golden Prairie Millet, CO; Rakshi Sprits Company, CO; and Koval Distillery, IL.

3:00 - 3:15 PM	Opening and welcome by Prof. Dipak Santra and Prof. Sanjib Bhuyan, Co-chairs of the Conference
3:15 - 3:45 PM	Craig Anderson, Dryland Genetics, LLC., Ames, IA.
3:45 - 4:30 PM	Gary Wietgrefe, Farmer and Millet Advocate, Rapid City, SD.
4:30 – 5:00 PM	Stum, Christopher, Farmer (owner, Trinity Grains, LLC.) and President, High Plains Millets Association, Towner, CO.
5:00 PM	Concluding the day with housekeeping (Dinner on your own)
DAY 3	**Thursday, August 3, 2023**
TRACK 1	**AGRONOMY/GENETICS**
TRACK 2	**PRODUCTS/ECONOMICS**
8:00 - 8:15 AM	Gather in the Gering Civic Center + Housekeeping (Dipak Santra)
8:15 - 10:00 AM	***SESSION I – TRACK 1 (MODERATOR/CHAIR: Calistus Efukho)***
8:15 - 8:30 AM	Dipak Santra (Title: Proso millet of the High Plains of the USA)
8:30 - 8:55 AM	Jürg Hiltbrunner (Title: 1. Millet research in Switzerland, and 2. Millet processing for other products than dehulled grains and flakes)
8:55 - 9:15 AM	S.K. Gupta (Title: Pearl Millet Research at ICRISAT: Regional priorities and Global implications)
9:15 - 9:35 AM	David Brenner (Title: Proso Millet Crop Vulnerability)
9:35 - 10:00 AM	**Q&A and Panel discussions**
10:00 - 10:15 AM	**Coffee break**
10:15 - 12 NOON	***SESSION II – TRACK 2 (MODERATOR/CHAIR: Jenna Zahller)***
10:15 - 10:35 AM	Nivedita Deka (Title: Prospects of Millet Production in Assam, India: A Farm level Study)
10:35 - 10:55 AM	John Westra - Director, UNL-PREEC and Agril. Economist (Title: Role of Panhandle Research and Extension Center in Nebraska Panhandle Agriculture)
10:55 - 11:15 AM	Niharika Borbaruah (Title: Consumers' Awareness on Millet Based Products in Assam, India)
11:15 - 11:35 AM	Jumbo Uche (Title: The Journey of a Millet Entrepreneur)
11:35 - 12 NOON	**Q&A and Panel discussions**
12 NOON - 1 PM	**LUNCH BREAK (on site)**

1:00 - 2:45 PM	***SESSION III – TRACK 2 (MODERATOR/CHAIR: Craig Anderson)***
1:00 - 1:20 PM	Sheila Purdum (Title: Millet Seed in Poultry Diets)
1:20 - 1:40 PM	Dipanjan Kashyap (Title: An Analysis of the Poultry Feed Supply Chains in India)
1:40 - 2:00 PM	Kishor Goswami (Title: Agricultural Raw Materials Import Competition for Animal Feeds in India)
2:00 - 2:20 PM	Sanjib Bhuyan (Title: An Empirical Analysis of India's Import Demand Functions for Millets, Corn, and Soybean)
2:20 - 2:45 PM	**Q&A and Panel discussions**
2:45 - 3:00 PM	**Coffee break**
3:00 - 4:45 PM	***SESSION IV – TRACKS 1 & 2 (MODERATOR/CHAIR: John Waithaka Ruguru)***
3:00 - 3:20 PM	Rituraj Khound (Title: Genetics and Genomics of Proso Millet (*Panicum miliaceum* L.)
3:20 - 3:40 PM	Pratiksha Baishya (Title: Proso millet Market and Consumer Study)
3:40 - 4:00 PM	Leon Kriesel (Title: Producing certified Proso millet Seeds)
4:00 - 4:20 PM	Calistus Efukho (Title: Producing Millets in Kenya)
4:20 - 4:45 PM	**Q&A and Panel discussions**
4:45 - 5:00 PM	**Vote of Thanks (Dipak Santra and Sanjib Bhuyan, Co-Chairs of the Conference)**
5:00 - 6:00 PM	Go and do as you like.
6:00 - 9:00 PM	**Conference Closing Banquet dinner (on site)**

THANK YOU for MAKING THIS CONFERENCE A SUCCESS!

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Opening and Keynote Talks

Welcome from the Organizers

Dr. Dipak Santra, Professor (Alternative Crops Breeding Specialist), Dept. of Agronomy and Horticulture, University of Nebraska-Lincoln Panhandle Research and Extension Center, Scottsbluff, NE.

Dr. Sanjib Bhuyan, Professor, Dept. of Agricultural, Food and Resource Economics, Rutgers University – the State University of New Jersey, New Brunswick, NJ.

Agricultural Research Centers in Western Nebraska: Challenges and Opportunities for Millet Production

Dr. John Westra, Director, University of Nebraska Panhandle Research and Extension Center, Scottsbluff, NE and Professor of Agricultural Economics, University of Nebraska-Lincoln

At the UNL Panhandle Research, Extension & Education Center (PREEC), we innovate and conduct research to make life better for Nebraska agricultural producers, rural communities, businesses, children, and families. More than 20 program specialists, extension educators and research scientists work with local stakeholders to identify and prioritize challenges facing western Nebraska. They share ideas and collaborate with colleagues across the nation and world to discover solutions to local problems.

In 1909, the University of Nebraska Experiment Station and the USDA jointly homesteaded a quarter section of land five miles east of Mitchell, NE. Initial research on 109 hectares (ha) was in crop production under gravity irrigation. Studies in sheep, swine, dairy, and beef production, in addition to other crop areas, soon followed. The 324 ha Experimental Range in Sioux County was deeded to the University of Nebraska by President Woodrow Wilson in 1918. The High Plains Agricultural laboratory (HPAL) at Sidney, NE, added 971 ha under management for dryland cropping systems in 1967.

The headquarters of the Panhandle Station moved to the former Hiram Scott College campus after the state had acquired the property after the school closed in the early 1970s. The headquarters and surrounding research plots (63 ha) are located just north of the city of Scottsbluff. A research feedlot at the Mitchel site was expanded in 2007 to accommodate more than 900 head of cattle in 105 pens.

Academic disciplines of faculty are entomology, plant pathology, integrated weed management, irrigation water management, dryland cropping systems, alternative crops breeding (including millet), dry edible bean breeding, soil fertility/nutrient management, crop physiology, feedlot nutrition/management, cow-calf production/range management, rangeland ecology, agricultural economics, and community vitality.

Agriculture in the Nebraska Panhandle is a diverse composition of livestock and crop production. The Panhandle consists of 16 counties in western and north central Nebraska, over 22,000 square miles (56,980 sq km) representing about 30 percent of Nebraska's land area. There are approximately 6,000 farms and ranches in this area, generating $2.2 billion in sales, almost 60 percent from livestock sales, and approximately 40 percent from crop sales. Farm and ranch operations vary in size.

The Panhandle's land and water resources are the key to the region's agricultural productivity. Three-quarters of the agricultural land is native rangeland and pasture which provides forage to raise livestock as well as valuable ecosystems for plants and wildlife. Crop production occurs on the remaining area. Temperature and precipitation vary with latitude and elevation. The average annual precipitation within the Panhandle region ranges from 12 inches (305 mm) in the northern region to over 19 inches (483 mm) in the southeast corner of the Panhandle. Sixty percent of the cropland in the area does not have irrigation water. Crops grown in these conditions are referred to as dryland or rain-fed crops.

Given the semi-arid climate, growers focus on practices that conserve soil moisture, including limiting the amount of tillage or using fallow periods. During the fallow period, no crops are grown for an entire year to allow soil moisture to recharge. Typically, dryland crops are grown using a two- to four-year rotation that includes a fallow period for one year. Winter wheat, proso millet, yellow field pea, sunflower, corn, and annual forages are the primary crops used in dryland crop rotations.

Proso millet is a warm-season grass that in western Nebraska is planted in July and harvested in September. Proso millet produces a small grain used for both feedstock and food grade production in both domestic and international markets. Proso millet prices are extremely volatile in the U.S., with twofold price differences common from one year to the next. This variation in price can result in large swings in the amount of proso millet area harvested in the Panhandle: from approximately 30,000 ha in 1997, to 45,000 ha in 2007, then down to 18,000 ha in 2012. The number of producers of millet has steadily declined over that period (1997-2017) from 375 to around 225 growers. In addition to volatility of prices received for millet affecting area planted to millet, planting decisions for millet primarily are a function of soil moisture at planting. As wheat is the primary cash crop grown in rotation in dryland systems in western Nebraska, having sufficient soil moisture for that crop determines if the land is in fallow or planted to millet.

So, research scientists at the Panhandle REEC are working to develop a decision support tool to help growers make planting decisions for crops like millet that are grown in rotation with winter wheat. Using 30-40 years of historical data from the HPAL site, researchers will build a model that incorporates physical and agroclimatic data, as well as production and price risk information for millet and winter wheat, to help producers determine if they should plant millet or allow the field to be fallow to conserve soil moisture. It is hypothesized that this tool will increase the profitability of these production systems that include millet, and may increase the area planted to millet, and improve millet production practices for growers in western Nebraska.

Sustainable Food for a World with Less Water

Craig Anderson, Dryland Genetics, LLC., Ames, IA.

Acreage Potential of Millets in North American Crop Rotations

Gary Wietgrefe, Farmer, Entrepreneur, and Millet Advocate, Rapid City, SD.

North American's millet potential is projected at 150,000 million acres (>60 million hectares) with institutional, rather than geographic, resistance. Of millets harvested for seed, proso has the most potential as a price competitive grain crop used in rotations with other grains.

United States historic millet acreages vary greatly based on inconsistent U.S. Bureau of Census and U.S. Department of Agriculture's (USDA) changes in reporting criteria. According to USDA survey's for Hay Millet, Johnsongrass, and Sudangrass, total acreage exceeded eight million acres (3.2 million ha) by 1926. The only millet planted and harvested for grain was proso. It was reported in twenty-five states in 1974, but since 1999 only three states, Colorado, Nebraska, and South Dakota are reporting proso acreages, prices and yields.

Nearly all proso is rotated with hard red winter wheat on the fringes of U.S. grain producing areas where 15-20 inches (400-500 mm) of annual precipitation has limited proso yields and caused 13-20% of annual plantings abandoned.

The 300,000 to 700,000 acres (120-280,000 ha) of U.S. proso grain harvested the last sixty years has been used for wild birdseed with ten-twenty percent exported, and approximately one to two percent used for seed and human consumption.

Since 1991, U.S. all wheat acreage has decreased approximately 40 million acres (16.2 million ha) as corn and soybean acres each increased approximately ten million acres (4 million ha) and over twenty million acres (8 million ha) transitioned to Conservation Reserve Programs (CRP).

Millet have been produced in Canada's Prairie Provinces as indicated by the town of Millet, Alberta. However, although proso can be produced in grain rotations, Statistics Canada reports harvested acreages of thirteen crops, but no millet acres are reported.

Although having no officially reported production of pearl, foxtail, Japanese, and brown top millets, their acreage is currently estimated in the range from one and a half to two million acres (607-809,000 ha) planted annually in the U.S. which is mainly used for grazing, hay, chopped, used as cover-crops, and also wildlife plots.

As new, higher yielding proso millet varieties enter the market, proso will be produced for grain and human food in higher moisture and higher yielding winter wheat environments. In the next few years proso is projected to grow to three million acres (1.2 million ha) harvested annually with

50% used for poultry, hog, and cattle feed, 20% converted to ethanol, 15-18% exported, 10-12% for wild birdseed, approximately 2% for food, and one percent used annually for seed.

The biggest opportunities for proso are double-cropping after winter wheat, especially in central Kansas where growing season precipitation is inconsistent and corn and soybean seed, and crop production prices greatly exceed proso.

Proso millet grain prices have historically been priced between corn and wheat on a cents-per-pound basis with organic and higher quality proso priced significantly higher in recent years as U.S. Plains droughts have limited yields. Opportunities exist to establish proso millet prices based on Chicago Corn Futures and Kansas City Winter Wheat Futures prices.

If the world experiences massive volcanic eruptions like caused the 1816 “Year without Summer”, proso millet is the most drought resistant crop and the only short-season grain that can be grown on a large scale for human consumption.

Faithwalk Farm

Christopher Stum, farmer and owner, Trinity Grains, LLC. and President, High Plains Millets Association, Towner, CO.

SESSION I - TRACK 1

Breeding, genetics, and genomics of proso millet as climate resilient food and feed crop of the USA

Dipak K. Santra[1], Rituraj Khound[1], Santosh Rajput[2], and James Schnable[3]. [1]Department of Agronomy and Horticulture, University of Nebraska-Lincoln, Lincoln, Nebraska; [2]Dryland Genetics Inc, 2500 N Loop Dr, Bldg. 7, Ste 7411, Ames, IA 50010, USA; [3]Center for Plant Science Innovation, University of Nebraska-Lincoln, Lincoln, Nebraska, USA.

Proso millet is a short-season, shallow-rooted, and low-water-requiring crop. It is an ideal rotational crop for wheat-based dryland cropping systems in semi-arid High Plains regions of the USA and is primarily used in the bird-food industry. Proso millet certainly is climate-smart, gluten-free, ancient, and small-grain cereal, which is healthy for humans and the environment. Proso millet breeding and genetics program at the University of Nebraska is the only one in the USA. Compared to other crops (e.g., wheat, corn, and rice) proso millet genomic research is extremely limited. The overall research goal is genetic improvement of proso millet through conventional and molecular breeding. Our objectives are to: (1) develop proso millet varieties through breeding, (2) characterize proso millet germplasm for genetic diversity based on DNA markers and important agronomic traits, (3) develop a genetic linkage map based on DNA markers, and (4) identify and map the genes for the important traits.

In 2014, we developed the first waxy proso millet variety, 'Plateau', which is commercially produced in the USA. Six more varieties were soon will be released for commercial production. The U.S. proso millet germplasm was evaluated for agronomic traits (e.g., plant lodging, seed shattering, and grain size) and cross-species DNA markers (e.g., switchgrass, foxtail millet, and sorghum). In a germplasm evaluation study, a total of 77 genotypes from 24 different countries were evaluated in the field at two locations. The genotypes showed significant variations for all the traits across locations. Many traits showed genotype x environment interactions and were highly correlated. Several genotypes were identified as sources of desired traits, such as maturity, lodging, and grain shattering. The genotypes formed six clusters based on morpho-agronomic data. Principal component analysis revealed that these nine traits explained maximum phenotypic variance and could be used as selection indices in proso millet breeding. Two genetic mapping populations were evaluated for the agronomic traits in the field. A total of 500 DNA markers were identified for proso millet. The agronomic traits were segregating in the mapping populations which indicated segregation of the genes controlling the traits.

In a Genome-wide association study (GWAS) study, the US proso millet core collection comprising 109 genotypes were grown at two locations in western Nebraska, of which 71 regionally adapted but globally diverse genotypes were eventually evaluated for five major morpho-agronomic traits, and GWAS was conducted to identify single nucleotide polymorphisms

(SNPs) associated with those traits. Analysis of variance showed that there was a significant difference among the genotypes, and all five traits were also found to be highly correlated with each other. Sequence reads from genotyping-by-sequencing (GBS) were used to identify 11,147 high-quality bi-allelic SNPs. Population structure analysis with those SNPs showed stratification within the core collection. The GWAS identified twenty marker-trait associations (MTAs) for the five traits. These MTAs can be the targets for future candidate gene identification. These genomic regions can also be used to develop genetic markers for marker-assisted selection in proso millet breeding. These results will form a strong foundation for proso millet breeding, genetics, and genomics research for the development of improved proso millet cultivars adapted to the region.

Keywords: Plant genetic resources, Water use, Broomcorn millet, Climate-resilient, and Ancient grain

Millet Research in Switzerland and Millet Processing into Products other than dehulled Grains and Flakes

Jürg Hiltbrunner[1], Gesa Gustodis[7], Hans-Georg Kessler[2], Sophie Klein[7], Roland Kölliker[4], Marco Loschi[6], Nadina Müller[6], Joan Oñate Narciso[3], Hans Ramseier[5], Rubina Rumler[7], Tamara Schmid[6], Regine Schönlechner[7], Daniel Ariza-Suarez[4] and Tiziana Vonlanthen.[1] [1]Agroscope, Reckenholzstrasse 191, CH-8046 Zurich, Switzerland; [2] Biofarm Genossenschaft, CH-4936 Kleindietwil, Switzerland; [3] Department of Food Technology, Engineering and Science, Universitat de Lleida – Agrotecnio CeRCA Center, Avda. Rovira Roure 191, E-25198 Lleida, Spain; [4] Molecular Plant Breeding, Institute of Agricultural Sciences, Department of Environmental Systems Science, Universitaetstrasse 2, ETH Zürich, CH-8092 Zurich, Switzerland; [5] Bern University Applied Sciences, School of Agriculture, Forest and Food Sciences HAFL, Laenggasse 85, CH-3052 Zollikofen, Switzerland; [6] Zurich University of Applied Science (ZHAW), Einsiedlerstrasse 34, CH-8820 Waedenswil, Switzerland; [7] Department of Food Science and Technology, Institute of Food Technology, BOKU - University of Natural Resources and Life Sciences Vienna, Muthgasse 18, A-1190 Vienna, Austria.

Field names (e.g. Hirslanden), parts of villages (e.g. Hirsmühle) or customs (e.g. http://www.hirsebreifahrt.ch/) bear witness to the cultivation of millet (*Panicum miliaceum* L.) in Switzerland in ancient times. After the First World War, only a few hectares were documented (Naef & Grisch., 1923), and consequently knowledge of millet cultivation and processing in Switzerland declined – both among farmers and millers as well as scientists.

The first variety trials were set up in 2001, and after promising initial results, production for human consumption at farm level for organic production started in 2005 with two Russian varieties (Krupnoskoroje and Quartet). Over the next decade, millet area increased steadily but slowly, peaking at 25-30 ha in 2014. Although production is economically attractive (CHF 1600/t), organic farmers need a contract with Biofarm Genossenschaft (Kleindietwil), a farmers' cooperative. This is because demand for Swiss millet is limited. Fortunately, in 2016 the supermarkets Migros and Coop started selling organic Swiss millet flakes. As a result, the area has increased to over 250 ha and more farmers became interested in growing millet because of the good yields and the dry and warm summer conditions in recent years.

To study new varieties, a variety trial of 20 varieties of different origins (genebank, USA, Russia, Poland, Ukraine) was started in 2018. In addition to agronomic observations, the genetic relationship between the varieties grown was also investigated.

Differences were observed for several parameters, e.g. lodging resistance and grain yield. The yield of the tested varieties varied between 1.5 and 6 t/ha, depending on the year and location.

Compared to Quartet, the millet variety grown by Swiss farmers, hardly any other variety produced higher yields.

Spaghetti from millet as well as millet mixed with corn, rice or durum wheat was produced and compared to classical durum spaghetti. The analytical results showed that a firmness comparable to durum spaghetti was obtained with pure millet, 50% millet mixed with 50% corn and rice flour (95:5), and 15% millet mixed with 85% durum wheat. The brownish appearance, slightly rough surface and nutty flavor of the millet spaghetti were particularly popular among consumers with a diet-conscious lifestyle. The millet pasta had a high content of iron, zinc and dietary fiber. Since the production processes were able to be implemented at industrial scale without major additional costs, market implementation seems feasible (Schmid et al., 2023).

When millet flour was used to bake bread (substitution of 20% wheat flour with millet flour), the resulting bread volume was smaller compared to that of pure wheat bread and differences were observed between the millet varieties tested in terms of crumb firmness and various rheological properties.

Some of the currently available millet varieties have interesting traits that can help in the development of other products for human consumption and offer an interesting option for farmers looking for climate-smart crops in Switzerland.

Keywords: Millets variety trial, bread making, pasta, Switzerland

References

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Schmid, T., Loschi, M., Hiltbrunner, J., Müller, N. 2023. Assessment of the suitability of millet for the production of pasta. Applied Food Research, 3(1), https://doi.org/10.1016/j.afres.2022.100247

Acknowledgments: Funding by BioSuisse and Foundation Hauser (Weggis), breeders for providing seeds, as well as inspiring discussions with various persons and the cooperativeness of the farmers where the trials were carried out, is gratefully acknowledged.

Pearl Millet Research at ICRISAT: Regional priorities and Global implications

S.K. Gupta, Principal Scientist (Pearl Millet and Finger Millet Breeding), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India.

Pearl millet grown on about 30 m ha in semi-arid and arid ecologies in Asia and Africa provides nutritious food for humans and its stover is an important component of livestock feed in these marginal ecologies. IFPRI's foresight analysis is quite optimistic indicating increased demand for millets in India and Sub-Sahelian African (SSA) countries by 2050. In a scenario, when pearl millet cultivation is being further pushed to more marginal ecologies across these regions, there is strong need to understand the challenges this crop is facing and then to strategize the approach for enhancing both genetic gains in productivity, nutritional traits, and resilience to climatic and biotic stresses.

Pearl millet is challenged by downy mildew, low soil fertility and extreme drought conditions in both the continents; while millet head miner, striga weed in WCA; and blast and drought in India are the major regional constraints to increase productivity. The production of pearl millet in SSA countries has increased in the last 30 years due to increase in area but there has been almost no productivity increase. On the other hand, India witnessed pearl millet productivity increase at an annual rate of 3%, but rapidly decreasing area is cause of concern.

Indian pearl millet breeding program took a paradigm shift in 1960-70s when hybrids started replacing OPVs leading to rapid increase in productivity, while WCA countries are now working towards for such a change to happen. Indian pearl millet program clearly defined its crop mega-environments, and with strong germplasm support from ICRISAT followed environment-adaptation specific breeding strategy in public and private sectors to develop hybrids (currently occupying about 5 m ha area in India) having high yield potential for different agro-ecologies. Recent investigations evidenced that trait-specific breeding followed in Indian hybrid breeding program led to differentiation of breeding materials into clear cut heterotic pools, separately for seed and restorer parents. Now moving further, highly heterotic B- (seed parent) and R- (restorer parent) heterotic groups have been identified to further elevate genetic gains in pearl millet.

ICRISAT and national programs are continuously restructuring breeding priorities based on farmer- and consumer-driven feedback and updated regularly. Greater emphasis is being laid on high grain yield productivity coupled with disease resistance to enhance cultivar diversity for better endowed environments (with >400 mm rainfall per annum), while screening and breeding approaches are fine-tuned to develop cultivars for highly drought-prone environments (< 400 mm annual rainfall). ICRISAT committed to continuously enhance genetic diversity in pearl millet cultivars recently identified heterotic pools among wide range of African and Asian based pearl millet populations which will go a long way in the development of high yielding cultivars. Recently, Leasyscan system has been standardized at ICRISAT to identify drought tolerant breeding lines/cultivars and a validation process is underway to integrate these new screening systems with breeding programs. Breeding efforts are underway to introgress drought tolerant QTLs in promising genetic backgrounds through forward breeding approaches. ICRISAT in collaboration with advanced ARIs and other research partners has also identified flowering-period heat tolerant sources which have shown high seed set under air temperatures >42°C to enhance cultivar diversity in summer cultivated pearl millet crop in North-Western India, and in several African and Central Asian countries where ambient temperatures are quite high in different crop seasons. Targeted breeding followed by shuttle breeding in target ecology has led to generation of new breeding materials having higher levels of heat tolerance.

Cultivars with improved nutritional traits like high grain Fe and Zn content have been bred and released to mitigate the micronutrient malnutrition. These biofortification traits are now mainstreamed in the breeding pipeline to enhance micronutrients in future pearl millet cultivars. Recently, ICRISAT released first biofortified pearl millet "*Dhanashakti*" in India, and "*Chakti*" in Africa; and released several biofortified hybrids having grain Fe >70ppm and Zn > 35ppm in India and Africa.

Efforts have been made continuously to map downy mildew and blast virulence pathogenicity, to identify disease resistance sources and utilize them in breeding programs to keep breeding programs ahead of pathogen. Multiple disease resistant composites have been developed against downy mildew and blast to provide new gene pools to derive disease resistant breeding lines, and efforts are underway to identify blast resistance in wild species.

To support the livestock feed industry, ICRISAT has been working on exclusive-forage-type cultivars with single/multi cut behavior, having high biomass productivity along with high crude protein and digestibility. While working with International Center for Bio-saline Agriculture (ICBA-Dubai), cultivars have been released for cultivation in salinity affected tracts of central Asian countries. Brazil released series of pearl millet cultivars with high biomass to support livestock feed industry, and cultivars with high grain productivity to support poultry feed industry. WCA programs are now re-orienting towards strengthening disease screening systems, initiating hybrid breeding, encouraging stakeholders especially private sector to invest in quality seed production to enhance millet productivity in the region.

The recent availability of pearl millet genome sequence information is helping to map genes of traits of interest. Genomic selection (GS) model has been recently standardized with high predictive ability of breeding value of hybrid parents (with 0.48-0.51for grain yield, and 0.8 to 0.9 for other important traits) and efforts are underway to further strengthen it to enhance the selection efficiency in future breeding programs. Efforts are in progress at ICRISAT towards introducing Rapid Generation Advancement (RGA) coupled with forward breeding for multiple traits, strengthening of screening protocols (diseases, lodging, early generation testing network), digitalization of breeding programs, identification of new germplasm for biotic and abiotic stresses, and introducing hybrid technology for Africa to finally move towards new phase of higher genetic gains and climatic resilience in pearl millet.

Keywords: Pearl millet, genetic gains, climate resilience, genetic diversity, heat, drought, nutritional traits, heterotic pols, genome sequence, genomic selection

Proso Millet Crop Vulnerability

David M. Brenner, Research Scientist, Iowa State University, Ames, IA.

The second Proso Millet Crop Vulnerability Statement (CVS) was prepared in 2020 and is posted online by the USDA along with Crop Vulnerability Statements for other crops (https://www.ars-grin.gov/CGC (under Forage and Turf Grass)). The 2020 CVS minimizes the threats from disease and insect problems, calls for better proso varieties with less lodging and shattering, and points out competition from subsidized crops as a problem. CVS statements are concise non-technical reports intended for reference by elected officials and their staffs. Potentially new policy and funding could be developed to support CVS priorities.

The 2020 report will be presented and ideas for the next revision sought from the audience. The 2020 CVS has two parts, (1) a seven-page report with tables and references, and (2) a one-page quad chart summary. In 2020 the authors were David M. Brenner, Dipak K. Santra, and J. Bradly Morris. Two of us are plant germplasm curators but only Dipak has experience in the proso millet industry.

SESSION II - TRACK 2

Prospects of Millet Production in Assam, India: A Farm level Study

Pranjal Protim Mudoi AND *Nivedita Deka*, Graduate student and Professor, respectively, Department of Agricultural Economics and Farm Management, Faculty of Agriculture, Assam Agricultural University, Jorhat, Assam, India.

The government of India has declared year 2018 as National year of millet and UN has declared 2023 as International Year of Millets. Considering the importance of millet, government of Assam, an Indian state has implemented Assam Millet Mission to meet the demand and increasing the nutrition quotient. In the beginning, Assam Millet Mission will be practiced in 25,000 hectares cropland. Subsequently, it will be extended to 50,000 hectares in the state. Out of several types of millets, Finger millet and Fox tail millet have mostly grown by the farmers. The growth rate in area (0.99%), production (2.46%) and productivity (1.46*%) of small millets in Assam has found to be positive revealing an increase production leading to significant growth in productivity.

A study on economics of millet production in Assam at farm level with 120 millet growers has shown that farmers have been growing millets as minor crop on the marginal lands with minimum of resources that gave an yield of 500-600 kg/ha only in farmers' fields. Yet, they are able to get positive return out of their millet production with an average return over variable cost of (1:1.12). However, due to problems such as low awareness about millet, lack of technical knowhow, high labour requirement for post harvest operations, lack of proper market etc, the crop has yet to emerge as an important one in the state. Awareness drive on the benefits of millet production and consumption, training on adoption of recommended practices that gives a yield of 1800-2000 kg /ha as per the package of practices, facilitating the farmers with mini processing unit at community level would help to popularise millet as prospective crop in the state.

Keywords: Prospects, growth, return, training, millet, Assam, India.

Consumers' Awareness on Millet Based Products in Assam, India

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India is the largest producer and top exporter of millets in the globe depicting a huge potential in both domestic and international market. In recent years, there has been a greater emphasis on millets production in the Indian state of Assam to assist farmers in dealing with climate change, health issues, and other critical aspects. However, as a rice-dominant state, the shift from rice-based food to millet-based food would take time; consequently, a survey was conducted with 105 individuals to assess their awareness of millet-based items accessible in the market places of urban areas of the Jorhat district of the state using a pre-structured questionnaire using various descriptive and inferential statistics. It was found that on an average 50 percent of the respondents, of which majority were women (62.1%) have been using millets-based products for less than a year and 57.9 percent of the respondents were aware of millet-based products.

The study showed that the major reason for purchasing these products was the health benefits the products claim (61.4 %). There was a significant relationship between consumers' awareness and their income ($p<0.05$). As the majority of the respondents (55.6%) preferred rice over millets, thus making it a reason for low consumption of millets in the study area. In conclusion, major recommendations to enhance the consumption of millets in the state include government emphasis on promoting awareness of millet-based products, developing locally produced millet-based products and easy accessibility of these products in the urban markets.

Keywords: Millets, market, export, consumers, Assam, India.

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SESSION III - TRACK 2

Millet Seed in Poultry Diets

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Three trials have been conducted with broilers, pullets and presently layers, respectively since August, 2022 feeding up to 20% millet seed in balanced diets. The first trial conducted in broilers tested 0, 10 or 20% millet seed which replaced primarily corn and some soybean meal in diets for broiler chicks from day old to market age – 7 weeks. Feed consumption and body wt. were greatest for the broilers fed 20% millet seed. Broilers consumed the millet seed readily and the millet seed was not ground, but fed whole. Trail 2 was with replacement pullets being raised for egg production. Millet seed was fed at 0, 10 or 20% if the ration from 7 days to 17 weeks of age to Dekalb White pullet chicks. The pullets gained weight equally on all 3 diets indicating ready acceptance of millet up to 20% in pullet rations. Millet seed was fed whole, not ground. Trial 3 – millet seed in layer diets is currently underway. A factorial design of 4 levels millet seed: 0, 10, 15 or 20% combined with 0 or 10% DDGS for a total of 8 diets. Dietary effects on feed intake, egg production, egg quality measurements will be made during the study. At this time, millet seed is a viable energy source for broilers, pullets and layer production.

An Analysis of the Poultry Feed Supply Chains in India [#]

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The poultry feed supply chains in India play a crucial role in supporting the growth and sustainability of the poultry industry. This paper provides an overview of the key aspects of poultry feed supply chains in different regions of India, including the production and sourcing of raw materials, manufacturing processes, distribution channels, and the role of various stakeholders such as feed manufacturers, distributors, and retailers. It also highlights the challenges faced by the poultry feed supply chains and offers recommendations for improvement in terms of infrastructure, technology adoption, collaboration, education, research and development, and policy support. Understanding and enhancing the efficiency and effectiveness of poultry feed supply chains is essential for ensuring a steady and reliable supply of quality feed to support the thriving poultry industry in India.

Keywords: Poultry feed, supply chain, stakeholders, India.

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Agricultural Raw Materials Import Competition for Animal Feeds in India

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The Indian economy heavily relies on the feed ingredient industry, which plays a vital role in ensuring the sustainable growth of the country's livestock and poultry sector by producing and supplying various feed ingredients like soybean meal, corn, wheat, barley, fishmeal, and other protein sources. This report aims to discuss the import of 12 specific commodities related to feed ingredients in India from the USA and other countries worldwide in the years 2000, 2010, and 2020, using data sourced from the United Nations Comtrade database.

The report reveals that India depends significantly on several Asian countries, with China being the major importer of these products. Furthermore, the cost of importing these products varies; India has diversified its import by importing feed ingredients from different countries, such as Argentina, France, Benin, and Togo, across different continents, mainly driven by cost-effectiveness. With a favorable trade policy and reduced export costs, the United States can potentially capture a share of India's import market for feed ingredients. USA's position as an exporter of the 12 commodities is not solid and competitive except for a few cases where it was a significant exporter of five commodities to India in some years; however, the export quantity is minimal. India is endeavoring to curtail its reliance on nations such as China for imports and increase domestic production; thus, the United States has the potential to hold a significant share in India's import market for these commodities through a favorable trade policy and reduced export costs.

Keywords: Feed import, feed ingredients, Indo-US trade.

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An Empirical Analysis of India's Import Demand Functions for Millets, Corn, and Soybean

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The demand for feed ingredients in India is increasing steadily, mainly driven by the growing demand for animal-protein-based products. According to a report by the USDA, the demand for feed ingredients in India is expected to grow by 7 percent annually, reaching 28 million metric tons by 2027. However, the production of feed ingredients in India is not enough to meet the growing demand, resulting in a supply gap (USDA, 2012). The supply gap in the feed ingredients is primarily due to inadequate infrastructure, poor quality of products, and limited availability of agricultural raw materials (NITI Aayog, 2018; APEDA, 2021). Limited availability of key feed ingredients, such as corn and soymeal, has contributed to an upward trend in their prices which has impacted prepared feed prices over few years (Singh, 2022).

The Indian feed industry relies heavily on imports to meet the demand for feed ingredients. India's imports of soybean meal, a primary protein source in animal feed, increased from 1.64 million metric tons in 2019-20 to 2.25 million metric tons in 2020-21. Similarly, imports of corn, wheat, and barley, the primary sources of carbohydrates in animal feed, have also increased significantly over the past few years (APEDA, 2021).

The commercial feed industry plays a crucial role in the growth of the country's livestock and poultry industries and is a critical part of the growing Indian economy. This sector primarily caters to the poultry (meat and egg) industry and mainly uses corn and soybean meals to produce commercial animal feed, supplemented by other coarse grains and oilseed meals depending on the comparative pricing. The importance of prepared animal feeds to support the growing demand for animal protein in India is undeniable. The supply gap (or excess demand) for agricultural raw materials to produce (manufacture) animal feed has raised the prices of prepared animal feeds in the country. Such a rise in animal feed prices adversely impacts meat prices, particularly poultry and egg prices downstream, impacting hundreds of millions of Indian consumers. Imports address some gaps in the supply of the necessary agricultural raw materials.[2]

[2] At present, imports are not sufficient to fulfill the supply gaps of agricultural raw materials (needed to manufacture animal feed) that exist because of India's import restrictions.

Reliable information is critical to decision making, whether policy decisions, business decisions, and so on. Given the importance of imports of some key feed ingredients (some of which are dual purpose, i.e., used for human consumption as well) and the related implications on feed prices and price of animal proteins (meat and eggs), it is important that we understand the factors that are driving such imports. For example, is the growth of urban population is driving such imports? or is it the investments in feed manufacturing facilities, or relative price of import, or growth of urban population, etc.? Such information that helps understanding the demand for feed ingredients in India, however, is not available.

Given the role of imports in India's feed industry's growth in providing the necessary prepared feed to raise animal protein (meat and eggs) to satisfy the growing demand for animal protein in India, the main goal of this research is to examine the determinants of imports of those key feed ingredients in India. Our research makes the following key contributions: (i) to the understanding of the determinants of import of feed ingredients and their implications in India, and (ii) to the literature on import demand in India. Thus, this report addresses the gap in the critical knowledge base on India's animal feed market by empirically analyzing India's import demand for a few key dual purpose agricultural commodities (dual purpose – used for both food and feed) feed ingredients: millets, corn, and soybean.

The stability of the import demand function is examined using two types of cointegration tests. We use an ARDL (auto regressive distributed lag) model to estimate the long-run elasticities. We also explore the existence of long-run relationship between import demand of those three agricultural commodities and factors that impact their imports, including import price, consumer expenditure on food, urban population, investment in the feed manufacturing sector, etc. We use United Nations Comtrade (aka UN Comtrade) database (https://comtradeplus.un.org/) as the source of our data for this study.

Keywords: Import demand, ARDL, VECM, India, animal feed.

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SESSION IV - TRACKS 1 & 2

Genetics and Genomics of Proso Millet (*Panicum miliaceum* L.)

Rituraj Khound AND *Dipak Santra*, Post-doctoral Associate and Professor, Dept. of Agronomy and Horticulture, University of Nebraska-Lincoln Panhandle Research and Extension Center, Scottsbluff, NE, respectively.

Proso millet (*Panicum miliaceum* L.) is one of the oldest cereals believed to be domesticated ~10,000 years ago in the semiarid areas of northern China. This cereal is valued for its remarkable water-use efficiency and short growing season. It is regularly used as a rotational crop in the winter wheat-based dryland cropping system in the High Plains of the USA. Proso millet forms a significant part of the human diet in several countries due to highly desirable nutritional and health-promoting properties. The use of its grains has been confined to the birdseed industry in the USA. The genetic improvement of this crop is impeded by the negligible genomic resources available to breeders and researchers. The overall goal of our study at PREEC was to develop breeding tools to complement conventional proso millet breeding. We identified 972,863 single nucleotide polymorphisms (SNPs) from low-pass genome sequencing of a diverse global population. The high-quality SNPs identified in this study were later used to investigate the population structure and phylogenetic relationships among the genotypes.

We conducted a genome-wide association study (GWAS) to identify SNPs associated with key morpho-agronomic traits in the US proso millet core collection. Twenty highly significant markers-trait associations (MTAs) were identified for five important traits. We also estimated the heading percentage of proso millet using unmanned aerial vehicle (UAV)- based high-throughput phenotyping. We developed a high-throughput method for identifying heading with high accuracy of ~92%. These resources generated in the project would make the existing proso millet genetic improvement programs more time-efficient and cost-effective. These resources could also be useful to advance the understanding of proso millet genetics and establish genomics-assisted breeding.

Proso Millet Market and Consumer Study

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With 2023 being declared the International Year of Millets (IYM2023) by the United Nations, the popularity of millets has been on the rise worldwide. The benefits of growing and consuming millets are manifold - being environmentally resilient crops, millets can help combat the adverse effects of climate change; millets are naturally gluten-free, rich in fiber and resistant starch, which helps aid digestion and regulate insulin resistance; and millets can be grown as short-duration intercrops to aid farmer profitability. Proso millet is the only type of millet cultivated in the US, the produce from which mostly goes towards the bird-feed market, leaving the overall market underutilized. In 2022, 507 thousand acres of proso millet were harvested in the US, producing 9403 thousand bushels of grain, with the average yield being 18.5 bushels per acre.

Following IYM 2023, there is anticipated to be an increase in the demand for millet in the market beyond birdseed. However, some significant limitations in expanding the scope of the proso millet market in the US include knowledge gaps between researchers, farmers, and consumers, lack of high-yielding varieties, product development, price volatility, etc. In this paper, we try to focus on potential research ideas to help overcome these bottlenecks and expand the proso millet market.

Producing Certified Proso millet Seeds

Leon Kriesel, Kriesel Certified Seed, Gurley, NE.

Producing Millets in Kenya

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