**Proso Millet Crop Vulnerability Statement**

June 17, 2020

**David Brenner, Agronomy, Iowa State University, Ames, IA, Dipak K. Santra, Department of Agronomy and Horticulture, University of Nebraska-Lincoln, Scottsbluff, NE and J. Bradley Morris, USDA-ARS, Griffin, GA**

**Objective**

To provide a short non-technical assessment of the state of United States’ proso millet (*Panicum miliaceum*) crop vulnerability, issues and evolving needs.

***Strengths***

Proso millet is a commercially substantial crop in the United States (Table 1).

**Organizational** - High Plants Millet Association (HPMA), founded in 2017, and administered by millet farmers in Colorado conducts annual meetings, maintains an informative web site, for producers, consumers and end-users, and promotes the millet industry (HPMA, 2020).

**Agricultural**

Proso millet’s water-efficient and short season 60-day growing cycle makes it climate-resilient since it can be grown after other crop failures or as a summer crop in rotation with winter crops. It does well in rotation with wheat, corn, sunflower, and pea in the U.S. High Plains (Lyon et al., 2008). Proso millet is also recognized by the FAO as a future smart food, for its water efficiency and resilience (Li and Siddique, 2018). In 2019, 377 metric tons of proso millet were produced in the USA (USDA National Agricultural Statistics Service 2020b) which is less than 1% of the world’s millet production of all the millet species combined (FAOSTAT, 2018, Das et al., 2019). World proso millet production data are unavailable, but China, India, and Russia are believed to be major producers.

**Bird Seed**

Before processing the seeds are glossy, like jewels, look great in bird feeders. White, red, and orange seeds are commercially available. Most grocery stores devote substantial shelf space to proso millet bird seed.

**Food for people**

The shiny hulls, prized for use in bird feed, are removed during processing and the internal, starchy white grain is both exported and consumed in the United States (Das et al., 2019).

North America - Proso millet grain is the “millet’ available in natural food stores in the United States. It is commonly used in artisanal breads but can be made into porridge and other foods. Proso millet is a healthy choice because it is a good source of protein, is gluten-free, and has a low glycemic index.

Export to Africa - Angola and Senegal import millet from the United States (Lyon et al., 2008). Consumers in these countries traditionally consume millet as couscous or porridge.

Export to Asia - Waxy proso millet grain has distinctive functionality demanded by East Asian consumers. The new cultivar ‘Plateau’ is the only cultivar grown in the United States for this export market (Santra et al., 2015). In Asia, waxy proso millet grain is made into traditional mochi candies and dumplings with a distinctive soft and stretchy texture (Sakamoto, 1996). Other grains with similar starch are also used for mochi, but proso millet is one of the traditional sources of waxy starch for this use.

**Genetic Resources**

The United States, National Plant Germplasm System (NPGS) proso millet collection is large and diverse with 704 accessions available for distribution originating from 33 countries, including ten accessions from China (USDA, 2020) where the crop originated (Hunt et al., 2014). There are other large germplasm collections; China, Ukraine, and Russia, each have more than 5,000 accessions of proso millet in their national germplasm collections. The ICARDA and NPGS collections both actively distributes germplasm internationally (Habiyaremye et al., 2017; Santra et al. 2019). The public online GRIN-Global database (USDA, 2020) provides proso millet germplasm observation data to help guide users, including 651 observations of proso millet seed starch types (Graybosch and Baltensperger, 2009), and seed weight data for all accessions.

***Weaknesses***

**Market**

Proso millet has a poor niche in modern foods since it is seldom used as an ingredient in modern convenience foods. In many parts of the world where it was a popular food, it is displaced by the major commodity crops such as wheat and rice (Dwivedi et al., 2012).

Livestock feed – Proso millet grain can be used in cattle fattening rations (Lyon et al., 2008). But in practice, it is not used in animal feed because the price is not competitive with subsidized commodity crops.

**Genetic Resources**

The 15 available cultivars in the United States have a narrow genetic base, which is a vulnerability (Rajput et al., 2016).

The publicly available GRIN-Global database is unfortunately lacking plant trait evaluation information for shattering (seed-fall) and lodging (plants falling over) prior to harvest (USDA, 2020). These traits are of the most interest in current proso millet plant breeding (Rajput et al., 2016).

Proso millet seed lots in storage have an estimated decline to 50% viability in 88 years (Walters et al., 2005). The NPGS collection includes 127 distribution seed lots that are between 40 and 60 years old and will need replacement. Current viability data indicates that the seed lots are generally healthy, and the few seed lots with declining viability can readily be renewed with fresh seeds. When fresh seed lots are needed for the germplasm collection, they are typically grown in a greenhouse using the same methods as for *Amaranthus* (Brenner and Widrlechner, 1998).

Crop wild relatives of proso millet should be better represented in the NPGS collection (Table 2). Proso millet has evolved into weedy forms with distinctive dark seeds and rapid shattering (seed-fall), however they have not evolved herbicide tolerance, so weedy proso millet is presently a controllable minor field weed (Colorado Dept. of Ag., 2009). Acquisition priorities should include wild proso millet, more of the related wild species representing both of proso millet’s two genomes, and especially the herbicide resistant weedy relative *Panicum* *capillare* that could play a role in development of herbicide tolerant cultivars (Brenner et al., 2019).

***Threats***

Lodging and seed shattering are the important threats in the main production area (Rajput et al., 2016), the high plains of Colorado, Nebraska, and South Dakota, where proso millet is well adapted. Outside of the main production area and especially in areas with higher humidity, and warmer nights, cinch bugs (*Blissus leucopterus*) are a threat (Dwivedi et al., 2012). Many harmful insects, diseases, and weeds are found in proso millet fields (McDonald et al., 2003, Dwivedi et al., 2012) but they are currently insignificant problems in the main production area (personal communication D. Santra). If someday production shifts to other regions the threats may rank differently.

***Opportunities***

The proso millet genome was recently sequenced (Zou et al., 2019), which will facilitate progress in plant breeding. Two active proso millet plant breeding projects in the United States are expected to deliver new cultivars with improved harvestability; availability of improved cultivars for producers will strengthen the industry.

Climate change is an opportunity for increased proso millet acreage in the Northern Great Plains since proso millet is a catch crop with a short drought-tolerant cropping season that is less susceptible to climate risk than competing wheat and corn crops (Lyon et al., 2008, Bathke et al., 2014).

The existing 4◦C refrigerated storage for the Ames, Iowa genebank’s proso collection seed lots will be improved with -20◦C freezer storage to extend seed viability.

Table 1

|  |  |  |  |
| --- | --- | --- | --- |
| **Crops of similar value to proso millet, USA, 2019** | | | |
| Crop | million dollars\* | Area harvested  acres\*\* | Area harvested hectares\*\* |
| Oats | 163 | 825,999 | 334,270 |
| Chickpeas | 117 | 403,992 | 163,490 |
| Peppermint oil | 105 | 52,411 | 21,210 |
| Proso millet | 83 | 465,002 | 188,180 |
| Lentils | 79 | 431,001 | 174,420 |
| Rye | 65 | 309,993 | 125,450 |
| Flaxseed | 56 | 319,013 | 129,100 |
| Spearmint oil | 41 | 18,508 | 7,490 |
| Safflower | 38 | 152,711 | 61,800 |
| Mustard seed | 17 | 89,995 | 36,420 |
| \* USDA National Agricultural Statistics Service 2020a  \*\* USDA National Agricultural Statistics Service 2020b | | | |

Table 2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Crop Wild Relatives of Proso Millet,**  **Genomic Makeup\*, and USDA\*\* Holdings** | | | | | |
|  | Species | Genome | Chromosomes | Accessions in the NPGS | Collection location |
| Proso millet | *Panicum miliaceum* | FFHH | 2n=4x=36 tetraploid | 723 | Ames, Iowa |
| Genome F, female (chloroplast) parent | *Panicum capillare* | FF | 2n=2x=18 diploid | 1 | Griffin, Georgia |
| *Panicum hallii* | FF | 2n=2x=18 diploid | 4 | Griffin, Georgia |
| *Panicum nephelophilum* | FF |  | 0 |  |
| Genome H, male parent | Unknown and undiscovered | HH | 2n=2x=18 diploid | 0 |  |
| Related to genome H | *Panicum repens* |  | 2n=2x=18 and 2n=4x=36 (variable, diploid and tetraploid) | 2 | Griffin, Georgia |
| *Panicum sumatrense* |  | 2n=4x=36 | 211 | Ames, Iowa |
| \* (Triplett et al., 2012; Hunt et al., 2014; Brenner et al. 2019) \*\*(USDA, 2020) | | | | | |

**References**

Bathke, D. J., R. J. Oglesby, C. Rowe and D.A. Wilhite. 2014. Understanding and Assessing Climate Change: Implications for Nebraska. Papers in the Earth and Atmospheric Sciences. 439. http://digitalcommons.unl.edu/geosciencefacpub/439

Brenner D.M., H.E. Bockelman, and K.A. Williams. 2019. North American Wild Relatives of Grain Crops. In: S. Greene, et al., editors, North American crop wild relatives. Vol. 2. Springer, Cham.p. 41–82 [doi: 10.1007/978-3-319-97121-6\_2](https://doi.org/10.1007/978-3-319-97121-6_2)

Brenner, D. M. and M. P. Widrlechner. 1998. Amaranthus seed regeneration in plastic tents in a greenhouse. Plant Genetic Resources Newsletter 116:1-4 Colorado Dept. of Ag. 2009. Wild proso millet fact sheet. 305 Interlocken Pkwy, Broomfield, CO 80021 https://www.colorado.gov/pacific/agconservation/wild-proso-millet

Das S., R. Khound, M. Santra, and D.K. Santra.2019. Beyond bird feed: Proso millet for human health and environment. Agriculture 9:64. doi:10.3390/agriculture 9030064.

Dwivedi, S., H. Upadhyaya, D. Senthilvel, C. Hash, K. Fukunaga, X. Diao, D. Santra, D. Baltensperger, and M. Prasad. 2012. Millets: genetic and genomic resources. In: J. Janick, editor, Plant Breed. Rev. 35:247–377. https://epdf.pub/plant-breeding-reviews-volume-35.html

FAOSTAT. 2018. Food and Agriculture Organization of the United Nations. http://www.fao.org/

faostat/en/#data/QC/visualize (accessed June 8, 2020).

Graybosch, R.A., and D.D. Baltensperger. 2009. Evaluation of the waxy endosperm trait in proso millet (Panicum miliaceum). Plant Breeding 128:70–73. https://naldc.nal.usda.gov/download/43943/PDFHabiyaremye C., J.B. Matanguihan, J. D’Alpoim Guedes, G.M. Ganjyal, M.R. Whiteman, K.K. Kidwell and K.M. Murphy. 2017. Proso Millet (Panicum miliaceum L.) and Its Potential for Cultivation in the Pacific Northwest, U.S.: A Review. Frontiers in Plant Science 7:1961. doi: 10.3389/fpls.2016.01961

HPMA. 2020. High Plains Millet Association <https://sites.google.com/view/hpma/home> (accessed May 12, 2020).

Hunt H.V., E. Badakshi, O. Romanova, C.J. Howe, M.K. Jones, and J.S.P. Heslop-Harrison. 2014. Reticulate evolution in Panicum (Poaceae): the origin of tetraploid broomcorn millet, P. miliaceum. J. Exp. Bot. 65:3165–3175. doi: http://dx.doi.org/10.1093/jxb/eru161

Li, X. and K.H.M. Siddique. 2018. Future Smart Food - Rediscovering hidden treasures of neglected

and underutilized species for Zero Hunger in Asia, FAO, Bangkok, 242 pp. http://www.fao.org/3/I9136EN/i9136en.pdf

Lyon, D.J., P.A. Burgener, K.L. DeBoer, R.M. Harveson, G.L. Hein, G.W. Hergert, T.L. Holman, L.A. Nelson, J.J. Johnson, T. Nleya, J.M. Krall, D.C. Nielsen, and M.F. Vigil. 2008. Producing and marketing of proso millet in Great Plains. EC 137. Univ. of Nebraska Extension Service. Lincoln.http://ianrpubs.unl.edu/live/ec137/build/ec137.pdf

McDonald, S.K., L. Hofsteen, L. Downey. 2003. Crop profile for proso millet in Colorado. USDA Crop Profiles, Western Regional IPM Center. <https://ipmdata.ipmcenters.org/documents/cropprofiles/COprosomillet.pdf>

USDA National Agricultural Statistics Service. 2020a. Crop Values 2019 Summary (February 2020) https://downloads.usda.library.cornell.edu/usda-esmis/files/k35694332/9w032m10t/hq37w596k/cpvl0220.pdf

USDA National Agricultural Statistics Service. 2020b. Crop Production 2019 Summary (January 2020) https://downloads.usda.library.cornell.edu/usda-esmis/files/k3569432s/sj139j59z/1257b842j/cropan20.pdf

USDA. 2020. Millet-proso. National Plant Germplasm System, Germplasm Resources Information Network (GRIN Global) database, National Germplasm Resources Laboratory, Beltsville. <https://npgsweb.ars-grin.gov/gringlobal/crop.aspx?id=226> (accessed May 5, 2020).

Rajput, S.G., D.K. Santra, and J. Schnable. 2016. Mapping QTLs for morpho-agronomic traits in proso millet (*Panicum miliaceum* L.). Molecular Breeding 36:37. doi: 10.1007/s11032-016-0460-4

Sakamoto, S. 1996. Glutinous-endosperm starch food culture specific to eastern and southeastern Asia. In R. Ellen, and K. Fukui, editors, Redefining nature: ecology, culture and domestication. Berg Publishers, Oxford, UK. p. 215–231.

Santra, D.K., R.F. Heyduck, D.D. Baltensperger, R.A. Graybosch, L.A. Nelson, G. Frickel, and E. Nielsen. 2015. Registration of ‘Plateau’ Waxy (Amylose-Free) Proso Millet. Journal of Plant Registrations 9:41–43. https://doi.org/10.3198/jpr2013.11.0067crc

Santra, D.K., R. Khound, and S. Das. 2019. Proso Millet (*Panicum miliaceum* L.) Breeding: Progress, challenges and opportunities. In: J.M. Al-Khayri, et al., editors, Advances in plant breeding strategies: Cereals. Vol 5. Springer, Cham.p.223–257. https://www.springer.com/gp/book/9783030231071#

Triplett, J.K., Y. Wang, J. Zhong, E.A. Kellogg. 2012. Five nuclear loci resolve the polyploid history of switchgrass (*Panicum virgatum* L.) and relatives. PLoS ONE 7(6): e38702. doi: [10.1371/journal.pone.0038702](https://dx.doi.org/10.1371%2Fjournal.pone.0038702)

Walters, C., L.M. Wheeler, and J.M. Grotenhuis. 2005. Longevity of seeds stored in a genebank: species characteristics. Seed Science Research 15:1–20. <https://doi.org/10.1079/SSR2004195>

Zou, C., L. Li, D. Miki, D. Li, Q. Tang, L. Xiao, S. Rajput, P. Deng, L. Peng, W. Jia, R. Huang, M. Zhang, Y. Sun, J. Hu, X. Fu, P.S. Schnable, Y. Chang, F. Li, H. Zhang, B. Feng, X. Zhu, R. Liu, J.C. Schnable, J-K. Zhu and H. Zhang. 2019. The genome of broomcorn millet. Nature Communications 10:491–500. https://doi.org/10.1038/s41467-019-08409-5