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Progress with Proso, Pearl and Other Millets

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INTRODUCTION

Paniceae is the largest tribe of the Poaceae (Gramineae), with more than 1400 species. Economically important species of this tribe include proso millet (*Panicum miliaceum* L.), foxtail millet (*Setaria italica* L. Beauv.), and pearl millet (*Pennisetum glaucum* L.R. Br.).

PEARL MILLET

Pearl millet is one of the two major crops grown to feed people living in the semi-arid, low input dryland agriculture regions of Africa and southeast Asia. People in northern Nambia are almost entirely dependent on pearl millet for food. Four countries in the Sahel of Africa, with a total population of 38 million, depend on pearl millet to provide over 1,000 calories per person per day (Dendy 1995). Pearl millet is adapted to poor, droughty, and infertile soils because it will produce more reliably under these conditions than most other grain crops. However, it readily responds to high fertility and moisture. Pearl millet grows best in light well-drained loamy to sandy soils. It can tolerate acid subsoils to as low as pH=4 and high in aluminum content (National Research Council 1996). Annual rainfall in the areas where this crop is mainly grown ranges from 250 to 700 mm but can be as high as 1500 mm. Pearl millet is an annual, sexual diploid (2*n*=14 chromosomes) with the A genome (Jauhar and Hanna 1998).

Primary breeding research efforts on pearl millet for grain have been carried out at Tifton, Georgia by USDA/ARS scientists Wayne Hanna, Glen Burton, and colleagues, and at the University of Nebraska by David Andrews and John Rajewski. Previous work by Bill Stegmeier in Kansas ceased with his death. Andrews and Burton have recently retired and future breeding efforts in pearl millet are seriously in doubt at this point. Commercial US cultivars are limited to forage hybrids. One recent release from the University of Nebraska takes advantage of extremely short day photoperiod requirements for floral induction, resulting in vegetative production throughout the growing season at latitudes north of Texas. This results in improved late season quality, but complicates production by limiting seed production to the tropics. At one stage as much as 35,000 acres were grown for grain in the southeastern US, but a rust epidemic reduced the acreage to zero. Currently new lines are rust resistant, but there is no commercial production at this time. Breeding and management work may make pearl millet more competitive with other feed grains, but efforts are needed to develop a market that will encourage production. A new ornamental type is expected to be released in the near future from Andrews' program that has purple pigmentation. His program also released several parental types during the past year.

PROSO MILLET

Proso millet is well adapted to many soil and climatic conditions. Being a short-season crop with a low water requirement, it grows further north (up to 54°N latitude) than the other millets and also adapts well to plateau conditions and high elevations (Matz 1986). Proso is found high in the mountains in the former Union of Soviet Socialistic Republics (USSR) up to 1200 m and in India up to 3500 m (Roshevits 1980). The proso plant is considered a short-day plant and usually an erect annual, 30- to 100-cm tall, with few tillers and an adventitious root system. Proso is produced throughout the central and northern Great Plains of the US including Nebraska, Kansas, Colorado, North Dakota, South Dakota, and Minnesota.

Proso (2*n*=36) is considered a self-pollinated crop, but natural cross-pollination may exceed 10%. Proso seeds are smaller than pearl millet and grain sorghum (*Sorghum bicolor* L. Moench), generally oval in shape and about 3-mm long and 2-mm wide. The seeds vary in color from white cream, yellow, orange, red, black, to brown.

Proso research the past several years has been concentrated in Nebraska and adjacent states. My breeding program in cooperation with Drew Lyon's management work and cooperation from colleagues in Colorado, Wyoming, and South Dakota has resulted in the release of 'Earlybird', 'Sunrise', and 'Hunstman'

(Baltensperger et al. 1995a,b, 1997). Current breeding efforts include development of similar types with higher yield, better harvestability and larger seed. We also have a program to release red types including various patterns of red and white seed color. However, primary research efforts have moved to the development of adapted proso types with waxy starch in cooperation with Robert Graybosch. These types are currently used for steam breads in southeast Asia, but the trait has been restricted to germplasm that will not flower and produce seed (short day types) during the growing season of the High Plains. We have selected three lines that produce seed in the region, but the average yield has been less than 50% of adapted normal types (Fig. 1). They also flower later, are lower in test weight, lodge worse, and are smaller seeded. We have since completed several cycles of recurrent adapted parent backcrossing and several lines that have the waxy trait in an adapted-genetic background will enter regional trials this summer. This trait has the potential to expand the export potential for proso and thus the acreage in this region, but will require market development and entrepreneurial activity to have a major impact on regional production.

FOXTAIL MILLET

The genus *Setaria* is widely distributed in warm and temperate areas. Foxtail millet is the most economically valuable of the genus. Foxtail millet is one of the world's oldest cultivated crops. Foxtail was the most important plant food in the neolithic culture in China, and its domestication and cultivation was the earliest identifiable manifestation of this culture, the beginning of which has been estimated at over 4,000 years ago (Chang 1968). Foxtail millet is also known as Italian millet, German millet, or hay millet (Baltensperger 1996). Malm and Rachie (1971) thoroughly reviewed the domestication of foxtail millets and the taxonomy.

Foxtail millet was and is by far the most important millet in China, although the growing area of it declined from 1986 to 1990 as maize increased (Jiaju and Yuzhi 1993). China produced more than 90% of the world foxtail output, according to 1981 to 1985 estimates (Dendy 1995).

In the US, foxtail millet was introduced from the old world about the middle of the nineteenth century as a forage crop. Nearly all foxtail millet cultivars grown in the US are the result of selections from land races rather than designed crosses and selections. Most of the foxtail millet breeding work took place over the period 1930 to 1965 in the former USSR, China, and India (Rachie 1971). Many related species, with 2*n* levels as multiples of the 2*n*=2*x*=18 chromosomes occur in China.

Foxtail millet ranks second in the total world production of millets and it continues to have an important place in world agriculture providing approximately six million tons of food to millions of people, mainly on poor or marginal soils in southern Europe and in temperate, subtropical, and tropical Asia (Marathee 1993). Its cultivation is successful even in areas with low rainfall from sea level up to 2000 m (Oduori 1993). It is cultivated in the US as a catch crop, especially for fodder and pet food for caged and wild birds. Foxtail can

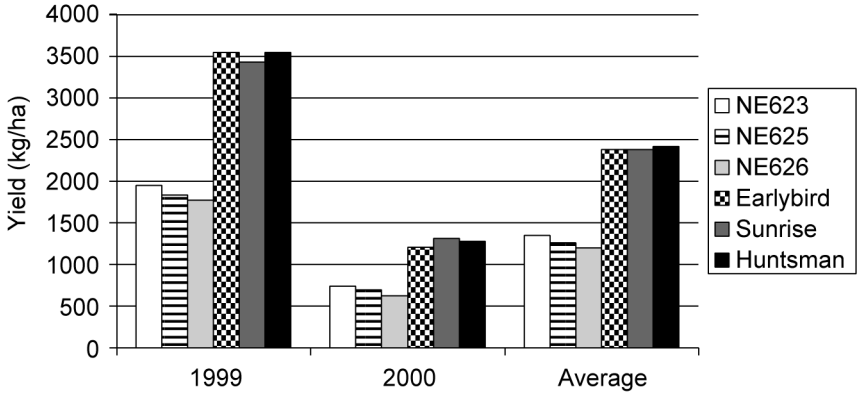

Fig. 1. Yields from High Plains regional trials in 1999 and 2000 and the two year average of experimental waxy starch types NE623, NE625, and NE626 compared with recent releases 'Earlybird', 'Sunrise', and 'Huntsman'.

yield as much as proso, but foxtail seeds are generally much smaller. Foxtail millet has about 500,000 seeds kg^{-1} or more than twice that of proso. Foxtail millet and proso millet both grow to a height of 0.5 to 2 m, but make little or no regrowth once they are cut.

Foxtail millet breeding has been very limited until the past several years (Siles et al. 2001a). Andrews has identified three lines with longer photoperiod and adaptation to eastern Nebraska during this time, while my program has focused on adaptation to the High Plains. The primary limitation of foxtail millet production in the High Plains of the US is that it serves as a carrier for both the wheat curl mite (*Eriophyes tullipae* Keifer), the carrier for wheat streak mosaic virus, and the virus itself. While adapted cultivars of foxtail are not seriously impacted by the disease, the crop serves as an over-summering host and adjacent wheat fields are frequently severely impacted. Germplasm has been identified with much higher levels of resistance that may help to expand the utilization of foxtail millet in the region (Marcon 1994). Several advanced lines developed from planned crosses to incorporate wheat streak mosaic resistance, increased head size, and improved seed yield are currently being evaluated (Siles et al. 2001b). It is anticipated that potential releases for the grain market, niche color for bird seeds, and large individual heads for caged birds as well as forage types will be released from this breeding program in the near future. South Dakota has been screening types primarily for the forage industry and Missouri has had recent efforts to look at grain types for the bird seed market through the efforts of Rob Myers. Foxtail millet continues to suffer from limited research and market development.

Management work of all three millets has included rotation studies throughout the High Plains (Daugovish et al. 1999; Lyon and Baltensperger 1995) and weed control work (Uludag et al. 1997). Mason and colleagues have worked extensively on pearl millet management (Maman et al. 1999). Row spacing work on proso has been conducted on modern cultivars by Agdag et al. (2001).

SUMMARY

Grain types of pearl millet and proso millet have been released and US acreage has continued to increase, especially for proso millet. Advanced lines of foxtail that have been selected for improved resistance to wheat streak mosaic are being tested for grain yield potential in the High Plains region. Foxtail millet lines are also being developed to better meet the market for individual heads for caged birds and for forage production. Proso millet germplasm is being developed with starch characteristics unique to the US market and may improve the export potential of the crop. Recent releases of pearl millet for forage based on manipulation of the photoperiod response are starting to be marketed. Management research has been limited, but new herbicides have been labeled that help in controlling weeds in all three crops. These millets reliably produce grain and forage under the most adverse conditions around the world. They have the potential to improve our cereal food supply, produce forage for livestock production, and provide for the leisure activity of feeding birds.

Recent research indicates the opportunities for pearl, proso, and foxtail millet as crops, but also indicates the shortage of work in this area. Further development has the opportunity to provide better adapted and higher yielding materials both for grain and forage, but these will require the development of niche markets and improvement in management techniques. Long term improvement in these crops will require a significant increase in basic research as virtually no effort is currently underway involving molecular genetics.

REFERENCES

Agdag, M., L. Nelson, D. Baltensperger, D. Lyon, and S. Kachman. 2001. Row spacing affects grain yield and other agronomic characters of proso millet. Commun. Soil Sci. Plant Analysis 32(13 & 14):2021–2032.

Baltensperger, D.D., L.A. Nelson, G.E. Frickel, and R.L. Anderson. 1995a. Registration of ‘Huntsman’ proso millet. Crop Sci. 35:941.

Baltensperger, D.D., L.A. Nelson, and G.E. Frickel. 1995b. Registration of ‘Earlybird’ proso millet. Crop Sci. 35:1204–1205.

Baltensperger, D.D. 1996. Foxtail and proso millet. p. 182–190. In: J. Janick (ed.), Progress in new crops. ASHS Press, Alexandria, VA.

Baltensperger, D.D., L.A. Nelson, G.E. Frickel, and R.L. Anderson. 1997. Registration of 'Sunrise' proso millet. Crop Sci. 37:1380.

Chang K. 1968. Archeology of ancient China. Science 162:519–526.

Daugovish, O., D.J. Lyon, and D.D. Baltensperger. 1999. Cropping systems to control winter annual grasses in winter wheat (*Triticum aestivum*). Weed Tech. 13:120–126.

Dendy, D.A. 1995. Sorghum and millets: Production and importance. p. 11–26. In: D.A.V. Denby (ed.), Sorghum and millets: Chemistry and technology. Am. Assoc. Cereal Chemists, Inc., St. Paul, MN.

Jauhar, P.P. and W.W. Hanna. 1998. Cytogenetics and genetics of pearl millet. Adv. Agron. 64:1–26.

Jiaju, C. and Q. Yuzhi. 1993. Recent developments in foxtail millet cultivation and research in China. p. 101–107. In: K.W. Riley, S.C. Gupta, A. Seetharam, and J.N. Mushonga (eds.), Advances in small millets. Oxford and IBH Publ. Co. Pvt., 66 Janpath, New Delhi, India.

Lyon, D.J. and D.D. Baltensperger. 1995. Cropping systems control winter annual grass weeds in winter wheat. J. Prod. Agr. 8:535–539.

Malm, R.N. and K.O. Rachie. 1971. *Setaria* millets: A review of the world literature. S.B. 513. Univ. Nebraska, Lincoln.

Maman, N., S.C. Mason, T. Galusha, and M.S. Clegg. 1999. Hybrid and nitrogen influence on pearl millet production in Nebraska: Yield, growth and nitrogen uptake, and nitrogen use efficiency. Agron. J. 91:737–743.

Marathee, J.P. 1993. Structure and characteristics of the world millet economy. p. 159–178. In: K.W. Riley, S.C. Gupta, A. Seetharam, and J.N. Mushonga (eds.), Advances in small millets. Oxford and IBH Publ. Co. Pvt. Ltd., 66 Janpath, New Delhi.

Marcon, A. 1994. Wheat streak mosaic virus resistance in foxtail millet, *Setaria Italica* L. Beauv., and factors related to resistance. M.S. thesis. Univ. Nebraska, Lincoln.

Matz, S.A. 1986. Millet, wild rice, adlay, and rice grass. p. 225–229. In: Cereal science. Avi Press, Westport, CT.

National Research Council. 1996. Lost crops of Africa. Vol. 1: Grains. National Academy Press, Washington, DC.

Oduori, C. 1993. Small millets production and research in Kenya. p. 67–73. In: K.W. Riley, S.C. Gupta, A. Seetharam, and J.N. Mushonga (eds.), Advances in small millets. Oxford & IBH Publ. Co. Pvt. Ltd., 66 Janpath, New Delhi.

Rachie, K.O. 1975. The millets. Importance, utilization and outlook. ICRISAT. Hyderabad, India.

Roshevits, R. 1980. Grasses: An introduction to the study of fodder and cereal grasses. Indian National Scientific Doc. Center. New Delhi.

Siles, M.M., D.D. Baltensperger, and L.A. Nelson. 2001a. Technique for artificial hybridization of foxtail millet [*Setaria italica* (L.) Beauv.]. Crop Sci. 41:1408–1412.

Siles, M.M., D.D. Baltensperger, L.A. Nelson, A. Marcon, and G.E. Frickel. 2001b. Registration of five genetic marker stocks for foxtail millet. Crop Sci. 41:2011–2012.

Uludag, A., D.J. Lyon, S.J. Nissen, and S.D. Kachman. 1997. Proso millet (*Panicum miliaceum*) response to CGA-152005, metsulfuron, and triasulfuron. Weed Technol. 11:138–143.