Sorghum and Pearl Millet for Crop Diversification, Improved Crop-Livestock Productivity and Farmers Livelihood in Central Asia

INTRODUCTION

Limited water resources, soil salinity and poor soil fertility are the major constraints to crop-livestock production in Central Asia. Adoption of crop species adapted to harsh drylands environments and further enhancement of their yield potential and quality provides a cost-effective and sustainable solution to meet feed, fodder and household food needs of farmers and pastoralist for their livelihood improvement.

One of the most promising research is the diversification of agro-biodiversity by using alternative, well-adapted, salt- and drought-tolerant crops in farming system on marginal lands. Thus, diversification makes it possible to cultivate better adapted species to water and soil salinity such as sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) along with traditional crops like cotton, wheat etc. Their use has two main advantages: first, it will help to create a stable grain production and fodder supply for developing a local livestock feeding system, and second, it will help to prevent erosion and improve soil productivity.

Sorghum [*Sorghum bicolor* (L.) Moench), grown on 43 million ha worldwide, is a major warm-season cereal of the semi-arid tropics. Pearl millet [*Pennisetum glaucum* (L.) R. Br.), grown on 26 million ha, is a major warm-season cereal in the arid and semi-arid regions of Africa, India and South Asia. In the developing countries of these regions, both crops are important components of low-resource agriculture, and are primarily grown for food uses. These are also valued as feed, stover (dry stalk after grain harvest), forage and energy crops. Both crops have high water-use efficiency, and are highly tolerant to drought, heat and soil salinity. These features make sorghum and pearl millet, especially suitable for crop diversification and crop-livestock productivity enhancement in Central Asia.

Sorghum and pearl millet for grain and forage purposes in Central Asia, however, have very little cultivar diversity. Farmers in the region are familiar with proso millet and its use for food, feed and fodder. Pearl millet with higher grain and fodder yield can partially replace proso millet and occupy new niches, leading to crop diversification and enhanced crop-livestock productivity in the region.

In response to these opportunities, ICBA together with ICARDA and ICRISAT initiated a new project in 2011. The main national partners are the Uzbek Production Center of Agriculture under the Ministry of Agriculture and Water Resources of Uzbekistan, Karakalpakstan Branch of the Rice Institute, Gulistan State University, Tajik Academy of Agricultural Sciences, Institute of Plant Husbandry and Kyzylorda Institute of Rice in Kazakhstan. This project on "Diversification of crops of sorghum and pearl millet to improve food supply and well-being of livestock farmers in Central Asia", is being implemented from 2011 to 2014 and is funded by the Islamic Development Bank. The aim of the project is to improve rural livelihoods and food security by using by marginal lands in Kazakhstan, Tajikistan and Uzbekistan by applying principles and practices of biosaline agriculture to achieve sustainable land and water resources management.

As part of this project, the partner institutions periodically arrange training sessions and workshops for researchers and farmers in the region.

This article represents some of the major findings emerging from the evaluation breeding results and seed multiplication of these two valuable cereals in different regional nurseries and discussions with scientists, administrators and farmers in the region; and an outline for future directions.

RESULTS

Under dry continental climate of Central Asia sorghum and pearl millet can be cultivated as main crops (planted in April to mid-May) or as second crop (planted in mid-June to early July) after wheat harvest. The appropriate maturity requirement both in main crop and second crop will depend on the time of onset of the frost. For instance, in northern part of Kazakhstan, Tajikistan and in Nukus (Uzbekistan), when planted as a main crop sorghum varieties maturing in 120-140 days can be taken only as a main crop as the frost starts early in this areas. Under Samarkand, Mirzachili steppe, Central Kyzylkum Desert and southern Kazakhstan conditions however, sorghum and pearl millet varieties can be taken as a main crop as well as a second

crop. Early maturity (65-70 days) multi-cutting pearl millet varieties fit well under the prevailing cropping system in all investigated agroecological systems. Screening of more than 52 improved lines of pearl millet through on-station and farmer-participatory on-farm multi-location trials under different field management practices identified Sudan Pop III, Guerinian-4, IP 6104, IP 6112, IP 22269, IP 19586, HHVBC Tall, ICMS 7704, Sudan Pop1, JBV3, ICMV 155, MC 94 C_2, and Raj 171 as the most salt/drought tolerant and highly productive varieties for food and forage production.

The pearl millet cultivars received from the ICBA and ICRISAT under Kyzylkum desert conditions produced between 38.0 and 96.4 t/ha^{-1} of green biomass, of which the cultivars Raj 171 (90.0 t/ha^{-1}), IP 19586 (91.6 t/ha^{-1}), and IP 22269 (96.7 t/ha^{-1}) performed best. If these cultivars are grown near the watering points in the vicinity of the herds (size of 2000 units) on 10 hectare area, the survival ratio could easily be doubled from 2 kg to 4 kg day^{-1} per animal during the severe winter season.

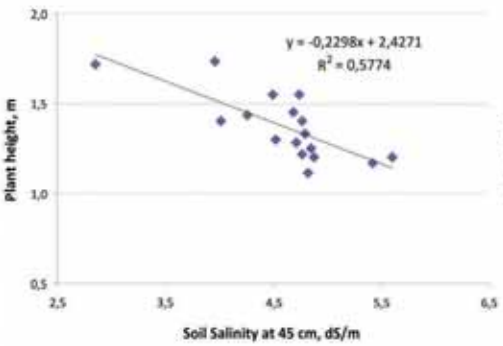
Among evaluated so far sorghum varieties ICSV 93046, ICSSH 58, SPV 1411, ICSR 93034, ICSV 25280, S35, Sugar Graze, Pioneer 858 at a plant height of 204-262 cm exceeded the standard Korabosh variety in 14.32-23.66 kg/plot of green matter and 1.85-4.01 kg/plot of dry matter. All of these improved lines of sorghum have demonstrated about 30% higher dry fodder and 25% higher seed yield than the local varieties.

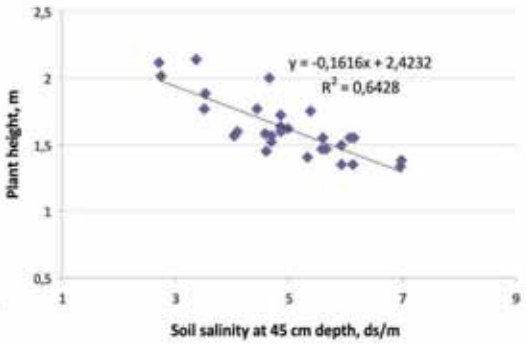
These two crops sowing with 30cm inter-rows space significantly increase the plant density and, consequently the fresh forage production at the end of harvesting of sorghum and pearl millet from the fields. Sorghum varieties maturing in 110-140 days can be taken only as a main crop as the frost starts early in this area. The early term seed bedding (March at soil temperature +5-10C) as was demonstrated in a trial in Kyzylkesek (Central Kyzylkum) allowed to obtain three cuts (7, 8-9.1 kg/plot green forage) until late October.

DEVELOPMENT OF SORGHUM AND PEARL MILLET VARIETIES RESISTANT TO ABIOTIC STRESS

Monitoring of irrigation water, ground water and soil salinity level (at different soil depth profile -15, 30, 45 cm) by using EC meter (Direct Soil EC meter) during sorghum and pearl millet vegetation season at Bayavut and Kyzylkesek farms (Uzbekistan), Shortanbay farm (Karakalpakstan) and at experimental station of Kyzylorda Institute of Rice Production (Kazakhstan) showng the trend (ecological raw) of increasing of salt tolerance among investigated non-conventional germplasm from ICRISAT compared with local varieties.

Average threshold salinity levels for examined pearl millet varieties ranged from 2.6 to 8.5 dS/m^{-1}; and from 2,4 up to 4.6 dS/m^{-1} for sorghum entries respectively. New released variety "Hashaki 1" has an intermediate position, while the lowest plant density (267000 plants/ha) was observed for Raj171. New local variety is resistant to moderate soil salinity and low quality water with grain yield 2.96 t/ha. Thus, sorghum and pearl millet varieties derived from ICRISAT and ICBA germplasm normally can be classified as moderately salt-tolerant crops. Sorghum was more sensitive than pearl millet to soil and water salinity under shallow (0,5-1,8 m) and saline water table (1, 5-3.8 dS/m^{-1}) as it was demonstrated in a trial in Shortanbay farm in Karakalpakstan.





LEAD TO SUCCESS IN LOCAL BREEDING PROGRAM

A new dual-purpose and fast maturing variety of pearl millet named "Hashaki 1" was released based on experiments conducted by ICBA and ICRISAT in 2007-2011 in collaboration with Uzbek Scientific Research Center of Agriculture (at Zangyota site, Corn Uzbek Station). This new variety was selected as the result of series of cross-pollinations of HHVBC Tall improved line from ICRISAT with local varieties. Relative

growth rates, biomass (fresh and dry) and grain production of the new released variety exceeded the local varieties by 2.0-2.5 times. As early maturing pearl millet material "Hashaki-1" performed well in dryland saline environments and could be widely planted as main crop in early spring or as second crop after the wheat harvest or in rice rotation system.

In 2011 "Hashaki1" was recognized by Uzbek State Varietals Commission as promising variety to be evaluated under different soil-climatic conditions as salt-drought and heat tolerant dual purpose crop.

Table1. Characteristics of some morphological, biological and agronomic traits of new promising local variety named "Hashaki 1" (average data 2007-2011).

Average plant height	207cm	The variety is distinguished by its expressive tillering and re-growing ability. Number of basal tillers ranging 3-12
Plant density:	90-110 (A) 180-220 (B)	A- as main crop for grain production; distance between rows - 60-70cm; B- summer crop for forage with distance between rows - 30-35cm
Period of vegetation (from seed germination until seed maturation)	90-86 days	Testing Assessment (1-5): Drought tolerance index– 5; Lodging index – 5; Frost tolerance index– 4; Stem fragility – 5
Green biomass	36.07 t/ha	The average yield of green biomass after two cuts varies 45.0 t/ha comparatively with local varieties 27.68 -30.54 t/ha
Absolute dry substances	14.43 t/ha	Two cuts: (first at time to 50% flower) and second cutting – before autumn frosts.
Grain yield	2.96 t/ha	Weight of 1000 seeds-11.8 g; Average weight of panicle with seeds-38,3
Content of juice in the stems	62.5%	Well used for all kind of livestock; showed good palatability.

Farmers showed interest to cultivate it mostly for forage (green biomass and silage).
At the moment seed production of this high-yielding variety is under development in order to provide high quality and certified seeds for increasing needs of biosaline agricultural production in Uzbekistan. The main objective of seed production of "Hashaki 1" variety is rapid multiplication by maintaining the varietals identity (a spatial field isolation of about 500-1000 m with periodically renovation from breeder seeds) and genetic purity.

SEED MULTIPLICATION TRIALS

On farm seed multiplication trials (of about 0.5-1,5 ha) and identification of seed production facilities on sentinel sites with participatory work of farmers requirements were firstly initiated in the region. Specialized on-farm seed multiplication trials for 4 promising sorghum ICSV 93046, SPV 1411 sorghum, 3 pearl millet (HHVBC Tall, IP 19586, MC94C$_2$) from ICRISAT along with locally new released Hashaki1 variety were established in Kyzylkesek and Zangyota sites in Uzbekistan; Abay farm southern Kazahstan and Gafurov Farm in Tajikistan. Selected farmers are producing the seed under fish nets and/or by using selfing-bags to protect from bird damage. In Tajikistan 28 farmers were identified and invited to form a social network for pearl millet

seed production. Seeds can be specially produced by separate or cluster farmers of nearby villages on a remunerative price to recover the cost of seed production, plus 30-50% profit.

Laboratory standard analytical methods and field performance were analyzed to quantify seed quality (germination rate; energy of germination; seed viability) of sorghum and pearl millet seed, produced by farmers. Variety purity and seeds maintained by farmers were also assessed for different seed sources. The seed quality assessment showed that farmer produced seed is generally of medium quality.

Seed producing farmer will visualize some benefit in producing the seed for an incentive, and hence can ensure adequate and timely supply of quality seeds. The International Centers and National Institutions in the target area of seed production are providing technical guidance for quality seed production.

BENEFITS FOR FARMERS

• In both sorghum and pearl millet, there is a preference for dual-propose varieties with almost similar - values for grain and stover. In this case, the plant height of both crops should be 1.5 - 1.8 m to enable high stover yield. And this higher stover yield will give sorghum and pearl millet the real advantage over proso millet. There is great interest of in growing sorghum and pearl millet for green forage as well.

• There is a good opportunity for crop diversification with both sorghum and pearl millet in salinity-affected areas (both high and moderate salinity). There is a greater scope and opportunity for these crops in medium-saline lands, where they can give higher grain and fodder (stover as well as green forage) yield.

• The grains of both sorghum and pearl millet can be used equally for livestock feed (mostly poultry feed - both in household and farm sectors) and for food products as it is currently the practice with proso millet. There is considerable knowledge in the region regarding the preparation of various types of food products (and its human health consequences) from proso millet, and hence the use of pearl millet grains for livestock feed and various types of food products will be a rather easy and quick process.

FUTURE DIRECTIONS

• Based on the results of initial preliminary evaluation in Central Asia, small-size nurseries of selected dual-purpose and forage type populations of sorghum and pearl millet should be constituted. These should continue to be evaluated, following farmer-participatory, in multi-location trials in Central Asia for at least two years before undertaking extensive on-farm trials and subsequent adoption by farmers.

• The trials should be conducted as a main crop as well as a second crop. Also, the trials should be conducted at a few selected locations under leached and un-leached treatments to assess yield potential and salinity tolerance with respect to both grain and fodder yield.

• In case of pearl millet, 2-3 cycles of simple mass selection within selected populations should be carried out to improved their productivity and uniformity with respect to plant height, flowering time, panicle traits (size and shape) and seed set index.

• For the longer-term, high-yielding and salinity-tolerant populations should be used in hybridization programs to develop varieties with greater yield potential and salinity tolerance. Hybrids have been found to have 25-30% grain yield advantage (and at least, as much fodder yield advantage) over varieties both in sorghum and pearl millet. To develop a hybrid program, a wide range of parental lines of these crops developed at ICRISAT should be evaluated for their adaptation in Central Asia and those found promising should be tested for their hybrid performance.

• The regional capacity for genetic improvement, seed production and crop management of sorghum and pearl millet should be enhanced with back up support from ICRISAT, ICBA and ICARDA.

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