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Potential of pearl millet as a forage crop in wheat-based double cropping system in Central Asia

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Abstract

Livestock is a vital resource for smallholder farmers' livelihoods in Central Asia, but shortage of winter season fodder is a major constraint to livestock productivity in this region. Three pearl millet populations were compared with a locally adapted improved maize variety in Kyrgyzstan and Tajikistan for their forage potential in wheat-based cropping system as a second crop after wheat harvest. Two medium-maturity, dual-purpose populations (HHVBC-Tall and Raj 171) significantly out-yielded locally adapted improved maize cultivars in both countries that had different productivity levels. While HHVBC-Tall had 6.56 t ha^{-1} of dry forage yield in Kyrgyzstan and 13.70 t ha^{-1} of dry forage yield in Tajikistan (28% higher than maize cultivars in both countries), Raj 171 had 18% higher dry forage yield than the locally adapted improved maize variety in Kyrgyzstan and 10% higher dry forage yield than locally adapted improved maize variety in Tajikistan. The benefit-cost ratio from forage production of both pearl millet populations was highest for HHVBC-Tall (0.89 in Kyrgyzstan and 1.56 in Tajikistan), followed by Raj 171 (0.74 in Kyrgyzstan and 1.20 in Tajikistan), which were much higher than those for maize varieties. These results showed that medium-maturity pearl millet varieties have good potential to fill in the fallow land after wheat harvest and significantly contribute to fodder security in Central Asia**.**

Introduction

Livestock production plays a vital role in smallholders' livelihoods, especially in the poorer sections of agricultural communities in Central Asia (ICARDA 2010). Consistent supply of fodder round the year has a direct bearing on livestock productivity, and hence on smallholders' livelihoods as feed and forage costs account for the highest share in the total cost of inputs for livestock production (Kerven et al. 2006). A recent survey to assess the current status of forage production and feeding practices of household farms was initiated in Kazakhstan, Kyrgyzstan and Tajikistan in 2007 under IFAD (International Fund for Agricultural Development)-funded project on "Community Action in Integrated and Market Oriented Feed–Livestock Production in Central and South Asia" and it was concluded in 2008 with a total of 314 respondents. Results of this survey showed that lack of winter fodder, non-functioning of the traditional rotational grazing management system and the absence of support for forage production were the main limiting factors for livestock production (ICARDA 2010). This study also showed that maize (*Zea mays*) and alfalfa (*Medicago sativa*) were the most common and popular forage crops. In some villages, sainfoin (*Onobrychis viciifolia*) and sorghum (*Sorghum bicolor*) were also grown. Relatively large differences in alfalfa biomass and maize fodder yields among households and villages were reported but overall yield levels were low, which resulted from the use of poor agronomic practices and the lack of access to improved varieties. Wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) are the major cereal crops grown in Kyrgyzstan and Tajikistan. In these areas farmers usually finish harvesting of winter wheat and barley during mid-June through mid-July and undertake next planting of these crops during the first fortnight of October. Thus, the land stays fallow for more than three months after wheat harvest, of which efficient use can be made through double cropping with forage crops. Apart from forage production, this cropping system would help arrest soil erosion, and prevent harmful runoff into nearby water bodies. There is also the possibility that double cropping can help break pest cycles that are encouraged by monocultures, and thus reduce pesticide use.

Pearl millet (*Pennisetum glaucum*), also known as bulrush or cattail millet, is an important grain and fodder crop, grown largely for grain and stover production on more than 28 million ha in the arid and semi-arid tropical regions of Asia and Africa (Yadav et al. 2012b). It is also grown as a green forage crop on a limited scale in parts of USA, South America and Australia. Being a C4 species, pearl millet has high photosynthetic efficiency and biomass production ability. It is also endowed with various adaptive features related to high levels of tolerance to abiotic stresses such as high temperatures during seedling emergence, growth and flowering, drought and soil salinity (Yadav et al. 2012a). Pearl millet also has higher water-use efficiency than other major warm season cereals such as sorghum and maize (Singh and Singh 1995), which are also used for forage production. Several studies have reported pearl millet having very high forage yield potential, exceeding even 20 t ha^{-1} of dry matter (Rai et al. 2012). In view of these attributes vis-à-vis its climate change resilience, pearl millet is recently being experimented as a grain and fodder crop in several countries in Western Asia and North Africa (WANA) and Central Asia regions. The introduction of pearl millet into the existing cropping systems in Central Asia as a second crop after wheat and barley harvest could be a promising alternative for forage production. There are no farmers or households in this region who are specialized in forage production, and it is very rare that households and farmers sell forages in the local markets. They grow forage crops only for feeding their own livestock, and hence are entirely dependent on household forage production. The objective of this study was to assess the forage potential of pearl millet as a second crop after wheat harvest in Kyrgyzstan and Northern Tajikistan.

Materials and methods

Earlier studies conducted in collaboration with the International Center for Biosaline Agriculture (ICBA) had identified a dual-purpose open-pollinated variety (Raj 171) and a dual-purpose High Head Volume B-Composite-Tall (HHVBC-Tall) among several populations and breeding lines as promising pearl millet materials adapted to WANA region (Rai et al. 2005). These populations and an Extra-Early-Maturing B-Composite (EEBC), all developed at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), were evaluated along with a local maize variety (Dilshod in Tajikistan and Oktyabrskiy 70 in Kyrgyzstan) in a randomized complete block design with four replications at two sites each in Tajikistan and Kyrgyzstan for two years during 2008 and 2009. The two sites included the research farm of Research Institute of Veterinary, Livestock and Pastures and a farmer's field in Kyrgyzstan; and two farmers' fields in Tajikistan. After the winter wheat harvest, pre-planting irrigation was provided. The field was plowed to a depth of 25–27 cm, which was followed by harrowing, leveling and opening the furrows at 70 cm spacing. Pearl millet was planted at the rate of 5 kg ha^{-1}, while maize was planted at the rate of 35 kg ha^{-1} in the furrow. Each plot consisted of 4 rows, 4.5 m long. At 10 days after planting, seedlings were thinned to single plants spaced at 10 cm in pearl millet and 7 cm in maize. Fields were fertilized with 120 kg ha^{-1} of ammonium nitrate 4–5 days after sowing, with a second application of ammonium nitrate applied at 80 kg ha^{-1} at 30 days after sowing, leading to a total 200 kg ha^{-1} of ammonium nitrate (nitrogen 34%) application. Hand weeding was done twice, first at 10 days after sowing and then at 30–32 days after sowing. Post-planting irrigation was done twice, first irrigation 10 days after sowing and second irrigation 35 days after sowing. Inter-cultivation was provided at the depth of 10–12 cm followed by each irrigation.

Time to 50% flower was recorded on plot basis. Five plants from each plot were used to record plant height. At early dough stage (which varied for the entries, depending on their flowering time), all plants were harvested to record fresh fodder yield. Random samples of five plants were also weighed for fresh weight and then oven dried at 60°C until constant weight was achieved to determine dry matter per plot. A fixed model analysis of variance, assuming two countries with two sites each for both years as providing eight test environments, was done following Gomez and Gomez (1984), and using Genstat software (Genstat 11th edition).

Results and discussion

There were highly significant differences (P <0.01) among the populations in population × environment interaction for dry forage yield, plant height and time to flower (data not presented). While the contribution of population × environment interaction to variability was 46% of those due to differences among the populations for dry forage yield, these were 20% and 11%, respectively, of those due to population differences for time to flower and plant height, which is expected considering that plant height and flowering time are highly heritable traits and hence less prone to genotype × environment interaction. The dry forage yields of all three pearl millet populations in Tajikistan were about twice of those in Kyrgyzstan (Table 1). Pearl millet composite HHVBC-Tall was the highest yielding population, with 28% higher dry forage yield than maize both in Kyrgyzstan (6.56 t ha^{-1}) and Tajikistan (13.7 t ha^{-1}), and it flowered 4–5 days earlier and was 60–70 cm taller than maize. Raj 171 had 8–10% less yield than HHVBC-Tall in both countries, although it flowered 10 days later than HHVBC-Tall in Kyrgyzstan and 2 days later in Tajikistan. The lower forage yield of Raj 171 appears to have resulted primarily from its shorter height as compared to HHVBC-Tall. EEBC flowered 14 days earlier than maize in Kyrgyzstan and 11 days earlier in Tajikistan, and it was the lowest-yielding population with 12% less forage yield than maize in Kyrgyzstan and 24% less yield in Tajikistan. It was also the shortest in plant height (133–134 cm) in both countries. While EEBC was the lowest-yielding population, it may provide a better option than HHVBC-Tall under conditions where wheat harvest leaves a small window for the second crop before the wheat planting in the following year.

HHVBC-Tall was developed by random mating 17 tall S1 progenies selected visually for high productivity from HHVBC. The latter had been constituted by crossing a random mated bulk of 38 elite inbred lines developed as potential seed parents with an *iniadi*

Table 1. Dry forage yield, time to flower and plant height of pearl millet populations and maize in Kyrgyzstan and Tajikistan.

Country	Population	Dry forage yield (t ha^{-1})	Time to 50% flower (days)	Plant height (cm)
Kyrgyzstan	Maize (local variety)	5.14	59	202
	HHVBC-Tall	6.56	55	260
	Raj 171	6.06	65	210
	EEBC	4.54	45	133
Tajikistan	Maize (local variety)	10.68	53	236
	HHVBC-Tall	13.70	48	306
	Raj 171	11.77	50	272
	EEBC	8.17	42	134
SE±		0.27	0.21	3.82

Table 2. Benefit-cost ratio for forage production from pearl millet populations and maize in Kyrgyzstan and Tajikistan.

			Pearl millet		
Country	Benefit-cost variable	Maize	HHVBC-Tall	Raj 171	EEBC
Kyrgyzstan	Fodder yield (t ha^{-1})	5.14	6.56	6.06	4.54
	Fodder price (US$ t^{-1})	53	53	53	53
	Total income (US$ ha^{-1})	272	348	321	241
	Production cost (US$ ha^{-1})	180	184	184	184
	Net benefit (US$ ha^{-1})	92	164	137	57
	Benefit-cost ratio	0.51	0.89	0.74	0.31
Tajikistan	Fodder yield (t ha^{-1})	10.68	13.7	11.77	8.14
	Fodder price (US$ t^{-1})	45	45	45	45
	Total income (US$ ha^{-1})	481	617	530	366
	Production cost (US$ ha^{-1})	259	241	241	241
	Net benefit (US$ ha^{-1})	222	376	289	125
	Benefit-cost ratio	0.86	1.56	1.20	0.52

germplasm accession ARD 119 from Togo and random mating it twice in the isolation. EEBC had been developed by random mating 286 extra-early-maturing S2 progenies derived from 43 *iniadi* accessions that flowered no later than the earliest-maturing male-sterile line 843 A under extended day length of 14.5 h at Patancheru (Rai et al. 1998). Thus, both are broad-based populations with large intra-population variability that can be effectively exploited for further improvement of their forage yield potential. In fact, one cycle of mass selection for grain yield in EEBC led to 12% increase in grain yield over the original EEBC, and similar or even higher genetic grains can be expected for forage yield in EEBC as well as in HHVBC-Tall.

Consultations with the farmers growing these trials showed that farmers would be willing to pay the same price for pearl millet forage as for maize forage on dry weight basis, and they did not differentiate among pearl millet populations with respect to forage quality, principally because there were no differences among the populations with respect to leaf diseases, which are visible indicators of forage quality. The net benefit from forages of HHVBC-Tall and Raj 171 was US$ 164 ha^{-1} and US$ 137 ha^{-1}, respectively, which was 78% and 49% higher than maize (US$ 92 ha^{-1}) in Kyrgyzstan; and it was US$ 376 ha^{-1} and US$ 289 ha^{-1}, respectively, which was 69% and 30% higher than maize (US$ 222 ha^{-1}) in Tajikistan. The benefit-cost ratio for maize varied from 0.51 in Kyrgyzstan to 0.86 in Tajikistan. It was much higher both for HHVBC-Tall (0.89 in Kyrgyzstan and 1.56 in Tajikistan) and Raj 171 (0.74 in Kyrgyzstan and 1.20 in Tajikistan) (Table 2). Thus, even though the fodder price both for maize and pearl millet was higher by US$ 8 per ton in Kyrgyzstan than in Tajikistan, and the production cost was higher by US$ 57 ha^{-1} for pearl millet and US$ 79 ha^{-1} for maize in Tajikistan, the benefit-cost ratio for both crops was more favorable in Tajikistan on account of disproportionately higher forage yield. These results show that introduction of higher yielding medium-maturity pearl millet as a forage crop will help livestock producers to have an access to cheaper forage resources and thus improve the efficiency of livestock production in Kyrgyzstan and Tajikistan, and perhaps in other Central Asian countries as well (Fig. 1).

Figure 1. Pearl millet as a new forage crop for Central Asia.

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