



Evaluation of nutritional components of different foxtail millet (*Setaria italica*) germplasm for hay

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ABSTRACT

Foxtail millet (*Setaria italica*) is highly adaptable to abiotic stresses, especially drought and poor soil. At present, few studies have analysed nutritional components and evaluated the nutritional value for hay from different foxtail millet germplasm resources. The objective of this study was to improve the selection and breeding efficiency of forage foxtail millet germplasm resources, which is important for the development and growth of livestock. The contents of 11 nutritional indices in hay of 82 foxtail millet germplasms were determined during 2014-15, and correlation and clustering of nutrient quality characteristics were performed. The results indicated that there were significant difference between varieties of crude protein and crude ash ($P<0.05$), there were extremely significant differences between varieties of moisture, crude fibre, carbohydrate, ether extract, phosphorus, iron, calcium, zinc, selenium ($P<0.01$). The 82 varieties were classified into six types by hierarchical cluster analysis, including higher protein, rich in minerals, higher ether extract, and higher carbohydrate, which may be of value in the application of cultivating higher quality forage millet and functional millet grass in northern summer millet region.

Key words: Forage quality, Foxtail millet, Hay forage, Nutritional components

Foxtail millet is a multipurpose, important, and ancient agricultural crop in China (Yang *et al.* 2012). It has some important agronomic characteristics, such as high water use efficiency, drought-resistance, tolerance of low soil fertility conditions, nutrient rich, high forage protein content, and reduced need for fertilizers and pesticides, which make it an environmentally friendly crop (Diao *et al.* 2011, Li *et al.* 2012). Although the crude protein and the ether extract of hay forage millet after grain harvest were lower than those of legumes, they were significantly higher than those of other cereal crops. In particular, the digestible components were higher than other cereal crops, and their feeding value was close to that of leguminous forage (He *et al.* 2010, Wu *et al.* 2005). By the classification criterion of legume and gramineous forages in America, the feeding value of 17 forage millet is middle and upper level, and it is a better forage variety (Ren *et al.* 2019).

There were many forage crops in China, such as forage maize, *Sorghum sudanense*. Four lines were selected as candidates for future forage variety breeding of foxtail millet (Zhi *et al.* 2012). Yang *et al.* (2011) indicated that foxtail millet, proso millet, maize and sorghum were optimal forage crops. To solve the problem of the lack of special forage millet varieties, Jicaogu 1 was bred for forage use from wild large-grain foxtail millet (Xia *et al.* 2016). The mixture of sainfoin with other forages, particularly millet,

may be beneficial for intensive production in cold climates (Sadeh *et al.* 2013). Swathed whole plant millet had greater dry matter (DM), crude protein (CP), and neutral detergent fibre (NDF) degradability compared to grass-legume hay (Lardner *et al.* 2016). While, few studies have analyzed nutritional components and evaluated the nutritional value for hay from different foxtail millet germplasm resources.

The main objective of this study was to examine 11 nutritional indices in hay of 82 foxtail millet germplasm resources. In addition, the correlation and clustering of nutrient quality characters were analyzed. This research evaluated the nutritional value for hay of foxtail millet after the harvest of grains.

MATERIALS AND METHODS

In this study, 82 cultivars from different ecological regions: Northern summer millet region (NSR) (N=40: yangu13, bao3100101, heng8735, hengyou17, jigu25, K359, yugu17, H332, zhenggu4, jiyoumi10, ji8846, ji9051, anai096, an4035, shi02-488, shi02-521, jigu19×shi96355, jigu14×jigu19, jigu24, shi203184, shi04-973, shi04-1580, shi97-130-1, shi97-74-1, shi97-73, fu 1, yintianhan, jigu22, H549hong, yugu18, heng0902, zheng10-1, Z281, K3970, C264, K3201, K2229, K1977, henglvgu1, jinlvgu), Northwest spring millet region(NWR) (N=25: gan63051, jinfen01, jinfen03, jinfen100, jinfen99, jingu21, jingu36, jingu41, jingu45, longgu10, longgu5, changnong0302, changsheng06, 2010xi7, changsheng08, jinfen96, fenxuan3, jinfen02, jingu52, changnong40, jingu30, taixuan5,

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Table 1 Method of detecting nutritional components

Component	Detection method	Reference
Moisture	drying	ISO 6496-1999
Crude protein	according to the Dumas principle	SN/T 2115-2008
Crude ash	550°firing	ISO5984:2002
Crude fiber	method with intermediate filtration	ISO6865:2000
Ether extract	hydrolysis, extract	ISO 6492-1999
Carbohydrate	100-moisture-ash-fat- - protein-crude fiber	-
Microelement	ICP-MS	Chen.2011

changzhi98188, changzhi2, taixuan2), Northeast spring millet region (NER) (N=3: cheng03-992, liaogu3, gonggu69) and some cultivars from Japan (N=2: huwei2, 50risu), India(N=3: yin0906, yin0907, yin90-39), and landrace(LR) (N=9: laohuanggu, lvsuigu, pilianggu, maonihuangxuan, 368, guchuansu, shangchong1, A40, A43) were used.

These cultivars was planted on June 20, 2014 after building soil moisture at the Qiema test station (N37°57'54.12", E114°36'48.70", 66 m amol) of the Institute of Millet Crops of Hebei Academy of Agricultural and Forestry Sciences in China. The experiment was fertilized at 600 kg compound fertilizer (the ratio N-P-K:26-10-15) per ha. This area had a total precipitation of 356.8 mm during growing season (June-September), and irrigation was not performed throughout the whole growth period. Crops were mowed closely to the ground. All straw samples after the harvest of grains were dry milled to powder in our lab with a sample pulverizer (QE-100g, Zhejiang Yili limited liability company), passing through a 0.42 mm mesh. Chemical composition was determined by the Hebei entry-exit inspection and quarantine technical center in 2015, including moisture (MC), crude ash (Ash), crude protein (CP), ether extract (EE), crude fibre (CF), carbohydrate

(CA), phosphorus (P), calcium (Ca), iron (Fe), zinc (Zn), and selenium(Se) (Table 1). Each experiment was repeated at least three times with thrice samples.

The analysis of variance (ANOVA), correlation and clustering (Euclidean distance) of nutrient quality characters was performed with SPSS statistics software 19.0 and DPS 14.1.

RESULTS AND DISCUSSION

Analysis of nutritional components in different millet germplasm resources: Among all 82 accessions, the coefficients of variation for moisture, phosphorus, and ether extract were large, 41%, 37%, and 30%, respectively. The coefficients of variation for carbohydrate and crude fibre were the lowest at about 10%. The range of crude protein content was 4.29–9.56% with the highest found in jinlvgu and the lowest in Z281. This was equal to sorghum and superior to wheat. The mean value of moisture, calcium, and iron of 82 varieties were consistent with previous results (Yang *et al.* 2011). For the selenium content, the range was 0.09–0.25 mg/kg with jigu24 being the highest and changnong0302 being the lowest. Phosphorus content was greater than the normal range of forage grass (0.03-0.09%) while zinc and selenium were within the normal range of forage grass (Zn:20–35 mg/kg, Se: ≤5 mg/kg). Selenium is necessary for humans and animals and has an important role in preventing Keshan disease and protecting the heart. Our studies showed that the selenium contents of Hebei varieties Jigu 24 and Jigu19×Shi96355 were higher than other varieties. These Hebei varieties could provide the resources rich in selenium for the cultivation of functional millet grass.

Moreover, the optimal range for the dietary ratios of Ca and P that maintains optimal ruminant performance is between 1 and 7. The imbalance of the ratios of Ca and P reduces the absorption of calcium, phosphorus, and other mineral elements. Therefore, the balance of calcium and phosphorus in livestock is essential for meeting their growth

Table 2 Pearson Correlations of the content of 11 nutritional components

Nutritional components	Moisture	Crude ash	Crude protein	Ether extract	Crude fiber	Carbohydrate	Phosphorus	Calcium	Ferrum	Zinc	Selenium
Moisture	1	-0.189	-0.242*	-0.094	-0.261*	-0.322**	-0.003	-0.234*	0.022	0.05	-0.05
Crude ash	-0.189	1	0.004	-0.173	-0.16	0.022	0.149	0.380**	0.330**	0.165	0.217
Crude protein	-0.242*	0.004	1	-0.053	-0.377**	0.343**	0.453**	0.449**	-0.012	0.450**	0.082
Ether extract	-0.094	-0.173	-0.053	1	-0.077	0.154	-0.025	0.006	-0.21	-0.271*	0.015
Crude fiber	-0.261*	-0.16	-0.377**	-0.077	1	-0.774**	-0.435**	-0.276*	-0.132	-0.310**	-0.319**
Carbohydrate	-0.322**	0.022	0.343**	0.154	-0.774**	1	0.327**	0.249	0.047	0.16	0.305**
Phosphorus	-0.003	0.149	0.453**	-0.025	-0.435**	0.327**	1	0.256*	0.14	0.484**	0.491**
Calcium	-0.234*	0.380**	0.449**	0.006	-0.276*	0.249	0.256*	1	0.380**	0.505**	0.402**
Ferrum	0.022	0.330**	-0.012	-0.21	-0.132	0.047	0.14	0.380**	1	0.304**	0.457**
Zinc	0.05	0.165	0.450**	-0.271*	-0.310**	0.16	0.484**	0.505**	0.304**	1	0.399**
Selenium	-0.05	0.217	0.082	0.015	-0.319**	0.305**	0.491**	0.402**	0.457**	0.399**	1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

and production performance (Yang *et al.* 2000). In our study, the ratios Ca and P ranged from 2.21 to 12.86. The ratios of Ca and P of 64 millet varieties were within the optimal dietary range for ruminants (1–7:1)

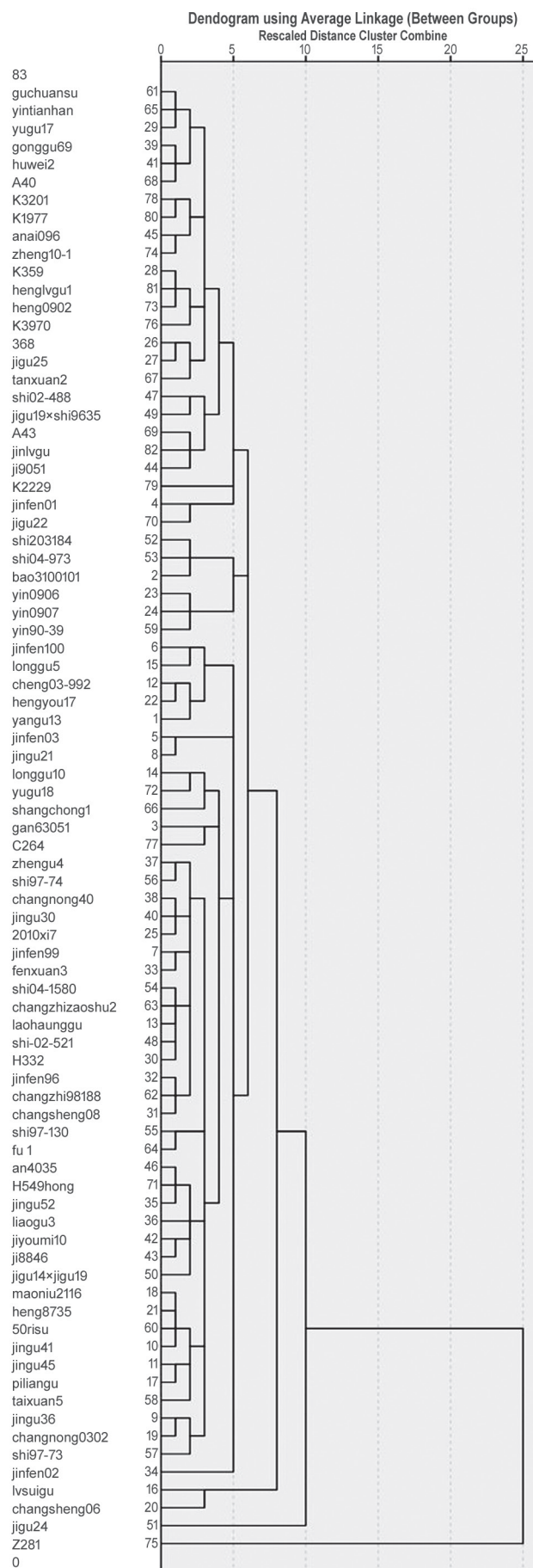
Finally, the results of variance analysis (ANOVA) indicated that there were significant difference between varieties of crude protein and crude ash ($P < 0.05$), there were extremely significant differences between varieties of moisture, crude fibre, carbohydrate, ether extract, phosphorus, iron, calcium, zinc, selenium ($P < 0.01$). F-value indicates that the decreasing order of the differences of 11 nutritional components in different millet germplasm resources are phosphorus > iron > calcium > zinc > moisture > crude fibre > carbohydrate > selenium > ether extract > crude ash > crude protein. In conclusion, the nutrient contents of millet stalks were significantly different among different varieties. It is very important in animal husbandry and the breeding industry to understand the nutritional composition of millet stalks and its feed value for its effective use.

Correlation analysis of nutritional quality traits: Crude protein was significantly positively related to carbohydrate, phosphorus, calcium, and zinc, but significantly negatively related to crude fibre. Ether extract was not significantly related to other nutritional indices. These results are consistent with previous studies (Zhi *et al.* 2012).

There was a significantly negative correlation between moisture and carbohydrate. In contrast, crude ash was significantly positively related to calcium and iron. Further, crude fibre was significantly negatively related to carbohydrate, phosphorus, zinc, and selenium while carbohydrate was significantly positively related to phosphorus and selenium. There was a significantly positive correlation between iron, calcium, zinc, and selenium. Zinc was significantly positively related to phosphorus, calcium, iron, and selenium while selenium was significantly positively related to phosphorus, calcium, iron, and zinc. Iron was not significantly related to phosphorus (Table 2).

Cluster analysis of 82 varieties of millet germplasm resources: The 82 varieties of millet germplasm resources were classified into six types by hierarchical cluster analysis (Euclidean distance) (Fig 1). Twenty five varieties of the first type, e.g. Jigu 25, contained higher crude protein, carbohydrate, minerals and lower crude fibre content than other varieties; these were high quality forage varieties. Jinlvgu, jigu25, taixuan2, shi02-488 and heng0902 contained the highest crude protein. A43, jinfen01, shi02-488, K3970, Jigu 19×shi96355 and ji9051 contained the lower crude fibre. A43 had higher carbohydrate, crude ash, iron, and zinc and lower crude fibre than other varieties. The carbohydrate and iron contents of Jinfen01; the crude ash content of K359, shi02-488, henglvgu1, and jigu22; and the calcium and zinc contents of K3970 were relatively higher than other varieties. Jigu 19×shi96355 contained higher crude ash and selenium; Ji 9051 contained higher calcium, iron,

Fig 1 Cluster analysis dendrogram of 82 varieties of millet germplasms based on their nutritional indices.



and selenium; and K2229 contained higher iron and zinc in comparison with other varieties.

The second type contained six varieties, including three India and three Hebei varieties, and had relatively higher carbohydrate and ether extract than other varieties. The crude fibre of yin90-39 and bao 3100101 were relatively lower while the iron and selenium of Shi 203184 and Shi 04-973 were relatively higher in comparison to other varieties. The third type, jigu 24, had relatively higher ether extract, crude ash, phosphorus, and selenium contents than other varieties. The fourth type, jigu 22 and 46 other varieties, was rich in minerals. Jigu14×jigu19 contained higher crude ash, iron, and selenium while shi 97-130, changzhizaoshu 2, shangchong 1, and yugu 18 contained higher crude ash and iron compared to other varieties. The crude ash of longgu 5 and changsheng 08 and the iron of K1977 and fu 1 were relatively higher than other varieties. The fifth type, changsheng06 and lvsuigu, had relatively higher ether extract, but the iron and selenium contents were very low. The sixth type was Z281 with the highest moisture and higher iron.

The nutritional value of forage millet generally depends on the content of various nutrients. High crude protein, ether extract, and low crude fibre indicate high nutritional value. Crude protein is an essential nutrient and a major source of protein for livestock. Our study indicates that 17 of 25 high quality forage varieties are from the northern summer millet region, therefore, the summer millet varieties may provide some advantages. Assessment of the nutritive value of pastures has mainly been concerned with the supply of energy, protein and minerals (Sadegh *et al.* 2013). The purpose of forage breeding is to produce the greatest nutrient content per unit area. Therefore, the summer millet varieties may provide some advantages. The samples in our study were mainly from the northern summer millet region and northwest spring millet region. Increased sampling from other regions is necessary to comprehensively and objectively evaluate the nutritional value of forage millet from different regions of China. Further studies are still necessary to measure the contents of acid detergent fibre (ADF) and neutral detergent fibre (NDF), the feeding value of 82 foxtail millet must be evaluated and classified according to two evaluation indices, feed relative value (RFV) and feed grading index (GI).

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