Introduction and Comparative Study on Proso Millet (*Panicum miliaceum* L.) Ningmi Varieties in Baicheng

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Abstract: According to the present problems of variety deterioration and low yield of proso millet (*Panicum miliaceum* L.) in Baicheng District of Jilin Province, Northeast China, six introducted proso millet varieties, Ningmi-11, Ningmi-13, Ningmi-14, Ningmi-15, Ningmi-16 and Ningmi-17 from Guyuan District of Ningxia Hui Autonomous Region, Northwest China, were cultivated in order to enrich the gene pool, renew the varieties and increase biodiversity of this kind of crop. Randomized complete block design was utilized as the method of field experiment. The growth stages, agronomic traits, yield-related traits of six experimental cultivars were compared with that of the local variety Jimi-1 used as regional check cultivar. The varieties of Ningmi-13, Ningmi-14 and Ningmi-15 had a longer growth days from planting to maturity; Ningmi-13 and Ningmi-14 presented high yield and good characteristics of agronomic traits, and the 2 varieties can be introduced and spread in Baicheng.

1 Introduction

Proso millet (*Panicum miliaceum* L.) is a kind of short-day plant, is one of the important species of the genus *Panicum*, and is one of the most popular cereals in Northern China, especially in arid and semi-arid regions. As one of main ancient crops of China, proso millet has been grown since prehistoric times, studied for a long time, is cultivited as food for human consumption and was recorded in many agricultural books in the history. Proso millet has the properties of drought resistance, barren tolerance, early-ripening and wide adaptability, and can be used as the last planted crop from late spring to early summer in North China, during which the soil moisture may be not abundant to the seedlings; it can be planted on poor soil; the seeds of proso millet have nutritive and medicinal values, the nutrients in the seeds are balance and easy to be absorbed by humanm bodies. There are abundant proteins in the seeds, of which the average protein content is 13.6%, and the maximum valueis as high as 17.9%[1]; proso millet seeds are rich of essential amina acids, especially methionin, with the content is 299 mg/100 g, which is two times of those in wheat, rice and corn, with the contents of 140 mg/100 g, 147 mg/100 g and 149 mg/100 g, respectively. The average content of fat in proso millet seeds is 3.6% higher than that in wheat flour and rice; there are various glasses of vitamins in its seeds, for example, Vitamin E, B_1 and B_2, of which the contents in seeds are 3.5 mg/100 g, 0.45 mg/100 g and 0.18 mg/100 g, respectively. The content of carbohydrates in proso millet is high, and reducing sugars, syrup and maltose can be produced by means of hydrolysis. Proso millet seeds and flour can be developed and used for making “health” food, for livestock and poultry feed, for brewing, as well as for extracting its hull pigment from

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colorful seeds of black, red, white, yellow and grey[2]. It has potential for developing and selecting high quality proso millet variaties.

As an important coarse cereals in Baicheng, Jilin Province, proso millet is widely used and a long planting history in this region. There are many problems in millet cultivation, breeding and industrial production of proso millet in Baicheng proso millet, for example, variety degeneration, genetical impurity, low and unstable yield, etc. In order to solve problems of variety deterioration and low yield there, effective measures should be taken to broaden the gene pool and enrich the biodiversity of proso millet in Baicheng District. Six Proso millet varieties, Ningmi-11, Ningmi-13, Ningmi-14, Ningmi-15, Ningmi-16 and Ningmi-17 were used as studying cultivars in this research. Ningmi are a series of high quality proso millet varieties, introduced from Guyuan District of Ningxia Hui Autonomous Region. These 6 varieties were cultivated and comparatively analyzed on characteristics of growth stages, agronomic traits, yield-related traits and economic traits, with the local variety Jimi-1 as regional check cultivar.

It was reproted that 6 introduced varieties of proso millet had many excellent characteristics in Longxi County, Gansu Province, which implys that plants can grow well under the similar ecological envrionment[3]. Researching work from Yang(2018) showed that proso millet variety of Neishu can be planted and introduced in Lingtai County, Gansu Province, for its short growth stage, ability of stress resistance, wide adaptability and high-quality characteristics[4]. According to the report on the introduction of proso millet from Westnorthen Shanxi Province, six cultivars with high adaptation and yield were selected by observing and analyzing in three years[5]. Findings from research work of Ge et al. (2009) revealed that high quality of proso millet induced from within and out Liaoning Province, were successfully cultivated in Shenyang District and suitable varieties were selected to be plant in large area in Liaoning Province[6]. Libing (2004) reported the seed yield of four introducing cultivars from the Institue of Grain Crop in Gansu Academy of Agricultural Science, which had strong drought tolerance and lodging resistance, was 20.6%-24.3% higher than that of the regional check cultivar, Longmi-4, and 50.6%-55.1% higher than that of the local variety in Yuzhong county[7]. Six varieties of proso millet introduced from the Loess Plateau, were planted and compared with the local varieties on properties of growth and development, drought resistance, yield potential and water-use efficiency, and three cultivars with high adaptation were selected to be used to cultivate in Southen Ningxia[8].

From the point of view of the basis of theory of crops introduction, it easily succeed to introduce crop varieties between low latitude, high altitude areas and high latitude, low altitude areas[9]. Comparing the altitude and latitude of Guyuan District and Baicheng District, the former is high altitude, low latitude area and the latter is low altitude, high latitude one. According to the Theory of Climate Similarity, the climatic factors, such as temperature, light condition, precipitation and frost-free period, etc are similar in Guyuan and Baicheng, and it is possible to successfully introduce proso millet between the two districts[10]. This study is aimed at the problems, which restrict the production of proso millet in Baicheng, such as intermixing, low yield, low-quality and low-benefit of local varieties, by means of the introduction of high quality ones, which were compared and analyzed with the check cultivar on the traits of yield and growth stage.

2 Materials and Methods

2.1 Introduction and Experiment Sites

2.1.1 Introduction Site

Guyuan (Latitude 35°30′-36°30′ N and longitude 105°9′-106°58′ E, at an altitude of 1248

m-2955 m above sea level), Ningxia, locates on the wolds of the Loess Plateau, and is characterized by a temperate continental climate, under which there is great temperature difference between day and night, the mean annual sunshine duration is 2518 h, the accumulated temperature above 10 ℃ is between 1925.0 ℃ and 2392.3 ℃, annual average air temperature is from 6.8 ℃ to 8.8 ℃, the frost-free period is 152 d, annual precipitation is about 400 mm. The climatic characters of this district are as follows: long and chilling winter, changeable temperature in spring, short and cool summer, drop fast in temperature in autumn, little precipitation in spring and early summer, a lot of disastrous weather, and large difference in area rainfall, ect[11].

2.1.2 Experiment Site

Baicheng (Latitude 44°13′55″-46°18′ N and longitude 121°38′-124°22′ E, at an altitude of 130-600 m above sea level), is in the western Jilin Province, which is characterized by a temperate continental monsoon climate, under which there is big temperature difference between day and night, the mean annual sunshine duration is 2919.4 h, the accumulated temperature above 10 ℃ is 2933.4 ℃, annual average air temperature is 4.9 ℃, the frost-free period is 157 d, annual precipitation is about 400 mm. The climatic characteristics of Baicheng are long and chilling winter, for which the local farming system is a year one ripe for crops under such climate, arid early spring, hot summer, cool and little rain autumn, simultaneous heat and moisture.

2.2 Plant Materials

There are 7 proso millet varieties used in this research, the 6 introducted proso millet varieties, Ningmi-11, Ningmi-13, Ningmi-14, Ningmi-15, Ningmi-16 and Ningmi-17, which were used as experimental cultivars; the local proso millet variety, Jimi-1, which was used as regional check cultivar.

2.3 Field Experimental Design

Field experiments were conducted at the Teaching and Research Farm of the Baicheng Normal University in 2018. The soil properties of 0-20 cm deep, including the contents of organic matter, total nitrogen, total phosphorus, available phosphorus and available potassium are presented in Table 1.

Table 1 Soil Properties of Field Experiments

Soil type	Organic matter ($g \cdot kg^{-1}$)	Total nitrogen ($mg \cdot kg^{-1}$)	Total phosphorus ($mg \cdot kg^{-1}$)	Available phosphorus ($mg \cdot kg^{-1}$)	Available potassium ($mg \cdot kg^{-1}$)	pH
Light chernozem	21.30	139.53	78.60	12.92	105.75	7.8

The field experiments was planned in a randomized complete block design (RCBD), the experimental plot was 20 m^2 (5 m × 4 m), with 3 replicates, the planting density was 6.5×10^5 plant· hm^{-2}. Chemical fertilizers were applied together with the organic fertilizer of farmyard manure, under the condition of appropriate scale of soil moisture, at the doses of nitrogen (N) 200 kg· hm^{-2}, phosphorus (P_2O_5) 100 kg· hm^{-2} and potassium (K_2O) 80 kg· hm^{-2}, respectively.

The cultivation treatment, management and weed control were operated regularly during the growth season in the field.

2.4 Indexes to be Determined

The traits of growth and development in all main time were investigated. The characterastics of agronomic traits included plant height, stem diameter, number of stem nodes, tillers per plant, ear length, etc; the yield traits included grain weight per ear, 1000-grain weight and yield, these parameters were determined by randomly selecting 10 plants in each plot.

2.5 Statistical Analysis

According to the basic principles of Field Statistics, the indexes of traits from all plots were anaylzed and calculated using statistical methods. The data were analyzed by using SPSS Version 17.0 for Windows. The means were compared by Duncan's test at 0.05 significance level.

3 Results

3.1 The Growth Period of Proso Millet in Different Stages

Table 2 The growth period of proso millet in 2018

Varieties	Sowing date	Emergence date	Heading date	Flowering date	Ripening date	Days planting to maturity
Jimi-1 (CK)	20 May	1 Jun.	25. Jul.	6 Aug.	6 Sep.	97
Ningmi-11	20 May	26 May	15 Jul.	23 Jul.	20 Aug.	85
Ningmi-13	20 May	31 May	18 Jul.	28 Jul.	1 Sep.	93
Ningmi-14	20 May	31 May	20 Jul.	1 Aug.	3 Sep.	95
Ningmi-15	20 May	30 May	17 Jul.	29 Jul.	2 Sep.	95
Ningmi-16	20 May	27 May	12. Jul	20. Jul	23 Aug.	87
Ningmi-17	20 May	28 May	14. Jul.	24. Jul.	25 Aug.	88

The sowing date of these proso millet varieties was May, 20, 2018. According to the comparison on the dates of proso millet with varietie in 2018 (Table 2), there are significant differences among varieties. The variety with earliest seedling emergence date, May, 26, was Ningmi-11; variey with the second earliest seedling emergence date, May, 27, was Ningmi-16; the variety with the latest seedling emergence date, Jume, 1, was Jimi-1, which is the local variety of Baicheng; the two varieties with the second latest seedling emergence dates, May, 31, were Ningmi-13 and Ningmi-14; the seedling emergence dates of Ningmi-15, Ningmi-16 and Ningmi-17 were May, 30, May, 27 and May 28. The vaiety which sprouted first was Ningmi-16; the varieties with heading dates ordered from early to late were Ningmi-16, Ningmi-17, Ningmi-11, Ningmi-15, Ningmi-13, Ningmi-14 and Jimi-1, which were July, 12, July, 14, July, 15, July, 17, July, 18, July, 20 and July, 25, respectively. The varieties with flowering dates ordered from early to late were Ningmi-16, Ningmi-11, Ningmi-17, Ningmi-13, Ningmi-15, Ningmi-14 and Jimi-1, which were July, 20, July, 23, July, 24, July, 28, July, 29, Augest, 1, and Augest, 6, respectively. There were significant differences among ripening dates of the 7 varieties; Ningmi-11 was the first one to mature, and Jimi-1 was the last one to mature. The varieties with ripening dates ordered from early to late were Ningmi-11, Ningmi-16, Ningmi-17, Ningmi-13, Ningmi-15, Ningmi-14 and Jimi-1, which were Augest, 20, Augest, 23, Augest, 25, September, 1, September, 2, September, 3, and September, 6, respectively. The variety with the shortest days from planting to maturity was Ningmi-11, of which it was 85 days; the variety with the longest one was Jimi-1, of which it was 97 days; the days from planting to maturity of Ningmi-14 and

Ningmi-15 were equal to each other, 95 days; the days from planting to maturity of Ningmi-13, Ningmi-17 and Ningmi-16 were 93 days, 87 days and 88 days, respectively.

3.2 The Morphological Traits of Proso Millet

The morphological traits of the 7 varieties were shown in table 3, there were 4 varieties, of which the ear shape was loose, they were Jimi-1, Ningmi-11, Ningmi-13, and Ningmi-14; there were 3 types of varieties, of which the ear shape was dense, Ningmi-15, Ningmi-16, and Ningmi-17. The seedling color of all the 7 varieties was green; the seed color of Jimi-1 was yellow, that of Ningmi-13 was white, those of Ningmi-11, Ningmi-14, Ningmi-15, Ningmi-16, Ningmi-17 was red.

Table 3 The morphological traits of different varieties

Varieties	Ear shape	Color of seedlings	Color of seeds
Jimi-1 (CK)	loose	green	yellow
Ningmi-11	loose	green	red
Ningmi-13	loose	green	white
Ningmi-14	loose.	green	red
Ningmi-15	dense.	green	red
Ningmi-16	dense	green	red
Ningmi-17	dense	green	red

3.3 The Agronomic Traits of Proso Millet

According to the comparison on major agronomic traits of the 6 varieties of Ningmi and the local variety Jimi-1 in 2018 (Table 4), the values of plant height ordered from high to low were of Ningmi-17, Ningmi-13, Ningmi-14, Ningmi-15, Jimi-1, Ningmi-16, and Ningmi-11; the values of plant height of Ningmi-17 and Ningmi-13 were significantly higher than those of other 5 varieties ($p<0.05$); the value of Jimi-1, Ningmi-11 and Ningmi-16 were significantly lower than those of others ($p<0.05$). The values of stem diameter ordered high to low of these 7 varieties were of Ningmi-14, Ningmi-17, Jimi-1, Ningmi-15, Ningmi-13, Ningmi-16 and Ningmi-11; the values of the 3 varieties, Ningmi-14, Ningmi-17 and Jimi-1, were significantly higher than those of the rest 4 varieties ($p<0.05$); the lowest value of stem diameter in the 7 varieties was 7.50 mm in Mingmi-11, which had no significant difference with that of Ningmi-16 ($p<0.05$). The values of main ear length ordered high to low were of Ningmi-13, Ningmi-17, Jimi-1, Ningmi-14, Ningmi-15, Ningmi-11, and Ningmi-16; the values of the Ningmi-13 and Ningmi-17 were significantly higher than those of the rest 5 varieties ($p<0.05$); the lowest value of main ear length in the 7 varieties was 30.87 cm in Mingmi-16, which was significantly lower than the other 6 varieties ($p<0.05$). The values of number of stem nodes ordered from high to low were of Ningmi-11, Ningmi-15, Ningmi-14, Ningmi-17, Ningmi-16, Jimi-1, and Ningmi-13; the values of Ningmi-11 and Ningmi-15 were significantly higher than those of other 5 varieties ($p<0.05$); the value of Ningmi-13 was significantly lower than those of others ($p<0.05$). According to the values of tillers per plant, the values of number of stem nodes ordered from high to low were of Ningmi-16, Ningmi-17, Ningmi-11, Ningmi-14, Ningmi-13, Jimi-1 and Ningmi-15; there was no significant difference in the values of tellers per plant between that of Ningmi-16 and that of Ningmi-17, which were significantly higer than those of other 5 varieties ($p<0.05$); there was no significant difference in the the values tillers per plant of Ningmi-11, Ningmi-14, Ningmi-13, Jimi-1 and Ningmi-15 ($p<0.05$). According to the results of effective tillers per plant of these 7

varieties, the values ordered from high to low were of Ningmi-16, Ningmi-17, Ningmi-13, Ningmi-15, Ningmi-11, Ningmi-14, and Jimi-1; the value of Ningmi-16 was significantly higher than those of other 6 varieties ($p<0.05$); there was no significant difference between those of Ningmi-17 and Ningmi-13 ($p<0.05$); there was no signinificant difference among Ningmi-11, Ningmi-14, Ningmi-15 and Jimi-1 ($p<0.05$).

Table 4 The agronomic traits of different varieties

Varieties	Plant height (cm)	Stem diameter (mm)	Main ear length (cm)	Number of stem nodes	Tillers per plant	Effective tillers per plant
Jimi-1(CK)	138.22±3.21 c	9.12±0.71a	40.76±1.63a b	8.21±0.48 b	2.10±0.11 b	1.61±0.23 c
Ningmi-11	135.37±2.36 c	7.50±0.65c	38.39±2.36 b	9.22±0.33 a	2.51±0.20 b	1.80±0.28 c
Ningmi-13	157.46±3.06 a	8.33±0.83 b	43.32±1.58a	7.60±0.66 c	2.33±0.22 b	2.25±0.15 b
Ningmi-14	150.69±5.65 b	9.42±0.53a	40.73±2.92a b	8.95±0.45 a	2.42±0.13 b	1.75±0.13 c
Ningmi-15	149.30±4.36 b	8.78±0.62a b	39.92±3.31a b	9.10±0.56 a	2.10±0.22 b	1.91±0.12 c
Ningmi-16	136.63±3.48 c	7.65±0.55c	30.83±2.67c	8.23±0.68 b	3.21±0.30 a	2.82±0.23 a
Ningmi-17	158.76±6.27 a	9.33±0.36a	42.35±2.78a	8.36±0.37 b	3.10±0.26 a	2.30±0.16 b

Means (±SD) labeled with different letters within each column are significantly different ($P < 0.05$) by Duncan's test, n = 10.

3.4 The Yield-related Traits and Yield of Proso Millet

According to the comparison on yield-related traits of the 7 proso millet varieties in table 5, the values of weight of ear ordered from high to low were of Jimi-1, Ningmi-14, Ningmi-11, Ningmi-15, Ningmi-17, Ningmi-13, and Ningmi-16; the values of weight of ear of Jimi-1 was significantly higher than those of other 6 varieties ($p<0.05$); the value of Ningmi-16 was significantly lower than those of others ($p<0.05$). The values of 1000-grain weight ordered high to low were of Jimi-1, Ningmi-15, Ningmi-16, Ningmi-17, Ningmi-11, Ningmi-14, and Ningmi-13; the values of the 4 varieties, Jimi-1, Ningmi-15, Ningmi-16 and Ningmi-17, were significantly higher than those of the rest 3 varieties ($p<0.05$); the lowest value of in the 7 varieties was 6.32 g in Mingmi-13, which was significantly lower than those of other 6 varieties ($p<0.05$). The values of yield per plot ordered high to low were of Jimi-1, Ningmi-14, Ningmi-13, Ningmi-11, Ningmi-16, Ningmi-17, and Ningmi-15; the values of Jimi-1, Ningmi-14, Ningmi-13 and Ningmi-11, were significantly higher than those of the rest 3 varieties ($p<0.05$). The values of yield ordered from high to low were of Ningmi-14, Jimi-1, Ningmi-13, Ningmi-11, Ningmi-16, Ningmi-17, and Ningmi-15; the values of the 3 varieties wiht high level of yield were significantly higher than those of other varieties ($p<0.05$), there was no significant difference among the 3 values of yield in Ningmi-14, Jimi-1 and Ningmi-13.

Table 5 The yield-related traits and yield of different varieties

Varieties	Weight of ear (g)	1000-grain weight (g)	Yield per plot ($kg/20m^2$)	Yield (kg/hm^2)
Jimi-1(CK)	17.56±1.25a	8.02±.035a	106.47±8.61a	5032.33±22.81a
Ningmi-11	13.83±1.71c	7.09±0.18ab	95.73±7.36a	4786.72±26.66b
Ningmi-13	10.36±2.46de	6.32±0.27b	99.81±6.68a	4985.52±18.68a
Ningmi-14	15.69±2.12b	6.87±0.16b	103.73±7.63a	5186.17±27.53a
Ningmi-15	11.66±1.63d	7.52±0.31a	77.62±5.16b	3879.81±19.26c
Ningmi-16	9.16±1.40e	7.33±0.24a	81.13±6.39b	4056.43±20.34c
Ningmi-17	11.36±1.65d	7.21±0.18a	78.50±6.80b	3925.26±23.21c

Means (±SD) labeled with different letters within each column are significantly different ($P < 0.05$) by Duncan's test, $n = 10$.

4 Conclusions and Discussion

According to the results of this experiment, the varieties of Ningmi-13, Ningmi-14 and Ningmi-15 had a longer growth days from planting to maturity, which means they were adaptable to the regional environment of Baicheng, and could grow normally in the introduction area. The 2 varieties, Ningmi-13 and Ningmi-14 presented high yield, especially Ningmi-14, which had a 154 kg/hm^2 higher yield than that of the local variety, Jimi-1. The agronomic traits and yield-related traits of Ningmi-13 and Ningmi-14 were much better than those of other 4 Ningmi varieties, and could adapt to the environment in Baicheng. Ningmi-15, Ningmi-16 and Ningmi-17 had the seed-shattering properties, which decreased the yield significantly during the growth period of proso millet.

The 2 proso millet Ningmi-13 and Ningmi-14 could be used as introducting varieties in Baicheng, which had the properties of high ability of adaptation, good agronomic traits and high-yield traits, etc.

There were significant differences in agronomic and yield-related traits of the 6 introducted Ningmi proso millet varieties, which may be caused by the diversities of characteristics of varieties, the difference in effective accumulated temperature or light conditions and other climatic conditions between the Baicheng and Guyuan[12].

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