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Yielding Ability and Stability and Adaptability of Proso Millet Varieties

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Abstract The yielding ability and stability and adaptability of eight proso millet varieties from Shanxi, Inner Mongolia, Heilongjiang and Hebei were analyzed and evaluated in different ecological regions including Zhangjiakou, Huanghua and Shijiazhuang in 2015. The results showed that Chishu No. 2 and Jishu No. 2 have stronger yielding ability, and their grain yields were 3 144.42 (highest) and 3 133.15 kg/ha respectively, ranking first and second in the test varieties. In areas with low fertility, especially in saline-alkali areas, they still have potential for high yields, so they are suitable for promotion in large areas in Hebei Province. Neimi No. 8 and Yanshu No. 11 showed special adaptability under different ecological conditions. They require high-fertility soil and can be planted in the spring millet area in north of Hebei.

Key words Proso millet, Yielding ability, Adaptability, Yield

1 Introduction

Proso millet is a product of long-term natural selection. It is thermophilic, early-maturing, and resistant to drought and infertility, with stable productivity and better economic efficiency[1]. In dry agriculture and disaster relief, it is irreplaceable for other crops[2-7]. Proso millet has rich nutrition, wide application and certain medicinal value and health-care function, and is one of the traditional Chinese herbal medicines in China. It can also be used to extract a variety of natural pigments and make cakes and is a good raw material for winemaking. It is one of the important raw materials for traditional food in northern China and occupies an important position in the diversified consumption of food. The stability of crop varieties refers to the more uniform and stable changes in the species under different environmental conditions, and relatively consistent production performance has been demonstrated in various environments[8]. The stability and adaptability of crop varieties often determine the promotion value and production efficiency of the varieties[9]. An excellent proso millet variety must be excellent in yield or other agronomic traits, and it can exert its potential for yield increase under widely varying environmental conditions. In addition to high yielding ability, it also has good stability and wide adaptability. Therefore, it is of great significance to scientifically and objectively evaluate the yielding ability and stability and adaptability of proso millet varieties. In order to clarify the responses of proso millet cultivars to different ecological regions in Hebei Province, eight proso millet varieties from Inner Mongolia, Shanxi, Heilongjiang and Hebei were planted in the spring millet area, summer millet area and Heilonggang saline-alkali area in 2015, and their yielding ability and stability and adaptability were analyzed to provide reference for breeding and promotion of proso millet.

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2 Materials and methods

The 8 test proso millet varieties were cultivated widely or newly bred in Shanxi, Inner Mongolia, Heilongjiang and Hebei (Table 1). The experimental sites are located in three different ecological regions in Hebei Province. The experimental station of Zhangjiakou Academy of Agricultural Sciences belongs to spring millet area; the Nandagang Farm in Huanghua, Cangzhou belongs to saline-alkali area; and the experimental station of Institute of Millet Crops, Hebei Academy of Agriculture and Forestry Sciences belongs to summer millet area. In different experimental sites, the test plan was the same. The area of each plot was 10 m^2. All the plots were arranged randomly. Tow replicates were arranged for each treatment. Management practices were the same as in the local area.

The millet plants in each entire plot were harvested for yield measurement. DPS software was used to conduct data processing. The yielding ability and stability and adaptability of proso millet were analyzed and evaluated through multiple comparisons and main effect, variance, variability and regression analysis of yield[10].

3 Results and analysis

3.1 Variance analysis of yield of the test proso millet varieties The results of variance analysis (Table 2) showed that the differences in yield between varieties, locations and variety × location reached extremely significant level. It indicated that different varieties, different locations and interaction between variety and location had great influence on the production of proso millet. In

addition to the variety, the output level of proso millet was also related to the ecological factors such as the environmental conditions and production conditions of the test site. That is, variety and location co-affect the yielding ability and stability of proso millet.

Table 1 Test proso millet varieties and their source

Variety	Source
Neimi No. 8	Ordos Agricultural Research Institute
Chishu No. 2	Chifeng Academy of Agricultural and Animal Sciences
Jinshu No. 8	Institute of Alpine Crops, Shanxi Academy of Agricultural Sciences
Jinshu No. 9	Institute of Alpine Crops, Shanxi Academy of Agricultural Sciences
Yanshu No. 11	Institute of Alpine Crops, Shanxi Academy of Agricultural Sciences
Yanshu No. 7	Institute of Alpine Crops, Shanxi Academy of Agricultural Sciences
Qishu No. 1	Qiqihar Branch of Heilongjiang Academy of Agricultural Sciences
Jishu No. 2	Institute of Millet Crops, Hebei Academy of Agriculture and Forestry Sciences

Table 2 Variance analysis of yield of the proso millet varieties

Source of variation	*df*	*SS*	*MS*	*F*	*Sig.*
Location	2	108 144 662.78	54 072 331.38	17 739.44	0.00
Variety	7	2 449 454.97	349 922.14	114.80	0.00
Variety × Location	14	1 356 820.19	96 915.73	31.80	0.00
Error	21	64 011.20	3 048.14	–	–
Total variation	47	112 025 174.56	–	–	–

3.2 Yielding ability and stability analysis of the test proso millet varieties The average yield of Chishu No. 2 was the highest, followed by that of Jishu No. 2. There was no significant difference between the two ($P>0.05$), but their yields were significantly higher than those of the other varieties ($P<0.01$). There were no significant differences in average yield among Qishu No. 1, Yanshu No. 11 and Jinshu No. 8, but their yields were significantly higher than those of the other three varieties ($P<0.01$). No significant difference was found in average yield between Yanshu No. 7 and Neimi No. 8, but their yields were significantly higher than that of Jinshu No. 9 (Yanshu No. 7, $P<0.01$; Neimi No. 8, $P<0.05$). The yield of Jinshu No. 9 was the lowest, and it was significantly lower than those of the other varieties (Neimi No. 8, $P<0.05$; other varieties, $P<0.01$) (Table 3).

The main effect value of the variety reflects the effect of the variety on the yield in the test. The rank of main effect values of the test proso millet varieties was consistent with that of yields. Among them, the main effect values of Chishu No. 2 (20.326 7) and Jishu No. 2 (19.575 0) were greater, ranking first and second in the test proso millet varieties. They showed stronger yielding ability. The main effect values of Qishu No. 1, Yanshu No. 11 and Jinshu No. 8 were 5.446 7, 3.985 0 and 3.065 0, ranking third, fourth and fifth in the test proso millet varieties. The yields of the three varieties above were higher. The main effect values of the other three varieties were negative (−22 643 3 − −12.913 3). The main effect value of Jinshu No. 9 was the smallest.

Variance and variability are important parameters for analyzing the stability of varieties. The smaller the value is, the more stable the production of variety is. Chishu No. 2 had the lowest variance and variability values, indicating that this variety is unresponsive to the environment and belongs to the type of yield stability. The variance and variability values of Yanshu No. 7, Jinshu No. 8 and Qishu No. 1 were the second, third and fourth lowest, suggesting that these three varieties have relatively wide adaptability to the environment, and their yielding stability is medium. The variance and variability values of Yanshu No. 11 were the highest, indicating that this variety is most sensitive to environmental changes and belongs to special type.

Table 3 Analysis on yielding ability and stability and adaptability of the test proso millet varieties

Variety	Yielding ability parameters			Yielding stability parameters		Adaptability parameters	
	Average yield in the three experimental sites//kg/ha	Main effect value	Rank	Variance	Variability	Regression equation ($Y=$)	Regression coefficient
Chishu No. 2	3 144.42 aA	20.326 7	1	7.868	1.338 1	21.477 0 + 0.993 92 x	0.993 9
Jishu No. 2	3 133.15 aA	19.575 0	2	383.909	9.380 5	45.402 2 + 0.863 57 x	0.863 6
Qishu No. 1	2 921.22 bB	5.446 7	3	101.310	5.168 4	−4.594 5 + 1.053 04 x	1.053 0
Yanshu No. 11	2 899.30 bB	3.985 0	4	415.550	10.546 5	−27.499 4 + 1.166 32 x	1.166 3
Jinshu No. 8	2 885.50 bB	3.065 0	5	70.879	4.376 5	14.033 1 + 0.942 06 x	0.942 1
Yanshu No. 7	2 645.82 cC	−12.913 3	6	43.233	3.727 7	−2.757 6 + 0.946 35 x	0.946 4
Neimi No. 8	2 586.90 cCD	−16.841 7	7	292.903	9.923 7	−36.338 1 + 1.102 99 x	1.103 0
Jinshu No. 9	2 499.87 dD	−22.643 3	8	191.926	8.312 7	−9.722 5 + 0.931 74 x	0.931 7

Note: Different lowercase letters in the same column indicate significant difference at the 0.05 level, and different capital letters in the same column indicate significant differences at the 0.01 level.

3.3 Adaptability analysis of the test proso millet varieties

Taking the average yield of all the varieties of each plot as the independent variable and the yield of certain variety in the plot as the dependent variable, a linear regression equation was established. The yield, regression coefficient and regression intercept were used to describe the yielding stability and adaptability of the test varieties[11-12]. An ideal, stable and adaptable variety is a variety with regression coefficient close to 0, larger regression intercept and higher yield. For varieties with moderate yielding stability and adaptability, the regression coefficient is close to 1 and the regression intercept is close to 0. If the regression coefficient of certain variety has large difference with 1 and its regression intercept is smaller, it indicates that this variety has special adaptability and is generally suitable for high-fertility and high-moisture conditions. If the regression coefficient of certain variety has small difference with 1 and its regression intercept is larger, it indicates that this variety also has special adaptability and is generally suitable for planting in areas with low fertility[13].

The regression coefficients of Neimi No. 8 and Yanshu No. 11 had large differences with 1, and their regression intercepts were smaller, it indicated that these two varieties are suitable for planting in high-fertility and high-moisture areas. The regression coefficients of Chishu No. 2 and Jishu No. 2 had small differences with 1, and their regression intercepts were larger, it suggested that these two varieties are suitable for low-fertility areas (such as saline-alkali areas).

4 Conclusions and discussions

In this study, 8 proso millet varieties that are widely planted or newly bred in Inner Mongolia, Shanxi, Heilongjiang and Hebei were selected and planted in spring millet area, summer millet area and Heilonggang saline-alkali area of Hebei Province, three areas of different ecological types. The yielding ability and stability and adaptability of test varieties were analyzed based on the yield results. The results showed that Chishu No. 2 and Jishu No. 2 had stronger yielding ability, with greater yielding ability effect values, and their yields were 3 144.42 and 3 133.15 kg/ha, ranking first and second in the test varieties. The regression coefficients of the two varieties were smaller, and their regression intercepts were larger, indicating that these two varieties have special adaptability and are suitable for planting in low-fertility areas, especially saline-alkali area, with high yield potential. The variance and variability of Chishu No. 2 were both lowest in the test proso millet varieties, suggesting that Chishu No. 2 is a stable variety. Chishu No. 2 and Jishu No. 2 are suitable for large-scale planting in Hebei Province. The regression intercepts of Neimi No. 8 and Yanshu No. 11 were smaller, and their regression coefficients were larger, indicating that these two varieties are suitable to be planted in high-fertility areas and can be promoted in the spring miller area in the north of Hebei. The other varieties had lower yields than Chishu No. 2 and Jishu No. 2, and were more sensitive to environmental changes. In contrast, they are not appropriate to be promoted in large areas in Hebei Province.

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