 DOI: 10.19601/j.cnki.issn1943 – 9903.2018.8.019

Variation and Statistic Analysis of Agronomic Traits of Recombinant Inbred Lines of *Brassica juncea* L.

Entang TIAN[1*], Lufeng LI[2], Shiyan JIA[3], Shuchun LIN[1]

1. Oil Crops Research Institute, Guizhou University, Guiyang 550025, China; 2. Agricultural Science and Technology Institute of Xiaoshan District of Hangzhou City, Hangzhou 311200, China; 3. Seed Control Station of Xiaoshan District of Hangzhou City, Hangzhou 31120, China

Abstract Correlation analysis and principal component analysis (PCA) were conducted for some agronomic traits of 139 recombinant inbred lines of *Brassica juncea* L. The results showed that under the environmental conditions in Guiyang, the flowering time, number of seeds per silique, plant height and thousand seed weight differed significantly among different lines. The results of principal component analysis showed that the lines could be classified into three groups. The results of Pearson correlation tests showed that the plant height was positively correlated with the flowering time ($P<0.05$), and the thousand seed weight was negatively correlated with the flowering time and number of seeds per silique ($P<0.01$).

Key words *Brassica juncea* L., Agronomic traits, Principal component analysis, Correlation analysis

1 Introduction

Brassica napus L. (AACC, $2n=38$), *Brassica juncea* L. (AABB, $2n=36$), and *Brassica rapa* (AA, $2n=20$) are three oil crops in China[1]. *B. juncea* is resistant to diseases, pests, barrenness, yellow seeds and drought, and can be used as vegetable and seasoning with important economic value[2-5]. China is an important center of origin for *B. juncea*, which is rich in germplasm resources. The continuous strengthening of the theoretical and applied research of *B. juncea* is of great significance to enhance the application of resistance genes in *B. napus* and *B. rapa*, promote the development of mountain agriculture in China, and ensure the safety of oil production in China.

Although *B. juncea* has many excellent properties, it has a disadvantage of low yield[6]. The agronomic traits and quality traits of *B. juncea* are quite different from those of widely-planted *B. napus*. *B. napus* has already been commercialized for F_1 hybrid production, but the related work of *B. juncea* has only just started[7]. To strengthen the genetic improvement and related research of the agronomic and quality traits and to constantly cultivate high-quality and high-yield varieties (lines) adapted to the needs of mountain agriculture is imperative for the breeding work of *B. juncea*.

In recent years, with the global warming, water resources are relative scarce. As a beneficial supplement of *B. napus*, *B. juncea* is increasingly drawing attention both at home and abroad. *B. juncea* has been used as oilseed-vegetable dual-purpose crop in China, especially in the central and western regions. In India, *B. juncea* is the major source of edible oil, and its crossbreeding system is constantly improved. In some arid regions of Canada and Australia, government departments have been expanding the planting area of *B. juncea*, so its growing area is constantly increasing[8].

In this study, a population of 139 *B. juncea* recombinant inbred lines was planted under the environmental conditions in Guiyang, and their flowering time, plant height, thousand seed weight and number of seeds per silique were investigated, among which correlation analysis and principal component analysis (PCA) were conducted to provide reference for the breeding of *B. juncea*.

2 Materials and methods

2.1 Experimental materials The F_5 population of 139 *B. juncea* recombinant inbred lines was selected as experimental materia. In October 2014, they were planted in the farm of Guizhou University, with three replicates for each line. Randomized block design was used, and two rows were arranged for each replicate. In the flowering period, three individual plants were selected randomly from each line, and they were bagged and subjected to selfing. Their seeds were harvested.

2.2 Experimental methods The flowering time started from when more than half of the plants in each plot bloomed. Before the seeds matured, ten siliques were selected from the middle of the main branch, and the number of seeds per silique was counted. The mean of seed number per silique was calculated. At the pod-

Received: April 1, 2018 Accepted: July 10, 2018

Supported by National Natural Science Foundation of China: QTL Mapping Combined with GWAS Strategy to Explore Major Regulation Genes for Glucosinolate Metabolism in *Brassica juncea* (31560422); Science and Technology Foundation of Guizhou Province of China: Positioning, Mining and Metabolic Mechanism of Major Genes Regulating Glucosinolate from Leaves and Seeds of *Brassica rapa* [Qian Ke He J Zi (2015) 2052]; Scientific Research Foundation for Returned Scholars, Ministry of Education: Mining of Glucosinolate-regulated Genes in *Brassica napus* and Analysis of Its Expression Dynamics [Jiao Wai Si Liu (2015) 1098]; Doctoral Talent Introduction Fund of Guizhou University: Screening of Glucosinolate Content in *Brassica Napus* Varieties and Development of Associated Markers [Gui Da Ren Ji He Zi (2014) 14]; Construction Program of Biology First-class Discipline in Guizhou (GNYL[2017]009).

* Corresponding author. E-mail: erictian121@163.com

ding stage, five plants were selected randomly from the center of each plot for measuring plant height, of which the mean was taken as the plant height of the plot. The seeds of the three bagged plants in each plot were harvested. Total 500 seeds were selected randomly and weighed, which was repeated three times. The average of the three measurements was calculated and multiplied by 2 as the thousand seed weight of the plot.

2.3 Statistical analysis The data obtained from the experiment was analyzed statistically using SPSS20 software, including descriptive statistics, correlation analysis, normal distribution map, clustering map, multiple comparison (*LSD* method) and so on.

3 Results and analysis

3.1 Variation of population traits The flowering period, number of seeds per silique, plant height and thousand seed weight of *B. juncea* recombinant inbred lines showed clear normal distributions under the environmental conditions in Guiyang City (Fig. 1). The mean flowering period of the population was 139.4 d, with coefficient of variation of 1.3%. There were 50 lines of which the flowering periods ranged from 137 to 139 d, accounting for 36.0% of the total; there were 65 lines with flowering periods within 139 – 141 d, accounting for 46.8%; there were 21 lines of which the flowering periods ranged from 141 to 143 d, accounting for 15.1%; and the flowering periods of the rest ranged from 143 to 145 d, accounting for 2.2%. The average number of seeds per silique was 20.9, and the coefficient of variation was 10.9%. There was only one line with seed number per silique ranging between 11 – 15, accounting for 0.7% of the total lines; there were 21 lines of which the seed number per silique ranged from 15 to 19, accounting for 15.1%; there were 95 lines with seed number per silique ranging from 19 to 23, accounting for 68.3%; and the seed number per silique of the rest was within 23 – 29, accounting for 15.8%.

The average plant height of the lines was 128.3 cm, with coefficient of variation of 10.7%. There were 20 lines with plant height ranging from 97 to 114 cm, accounting for 14.4% of the total lines; there were 64 lines of which the plant heights were within 114 – 131 cm, accounting for 46.0%; there were 43 lines with plant height ranging from 131 to 148 cm, accounting for 30.9%; and the plant heights of the rest lines ranged from 148 to 166 cm, accounting for 8.6%. The mean thousand seed weight of the population was 2.9 g, with coefficient of variation of 10.6%. There were 42 lines of which the thousand seed weight ranged from 2.28 to 2.68 g, accounting for 30.2%; there were 70 lines of which the thousand seed weight ranged within 2.68 – 3.08 g, accounting for 50.4%; there were 22 lines with thousand seed weight ranging from 3.08 to 3.48 g, accounting for 15.8%; and the thousand seed weight of the rest lines ranged within 3.48 – 3.89 g, accounting for 3.6%.

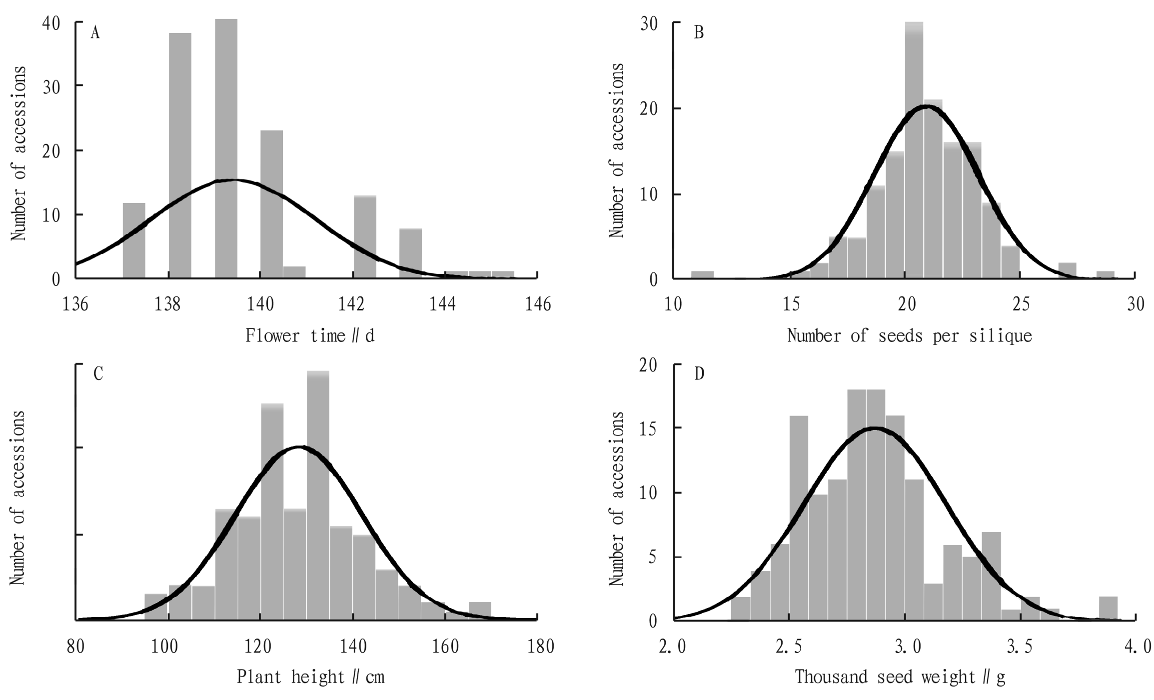

Fig. 1 Normal distributions of agronomic traits of *Brassica juncea* recombinant inbred lines

3.2 Correlation analysis Pearson correlation analysis was performed on the correlation between agronomic traits in the recombinant inbred population (Table 1). The plant height was positively correlated with the flowering period with correlation coefficient of 0.503 ($P < 0.001$). There were significant negative correlations between thousand seed weight and flowering period (correlation coefficient −0.488, $P < 0.001$), thousand seed weight and seed number per silique (correlation coefficient −0.420, $P < 0.001$). The seed number per silique was positively correlated with the flowering period, but the correlation was not significant ($P > 0.05$). There were insignificant negative correlations between thousand seed weight and plant height, plant height and seed number per silique ($P > 0.05$).

Table 1 Coefficients of correlation between agronomic traits of *Brassica juncea* recombinant inbred lines

Trait	Flowering period	Seed number per silique	Plant height
Seed number per silique	0.075 (P = 0.378)	–	–
Plant height	0.503 (P < 0.001)	–0.088 (P = 0.304)	–
Thousand seed weight	–0.488 (P < 0.001)	–0.420 (P < 0.001)	–0.114 (P = 0.181)

3.3 Cluster analysis Principal component analysis was performed for the 139 lines with the main indicators of flowering period, seed number per silique, plant height and thousand seed weight. Among the four principal components, the first principal component (PCA1) explained 45.8% of the variation, the second principal component (PCA2) explained 31.5% of the variation, the third principal component (PCA3) explained 14.4% of the variation, and the fourth principal component (PCA4) explained 8.3% of the variation. The first two principal components together accounted for 77.3% of the variation, so PCA1 and PCA2 were selected as the X-axis and Y-axis for charting. The 139 lines were classified into three clusters (Fig. 2). In Cluster I, the number of lines was 4, accounting for 2.9%; in Cluster II, the number of lines was 134, accounting for 96.4%; and in Cluster III, the number of lines was 1, accounting for 0.7%. There were significant differences in all the agronomic traits except plant height among different clusters (P < 0.01) (Table 2). Among the three clusters, the flowering period ranked as Cluster I's > Cluster II's > Cluster III's; the seed number per silique ranked as Cluster I's > Cluster II's > Cluster III's; the thousand seed weight ranked as Cluster III's > Cluster II's > Cluster I's; and the plant height ranked as Cluster II's > Cluster I's > Cluster III's.

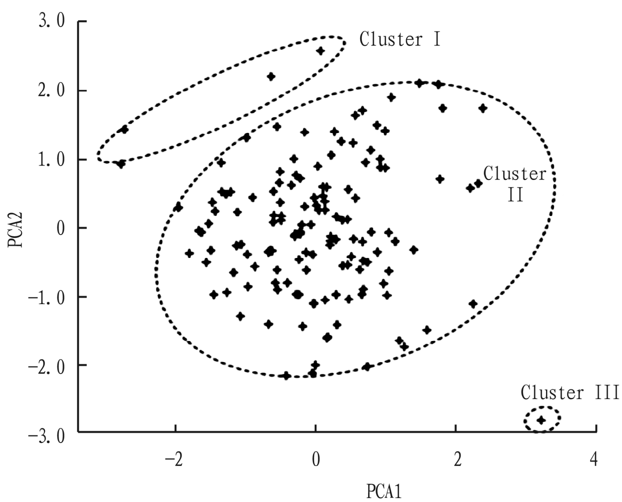

Fig. 2 Principal component analysis of *Brassica juncea* recombinant inbred lines

Table 2 Variation of agronomic traits in the three clusters of *Brassica juncea* recombinant inbred lines

Trait	Cluster	Mean	Standard deviation	Coefficient of variation // %
Flowering period // d	I	141.9 A	2.45	5.8
II	139.4 B	1.71	4.4	
	III	138.0 C		
Seed number per silique	I	25.7 A	2.39	9.3
	II	20.9 B	2.07	9.9
	III	11.6 C		
Thousand seed weight // g	I	2.4 C	0.42	17.7
	II	2.9 B	0.34	11.8
	III	3.9 A		
Plant height // cm	I	126.8 A	20.52	16.2
	II	128.4 A	13.67	10.6
	III	124.3 A		

Note: Different capital letters of the same agronomic trait indicate significant differences at the 0.01 level.

4 Conclusions and discussion

This study examined the performance of agronomic traits of the recombinant inbred population of *B. juncea* in Guiyang City, and principal component analysis and correlation analysis were performed for them. The results have a certain guiding significance for the breeding of *B. juncea* and future research on the regulation mechanism of agronomic traits.

The research on *B. juncea* is relatively backward compared to *B. napus*, so quality breeding should be vigorously developed in the future. At present, Canada has taken the lead in breeding double-low *B. juncea* varieties (lines)[9], which can be used for the double-low breeding of *B. juncea* in the future, thereby fundamentally improving the quality of *B. juncea* for oil purpose. Agronomic traits are other indicators of the continued improvement of *B. juncea*. For example, small seed size and low pod density result in much lower yield of *B. juncea* compared to *B. napus*. At present, it can only be used as an alternative crop for *B. napus* under harsh conditions, and its excellent characteristics such as strong resistance cannot be fully displayed. Vigorously carrying out breeding research of *B. juncea* can provide more suitable economic crop for China's vast mountainous agricultural production, which is of great significance for promoting the development of mountain agriculture in China.

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bank of local germplasm resources, followed by a target trait genetic group, thus mining the special functional genes and laying a foundation for local resource development.

4.3 Raising awareness of characteristic vegetable resources and developing rationalized development plan for characteristic vegetable resources In Luotian County, micro-business platform has been constructed to sell local specialties (dried radish, wild vegetables). At present, Luotian County has carried out e-commerce targeted poverty alleviation strategies to drive local farmers to get rid of poverty and get rich. Other cities can build similar platforms. Local specialties such as yam, pearl flower, *Osmunda japonica* Thunb, scallion, *P. sibiricum* have high nutritional value. However, yam diseases are serious, and pearl flower cuttings have a low survival rate. Considering key technologies that constrain local resources, the technology of tissue culture can be used to solve the problem of seedling preservation, purification and detoxification under the assistance of universities and research institutes. At the same time, functional deep processing products or fruit and vegetable health foods should be developed through the combination with modern science and technology to improve the development and utilization of characteristic vegetable resources[16-17]. Of course, attention must be paid to development and protection simultaneously in order to promote the healthy development of the characteristic vegetable industry.

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