Effect of Breeding Selection and Environmental Factors on Plant Height and Node Number in Soybean

QI Xiao-min, REN Xiu-hui, MAO Ting-ting, HAN Ying-peng, LI Wen-bin, JIANG Zhen-feng

(Key Laboratory of Soybean Biology in Chinese Ministry of Education, Key Laboratory of Soybean Biology and Breeding/Genetics of Chinese Agriculture Ministry, Northeast Agricultural University, Harbin 150030, China)

Abstract: To analyze the effect of breeding selection on plant height and node number in soybean, 141 soybean popular varieties cultivated from 1949 to 2010, as well as three RIL populations were observed. The 141 soybean lines were divided into six groups and were planted in 2010 and 2011 in Harbin; while three RIL populations were planted in Hulan and Harbin in 2012. Plant height and node number declined from 1950's to 1970's, and increased in 1980's, then declined from 1980's to 2010's. There was significant difference in plant height between different planting years while not in node number. Plant height and node number varied significantly between soybean varieties released in different breeding stages. Moreover, significant difference could be seen from plant height and node number between two planting locations in three RIL populations.

Key words: Soybean; Plant height; Node number; Breeding stage

中图分类号: S565.1 **文献标识码**: A **文章编号**: 1000-9841(2014)01-0001-05

育种选择及环境条件对大豆株高及节数的影响

祁晓敏, 任秀慧, 毛婷婷, 韩英鹏, 李文滨, 姜振峰

(东北农业大学大豆生物学教育部重点实验室, 东北农业大学农业部东北大豆生物学与遗传育种重点实验室, 黑龙江 哈尔滨 150030)

摘要: 将黑龙江省1949~2010年审定的141份主栽大豆品种和3个重组自交系群体在不同地点进行种植,研究育种时期、种植年份、不同品种和种植地点对大豆株高和节数的影响规律。结果表明:大豆株高和节数随育种年代表现为先降低后小幅升高然后再次降低的规律;不同种植年份的大豆株高差异显著,而节数差异不显著;不同品种间的大豆株高和节数差异也达到显著水平;基于3个RIL群体的2个种植地点研究结果表明不同种植地点的大豆株高和节数差异显著。

关键词: 大豆;株高;节数;育成时期

The agricultural production had increased by the use of new types of crops and new farming methods in 1960's, which was named as the green revolution. The characteristic of this green revolution was the breeding and widely cultivation of dwarf crop varieties such as dwarf wheat and rice. The increased planting density of dwarf varieties could enhance green leaf area per unit area, enlarge population light energy capture, thus resulted in improved seed number and seed weight as well as higher yield[1-4]. The success in gramineous crops offered a direction for yield improvement of soybean.

Node number, pod number and biological yield of soybean were related significantly to plant height. Dwarf plant with short internode length could enhance the lodging resistance in soybean and keep the biggest harvest index by harvesting more seeds. So soybean breeders focused on decreasing plant height to increase soybean yield[5-7]. Cooper resulted that soybean yield could be increased by planting dwarf soybean varieties, and released the first soybean variety Elf in 1977 and other four soybean varieties, Caome, Pixie, Spirit and Hobbit from 1979 to 1996, respectively. Furthermore, many high yield records in soybean were reported with those dwarf soybean varieties coupled with solid planted technologies and modern machines[8]. Similar results were also reported in China. The highest yield about 5 955.0 $kg \cdot ha^{-1}$ was observed by cultivated semi-dwarf soybean varieties Xindadou 1 and Shidadaou 1 with plant height of 76.3 cm and 74.5 cm, respectively[9].

Plant height is also an important trait related to eco-condition. In particular region, suitable plant height

Received: 2013-12-26

Foundation item: Innovation Funds of Undergraduate of NEAU; The National Key Technology R&D Program(2011BAD35B06-1); National Science Foundation for Post-doctoral Scientists of China(2012M520700); Research Foundation of NEAU(2012RCB38).

Biography: QI Xiao-min(1990-), female, undergraduate, working at genetics and breeding in soybean. E-mail: qxm15845677964@163.com.

Corresponding author: JIANG Zhen-feng(1976-), male, Ph. D, working at genetics and breeding in soybean. E-mail: jzhf2006@126.com.

could acquire more production in soybean. Some results had been reported that soybean variety planted to fertile soil should be dwarf, short internode length and kept suitable nodes number with the most pods in main stem[10]. The mechanism for high yield might be the acquirement of more light energy and strong lodging-resistance[11].

Although relationship between yield and plant height in soybean had been well documented, fewer reports about the effect of breeding selection and environmental condition on plant height and node number in soybean. The clarification of these relationships could facilitate the soybean production in farm condition. So the plant height and nodes number of the soybean cultivars planted widely in different breeding stages and three RILs planted in different locations were analyzed in present study to 1) clarify the effect of breeding selection and environmental conditions on plant height and nodes number; 2) offer a theoretical direction for soybean production.

1 Materials and methods

1.1 Plant materials

A total of 141 popular soybean varieties released from 1949 to 2010 in Heilongjiang province were collected, and divided into six groups (Table 1). Furthermore, 3 recombination inbred lines (RILs) including 148, 109 and 153 individuals derived from Hefeng 47 × Heinong 37, Heinong 44 × Hefeng 47 and Dongnong 46 × Kenjian 23, respectively, were planted to observe the effect of different planting locations on plant height and node number.

Table 1 Soybean cultivars in different breeding stages

Released year	Cultivars	Amounts
Before 1959	Jinyuan 2, Suihuasilihuang, Sunwudabaimei, Yuanbaojin, Zihua 2, Zihua 3, Mancangjin, Fengshou 2, Jingshan-pu, Fengshou 6	10
1960-1969	Heihe 3, Heinong 4, Heinong 6, Heinong 7, Heinong 8, Fengshou 1, Mufeng 1	7
1970-1979	Hefeng 14, Hefeng 15, Heinong 10, Mushi 1, Nenfeng 2, Suinong 1, Suinong 2, Suinong 3, Hefeng 21, Heihe 4	10
1980-1989	Heinong 19, Suinong 4, Beifeng 2, Dongnong 37, Hefeng 25, Heihe 5, Heihe 6, Hefeng 29, Kenfeng 1, Fengshou 20, Hefeng 30, Heihe 7, Suinong 7, Suinong 8	14
1990-1999	Fengshou 10, Heinong 35, Heinong 37, Kennong 4, Hefeng 35, Suinong 10, Suinong 11, Heihe 14, Heihe 15, Heinong 40, Suinong 12, Heihe 16, Dongnong 44, Heihe 17, Heihe 18, Suinong 15, Suinong 16	17
2000-2010	Hefeng 39, Hefeng 40, Heihe 23, Beijiang 91, Heihe 26, Kennong 18, Suinong 17, Hefeng 43, Heihe 27, Heinong 43, Kenjian 17, Kenjian 27, Suinong 18, Suiwuxing 1, Kennong 19, Heihe 30, Heihe 31, Heinong 46, Kenjian 28, Suinong 14, Suinong 21, Heihe 32, Heihe 35, Heihe 36, Heinong 48, Kangxian 4, Hefeng 49, Heihe 38, Heinong 49, Suinong 22, Beidou 3, Beidou 5, Hefeng 50, Heihe 39, Heihe 40, Heihe 41, Kenfeng 16, Kenjian 7, Kennong 26, Suinong 23, Suinong 28, Beidou 10, Heihe 43, Heihe 45, Heihe 46, Heihe 48, Heinong 50, Heinong 51, Heinong 52, Heinong 53, Heinong 55, Huajiang 4, Kangxian 6, Suinong 24, Suinong 25, Fengshou 25, Beidou 14, Beidou 16, Beidou 19, Hefeng 53, Hefeng 54, Hefeng 55, Hefeng 57, Heihe 49, Heinong 58, Heinong 60, Heinong 61, Heinong 62, Heinong 64, Heinong 66, Heinong 68, Kangxian 8, Kenfeng 22, Suinong 26, Suinong 27, Heihe 50, Heihe 51, Suinong 29, Suinong 30, Suinong 31, Heihe 52, Heihe 53, Suinong 32	83

1.2 Experiment design

The 141 soybean varieties were planted at field trail site of Northeast Agricultural University in Harbin in 2010 and 2011. Random block design with 2 replicates was adopted. Rows were 3 m long and 0.6 m wide with a mean distance of 5 cm between plants. In 2012, the three F_8 recombinant inbred lines (RILs) that were advanced by single seed descent were planted at Harbin and Hulan, respectively. Random block design with two replicates was adopted. Three rows plots were used and rows were 2 m long and 0.6 m wide with a mean distance of 5 cm between plants.

1.3 Measure methods

Five plants in middle rows were selected to measure plant height and node number followed the soybean germplasm resource description criterion and data standard.

1.4 Data analysis

Data description, ANOVA analysis and correlation analysis were all calculated using Excel 2010 and SPSS 19.0 software.

2 Results

2.1 Plant height of soybean varieties widely cultivated in different breeding stages

Two significant changes could be observed by ana-lyzing plant height of soybean cultivated widely in different breeding stages. Firstly, the plant height of soybean decreased significantly from 1950's to 1970's. The plant height in average declined from 95.04 cm in 1950's to 75.95 cm in 1970's. Furthermore, the range of plant height was the smallest in all the six groups with the second plant height of 132 cm, suggesting that plant height in different breeding stage were relatively high. Secondly, the plant height in 1980's reached 84.4 cm, then decreased again to a dwarf plant of 79 cm which didn't change significantly until now (Table 2).

Table 2　Description of plant height of different breeding stages of soybean (cm)

Item	Released year						
	Before 1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2010	Average
Average	95.04	88.91	75.95	84.4	79.34	79.49	83.86
Std.	10.43	11.56	11.94	14.01	14.91	14.31	12.86
Min.	57	52	52	50	50	50	51.83
Max.	132	128	118	137	122	122	126.5
Range	55	66	56	87	72	72	68.00

ANOVA analysis for breeding stage, variety and planting year of plant height was also conducted in present study (Table 3). Significant differences in plant height were observed in different breeding stages, different varieties and planting years, suggesting that plant height was a environment-sensitive trait.

Table 3　ANOVA analysis of plant height of different breeding stages of soybean

Item	Breeding stages		Varieties		Years	
	Between groups	Within groups	Between groups	Within groups	Between groups	Within groups
Mean square	4.46	2.78	4523.84	1437.1	0.73	0.23
F	1.61**		3.15**		3.22**	

** : significant at the 0.01 level. The same below.

2.2 Node number of soybean varieties widely cultivated in different breeding stages

Node number was correlated with plant height in soybean and similar results were observed to plant height. The node number decreased from 1950's to 1970's; then increased in 1980's and decreased again. However, the range was smaller than plant height (Table 4). ANOVA analysis for node number showed that node number in different breeding stages and in different varieties was different significantly. However, no significant difference was observed in varied years (Table 5).

Table 4　Description of node number of different breeding stages of soybean (individual)

Item	Released year						
	Before 1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2010	Average
Average	17.51	16.89	16.53	17.35	16.76	16.5	16.89
Std.	2.13	2.25	2.723	2.42	2.78	2.4	2.59
Min.	13	12	11	11	10	10	10
Max.	23	22	23	25	25	24	25
Range	10	10	12	14	15	14	15

Table 5 ANOVA analysis of node number of different breeding stages of soybean

Item	Breeding stage		Varieties		Years	
	Between groups	Within groups	Between groups	Within groups	Between groups	Within groups
Mean square	2.83	0.23	15413.38	1444.81	4.41	2.82
F	12.53**		10.67**		1.56	

2.3 Plant height and node number of three RILs planted in two different locations

To clarify the effect of planting location on plant height and node number, three RILs were planted in Harbin and Hulan in 2012. Different plant height and node number in 3 RILs were shown in Table 6. The lowest plant height was only 27 cm, the tallest plant height reached 176 cm, and the range was 149 cm; the least node number was only 6 the most was 26, and the range reached 20, suggesting that these three RILs were suitable for the analysis of plant height and node number. Moreover, ANOVA analysis showed that plant height and node number were both significantly different, suggesting that different planting locations had a significant effect on plant height and node number(Table 7).

Table 6 Description of plant height and node number of different breeding stages of soybean

Trait	Range	Min.	Max.	Average	Std.
Plant height/cm	149	27	176	84.07	19.92
Node number	20	6	26	15.05	2.88

Table 7 ANOVA analysis of plant height and node number of different breeding stages of soybean

	Plant height		Node number	
	Between groups	Within groups	Between groups	Within groups
Mean square	755.17	324.12	18.43	6.21
F	2.33**		2.97**	

2.4 Correlation analysis between plant height and node number

Significant differences were observed among soybean varieties released in different breeding stages and among three RILs planted in two varied locations. The correlation index were 0.66 and 0.69, respectively.

3 Conclusion and discussion

Dwarf plant suitable to soil condition could improve yield in soybean. For example, the sample of high yield in soybean in China had been reported one by one since 'Eighth Five-Year Plan', most of varieties involved were semi-dwarf plants of 60-85 cm. Later, solid-planted mode with semi-dwarf soybean was introduced to Heilongjiang province, Northeast China in 1990's and then formed the technology of high yield of solid-seeded soybean. The key for the technology was the application of soybean lines with 40-60 cm stem. The yield could be increased 16%-22% when the planting density was 400 000 individuals per hectare[12]. Similar results for plant height were shown in present study. Though the plant height of soybean fluctuantly changed, the overall trend was declining to reach a suitably dwarf stem and gaining a high yield.

The soybean varieties released in different breeding stages had varied plant height and node number. The reason might be as follows. Firstly, there were six maturity groups in Heilongjiang province, which needed different varieties with different plant height and node number; secondly, change of plant height was correlated to the breeding goal in different breeding stages. In 1950's, most varieties were high and thriving and lodged when cultivated in farm, dwarf soybean lines were bred to meet the need. So plant height declined rapidly[13]. However, in 1980's, solid-seeded cultivated mode was introduced and then semi-dwarf soybean varieties were bred, so plant height declined again.

Plant height changed evidently between different years and locations in present study. The reason was that during the vegetative period, the weather, nutrition condition in soil and cultivated technology could affect plant growing of soybean. Cheng et al. reported that plant height of soybean was only 30-33 cm in drought growing season while it could reach 84. 1 cm in the growing season with ample rainfall. They concluded that the most important factor was rainfall and second was temperature[14]. Similar result could be found in maize that plant height of maize changed in different years and further analysis showed that rainfall was the most important influencing factor[15].

Yield could be influenced by plant height and node number in soybean. Some reports had showed that the increment of plant height depended on the increment of node number[10], suggesting that evident correlation existed between plant height and node number in soybean. Similar results were showed in present study. Correlation analysis between plant height and node number was different significantly. However, few researches about node number were reported, more studies should be conducted to clarify relationship between plant height and node number to facilitate the breeding of new soybean lines with high yield.

References

[1] Peng J, chards D E, Haltley N M, et al. 'Green Revolution' genes encode mutant gibberellin response modulators[J]. Nature, 1999, 400:256-261.

[2] Sasaki A, Ashikari M, Ueguehi-Tanaka M, et al. Green revolution: a mutant gibberellin-synthesis gene in rice[J]. Nature, 2002, 416: 701-702.

[3] Hedden P. The genes of the Green Revolution[J]. Trendsin Genetics, 2003, 9:5-9.

[4] Asano K, Yamasaki M, Takunoc S, et al. Artificial selection for a green revolution gene during *japonica* rice domestication[J]. Proceedings of the National Academy of Sciences of the United States of America, 2011, 108(27):11034-11039.

[5] Wang L Z, Wang J L. Soybean genetics and breeding[M]. Beijing: Science Press, 1992. (in Chinese).

[6] Dong Z. Soybean yield and physiology[M](second edition). Beijing: China Agricultural Science and Technology Press, 2012. (in Chinese).

[7] Wilcox J R, Tuneo S. Interrelationships among height, lodging and yield in determinate and indeterminate soybeans[J]. Euphytica, 1981, 30(2):323-326.

[8] Cooper R L. Breeding semidwarf soybeans[J]. Plant Breeding Reviews, 1985, 3:289-311.

[9] Luo G T, Zhan Y, Liu S L, et al. The creation of the highest yield records on Xindadou 1 and Shidadou 1 of soybean cultivars[J]. Soybean Science, 2001, 20(4):270-273. (in Chinese with English Abstract).

[10] Wang J. Question on soybean yield and mechanical-harvest[J]. Agricultural Sciences in China, 1964, 6:17-22. (in Chinese with English Abstract).

[11] Wang L Z. Soybean research within 50 years[M]. Beijing: China Agricultural Science and Technology Press, 2011. (in Chinese).

[12] Hu X P, Liu Z T, Guo T, et al. Study on dwarf and semi-dwarf soybeans breeding by using American semi-dwarf soybean germplasm resources[J]. Soybean Sicence, 2001, 20(3):209-214. (in Chinese with English Abstract).

[13] Wang J L. Some questions about soybean breeding related to varieties in soybean production of Heilongjiang province[J]. Journal of Northeast Agricultural University, 1965(2):85-88. (in Chinese with English Abstract).

[14] Cheng B R, Jin Y S, Li Y. Relation between plant height and meteorologic condition and yield in soybean[J]. Meteorology in Heilongjiang, 1996(2):46. (in Chinese with English Abstracts).

[15] Shi Z S, Li H Y, Li F H, et al. Relationship between the inter annual change of maize height and yield[J]. Journal of Maize Sciences, 2013, 21(5):24-29. (in Chinese with English Abstract).