Preliminary studies on root morphological traits in *Brassica napus* L.

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Abstract

Plant root system plays a crucial role in plant growth and root system morphology contributes also a great deal to the final crop yield. The research on root system is generally difficult, but the morphological traits are more visible and simple compared with physiological traits. Three Polima cytoplasm male sterile lines and four restoration lines were used as parents to get twelve hybrid combinations with NCII genetic design. The plot trials for F_1s and their parents, 3 counterpart maintainers of CMS and two lodging resistant varieties were arranged in the field in a randomized complete block design with 3 replications. Eight root traits and plot yield were investigated. We clearly demonstrated that the same root characteristics in different parents had the real genetic differences. There were no significant difference in the root morphological traits between CMS lines and maintainer lines. The main root length of hybrids, CMS lines and maintainers was significantly longer than that of restorers. Hybrids had significantly more lateral roots than CMS lines, maintainers and restorers. The main root length, maximum lateral root length, root thickness, main root dry weight, lateral root dry weight, root dry weight and root volume of lodging resistant varieties were significantly better than those of other materials. Plot yield of all 12 hybrids showed positive heterosis and root trait also showed heterosis in a part of crosses. The results of correlation analysis on all 24 test materials showed that there were significant correlations among maximum lateral root length, main root dry weight, lateral root dry weight, root dry weight and root volume, in which root dry weight and root volume had the highest correlation coefficient (r=0.9671**). Plot yield had a positive correlation in a certain degree with maximum lateral root length, root thickness, main root dry weight, lateral root dry weight, root dry weight, and root volume, but did not reach significant levels.

Key words: *Brassica napus* L., root system, morphological traits, yield

Introduction

Plant root system plays an important role in plant growth. The morphology of root system has important contribution to yield, but there are fewer researches because it grows in the soil. To improve fertilizer utilization rate, it is critical to improve root-related morphological and physiological traits. Although roots grow in soil and its morphology is relatively difficult to study, it is relatively intuitive and simple compared with the root physiological traits. From the experience of genetic improvement on above-ground traits in plants, we also realize that root morphological researches should be important in crop production. Analysis on the existing data about genetic character of root traits, we can find root characters such as root length, root diameter, have a higher narrow genetic rate, therefore selection in the early generation is effective (Wang Xiu-quan et al., 2002). From this analysis on the root form, establishing root morphology breeding aiming "ideal root" is possible to make a breakthrough and bring about the genetic improvement of root traits (Wu Wei-ming et al., 2005).

The experiment was conducted to study on root characters and plot seed yield of different *Brassica napus* varieties (lines) was investigated in order to understand whether the genetic differences in root traits actually exist among different *B. napus* lines.

Materials and methods

Experiments were conducted in the test field of Oil Crops Research Institute of Chinese Academy of Agricultural Sciences. The soil of test field was sandy loam and had uniform fertility. Seeds were sown on September 18, 2005. The plot experiment was conducted in a randomized incomplete block design with three replications. There were 8 rows in each plot and the rows were 2.3 m long and 0.33 m between each row.

Five plants were randomly selected to be harvested at the maturity period each plot. Soil was dug out about 20 cm in diameter and 50 cm in depth and rinsed thoroughly with water to get root samples. For the root samples, main root length, maximum lateral root length, number of lateral root, root thickness, main root dry weight, lateral root dry weight, root dry weight, and root volume were investigated. The root thickness was measured at the point of 1 cm below the cotyledon node using vernier caliper, root dry weight was the sum of main root dry weight and lateral root dry weight, root volume was tested with drainage method. Seed yield of each plot were weighed after being threshed and completely dried.

Results and Analysis

Difference of root morphological traits among different hybrid parents

The results of variance analysis from three replication data of the seven parents (three CMS and four maintainer lines) for different root morphological traits respectively showed that only the number of lateral root hasn't significant difference among different parents among the eight root traits (Table 1). From the phenotypic value of root traits listed in Table 2, it could be

seen that various traits among parents were quite different. The greatest difference among these traits was root dry weight. The root dry weight of R3 was approximately three times of that of 8908A. The second was the root volume. The root volume of R3 was about twice of that of 8908A. Although 8908A had some advantages at root length, its thinner roots resulted in the lower root volume and root dry weight than other parents. The main root of R3 was obviously thicker than other parents, and therefore both root volume and root dry weight of R3 had advantages over the other strains.

Table 1 Results of variance analysis on root morphological traits among different hybrid parents

	MRL	MLRL	NLR	RT	MRDW	LRDW	RDW	RV
F Value	3.21	5.13	1.989	3.099	3.03	8.786	4.514	7.721
Probability	0.041*	0.008**	0.146	0.045*	0.048*	0.001**	0.013*	0.001**

Note: MRL (Main Root Length), MLRL (Maximum Lateral Root Length), NLR (Number of Lateral Root), RT (Root thickness), MRDW (Main Root Dry Weight), LRDW (Lateral Root Dry Weight), RDW (Root Dry Weight), RV (Root Volume). * means significant level at 0.05, ** means significant level at 0.01. It's the same at the following tables.

Table 2 Difference of root morphological traits among different hybrid parents

Parent	MRL		MLRL		NLR		RT		MRDW		LRDW		RDW		RV	
1055A	29.2	ab	14.1	AB	5.7	bc	0.97	b	5.67	a	0.99	B	6.66	a	18.4	AB
6098A	29.5	ab	9.3	C	5.4	c	1.04	ab	4.85	abc	0.71	B	5.56	ab	14.3	BC
8908A	31.9	ab	16.7	A	7.7	abc	0.87	b	4.01	c	0.62	B	4.63	b	12.4	C
R1	27.1	b	15.5	AB	7.8	ab	1.07	ab	5.06	ab	1.23	AB	6.29	ab	18.1	AB
R2	27.7	b	12	BC	7.5	abc	0.97	b	4.53	bc	0.73	B	5.26	ab	13.8	BC
R3	27.9	b	12.6	ABC	8.3	a	1.25	a	4.9	abc	1.83	A	6.73	a	22.4	A
R6	28.6	b	13.1	ABC	7	abc	0.94	b	4.67	bc	0.76	B	5.43	ab	13.9	BC

Note: The same as Table 1. LSD Results: Labeled with the same letter indicates no significant difference, with the different letter indicates significant at 0.01 (capital letter) or 0.05 (small letter) level.

Difference of morphological traits between CMS lines and maintainer lines

In order to test whether there was significant difference in morphological traits between CMS lines and their correspondent maintainer lines which had the basically same genetic background, significant difference tests were carried out for each root trait between three CMS lines and three correspondent maintainer lines. Results showed every root trait have not significant difference between CMS lines and maintainer lines (Table 3). It indicated that there was little relevance between root traits and fertileness. Average values of CMS lines and maintainer lines for each root trait were listed in Table 4.

Table 3 Results of difference in morphological traits between CMS lines and maintainer lines

	MRL	MLRL	NLR	RT	MRDW	LRDW	RDW	RV
t Stat	0.8813	0.8873	-1.5797	-2.4249	-0.3595	0.4051	-0.0921	-0.5829
Probability	0.2356	0.2343	0.1275	0.0681	0.3768	0.3623	0.4675	0.3095

Difference of root morphological traits among different types of strains

Single plant phenotypic values of each root morphological trait for different types of *B. napus* and the significant level of difference were listed in Table 4. Hybrids had significantly more lateral roots than CMS lines, maintainers and restorers. The main root length of hybrids, CMS lines and maintainers was significantly longer than those of restorers. As far as the lodging resistant varieties were concerned, except its number of lateral root was significantly fewer than that of hybrid, maximum lateral root length, root thickness, main root dry weight, lateral root dry weight, root dry weight and root volume were significantly better than those of other materials. Maximum lateral root length, main root dry weight and root dry weight, those three root traits were all did not have significant difference among CMS lines, maintainers, restores and hybrids.

Table 4 Difference of root morphological traits among different fertileness materials

	MRL		MLRL		NLR		RT		MRDW		LRDW		RDW		RV	
S	30.2	b	13.4	b	6.3	c	0.96	C	4.84	B	0.77	bc	5.61	B	15.0	BC
M	29.6	b	12.6	b	7.2	bc	1.07	BC	4.50	B	0.65	c	5.15	B	13.7	C
R	27.8	c	13.3	b	7.7	b	1.06	BC	4.79	B	1.14	b	5.93	B	17.1	B
H	30.1	b	13.9	b	8.9	a	1.09	B	5.00	B	1.09	bc	6.09	B	17.4	B
L	33.8	a	16.1	a	7.7	b	1.26	A	6.84	A	1.62	a	8.46	A	22.8	A

Note: S presents sterile lines; M presents maintainers; R presents restores; H presents hybrids; L presents lodging resistant varieties.

Heterosis of root traits and plot seed yield

Table 5 presented the heterosis rate of 8 root traits and plot yield in 12 hybrids. The heterosis rates were calculated according to the comparison of hybrid with the average of both parents. Table 5 showed there was heterosis in plot seed yield in all 12 hybrids, and the heterosis rate was 7.5-37.7%. Every root trait had heterosis in a part of the crosses. But in three hybrids of 1055A×R6, 8908A×R1 and 8908A×R6, there was no evident heterosis in most root traits, their phenotype value were lower than their parents'. However, heterosis of all root traits was found in three hybrids derived from the crosses used R2 as male parent. It indicated that root traits of R2 had better general combining ability.

Table 5 Root traits and plot seed yield in hybrids (%)

Combination	MRL	MLRL	NLR	RT	MRDW	LRDW	RDW	RV	PSY
1055A×R1	17.2	-25.4	-5.0	3.2	4.2	2.6	3.1	4.1	34.0
1055A×R2	12.4	40.4	67.1	13.4	27.0	54.1	36.5	40.6	13.7
1055A×R3	18.4	12.9	5.3	6.4	2.3	-1.7	1.2	30.9	7.5
1055A×R6	-3.1	5.5	-7.0	-2.5	-13.4	4.9	-11.8	-5.2	26.6
6098A×R1	13.5	11.6	24.2	4.1	3.8	-1.4	3.5	5.3	18.3
6098A×R2	11.9	38.3	8.3	10.5	14.2	18.4	15.7	15.6	37.7
6098A×R3	12.6	4.1	16.2	8.3	1.4	25.3	6.4	27.0	12.6
6098A×R6	-8.2	42.6	82.3	26.9	35.2	71.4	41.3	48.9	37.0
8908A×R1	-16.3	-29.6	-17.7	-2.6	-24.4	-20.1	-27.1	-24.0	26.9
8908A×R2	6.7	22.9	35.4	13.7	19.1	24.4	19.9	22.4	18.9
8908A×R3	4.2	-12.3	7.2	-2.2	12.2	2.8	10.5	-7.0	21.7
8908A×R6	-12.7	-19.2	1.4	-2.8	-13.4	-17.0	-13.9	-16.3	26.8

Note: PSY presents plot seed yield

Correlation among root traits and plot seed yield

The results of correlation analysis among all 24 tested materials showed that there were significant positive correlation ($P<0.01$) among maximum lateral root length, main root dry weight, lateral root dry weight, root dry weight and root volume, in which root dry weight and root volume had the highest correlation index (r=0.9671**). Significant positive correlation also existed between root thickness and main root dry weight, lateral root dry weight, root dry weight, root volume, but the correlation between root thickness and maximum lateral root length was not significant. The number of lateral root had significant positive correlation with maximum lateral root length and lateral root dry weight at 0.01 level, had significant positive correlation with root dry weight at 0.05 level, but not significantly correlated with other traits. The main root length did not significantly correlate with other root traits in this experiment. Plot seed yield had positive correlation in a certain degree with maximum lateral root length, root thickness, main root dry weight, lateral root dry weight, root dry weight, and root volume (correlation coefficients above 0.28), but did not reach statistically significant levels.

Table 6 Correlation coefficients among root traits and plot seed yield

	MRL	MLRL	NLR	RT	MRDW	LRDW	RDW	RV	PSY
MRL	1.0000	0.3877	-0.0176	0.0800	0.3173	0.0944	0.2700	0.2757	0.0303
MLRL		1.0000	0.6684**	0.3532	0.5543**	0.5983**	0.6019**	0.5588**	0.3608
NLR			1.0000	0.4088	0.3561	0.5582**	0.4389*	0.3941	0.2011
R T				1.0000	0.7420**	0.8567**	0.8224**	0.8525**	0.2816
MRDW					1.0000	0.7208**	0.9581**	0.9225**	0.3221
LRDW						1.0000	0.8493**	0.8809**	0.2972
RDW							1.0000	0.9671**	0.3310
R V								1.0000	0.3993
PSY									1.0000

Discussion

Previous studies in rice showed that root dry weight per plant, adventitious roots per plant, root thickness, dry weight per unit length were all closely related with yield and yield components. The two-line hybrid rice showed superiority in root traits. With the level of rice grain yield increased, its root traits also had been markedly improved (Dong Gui-chun et al., 2002; Liu Tao-ju et al., 2002). Our research results also showed plot seed yield had positive correlation in a certain degree with root traits. These results indicated that the improvement of root traits might promote the increase of grain yield. However, it remains to be further confirmed whether the effects are significant. Different genetic materials and different environments may result in discrepancies. In this study, the most developed root materials were two lodging-resistant varieties, except their number of lateral root was significantly fewer than that of hybrid, maximum lateral root length, root thickness, main root dry weight, lateral root dry weight, root dry weight and root volume were all significantly better than those of other materials. In fact, compared to other materials, these two lodging-resistant varieties also had obvious advantages on disease resistance and drought resistance, although their yield was not the highest. In the hot and drought stress environment, varieties with developed root system will demonstrate the advantages in yield because of their strong resistance to stress and less impacted by environment. So the selection on rapeseed root trait, not only may promote the increase of grain yield, but also could significantly improve the yield stability.

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