Heterosis and breeding of high oil content in rapeseed (*Brassica napus* L.)

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ABSTRACT

High oil content is one of the most important characteristics for rapeseed (*Brassica napus* L.) breeding. In this study, eleven canola *Brassica napus* lines (varieties) with different oil content (32.48%-52.61%) and genetic background, were chosen to make sixty-two reciprocal crosses in order to test the heterosis of oil content in *Brassica napus* L. and identify the breeding potential for high oil content hybrids. Results showed that out of 62 crosses, 30 crosses exhibited positive mid-parent heterosis and 7 exhibited positive over-parent heterosis for seed oil content, which accounted for 48.39% and 11.29%, respectively. The positive mid-parent heterosis percentage and over-parent heterosis percentage ranged from 0.43% to 9.86% and 0.46% to 8.67%, respectively. The results suggested that: 1) obviously positive mid-parent and over-parent heterosis exhibited in the combination between two low oil content parents, but the oil content of their F1 hybrid was still low; 2) small positive mid-parent and over-parent heterosis could be gotten in some combinations if the oil contents of their parents were at the same level, whether at a medium or high level; 3)obviously negative mid-parent and over-parent heterosis existed in hybrid combinations between low and high oil content parents; 4) it is essential that both two parents should be high oil content if we would like to get a high oil content hybrid. A registered canola cultivar Zhongshuang 11 with oil content of 49.04% and a canola hybrid with oil content of 49.84% was developed in our breeding group very recently.

Key words: *Brassica napus* L. - Oil content – Heterosis - Zhongshuang 11

INTRODUCTION

Rapeseed (*Brassica napus* L.) is one of the most important edible oilseed crops in the world, as well as a major potential source of bio-diesel production in Europe (Wang, 2005). In the crushing industry, about 80% of the value of rapeseed is related to oil production. One percentage point increasing of oil content in rapeseed is equivalent to 2.3~2.5 percentage points increasing in seed yield. Therefore, breeding for high seed oil content becomes one of the most important objectives in oilseed breeding programs around the world.

It is well known that the utilization of heterosis is an effective way to increase crop yield. Brandle and McVetty (1989) reported a high-parent heterosis with 120% for seed yield in *B. napus*. Qi et al. reported the over parent percentage of seed yield per plant was 70.24% (30.70-218.0%). In several countries hybrids played an important role in the expansion of *B. napus* cultivation (Becker et al., 1999; Miller, 1999; Fu, 2000). However, little is known for the heterosis of seed oil content in *B.napus*. Shen et al. (2002) said that mid-parent heterosis for seed oil content was ranged from -1.55% to 7.44% only. So a further study of seed oil content heterosis is helpful to the improvement of hybrid seed oil content in *B. napus* .

MATERIALS AND METHODS

A total of eleven canola quality *Brassica napus* L. lines (cultivars) with different genetic background and significant difference in oil content were used as parents in this study (Table 1). 56 reciprocal crosses were produced from the following eight parents: one high oil content line (53165), five medium oil content lines (variety) (56366, 52276, 54285, 51218, Zhongshuang 9) and two low oil content lines (51070, 93275), based on Griffing's Diallel design. 56 F1 hybrids and their parents were planted according to a randomized complete block design with two replications at the experimental farm of Oil Crops Research Institute (OCRI) in 2006. Three high oil content lines (53110, 61616 and 6F313) were used to supplement the experiment in 2008 using the same procedure as described above. The oil content (OC%, w/w) of rapeseed seeds was analyzed using a Foss NIRSystems 5000 near-infrared reflectance spectroscopy (Foss NIRSystems Inc.) according to WinISI III manual instructions for routine analysis (Foss-tecator Infrasoft International LLC). In excess of 3.5 g of each intact sample were scanned in a 36 mm inner-diameter ring cup. Mid-parent heterosis(%) =(F1-MP)/MP×100, over-parent heterosis(%)=(F1-HP)/HP×100. MP and HP were medium and higher oil content parent value, respectively.

Table 1 Oil contents of the parents used in crossing

Lines B* (cultivars)	Oil content in 2007	Lines A* (cultivars)	Oil content in 2009
53165	52.61	53110	47.78
56366	43.61	61616	50.16
52276	43.22	6F313	47.46
54285	41.61		
51218	40.72		
Zhongshuang 9	41.98		
51070	36.02		
93275	32.48		

RESULTS

Oil content mean performance of parents and their hybrids

The mean oil content of the eight parents (53165, 56366, 52276, 54285, 51218, Zhongshuang 9, 51070 and 93275) was 41.53% (Table 1), and the mean oil content of their F1 plants was 41.21% (Table 2) in 2007. The mean oil content of the three high oil parents (53110, 61616, 6F313) was 48.58 % (Table 1) and the mean oil content of their F1 plants was 48.60% (Table 2) in 2009.

Heterosis of oil content in different combinations

Table 2 showed that out of 62 crosses, 30 crosses exhibited positive mid-parent heterosis for seed oil content and 7 crosses exhibited positive over-parent heterosis, which accounted for 48.39% and 11.29%, respectively. The positive mid-parent heterosis percentage and over-parent heterosis percentage ranged from 0.43% to 9.86% and 0.46% to 8.67%, respectively. The positive mid-parent heterosis existed mostly in some combinations between L×L, M×M, L×M (or M×L) and H×H, while very few positive mid-parent heterosis exhibited in L×H (or H×L) or M×H (or H×M) combinations. Positive over-parent heterosis was found only in combinations between L×L, M×M and H×H.

Significantly negative over-parent heterosis exhibited in all combinations between L×H (or H×L), M×H (or H×M) and L×M (or M×L) and its percentage value ranged from -0.25% to -22.20%. Significantly negative mid-parent heterosis also exhibited in most of the combinations between L×H (or H×L) and M×H (or H×M) and its percentage value ranged from -0.18% to -10.43%.

There were significant differences of the mid-parent and over-parent heterosis between some crosses and their reciprocals, e.g., 51218×56366 and its reciprocal, 54285xZhongshuang 9 and its reciprocal. These differences should be due to the significant cytoplasmic effects of there parents. So it implied that there were significantly positive cytoplasmic effects for parents 51218 and Zhongshuang 9 while there were significantly negative cytoplasmic effects for parents 56366 and 54285.

Table 2 Heterosis of oil content in different combinations

Combination	P1	Cross			reciprocal			P2
		P1×P2	Mid-parent heterosis(%)	Over-parent heterosis(%)	P2×P1	Mid-parent heterosis(%)	Over-parent heterosis(%)	
L×L or M×M 2007	51070	37.24	8.73	3.39	36.27	5.9	0.69	93275
	51218	42.33	0.86	-2.06	43.00	2.45	-0.51	52276
	51218	42.51	3.27	2.16	43.43	5.5	4.37	54285
	51218	42.75	1.39	-1.97	37.65	-10.71	-13.67	56366
	51218	41.66	0.75	-0.76	39.55	-4.35	-5.79	Zhongshuang 9
	52276	43.12	1.66	-0.23	43.09	1.59	-0.3	54285
	52276	42.85	-1.3	-1.74	40.61	-6.46	-6.88	56366
	52276	42.5	-0.23	-1.67	42.93	0.77	-0.67	Zhongshuang 9
	54285	40.92	-3.97	-6.17	42.33	-0.66	-2.94	56366
	54285	40.38	-3.39	-3.81	45.62	9.15	8.67	Zhongshuang 9
	56366	41.26	-3.59	-5.39	43.81	2.37	0.46	Zhongshuang 9
	Mean	41.59	0.38	-1.66	41.66	0.50	-1.51	
L×M 2007	51070	34.82	-9.25	-14.49	40.62	5.86	-0.25	51218
	51070	39.79	0.43	-7.94	40.79	2.95	-5.62	52276
	51070	38.61	-0.53	-7.21	38.59	-0.58	-7.26	54285
	51070	38.28	-3.86	-12.22	38.02	-4.51	-12.82	56366
	51070	39.98	2.51	-4.76	40.57	4.03	-3.36	Zhongshuang 9
	93275	36.25	-0.96	-10.98	40.15	9.70	-1.40	51218
	93275	38.78	2.46	-10.27	39.19	3.54	-9.32	52276
	93275	38.15	2.98	-8.32	39.72	7.22	-4.54	54285
	93275	38.55	1.33	-11.60	36.09	-5.14	-17.24	56366
	93275	39.71	6.66	-5.41	40.9	9.86	-2.57	Zhongshuang 9
	Mean	38.29	0.18	-9.32**	39.46	3.29	-6.44**	
L×H or M×H 2007	51070	40.97	-7.56	-22.14	41.13	-7.2	-21.84	53165
	93275	40.94	-3.78	-22.2	40.96	-3.74	-22.16	53165
	51218	42.64	-8.64	-18.97	41.8	-10.43	-20.56	53165
	52276	44.8	-6.51	-14.86	44.01	-8.16	-16.36	53165
	54285	42.3	-10.22	-19.61	47.03	-0.18	-10.62	53165
	56366	46.91	-2.5	-10.85	48.97	1.78	-6.94	53165
	Zhongshuang 9	46.95	-0.74	-10.78	44.81	-5.26	-14.84	53165
	Mean	43.64	-5.71*	-17.06**	44.10	-4.74*	-16.19**	
Mean		40.93	-1.21	-8.25	41.49	0.19	-6.94	
H×H 2009	53110	50.57	3.27	0.82	49.98	2.06	-0.36	61616
	53110	46.35	-2.67	-2.99	46.25	-2.88	-3.2	6F313
	61616	48.81	0	-2.69	49.63	1.68	-1.06	6F313
	Mean	48.58	0.2	-1.62	48.62	0.29	-1.54	

M: medium-oil content variety (line); L: low-oil content variety (line); H: high-oil content variety (line);
* and **: Significantly different at the 0.05 and 0.01 probability level, respectively, The same below.

Breeding of high oil content cultivars

Zhongshuang 11, an open pollinated *Brassica napus* canola cultivar with high oil content, high resistance to shattering, lodging and *S. Sclerotiorum* was bred by multiple crossing (medium oil content cultivar Zhongshuang 9 and two high oil content parental lines) and microspore culture technique. It was registered and released in China in 2008. In National Regional Trial during 2006-2008, the oil content of Zhongshuang 11 reached 49.04%, which is the highest oil content record for registered cultivars in China. The contents of erucic acid and glucosinolates were 0 and 18.84μmol·g-1 (in meal), respectively (Table 4). The index of shattering resistance was 0.76 which was 2.4 times of Zhongshuang 9. In field assessment of resistance to *S. Sclerotiorum*, the disease incidence of Zhongshuang 11 was lower than that of Qinyou 7 by 8.59%. The oil yield of Zhongshuang 11 was 1230 kg/ha averagely in National Regional Trial, 6.31% higher than the control hybrid variety Qinyou 7.

The oil content of a new three-line CMS hybrid 86155 (86A×74155) achieved 49.84% in National Regional Trial during 2008~2009. At the same time, its yield was 5.50% higher than the control hybrid variety Qinyou 7.

Table 3 Seed quality and yield of two high oil content cultivars bred recently by us*

Cultivar	year	Average oil yield (kg/hm^2)	Compared to Qinyou 7 (%)	Oil content (%)	Erucic acid	Glucosinolates μmol·g-1 (in meal)
Zhongshuang 11	2006-2007	1307.4	+4.25	48.99	0	18.96
	2007-2008	1182.45	+8.75	49.08	0	18.72
	Mean	1230	+6.31	49.04	0	18.84
86155	2008-2009	1259.48	13.58	49.84	0	22

*：The results were from the report of National Regional Trial in China.

DISCUSSION

It is well known that the utilization of heterosis is one of the most effective ways to increase crop yield. However, negative or absence of heterosis for oil content is a common phenomenon in oil seed Brassicas (Brandle and McVetty, 1990; Schuler et al., 1992; Falk et al., 1994, Teklewold and Becker, 2005). In this study, although there existed certain positive mid-parent or over-parent heterosis in L×L, M×M, L×M (or M×L) and H×H combinations, it was difficult to obtain high oil content F1 hybrid when a combination was made between a high oil content parent and a medium or low oil content parent since the heterosis effect was significantly negative in such an occasion. Therefore it is essential that both two parents should be high oil content if we would like to get a high oil content hybrid. The breeding experience of our high oil content hybrid 86155 (with oil content of 49.84%) approved this suggestion. Whether such a phenomenon is also common for some other traits such as yield or not needs further investigation. In addition, cytoplasmic effect is another thing that should be considered seriously in the breeding of high oil content *B. napus.*

ACKNOWLEDGEMENT

This project was supported by National Key Basic Research Program (2006CB101607) and National High Technology Research and Development Program of China (2007AA100106).

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