Study on heterosis among subspecies or varieties in *B. campestris* L.

WANG Junsheng, WANG Xuefang, ZHANG Yanfeng, ZHANG Zhi, TIAN Jianhua, LI Dianrong

Hybrid Rapeseed Research Center of Shaanxi Province, Shaanxi Rapeseed Branch of National Oil Crops Genetic Improvement Center, Dali 715105, China Email: arsrc@public.xa.sn.cn; lidr@people.com.cn

Abstract

35 hybrids were produced through crossing 5 sterile lines (subspecies or varieties in *B. campestris* L., such as Chinese-cabbage, no-heading Chinese-cabbage, purple Tsai-tai and rapeseed in *B. campestris* L.) with 7 restoring lines using NCII mating design. Their genetic effect of agronomic characters and yield characters as well as vegetative and yield heterosis of F_1 were studied for the application value of the germplasm resource of *B.campestris* L in rapeseed breeding. The results indicated that ①yield per plant was controlled completely by dominant genes, and length of main inflorescence, except for additive genes, was mainly controlled by dominant genes too. ②plant height, No. of primary branches, siliques of primary branches, siliques of main inflorescence, seeds per silique and 1000-seed weight were controlled by additive and dominant genes together. ③No. of secondary branches, siliques of secondary branches, siliques per plant and density of silique were mainly controlled by additive genes. The mean heterosis of all vegetative characters were positive in F_1 generation, that of petiole fresh weight was the highest (44%) and significant at 0.05 levels. Except No. of leafs, width of root-stem zone, Length of root and fresh weight of root system, other characters showed higher positive over-parent heterosis in F_1 generation .The mean-heterosis of plant height, effective branch height, length of main inflorescence, seeds per silique, 1000-seed weight and yield per hectare were positive significant at 0.05 or 0.01 levels and the mean-heterosis and over parent heterosis of yield per hectare were positive significant at 0.05 or 0.01 levels in F_1 generation, their value were 63% and 48%, respectively. All these showed yield heterosis of subspecies or varieties in *B. campestris* L. was better, so its utilization value is rather high in production.

Key words: *B .campestris* L., Subspecies, Varieties, Heterosis, Agronomic character

Introduction

Brassica campestris originated from china, it has a very long cultivation history [1], extensive germplasm and plentiful genetic diversify [2]. It is not only important oil crop, but also rather important vegetable crop. The yield of *B.campetris*. is lower and its *heterosis* utilization is very difficulty, so its production is restricted. However, it has some outstanding peculiarity, such as early-maturing and cold-resistant, as a result, it is still cultivated extensively in some area in China. In order to raise its yield, we need to utilize heterosis. WANG et al.[3,4] thought there were some high oil content germplasms in Chinese-cabbage, No-heading Chinese-cabbage, purple Tsai-tai and Caixin. Our study further indicated purple Tsai-tai had early-maturing, short flower-period, rapid wooden growth of stem and branch, rapid, shorter plant height, more branches etc. Chinese cabbage had rapid leaf born rate, more leaves, strong vegetative body, more pods, more seeds etc. In this paper, some hybrids were produced through crossing Chinese cabbage, No-heading Chinese-cabbage, purple-Tcaitai and rapeseed in *B.campestris* L which were bred by ourselves and studied on their vegetative and yield heterosis and genetic effect. This will provide theory for rapeseed high yield breeding in *B. campestris*.

1 Materials and methods

1.1 Materials and Designs

35 hybrid combinations were produced through crossing 5 sterile lines with 7 restoring lines by NCII mating design. They and their parents were planted in trial field of Hybrid Rapeseed Research Center of Shaanxi Province according to complete random block design with three replications and three rows per block, each row was 2.6m, the distance of row and between individuals was 0.4m×0.167m. Management of trail field was same as ordinary production field. Before winter coming, 10 plant were sampled from each blot to measure their vegetative characters. Before maturity, 5 plants were sampled from each blot to measure their agronomic characters to determine their heterosis and genetic effects of all characters. The classification of 12 parents was listed in table 1.

Table 1 Parent and classification of parents

Parent	Type or Classfication	Parent	Type or classfication	Parent	Type or classfication
Bai-1A	Chinese cabbage	Bai-4A	Rapeseed *B.campestris* L	03h136	Rapeseed *B.campestris* L
Tai-2A	Purple Tsai-tai	03h164	Rapeseed *B.campestris* L	01v1003	No-heading Chinese-cabbage
Qing-2A	No-heading Chinese-cabbage	99CH381	Rapeseed *B.campestris* L	03v843	Chinese cabbage
Bai-21A	Rapeseed *B.campestris* L	21CH334	Rapeseed *B.campestris* L	03v1039	No-heading Chinese-cabbage

1.2 Statistical analysis

The heterosis and genetic variance components of all characters were estimated by adopting additive-dominant model and conducting MINQUE (1) method of *Genetic Model of Quantitative Characters* written by Zhu Jun[5]. The Standard error of all parameters and their significance were estimated by sampling randomly the block using Jack-knife method [6].

2 Results and analysis

2.1 Heterosis analysis of vegetative characters

The performance of vegetative characters, reflecting vegetative vigor of hybrids in the period of vegetative growth, is the base of reproductive growth and yield heterosis. So analyzing vegetative heterosis is the reference for screening strong combinations. Heterosis of vegetative characters in F_1 among subspecies or Varieties(Table2) showed that petiole fresh weight had the highest average heterosis in F_1, it got to 44%, and weight of stem and leaves, fresh weight per plant, petiole length, the biggest leaf width, the biggest leaf length, width of root-stem zone, leaves, fresh weight of root, length of root were 41%, 37%, 20%, 19%, 17%, 14%, 10%, 6% and 3%, respectively, and petiole fresh weight got to difference at 0.05 level, weight of stem and leaves, petiole length, petiole width and the biggest leaf length were all got to difference at 0.1 level. The over-parent heterosis of only the biggest leaf width among all vegetative characters of F_1 got to the difference at 0.1 level. For other traits, some of them had stronger over-parent heterosis, such as petiole weight, weight of stem and leaves and fresh weight per plant were 34%, 29% and 25%, but they didn't get to significant level.

Table 2 Heterosis of vegetative characters of hybrid F_1 among subspecies or varieties in *B. campestris* L.

Item	Leaves	Petiole fresh weigh	The biggest leaf length	The biggest leaf width	Petiole length
Pre(F_1)	9.00	7.13	27.11	11.90	14.90
Hpm(F_1)	0.10	0.44*	0.17+	0.19+	0.20+
Hpb(F_1)	0.02	0.34	0.11	0.15+	0.10
Item	Width of root-stem zone	length of root	Fresh weight of root	Weight of stem and leaves	Fresh weight per plant
Pre(F_1)	1.27	14.11	7.86	91.57	102.63
Hpm(F_1)	0.14	0.03	0.06	0.41+	0.37
Hpb(F_1)	0.00	-0.04	-0.11	0.29	0.25

Note: Pre(F_1), Hpm(F_1)Hpm(F_1) denote genetic value, average heterosis and over parent heterois of F_1. *, ** denote significance at 0.05 and 0.01 levels respectively. The following tables are the same.

2.2 Heterosis analysis of main agronomic characters and yield

Table3 showed that F_1 average heterosis of other traits except silique density were all positive. In them, plant height, length of inflorescence, seeds per silique, 1000-seed weight and yield per hectare all got to significant at 0.05 or 0.01, and the average heterosis of yield per hectare was the highest, reaching 63%. These indicated that there were stronger heterrosis among subspecies or varieties in *B.campestris*, so it was worth to utilize. Among all traits of F_1, only the over parent heterrosis of yield per hectare and plant height were significant at 0.05 levels, while seeds per silique got to significance at 0.1 levels, other traits were all negative heterosis.

Table3 Heterosis of agronomic and yield characters of hybrid among subspecies or varieties

Item	Plant height	Effective branch height	Length of main inflorescence	Effective Primary branches	Siliques of Effective primary branches	Secondary branches	Siliques of secondary branches
Pre(F_1)	124.71*	15.93	50.92+	10.60	295.09+	11.99	103.23
Hpm(F_1)	0.21 **	0.12*	0.25*	0.02	0.16+	0.01	0.01
Hpb(F_1)	0.09 *	-0.43**	0.09	-0.14*	0.01	-0.39*	-0.43*
Item	Silique density	Siliques of main Inflorescence	Siliques per plant	Seeds per silique	1000-seed weight	Yield per plant	Yield per hectare (Kg/hm2)
Pre(F_1)	1.20	60.73	452.92*	23.35*	2.71	28.18**	2853.55**
Hpm(F_1)	-0.04	0.20+	0.10	0.21*	0.07*	0.39+	0.63**
Hpb(F_1)	-0.13*	-0.01	-0.07	0.08+	-0.01	0.24	0.48**

2.3 Genetic effect analysis

The genetic effects of all agronomic characters of hybrids among subspecies or varieties were listed in table 4. The additive effect of yield per plant and yield per hectare were zero, while their dominant effects were 0.474 and 0.878 and got to significance at 0.05 or 0.01 levels, so they were all controlled by dominant genes. The ratios of Va/Vp and Vd/Vp of plant height, effective primary branches, siliques of effective primary branches, siliques of main inflorescence, seeds per silique and 1000-seed weight were all got to significance at 0.05 or 0.01 levels, therefore, these traits were all controlled by additive genes and dominant genes. The ratios of Va/Vp of branch height, secondary branches, siliques of secondary branch, siliques per plant and siliques density were also got to significance at 0.05 or 0.01 levels, but their Vd/Vp were not significance at 0.05 level, which indicated these traits were mainly controlled by additive genes. The Vd/Vp of length of main inflorescence got to significance at 0.05 level, but its Va/Vp was not significance, therefore, it was mainly controlled by dominant genes, additive gene effect was smaller for it.

3 Discussion

B. campestris is classified into 3 subspecies, Chinese-cabbage, No-heading Chinese-cabbage and turnip, and every subspecies has different varieties. Their germplasm resources are very rich in china. Li Jiawen [7] thought rapeseed in *B. campestris* was only a variety descendant of No-heading Chinese-cabbage, so their origin is similar and their chromosomes are AA=20, therefore, there are stronger compatibility among them, and their seed production of F_1 is rather good, so we can directly utilize the hybrid between vegetable *B. campesstris* and rapeseed in *B.campestris*. This was identified in our rapeseed breeding practices.

Table4 Genetic analysis of agronomic and yield characters of hybrids among subspecies or varieties in *B. campestris*

Characters	Va/Vp	Vd/Vp	Ve/Vp	Hn	Hb
Plant height	0.317*	0.533**	0.149*	0.317*	0.851**
Branch height	0.632**	0.056+	0.312**	0.632**	0.688**
Length of main florescence	0.222+	0.464**	0.313*	0.222+	0.687*
Effective primary branches	0.542**	0.074*	0.384**	0.542**	0.616**
Siliques of primary branches	0.248**	0.210**	0.542**	0.247**	0.458**
Secondary branches	0.389*	0.081	0.530*	0.389*	0.470*
Siliques of secondary branches	0.332*	0	0.668**	0.332*	0.332*
Siliques of main inflorescence	0.31*	0.376*	0.315**	0.309*	0.685**
Silique per plant	0.287**	0.100	0.614**	0.287**	0.386**
Silique density	0.226*	0.239+	0.535*	0.226*	0.465*
Seeds per silique	0.335*	0.422*	0.243*	0.335*	0.756**
1000-seed weight	0.461**	0.293*	0.246*	0.461**	0.754**
Yield per plant	0	0.474*	0.526**	0	0.474*
Yield per hectare	0	0.878**	0.122*	0	0.878**

Note: *Va*,*Vd*,*Vm*,*Ve*,*Vp* denote additive, dominant, maternal, residual and phenotype variances respectively; *Hn* is narrow hereditary capacity.

At present, utilization of crops heterosis includes varieties, subspecies, and interspecific hybridization[8], but only hybridization among varieties were mainly utilized in crop production. Generally speaking, the genetic diversity of varieties in subspecies is smaller, so to utilize their hybrids is limited in production, however, the F_1 of subspecies has stronger heterosis[9]. This study indicated that the average heterosis and over-parent heterosis of yield per hectare got to 63% and 48%,respectively. We analyzed 9 high yield combinations whose yield were over 3000Kg/hm^2 .The results indicated that 8 combinations were subspecies or varieties. So it is easier to select better combinations among subspecies or varieties in *B.campestris*. At the same time, these high yield combinations had more siliques per plant and higher 1000-seed weight, which came from the genes of vegetable of *B.campestris*.

From above results, for the fresh weight of F_1 among subspecies or varieties, its average vegetative heterosis and over parent heterosis got to 37% and 25%. This was related to the stronger heterosis of fresh weight per plant, petiole fresh weight, the biggest leaf length, the biggest leaf width, petiole length, fresh weight of stem and leaves etc, which may be the cause of stronger heterosis in yield per hectare.

Grasping genetic effects of all characters is helpful to select and breed varieties. If the characters were controlled by additive genes, it was easier to breed excellent variety because of its additive effects in segregation generations; if these characters were controlled by dominant genes, the best performance in F_1 was not repeated in later generations, selecting it directly was not good. In all characters studied in the paper, plant height, effective primary branches, siliques of main inflorescence, seeds per silique and 1000-seed weight were controlled by additive and dominant genes altogether, effective branch height, effective secondary branches, siliques of secondary branches and siliques per plant were mainly controlled by additive genes, but yield per plant and yield per hectare were both controlled by dominant genes, and showed stronger heterosis in F_1, which was not same as the former study because of distant blood relationship.

References

1 Liu Hou-li.Origin and evolution of rapeseeds. *Acta agronomica sinica*.1984, 10(1):9-18

2 He yu-tang, Tu jin-xing, Fu ting-dong, Li dian-rong, Chen bao-yuan. Genetic Diversity of Germplasm Resources of *Brassica* campestris L. in China by RAPD Markers. *Acta agronomica sinica*, 2002, 29(5).

3 WANG Xue-fang, ZHANG Yan-feng, LI Dian-rong, TIAN Jian-hua, WANG Zhu-yun. Analysis on Oil Content of Vegetable Materials of Chinese Cabbage Type.and Application in Rapeseed Breeding. *Acta Agriculture Boreali-occidentalis Sinica*, 2004,13(2):20-23.

4 WANG Xue-fang, LI Dian-rong, HU Jing-jiang, TIAN Jian-hua, WANG Jun-sheng. Analysis and Exploitation of Agronomic Traits of Vegetable Germplasms of *Brassica campestris. Acta B ot Borea l-Occident Sin.* 2005,25(7):1133-1439.

5 Zhu, J. 1997. Analysis Methods for Genetic Models. Chinese Agricultural Publish House. Beijing.

6 Zhu jun, Ji dao-fan, Xu fu-hua. A genetic approach for analysis intra-cultivar heterosis in crops.Acta genetic sinica, 1993,20(3):262-271.

7 Li jia-wen. Derivation and variation of vegetable crop in chaina. China agricultual sciences.1 981(10:90-95.

8 Yuan long-ping**.** Strategy and assumption of hybrid rice breeding. Hybrid rice,1987(1):1-3

9 Cheng shi-hua, Zhai hu-qu. Breeding Strateg ies for Super ior High- yielding in Hybr id Rice**.** Research of agricultural modernization.2000,21(3):147-150,154.