Considerations on heterosis utilization in rapeseed (*Brassica napus*)

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1.Ways to utilize heterosis in China

In recent years, rapeseed hybrid varieties grown on 4.8~4.9 million hectares in China covering about 70% of the average area of 7 million hectares yearly

- **Heterosis in rapeseed has been exploited in multiple ways in China. Three-line system based on CMS (Cytoplasmic Male Sterility) is the major approach to develop hybrids**

Rapeseed varieties registered in China in 2000-2005

Total	217				Percentage %
Conventional	47				21.7
Hybrid	170				78.3
Of hybrid	CMS	GMS (Genetic MS)	EMS (Ecotype MS)	GC (Gametocides)	
	107	47	12	4	
Percentage (%)	62.9	27.6	7.1	2.4	100.0

Data provided by Mr Zhang Dong-xiao

2. Rapeseed origin,evolution and breeding of three-line system

***Brassica napus* originated in Mediterranean of Europe**

	CMS	Restorer line	Maintainer line
Polima cms	European varieties	European varieties	Asian and African varieties
Shan 2A cms	European varieties	European varieties	Asian varieties

CMS and restorer line are easily found among the varieties in the center of origin

Middle East, India and the western China are centers of origin of *Brassica juncea*

Name of sterile line	CMS	Restorer line	Maintainer line
Yunnan Ouxin A cms (Southwest China)	Varieties in Xinping town of Yunnan	Local varieties of Yunnan	European varieties
Indian Ms-4 cms	Indian RLM-198	Indian varieties mainly	European Ej-33

CMS and restorer line are easily found among the varieties in the center of origin

- North-west of China is one of the center of origin of *Brassica rapa*, and southern forms of *Brassica rapa* developed from the north-western forms
- Male sterility is likely to occur if the north-western *Brassica rapa* (female) is crossed with the southern *Brassica rapa* (male)

- Male sterility will not express if southern forms of *Brassica rapa* (female) are crossed with the northern *Brassica rapa* (male)
- Restorer gene is present in Chinese northern *Brassica rapa* varieties but the southern *Brassica rapa* varieties are mainly maintainer lines

Chinese male sterile cytoplasm of rice was found among wild rice in Hainan Island, which is one of the centers of origin of rice. The varieties in Philippians and south China are mainly restorers and those in Yangtze River valley and northeast China are mainly maintainers

- *To conclude, male sterile cytoplasm and restorer gene are likely to be found among the primitive populations close to the center of origin. On the contrary, the male sterile maintainer line is easily to be found among the populations of highly developed lines and far from the center of origin*

3. Quality traits and heterosis

- The heterosis of agronomic traits: heterosis on vegetative mass is greater than that of seed yield, and the later is greater than that of quality trait (vegetative heterosis > seed yield trait heterosis > seed quality trait heterosis).

- **The average rate of heterosis of 9 rapeseed varieties is: vegetative traits- 25.05 %-30.15 %, individual plant yield 7.92 %, oil content 3.67 % (Zhang Shufen, 1992), and negatively correlated with protein content (Serney, 1993)**
- **The average rate of heterosis of sorghum is 43.3 % for 4 yield traits, -13.02 % for 4 quality traits (Zhang Wenyi, 1983).**

Reasons for weak heterosis of quality traits

- First, quality trait relates to not only “source, sink and flow”, but also the matter transformation in the “sink”. The physiological and biochemical processes are more complicated.

- **Second, it is determined by the quality trait itself:**

  (1) The quality is judged by man's demand

  (2) The direction of artificial and natural selection is different, so it is very rare to have a fine quality material in wild type

- **(3) I read a large number of papers, and found that the majority of the fine quality traits are controlled by recessive genes, if they are main effect genes, such as:**

Crop	Traits	Genes
rapeseed	low erucic acid content	recessive, el1el2
rapeseed	Low glucosinolate content	recessive, g1g2g3
cotton	gossypol free	recessive genes
cotton	High lysine content	recessive genes
cotton	high oil content	recessive genes
maize	glutinous maize	recessive genes
maize	High sugar content	recessive genes
sorghum	High lysine content	recessive genes
sorghum	Low tannin content	recessive genes
persimmon	Low tannin content	recessive genes

What is the reason ?

- Wild species have the dominant trait (AA) of poor quality. The high quality trait of aa gene is resulted from artificial selection when AA gene mutated to be Aa

- Thus, it is not easy to use the dominant effect of heterosis because the majority of high quality traits are controlled by major recessive genes
- To utilize the heterosis of high quality trait,the parents must have high quality.

4. Disease resistance and heterosis

- Disease resistance trait has the same direction of both artificial selection and natural selection.

- More disease resistant resources are found in wild species

- The author found, having read a large number of publications, that majority of disease resistant traits are controlled by dominant genes if they are controlled by major gene such as:

Crop	Traits (resistance to)	Genes
rapeseed	white rust	3 dominant genes
rapeseed	blackleg at seedling stage	one dominant gene
rice	blast	1 to 3 dominant genes
sunflower	downey mildew	dominant genes
sunflower	rust	dominant genes
sunflower	sclerosporiosis	dominant genes
cotton	angular leaf spot	dominant genes
cotton	wilt	dominant genes
soybean	frogeye leaf spot	dominant genes
soybean	downey mildew	dominant genes
soybean	frog eye	dominant genes

- Among the 8 sources of resistance to bacterial leaf blight in rice, 5 are dominant, 2 are incomplete dominant, and only one is recessive.

because

1. The resistance can only express when it is controlled by dominant gene (RR)(Rr), and the trait would be eliminated through natural selection before it is getting homozygous if it is controlled by recessive gene (rr)

2. The wild species due to natural selection are usually highly resistant to diseases and the wild trait is usually dominant

- Thus, it is a very effective and simple way to solve the problem of disease resistance by using F1
- RR × rr → Rr (resistant to disease)
- R1R1 r2r2 × r1r1R2R2 → R1r1R2r2 (resistant to 2 physiological races of disease
- RRbb × rrBB → RrBb (resistant to 2 diseases)
- r1r1r2r2 (horizontal resistance) × RR (vertical resistance) → F1 (strong and stable resistance)

6. The “source and sink” are surplus and the “flow” is limited for higher yields in rapeseed hybrids

- The average rate of heterosis yield parameters are
- pods per plant: 73.3 %,
- seeds per pod : 17.5 %,
- 1000-seed weight: 1.8 %,
- Biomass : 25-30 %

(based on analysis of 46 hybrid varieties in 6 years)

- Leaf and pod surface, producing photosynthetic products, are the “source”, seed and pod is the “sink”. That the hybrid seed is not full enough and the heterosis rate of 1000-seed weight is low means that the flow is not so smooth

Hybrids have surplus “source and sink”, but insufficient “flow”. Therefore, the relationship between “source, sink and flow” has to be harmonized to make more photosynthetic product “flow” to “sink” to further enhance the hybrid rapeseed yields

- **Harvest index is the criterion of judging whether it is harmonizing between the “source”, “sink”, and “flow” of hybrid or not ;**
- The harvest index of hybrid rapeseed varieties is lower than that of conventional varieties.
- It’s important to enhance the harvest index for hybrid yield improvement.


thanks