A strategy for breeding of the yellow-seeded hybrid in *Brassica napus* L.

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Abstract

Through more than 20 years research on the genetic rule of seed color in *Brassica napus* L., we found that there were different main effect genes and QTLs controlling the seed color of the yellow-seeded lines (*B. napus* L.) bred from different genetic sources. The same status consist in black-seeded lines (*B. napus* L.). The inheritance of the seedcoat color in yellow-seeded *B. napus* L. was mainly controlled by one or two major genes mixed with the effects of polygenes (QTLs), the QTLs had important influences on the seedcoat color, the effects of additive and dominance were also very obvious, and which was the main reason that the seedcoat color was different among the plants.

A strategy for breeding of the yellow-seeded hybrid in *B. napus* L. had been put forward in the paper. According to the strategy, the yellow-seeded *B. napus* L. lines with a complete dominance yellow-seeded main effect gene (their genotype were supposed as $Y_1Y_1s_is_is_js_j$) and the black-seeded lines with genotype $y_1y_1s_is_is_js_j$ would be developed. The hybrids with genotype $y_1Y_1s_is_is_js_j$ would have 100% yellow seed rate and good yellow- seeded degree, the seed color of the hybrids were almost as same as their yellow- seeded parent.

According to the strategy, the yellow-seeded *Brassica napus* hybrid varieties *Yuhuang No.1* and *Yuhuang No.2* have been registered in China in 2003 and 2004 respectively.

Key words: breeding strategy, yellow-seeded hybrid, complete dominance yellow-seeded gene, *B. napus* L.

Introduction

It is widely accepted that the yellow-seeded rapeseed has a series of advantages, such as thinner seedcoat, lower cellulose, lignin and polyphenol content, higher oil and protein content, clear oil and higher feeding value than brown- or black-seeded materials. We began to collect and create the yellow-seeded germplasms of *B. napus L.* from 1980, till now the seven breeding programs have been carried out. The results showed that the yellow-seeded germplasms of *B. napus L.* could be gotten from ①the progeny of (*B.campestris* ×*B.oleracea*) ×*B.napus;* ②the progeny of (*B.napus*×*B.juncea*); ③the progeny of (*B.napus*×*B.campestris*); ④the progeny of (*B.napus*×*B.carinata*); ⑤the progeny of intervarietal hybrid in *B.napus;* ⑥irradiated progeny of *B.napus* (by Co^{60} radial); ⑦the progeny of (*B.campestris* × *B. oleracea* var. *aceaphala*). More than one hundred yellow-seeded *B. napus* lines with different genetic background and yellow-seeded degree (YSD) had been created from these programs (Tang et al, 1997; Li et al, 2001).

We studied the formation mechanism and dynamic changes of pigments and related characteristics in the different developmental stages of testa of yellow- and black-seeded *B napus* by using three pairs of near isogenic lines. The research included ①pigments: chlorophyll, carotinoid, melanin, polyphenols, flavonoid and anthocyanidin; ②activity of related enzymes: polyphenol oxidase (PPO), phenylalanin ammonia- lyase (PAL), tryosinase(TRO), glutamine synthetase (GS), peroxidase(POD), 4-coumarate-CoA ligase (4CL), Cinnamyl-alcohol dehydrogenase (CAD), sinapyl-alcohol dehydrogenase (SAD) and ferulate 5-hydroxylase (F5H); ③related substances in seedcoat: total phenylalanine, tyrosine, lignin content, husk content, cellulose content, total sugar content; ④secondary metabolites:ρ-camarin acid, Caffeic acid, ferulic acid, sinapic acid, ρ-hydroxycinnamic acid, tannin, condensed tannin. The physiological studies showed that excepting total sugar content and activity of GS enzyme in seedcoat, there were much difference between yellow- and black-seeded B. napus L. in all substances and activity of related enzymes researched in seedcoat (Ye et al, 2001; Zhang et al, 2002; Liang et al, 2003, 2004), which means that formation mechanism of seedcoat characteristics and pigments are very complex, the yellow-seeded trait should be affected by a lot of structure genes and some of regulator genes.

Through more than 20 years research on the genetic rule of seed color and breeding for yellow-seeded materials in *Brassica napus* L., some yellow-seeded *B. napus* L. lines and hybrid cultivars with a complete dominance yellow-seeded main effect gene had been bred. Following is the main research results and breeding strategy for yellow-seeded *B. napus L.*.

Materials and methods

The five experiments had being done for the heredity of the seedcoat color in *B. napus* L. : ① the F0, F_1 and F_2 of 7×7 complete diallal cross of seven yellow-seeded lines (*Brassica napus* L.) from different genetic sources; ② the F0, F_1 and F_2 of the crosses between 2 yellow-seeded lines (*Brassica napus*L.) and 20 black-seeded lines; ③ the F0, F_1, F_2 of 11 yellow-seeded lines (*B. napus L.*) test cross with *Zhong-you 821* or *SC94004*(black-seeded *B.napus L*); ④ the P_1,F_1,P_2,B_1,B_2 and F_2 of GH06(yellow-seeded *Brassica napus* L.)×94005(black-seeded *Brassica napus* L.) and GH06×A800(Black-seeded *B. napus* L.) were studied by applying the major gene plus poly-gene model of quantitative traits genetic system through a joint analysis

of multi-generations. ⑤ the F0, F_1, F_2 populations of 5×5 complete diallal cross of five recombined inbred lines with different seed color.

Results

The genetic studies showed that ①the yellow-seeded lines from different genetic sources had different yellow-seeded genes, which had complete dominance or partial dominance or recessive effect, if all of the genes were aggregated in one yellow-seeded line through the composite crossing, the new yellow-seeded line (*B. napus*) would be 100% yellow-seeded ratio, high yellow-seeded degree and stable in heredity. ② there were different black-seeded genes which had different effect in a black-seeded line, if we hope get a good yellow-seeded hybrid of yellow-seeded line crossed with black-seeded line, it was necessary to choose homozygote dominance yellow-seeded line and homozygote recessive black-seeded line. ③ the seed color of some yellow-seeded mutants was controlled by one major complete dominance yellow-seeded gene and some modifier genes, however, the effects of additive and dominance of the modifier genes had important influences on the seedcoat color, it would be the main reason that the seedcoat color was different among the plants. ④ the yellow-seeded degree of seeds in F_1 plant would be as same as its yellow-seeded parent when the improved yellow-seeded mutants crossed with some improved black-seeded lines.

we suppose that the complete dominance yellow-seeded gene from mutant is Y_1Y_1, the recessive yellow-seeded genes from *B.rapa* or *B.juncea* are $y_2y_2y_3y_3$, $s_is_is_js_j$(i=1,2,…,j=1,2,…)are yellow-seeded QTLs, and $S_iS_iS_jS_j$ are black-seeded QTLs. The perfect yellow-seeded genotype should be $Y_1Y_1y_2y_2y_3y_3s_is_is_js_j$. The breeding strategy for yellow-seeded *B. napus* L., black-seeded *B. napus* L. and yellow-seeded hybrid was put forward as fallow:

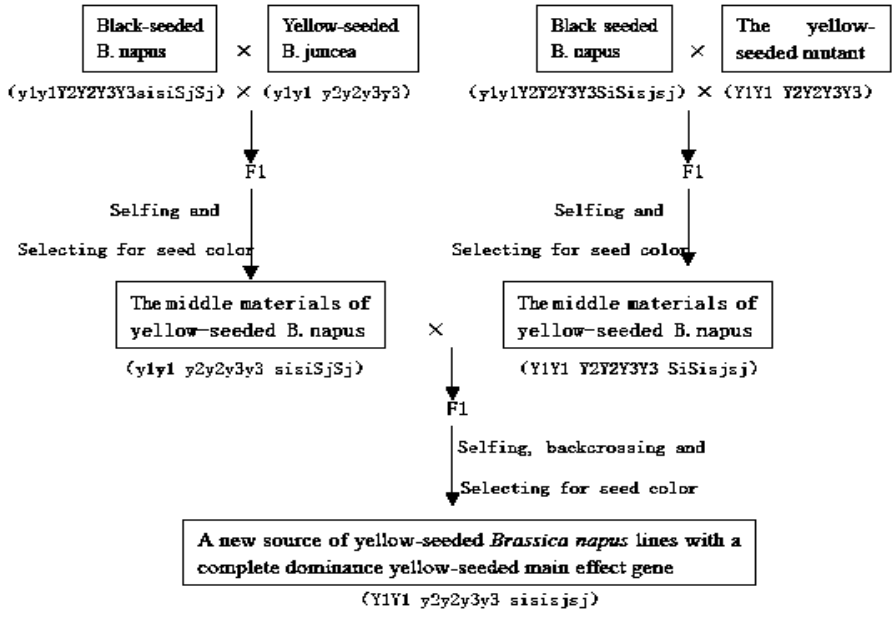

Fig. 1 The breeding strategy for yellow-seeded *B. napus L.*

Most of the black-seeded cultivars would have a few of genotypes about the pigments synthesis because no selected stress on them before, according to the supposition above, the genotypes would be ①$y_1y_1Y_2Y_2Y_3Y_3\ S_iS_is_js_j$, ②$y_1y_1Y_2Y_2Y_3Y_3s_is_is_js_j$, ③$y_1y_1Y_2Y_2Y_3Y_3s_is_iS_jS_j$, ④$y_1y_1Y_2Y_2Y_3Y_3S_iS_iS_jS_j$. If the perfect yellow-seeded genotype $Y_1Y_1y_2y_2y_3y_3s_is_is_js_j$ being used as female to test cross by plant to plant with some black-seeded lines with high yield and good quality, the seeds color of some F_1, which its black-seeded parent plant's genotype was $y_1y_1Y_2Y_2Y_3Y_3\ s_is_is_js_j$, would be yellow as its female, we should harvest the selfing seeds of the black-seeded parent plant and the black seeds parent lines would be improved. Naturalness, the perfect genotype of black-seeded parent would be gotten from the segregative generations of the crosses between yellow-seeded lines and black-seeded lines with high yield and good quality.

The genotype of the hybrids should be $Y_1y_1Y_2y_2Y_3y_3s_is_is_js_j$, the color of F_2 seeds in F_1 plant would be yellow just like its yellow-seeded parent.

According to the breeding strategy for yellow-seeded *B. napus L.* hybrid, we bred the hybrid cultivar *Yuhuang No. 1* with better yield in 1998, its seeds are bright yellow color, higher oil and protein content, lower cellulose, lignin and polyphenol content. Cultivar *Yuhuang No. 1* was registered in China in 2003. The yield of *Yuhuang No.1* was 10-15% higher than black-seeded CK, and the selling price was 15-20% higher than that of black-seeded cultivars, so the income of the farmers who plant *Yuhuang No.1* will be increased by 1,200-1,500Yuan (RMB) /ha./year. Another yellow-seeded *B. napus L.* hybrid cultivar *Yuhuang No. 2* was registered in China in 2004. till now the planting area of *Yuhuang No.1* and *Yuhuang No. 2* have more than one million ha. in past five years in China. The yellow-seeded *B. napus* oil and meal had been used in commerce from 2004 and the selling price was 10-20% higher than that of black-seeded *B. napus* L..

Conclusions

The genetic study and breeding practice for yellow-seeded *B. napus L.* showed that ① the heredity of seed color in yellow-seeded *B. napus* L. lines would be stable when the homozygous genotype being bred, the heredity of seed color in segregative generations was true of Mendel's law of segregation; ② the sufficient expression of the complete dominance yellow-seeded major gene depended on two conditions, one was favorable genetic background (QTLs) for yellow-seeded trait in yellow-seeded parent, and another was homozygous genotype black-seeded parent with recessive black-seeded major gene and some favorable genetic background (QTLs) for yellow-seeded trait.

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