Variation in seed color and relationship to oil content in a yellow-seeded landraces in *Brassica rapa* L.

JIANG Jun, NIU Yingze, YU Qing, GUO Shingxing

Rapeseedseed research center, Sichuan Agricultural University, Yaan Sichuan, 625014, China
Email: nyz@sicau.edu.cn

Abstract

Ya'an Yellow Rape is a long, widely planted landrace of *B. rapa* L. in Ya'an district, a western mountainous area in Sichuan Province, People's Republic of China. It possesses a number of desirable characteristics such as early maturity, tolerances to barren soils and to dim and wet weathers, high rates of yellow seeded plants and high oil content. From 2004 to 2006, consecutive observations were done to investigate the variation in seed color and oil content in the population, also the relationship of seed color with oil content. The results showed that: (1) Seed colors in the population can be roughly classified into two kinds, i.e., yellow color and brown color. Yellow -seeded plants constituted a majority of the population (76.67~78.33%). The ratio of yellow seeded plants to brown seeded plants was about 3:1. (2) Seed color in a single plant was uniform. Namely, yellow-seeded plants bore yellow seeds only, while brown-seeded plants bore brown seeds only. (3) Seed color in the yellow-seeded plants could be further subdivided into three types: pale yellow, fine yellow and brownish yellow. Oil contents of the different yellow seeds were, however, not considerably different. (4) The average oil content of yellow-seeded plants was remarkably different (3.45%) from one of brown seeded plants, but the distribution ranges of the two types of plants in oil content were overlapped. (5) It was supposed that the yellow seed trait of the landrace was controlled by a dominant gene and the oil content was controlled by both major qualitative gene(s) and minor quantitative genes. (6) A preliminary selection only based on the oil content was made and a considerable progress in rate of yellow seeded plants and oil content was obtained. The investigations also showed that there was a great variation in both seed color and oil content in the population. Further selection can be effective for improvement of oil content in this population.

Key words: *B. rapa* L., landraces, yellow seed, oil content

Introduction

Since the 1980's, breeding for high quality rapeseed has been strongly emphasized in China. The main efforts have been made towards the double-low contents, i.e., low erucic acid and low glucosinolates. Not much effort has been paid to breeding for high oil content in rapeseed (Liu, 1992)[1]. In recent years, the demand for vegetable oils in China has increased quickly. Rapeseed is regarded as the primary oil crop for vegetable oil production in China. About 50% of the edible vegetable oil is extracted from rapeseed (Guo, et. al., 1996)[2]. Production of vegetable oil in rapeseed can be further increased with increased seed yield per unit area, increased planting area or increased oil content in the seed. It is difficult to further increase the unit area yield of rapeseed in China as hybrid rapeseed has been widely popularised at present. It is also difficult to further enlarge the planting areas (Zhou, et. al., 1996)[3]. So breeding for higher oil content is the main approach to increase of oil production in rapeseed. Studies have shown that 1% of increase in oil content equals to 2.3-2.5 % increase in seed yields (Wang, 2004)[4]. Previous studies have shown [5-7] that yellow seeded rapeseed has generally a higher oil content in seed (Chen et al, 2005; Josson, 1977; Guan, 1985). Compared with black and brown seeds, yellow seeds possesses a thinner seed coat, higher oil and protein contents, less cellulose, polyphenol compound, tannin and tannic acid contents. Yellow seeded rapeseed has become an important breeding objective in rapeseed.

Collection and evaluation of high oil rapeseed germplasm are the primary work in high oil rapeseed breeding. Sichuan Agricultural University has collected a number of local superior *B. rapa* cultivars to identify for high oil content resources. Ya'an Yellow Rape was one of the best high oil content landraces with high breeding potential. It is a yellow seeded, high oil content landrace of *B. rapa* L., preferred by the local farmers. It has been long cultivated and is still widely planted in Ya'an district, a western mountainous region in Sichuan Province, People's Republic of China. It is an open pollinated, genetically balanced population with typical self- incompatibility. It has a number of superior characteristics such as early maturity, high yellow seed rates, high oil content, good adaptation (or tolerances) to the barren soil and/or to the dim and wet weather. Its seed oil content is normally 45~46%, over 5 percent points higher than B. napus types. However, a wide variation in both seed colour and oil content was observed in the population. In the present study the variation in seed colour and the relationship between seed colour and oil content were studied in Ya'an Yellow Rape. It is hoped to provide useful information for the further improvement of the variety and for utilization in high oil rapeseed breeding.

Material and Methods

Material

The material used in this study was a seed sample of Ya'an Yellow Rape collected from the local farmers in Ya'an by the

Rapeseed Research Centre, Sichuan Agricultural University in 2003.

Methods

Field observation

From 2003 to 2006, a population of 2500 to 4000 individual plants of Ya'an Yellow Rape was planted on the Teaching and Research Farm of Sichuan Agricultural University, in a plot of 200 to 330 m^2, with a density of about 120000 plants per hectare. The crop was sown in mid-October and harvested by the end of April. Sample plants were randomly taken each year in the population at harvest. The seed colour and oil content were examined for each plant in the lab. In 2005, the top 20 plants with the highest oil contents were selected to form a sub-population. In 2006, the sub-population was further observed for changes in seed colour and oil content. The selected 20 plants were all yellow-seeded, with an oil content of 49.35 -53.01% (average 50.36%).

Seed-colour classification

Classification of seed-colour was made according to Li(2004)[8] and Liu (2005)[9]. The observation was done visually with the help of a 5x magnifying glass. Seed colour was normally classified into two classes: yellow and brown. In 2006, the yellow seeded plants were further classified into three subgroups, i.e., pale yellow, fine yellow and brownish yellow. The oil content of different subgroups of yellow seeded plants was determined.

Determination of oil content

Oil content of seeds harvested from individual plants was determined with a NIRS instrument, model NIR5000 made in Demark. The instrument was finely calibrated for analyses of rapeseed oil content and fatty acid profile. Results of the high oil and the low oil samples were confirmed by the standard Soxhlet extraction method (Guan, 1985)[7] using EXTRACTION SYSTEM B-811 made by BUCHI Company in Swiss. The oil content determined by NIRS was highly consistent with that by Soxhlet extraction method.

Results

Variation of Ya'an Yellow Rape in seed colour and oil content

The seed-colour of individual plants was scored visually in three successive years 2004, 2005 and 2006, and the corresponding oil contents of the yellow and the brown seeds were statistically analyzed. Two kinds of seed colour, i.e., yellow and brown, could be distinguished in Ya'an Yellow Rape. The average rate of yellow seeded plants was 77.59% and the rate of brown seeded plants 22.41%. The difference in yellow-seeded plant rate was minor over the three years (Table 1). As shown in Table 1, the ratio of yellow-seeded plants to brown-seeded plants was 3:1, indicating that the yellow seed colour was controlled by a single dominant gene. However, this needs confirmation.

Oil content of seeds collected from yellow-seeded plants was consistently higher than those from brown-seeded plants. The oil content averaged over the yellow-seeded plants was 46.081%, while that over the brown-seeded plants 43.36%. The difference in averaged oil content between yellow and brown seeded plants was 3.45%, significant at 1% level (Table 1).

Table 1 Seed color and oil content of Ya'an Yellow Rape

Year	Plants	Seed color		Plant rate, %		Averaged oil content, %		
		Yellow	Brown	Yellow	Brown	Yellow seed	Brown seed	Difference
2004	240	188	52	78.33	21.67	-	-	-
2005	120	92	28	76.67	23.33	46.91	43.11	3.80**
2006	488	378	110	77.46	22.54	46.71	43.60	3.11**
Sum/mean	848	658	190	77.59	22.41	46.81	43.36	3.45

** significant at 1% level

Seed colour of individual plants

848 plants of Ya'an Yellow Rape were totally scored From 2004 to 2006, including 658 yellow-seeded and 190 brown-seeded plants. We found that the colour of seeds from a single plant was uniform. Namely, the seeds of a single yellow-seeded plant were all yellow, and the seeds of a single brown-seeded plant were all brown. We did not observe any plants with mixed seed colours. This implied that the seed colour of Ya'an Yellow Rape was controlled by the genotype of the mother plant.

Difference in yellow colour and oil content in the yellow seeded plants

In 2006, 254 yellow-seeded plants were further observed individually to asses the differences in yellow colour and oil content. With a more careful observation, the seed colour of the yellow-seeded plants could be subdivided into 3 types: pale yellow, fine yellow and brownish yellow. The pale yellow and fine yellow seeded plants were main types, accounting to over 87% whereas the brownish yellow seeded plants a minor type (Table 2).

The oil contents of the three subgroups of yellow seeded plants were presented in Table 2. It appeared that the brownish yellow seeded plants had higher averaged oil content (47.84%) than the other subgroups (oil contents 46.79% and 45.92%, respectively) although these subgroups had wider distribution of oil contents. However, the brownish yellow seeded plants had averaged oil content similar to the other subgroups in the 50 highest oil content plants from the 254 sample plants. The results showed that the three subgroups of yellow seeded plants were not markedly different in seed oil content.

Table 2:Difference in yellow color and oil content in the yellow seeded plants in Yaan Yellow Rape

Seed color	Whole sampling population			The top 50 highest oil content plants		
	No. of plants	Range of oil content, %	Mean of oil content, %	No. of plants	Range of oil content, %	Mean of oil content, %
Pale yellow	108	39.77~51.36	45.92	15	49.29~51.36	50.27
Fine yellow	114	39.07~51.90	46.79	24	49.28~51.90	50.11
Brownish yellow	32	39.95~50.95	47.84	11	49.51~50.95	50.11
Total	254	39.07~51.90	46.85	50	49.28~51.90	50.16

The distribution of variation in oil content

In 2006, the oil content of 488 plants of Ya'an Yellow Rape was determined individually, and the distribution of variation in oil content was assessed (Table 3 and Fig. 1). It can be seen that there was a wide range of distribution in the variation of oil content in whole population as well as in the two groups of plants, i.e., the yellow seeded plants and the brown seeded plants. A binomial distribution, instead of a normal distribution, was found in the whole population. However, in the each group of plants the distribution of oil content was near normal. The yellow seeded group had higher average oil content (Table 3, Fig.1). This indicated that the oil content was a complex character in Ya'an Yellow Rape, which may be controlled by both major qualitative gene(s) and minor quantitative genes.

Table 3 Variation of oil content in seeds harvested from plants with different seed colors

Population	Plants	Range	Mean	Standard deviation	C.V. (%)
Yellow-seeded	378	40.02-53.54	46.71	2.64	5.64
Brown-seeded	110	38.87-49.04	43.60	2.29	5.25
Whole	488	38.87-53.54	46.01	2.87	6.24

Effects of bulk selection in the landrace

In 2005, a bulk selection only based on the oil content was done with the 120 sample plants observed. Twenty (16.7%) highest oil content plants were selected and a new population was composed of an equal amount of seed from each plant. The oil content of the 20 plants ranged from 49.35% to 53.01% with an average of 50.36%. The new population was evaluated in 2006 for the yellow-seeded plant rate and oil content. It was shown that the yellow seeded plant rate and the oil content were both markedly increased (Table 4), indicating effectiveness of bulk selection. Further bulk selection was continued in 2006.

Table 4 Effects of bulk selection on yellow seeded plant rate and oil content (2006)

Population	Plants observed	Yellow seeded plant, %	Oil content, %
Original population	120	76.67	46.05
Daughter population	299	86.62	47.95
Increase		9.95	1.90

Discussion

Yellow seeds are generally believed to be a character related to high oil content in rapeseed. Much attention has been paid to the character in high oil rapeseed breeding. In this study Ya'an Yellow Rape was identified to be a unique landrace with a high rate of yellow seeded plants and especially high oil content. In the three-year observation the yellow seeded plant rate and the oil content in the population were virtually constant (Table 1). This suggested that the population has been genetically equilibrated although it is allogameous because of self-incompatibility. However, there is still a great variation in both seed colour and oil content among the plants within the population. So there is possibility of further improvement for higher oil content through selection within the population.

In many previous studies[7,10], yellow seeds were found to coexist with brown or black seeds in the same plant, or sometime even in the same silique (Heyn, 1973; Jonsson, 1979; Schwetka, 1981; Hawk, 1982). In the present study the seed colour was found to be uniform in a single plant. No mixed seed colours were observed in a single plant. This indicated that the seed colour of Yaan Yellow Rape was determined by the genotype of mother plant, which is consistent with the observation by Li (1992)[11] in *B. rapa*. According to the ratio of yellow-seeded to brown-seeded plants in the population, i.e., 3:1, the yellow seed trait appeared to be controlled by a dominant gene. The inheritance of the yellow seed character in the population needs to be further studied.

In Ya'an Yellow Rape the yellow colour of seed can further be roughly classified into three groups, pale yellow, fine yellow and brownish yellow. This indicated that the yellow seed colour is also inherited with complexity in *B. rapa* L. However, the oil contents among the three subgroups of yellow seeds were not considerably different. It therefore seems not necessary to pay much attention to the degree of yellow color of the seed in selection for high oil content.

It is also seen in Ya'an Yellow Rape that the distributions of oil content of the yellow-seeded and the brown- seeded plants were highly overlapped. This implied that there were low oil content individual plants in the yellow-seeded group while there were high oil content individual plants in the brown-seeded one. So the yellow seeded trait should not be considered as the sole character for high oil content in breeding.

A considerable progress in both yellow-seeded plant rate and oil content was made through bulk selection only based on oil content. Similar results of selection were obtained by Dong et. al. (1999)[12]. However, there is a great variation in both seed

color and oil content within the population, so further selection can be effective for improvement of oil content in this population.

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