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Effect of structural ideotypes on yield attributes, seed yield and their inheritance in Yellow Sarson (*Brassica rapa* L. var. Yellow Sarson)

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Abstract

The experiments were conducted in three replications for two consecutive years at Instructional Farm Jaguli, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal. The different plant ideotypes (Waxy petalous, waxy apetalous, nonwaxy petalous and nonwaxy apetalous) of *Brassica rapa var Yellow Sarson* were studied during the investigation. Four ideotypic groups showed significant variation for most of the traits in both the years. Waxy apetalous group recorded highest mean values for most of the traits including seed yield per plant in two consecutive years whereas Nonwaxy petalous groups recorded lower seed yield, 1000 seed weight and plant height. In waxy apetalous group, seed yield per plant showed significantly positive correlations with plant height, number of primary branches, number of siliquae per plant, number of seeds per siliqua and 1000 seed weight while in waxy petalous group, seed yield per plant showed significantly positive correlations with number of primary branches, number of seeds per siliqua, and 1000 seed weight. In nonwaxy apetalous group, seed yield per plant showed positive correlations with number of primary branches and number of siliquae per plant. In nonwaxy petalous group, seed yield per plant showed significantly positive correlation with number of primary branches, number of seeds per siliqua and hundred seed weight.

Keywords:, *Inheritance, structural ideotypes, Yellow Sarson, yield*

Introduction

Rapeseed-mustard (*Brassica species*) crops is the second most important oilseed crop after groundnut and contributing about more than 30% of the total oilseed production in the country. The genus *Brassica* comprises 37 species as an annual and biennial herb and many of them are similar in appearance. *Brassica rapa* is most variable and most widespread among the various *Brassica species.* Seed yield is a very complex entity influenced by several components. For a rational approach to the improvement of yield it is essential to have some information on the nature of inheritance and their association with yield and different yield components. The most important yield components are number of branches, siliqua per plant and 1000 seed weight. Kumar *et al*. (1985) suggested that selection of component characters rather than yield itself can help substantially to increase seed yield in *Brassicas*. Chauhan and Singh (1979) suggested for a compromise in selection programme for siliqua number per plant, length of siliqua bearing branches etc. Yield components are a predictable outcome of the sequential development of the component characters. The metabolic input of the plant during flowering would be diverted to a rapidly increasing number of growing points in the inflorescence, with the result that there is likely to be intense intra-plant competition for metabolites between pods developing on the main stem and newly formed shoots in the leaf axis. One of the effective approaches is to look for the morphological ideotype, which appears with erect leaf posture, and/or splitting leaf shape, and /or waxed leaf surface, and/ or apetalous flowers, tetralocular and upright siliqua, basal and compact branching etc. (Shikari and Sinhamahapatra, 2004; Goswami and Sinhamahapatra, 2008). Among the brassica, apetalous flower behavior is a trait of particular interest. Waxiness of leaves and stem also found to tolerance to white rust (*Albugo candida*) as well as flea beetles (*Phyllotreta cruciferae*). Combination of white flower colour and leaf waxiness was found to be resistance to aphid *(Lipaphis erysimi*) and white rust. Apart from the above features, apetalous flower morphology is also very interesting as rapeseed plant has a bright coloured flowers at the top layer for an extended period. Siliqua locule number has been taken as a morpho-physiological character to find out the effect of bilocular and tetralocular siliqua on yield and its components of *B. rapa* var. Yellow Sarson. It is well-known that multilocular types put up with greater number of seeds per siliqua than the bilocular types (Sinhamahapatra *et al*., 2010). Siliqua locule number is a monogenic trait whereas bilocular type is dominant over multilocular type. A spontaneous nonwaxy mutant was isolated from the population of the Brassica variety B-9. This mutant was crossed and tested for several generations. In the non-waxy mutant population, a plant was isolated with apetalous character and this mutant was subsequently crossed and used as one parent and waxy petalous lines were used as other parents to develop the present materials.

Materials and Methods

The field experiments were conducted at Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Jaguli, Nadia, West Bengal. The situation of the experimental site comes under Gangetic new alluvial plains of West Bengal with sandy loam soil and with almost neutral pH. The experimental materials (advance generation lines) were sown in a randomized block design with three replications after ploughing by tractor. The material used for the present studies are as follows:

The above materials represent the seeds of true breeding recombinant lines having features waxy, non-waxy, apetalous, petalous, bilocular (two chambered), tetralocular (four chambered), top, mid and basal branching, white flower, yellow flower, erect, horizontal siliqua arrangement. Crossing has been done in all possible combination in Half-diallel fashion in first year. The seeds of all the seven parents and their twenty-one F_1 progenies were sown in three replications following randomized block design in the second year. Fertilizer @ 60: 40: 40 Kg/ha of N: P: K in the form of Urea, SSP and MOP were applied as a basal dose with half of nitrogen applied latter as top dressing. Spacing between rows was kept 30 cm and for plant to plant 10 cm maintained through thinning. Data were recorded from ten randomly selected competitive plants from each replication after harvesting. Data were also recorded separately for inheritance studies and analyzed the data through IDOSTAT.

Parents and their characteristics used in present research work

Abbreviations	Features
W/AP/YF/MB/4CH/E	Waxy/ Apetalous/ Yellow flower/ Mid branching/ Four chambered/ Erect
NW/AP/YF/BB/2CH/E	Non-waxy/ Apetalous/ Yellow flower/ Basal branching/ Two chambered/ Erect
W/P/WF/NB/4CH/E	Waxy/ Petalous/ White flower / Non branching/ Four chambered/ Erect
W/P/WF/NB/2CH/E	Waxy/ Petalous/ White flower/ Non branching/ Two chambered/ Erect
W/P/YF/MB/2CH/E	Waxy/ Petalous/ Yellow flower/ Mid branching/ Two chambered/ Erect
W/P/YF/MB/4CH /E	Waxy/ Petalous/ Yellow flower/ Mid branching/ Four chambered/ Erect
W/P/YF/MB/4CH /H	Waxy/ Petalous/ Yellow flower/ Mid branching/ Four chambered/ Horizontal

Results and Discussion

The waxy apetalous group recorded highest mean values for plant height (136 cm), number of seed per siliqua

Table 1: The Mean and range of different characters in yellow sarson

Parameter	Group	Plant Height (cm)	Number of primary branches	Number of siliquae per plant	Number of seeds per siliqua	1000 seed weight (g)	Seed yield per plant (g)
Mean	Waxy Apetalous	136	6.9	44.8	25.4	4.6	4.89
	Waxy Petalous	122	8.7	38.4	23.8	4.5	4.77
	Nonwaxy Apetatous	120	8.1	44.2	20.2	4.0	4.3
	Nonwaxy Petalous	111	10.2	46.8	25.2	4.0	4.1
Range	Waxy Apetalous	121-146	0.0-14.4	21.3-56.7	16.0-35.4	4-6	4.2-5.9
	Waxy Petalous	99-138	3.4-18.5	29.6-51.8	15.0-36.1	4-5	4.3-5.3
	Nonwaxy Apetatous	110-138	6.1-11.1	27.7-55.5	16.2-35.4	3-4	3.4-5.7
	Nonwaxy Petalous	94-133	8.1-11.9	29.6-62.9	16.3-35.4	3-4	3.8-5.1
Sem±		1.4	0.7	2.4	0.6	1.0	0.1
CD (P=0.05)		4.8	2.5	8.6	2.2	1.1	0.3

(25.39), 1000 seed weight (4.6 g) and seed yield per plant (4.89 g) whereas highest mean values for number of siliquae per plant and number of primary branches were recorded by non waxy petalous group (Table 1). The comparable and higher yield performance of the groups was achieved through the most yield attributes like number of primary branches, number of seeds per siliqua and 1000 seed weight. Mendham *et al.* (1991) suggested that apetalous flower have potential to increase the number of pods and reduce the number of seed abortion by improving the transmission of radiation in the developing pods at the base of each raceme. Sinhamahapatra *et al.* (2010) suggested that seed yield of waxy apetalous and non-waxy apetalous groups were significantly higher than the waxy petalous and nonwaxy petalous groups.

The analysis of variance (Table 2) revealed that all the groups together showed significant variation for all the characters under studies viz. plant height, number of primary branches, number of siliquae per plant, number of seeds per siliqua, 1000-seed weight and seed yield per plant. Waxy apetalous group showed significant variation for all the characters while waxy petalous group showed significant variation for all the characters except seed yield per plant. Nonwaxy apetalous group showed significant variation for all the characters except 1000-seed weight while nonwaxy petalous group showed significant variation for all the characters except 1000-seed weight and seed yield per plant. Among the four groups waxy apetalous is superior in seed yield followed by waxy petalous group. It is reported that waxiness is desirable traits (Jambhulkar *et al.*1995) and apetalous flower is beneficial for improving yield (Mendham *et al.* 1991, Sinhamahapatra *et al.* 2010).

Table 2: Analysis of variance for different characters in Yellow Sarson

Source	df	Mean Sum Square					
		Plant Height (cm)	Number of primary branches	Number of siliqua per plant	Number of seeds per siliqua	1000 seed weight (g)	Seed yield per plant (g)
Replication	2	18.0	24.9**	6.9	2.6	0.2	0.2*
Group	3	3091.6**	58.3**	393.4**	170.5**	0.2**	3.3**
Error (a)	6	6.0	1.5	18.5	1.2	0.1	0.03
Waxy Apetalous	9	195.2**	38.1**	326.1**	264.0**	0.1**	0.8*
Waxy Petalous	9	518.7**	76.9**	152.7**	280.6**	0.1**	0.3
Nonwaxy Apetatous	9	251.2**	6.1**	243.8**	179.8**	0.1	1.9**
Nonwaxy Petalous	9	548.3**	4.7**	241.4**	254.8**	0.1	0.3
Error (b)	72	4.9	0.7	5.7	1.2	0.2	0.3

*Significant at 5%, ** Significant at 1%

Therefore, for developing a useful plant type waxy apetalous plants would be more desirable to improve the yield. Further, analysis of variance also indicated that there is sufficient variation found among the ten lines listed above for each group. In both waxy apetalous (Table 3) and non-waxy apetalous (Table 4) groups, seed yield per plant showed significantly positive correlations with number of primary branches and number of siliquae per plant.

Table 3: Correlation among different characters of waxy apetalous group

Characters	Height up to first fruiting branch	Number of primary branches	Number of siliquae per plant	Number of seeds per siliqua	1000 seed weight (g)	Seed yield per plant
Plant Height (cm)	-0.56**	0.56**	0.78**	-0.06	2.2	0.56**
Height up to first fruiting branch		-0.95**	-0.91**	0.46**	4.2*	-0.88**
Number of primary branches			0.92**	-0.56**	-4.7**	0.91**
Number of siliquae per plant				-0.45*	-2.4	0.90**
Number of seeds per siliqua					2.4	0.69**
1000 seed weight (g)						0.31*

*Significant at 5%, ** Significant at 1%

Table 4: Correlation among different characters of nonwaxy apetalous group

Characters	Height up to first fruiting branch	Number of primary branches	Number of siliquae per plant	Number of seeds per siliqua	1000 seed weight (g)	Seed yield per plant
Plant Height (cm)	0.28	0.48**	0.32	0.33	4.6**	-0.02
Height up to first fruiting branch		-0.16	-0.41*	-0.11	-0.9	-0.19
Number of primary branches			0.89**	0.34	6.4**	0.56**
Number of siliquae per plant				0.22	5.7**	0.57**
Number of seeds per siliqua					-1.7	-0.02
1000 seed weight (g)						0.16

*Significant at 5%, ** Significant at 1%

In waxy apetalous group, seed yield per plant showed significantly positive correlations with plant height, number of seeds per siliqua and 1000-seed weight while in nonwaxy group, all these three characters showed non-significant correlations with seed yield per plant. waxy apetalous group recorded higher mean values for plant height, number of seeds per siliqua and 1000-seed weight than nonwaxy apetalous group. It may be suggested that nonwaxy apetalous group recorded lower seed yield due to its lower mean values for the above traits. Therefore, nonwaxyness of the plant might have influenced negative effect on plant height, number of seeds per siliqua and 1000-seed weight to reduce seed yield per plant. In both waxy petalous (Table 5) and nonwaxy petalous (Table 6) groups, seed yield per plant showed significantly positive correlations with number of primary branches, number of seeds per siliqua and 1000-seed weight. Seed yield per plant showed significantly negative correlations with height up to first fruiting branch in both the groups. However, waxy petalous group recorded higher seed yield per plant along with 1000-seed weight and plant height in comparison with nonwaxy petalous group. Therefore, to construct a high yielding plant ideotype waxy and apetalous traits should be introduced (Sinhamahapatra *et al.* 2010).

Inheritance among different contrasting characters of Yellow Sarson

Five contrasting characters has been studied in present

Table 5: Correlation among different characters of waxy petalous group

Characters	Height up to first fruiting branch	Number of primary branches	Number of siliquae per plant	Number of seeds per siliqua	1000 seed weight (g)	Seed yield per plant
Plant Height (cm)	0.05	0.39*	0.47**	0.07	-0.2	0.04
Height up to first fruiting branch		0.22	0.46**	0.01	5.5**	-0.63**
Number of primary branches			0.85**	-0.71**	-1.0	0.37*
Number of siliquae per plant				-0.61**	1.7	0.22
Number of seeds per siliqua					-0.3	0.50**
1000 seed weight (g)						0.63**

*Significant at 5%, ** Significant at 1%

Table 6: Correlation among different characters of nonwaxy petalous group

Characters	Height up to first fruiting branch	Number of primary branches	Number of siliquae per plant	Number of seeds per siliqua	1000 seed weight (g)	Seed yield per plant
Plant Height (cm)	-0.03	0.57**	0.42*	0.11	0.8	0.32
Height up to first fruiting branch		-0.52**	-0.63**	0.51**	5.8**	-0.72**
Number of primary branches			0.62**	-0.11	-1.8	0.52**
Number of siliquae per plant				-0.09	-1.9	0.22
Number of seeds per siliqua					4.8**	0.51**
1000 seed weight (g)						0.54**

*Significant at 5%, ** Significant at 1%

Table 7: Inheritance studies among the contrasting characters of yellow sarson

Generation	Crosses	Phenotypes observed in F1	Phenotypes observed		Expected ratio	χ2	df	*P-value*
Wax on the plant			Waxy	Nonwaxy				
F_2	Waxy X Nonwaxy	Waxy	954	303	3 : 1	0.54	1	0.46
	Homogeneity	-	-	3 : 1	0.68	1	0.41	
BC	F1 X Non-waxy	275	245	1 : 1	1.73	1	0.19	
	Homogeneity	-	-	1 : 1	0.31	1	0.58	
BC	F1 X Waxy	522	0	-	-	-	-	
Flower Colour	YellowFlower	White Flower						
F_2	Yellow X White	Yellow	1416	460	3 : 1	0.23	1	0.63
	Homogeneity	-	-	3 : 1	0.38	1	0.54	
BC	F1 X White Flower	470	436	1 : 1	1.28	1	0.26	
	Homogeneity			1 : 1	0.10	1	0.75	
BC	F1 X Yellow Flower	890	0	-	-	-	-	
Petal of Flower	Petalous	Apetalous						
F_2	Petalous x Apetalous	Petalous	1553	496	3 : 1	0.69	1	0.41
	Homogeneity	-	-	3 : 1	0.46	1	0.50	
BC	F1 X Apetalous Flower	440	414	1 : 1	0.79	1	0.37	
	Homogeneity			1 : 1	0.86	1	0.35	
BC	F1 X Petalous Flower	873	0	-	-	-	-	
Locule of Siliqua	Bilocular	Tetralocular						
F_2	Bilocular x Tetralocular siliqua	Bilocular	1840	592	3 : 1	1.20	1	0.27
	Homogeneity	-	-	3 : 1	0.76	1	0.38	
BC	F1 X Tetralocular siliqua	542	507	1 : 1	1.17	1	0.28	
	Homogeneity	-	-	1 : 1	0.53	1	0.47	
BC	F1 X Bilocular siliqua	1090	0	-	-	-	-	
Siliqua Orientation	Erect	Horizontal						
F_2	Erect x Horizontal	Erect	968	305	3 : 1	0.73	1	0.39
	Homogeneity	-	-	3 : 1	0.61	1	0.43	
BC	F1 X Horizontal siliqua orientation	277	258	1 : 1	0.67	1	0.41	
	Homogeneity	-	-	1 : 1	0.09	1	0.76	
BC	F1 X Erect siliqua orientation	548	0	-	-	-	-	

studies, the contrasting characters are wax on the plant (waxy/non waxy), flower colour (yellow/white), petal of flower (petalous/apetalous), locule of siliqua (bilocular/ tetralocular), siliqua orientation (erect/horizontal). The F1 hybrids of waxy x non-waxy crosses were all waxy suggesting the dominance of waxy trait over non-waxy (Table 7). The data on segregation in the six F2 populations suggested a 3:1 ratio for waxy : non-waxy plants. The good-fit of a 3 (waxy) : 1 (non-waxy) ratio using chi-square test (÷2 = 0.54; *P* = 0.46) indicated that waxyness is governed by a single major gene. In the BC generation of F1 × non-waxy parents, the segregation of waxy : non-waxy plants fitted well to a 1 : 1 ratio (÷2 = 1.73; *P* = 0.19). No non-waxy plant was observed in the BC generation of F1 × waxy parents. These observations in backcross generations confirmed the validity of the F2 data. Zhou *et al*. (1995) found 15 : 1 ratio for waxy : non-waxy in F2 and suggested the waxness character was controlled by two pairs of recessive genes in *B. napus*. The F1 hybrids of yellow × white flower crosses were all yellow flower suggesting the dominance of yellow trait over white. The data on segregation of flower colour in the ten F2 populations suggested a 3 : 1 ratio for yellow : white flower. The good-fit of a 3 (yellow) : 1 (white) ratio using chi-square test (÷2 = 0.23; *P* = 0.63) indicated that flower colour is governed by a single major gene. In the BC generation of F1 × white flower parents, the segregation of yellow : white plants fitted well to a 1 : 1 ratio (÷2 = 1.28; *P* = 0.26). No white flower plant was observed in the BC generation of F1 × yellow flower parents. These observations in backcross generations confirmed the validity of the F2 data. Zhang *et al.* (2000) in *B. napus* and Sachan *et al*. (2007) in *B. rapa* reported similar inheritance pattern of flower colour.

The F1 hybrids of petalous × apetalos flower crosses were all petalous suggesting the dominance of petalous trait over apetalous. The data on segregation in the ten F2 populations suggested a 3 : 1 ratio for petalous : apetalous flower. The good-fit of a 3 (petalous) : 1 (apetalous) ratio using chi-square test (÷2 = 0.69; *P* = 0.41) indicated that petalous trait is governed by a single major gene. In the BC generation of F1 × apetalous parents, the segregation of petalous : apetalous plants fitted well to a 1 : 1 ratio (÷2 = 0.79; *P* = 0.37). No apetalous flower plant was observed in the BC generation of F1 × petalous flower parents. These observations in backcross generations confirmed the validity of the F2 data. Singh (1961a and 1961b) in *B. rapa*, Cours and Williams (1977) also reported similar inheritance pattern in *B. rapa*. The F1 hybrids of bilocular × tetralocular crosses were all bilocular suggesting the dominance of bilocular trait over tetralocular. The data on segregation of locule number in the twelve F2 populations suggested a 3 : 1 ratio for bilocule : tetralocule. The good-fit of a 3 (bilocular) : 1 (tetralocular) ratio using chi-square test (÷2 = 1.20; *P* = 0.27) indicated that locule number is governed by a single major gene. In the BC generation of F1 × tetralocular parents, the segregation of bilocular : tetralocular fitted well to a 1 : 1 ratio (÷2 = 1.17; *P* = 0.28). No tetralocular plant was observed in the BC generation of F1 × bilocular parents. These observations in backcross generations confirmed the validity of the F2 data. Roy and Sinhamahapatra (2011) also reported similar inheritance pattern of siliqua locule number in *B. rapa*. The F1 hybrids of erect × horizontal siliqua orientation crosses were all erect suggesting the dominance of erect trait over horizontal. The data on segregation of siliqua orientation in the six F2 populations suggested a 3 : 1 ratio for erect : horizontal. The good-fit of a 3 (erect) : 1 (horizontal) ratio using chi-square test (÷2 = 0.73; *P* = 0.39) indicated that siliqua orientation is governed by a single major gene (Table 7). In the BC generation of F1 × horizontal parents, the segregation of erect : horizontal plants fitted well to a 1 : 1 ratio (÷2 = 0.67; *P* = 0.41). No horizontal plant was observed in the backcross generations of F1 × erect parents. These observations in BC generation confirmed the validity of the F2 data.

All the five characters, waxyness, yellow flower colour, apetalous flower, bilocular siliqua and erect orientation of siliqua were monogenically control. Therefore, their manipulations to transfer in any genotype are easy.

Conclusion

It has been concluded according to above research findings that the introgression of apetalous flower, bilocular siliqua, erect orientation of siliqua in yellow apetalous lines of *B. rapa* may be boon for the development of new materials.

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