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Relationship between seed yield and yield components in bilocular and tetralocular yellow sarson *(Brassica rapa)*

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ABSTRACT

The inheritance of siliqua locule number was investigated utilizing two parental lines each of bilocular and tetralocular siliqua group. Bilocular siliqua was dominant over the tetralocular siliqua in both crosses and the trait is controlled by a single major gene. Seventeen advanced breeding lines of each tetralocular and bilocular group were grown during 2004–05 and 2006–07 in group balanced block design with three replications to study the association between seed yield and its component traits. In tetralocular group seeds/siliqua, siliquae on branches, siliquae on main raceme and number of branches showed significant and positive correlation with seed yield/plant and also high positive direct effect on seed yield/plant. Regression analysis showed that 91% of total variation in seed yield could be explained by the variation in siliquae on branches, seeds/siliqua and length of siliqua. In bilocular group plant height, siliquae on main raceme, seeds/siliqua and siliquae on branches exerted high direct effects on seed yield/plant which also showed significant and positive correlation with seed yield/plant. Multiple regression analysis revealed that 92% of total variation in seed yield/plant could be explained by number of branches and siliquae on branches. Selection criteria for yield improvement in the light of yield formation process have been discussed for the groups of yellow sarson.

Key words: Association, Inheritance, Siliqua locule, Yellow sarson, Yield components

Indian rapeseed *(Brassica rapa* L. Syn *Brassica campestris* L.), containing three ecotypes, namely yellow sarson, brown sarson and toria, is the second largest oilseed brassica grown mostly in north-eastern parts of India. All the prevalent cultivars of yellow sarson possess bilocular siliqua, although tetralocular types are found which has more number of seeds and more space for seed development as well as improved source capacity having greater pod wall surface (Sharma and Ghildiyal 1992, Katiyar *et al.* 1998). Number of seeds/siliqua has been reported to be positively associated with seed yield (Ramanujam and Rai 1993). Varshney (1987) reported that a single major gene controls the inheritance of siliqua locule number in *Brassica campestris* with dominance of bilocular over tetralocular siliqua. In spite of these advantages, scanty literature is available elucidating the relationship of seed yield and yield components in tetralocular types (Shikari and Sinhamahapatra 2004).

The present study was undertaken to obtain information on the inheritance of this trait and simultaneously the relationship of seed yield and its components in both bilocular and tetralocular types. Relative importance of yield attributes in the formation of yield for both the types has been studied using correlation, path analysis and multiple regression analysis.

MATERIALS AND METHODS

To study the inheritance of siliqua locule number, four parental lines of *B. Rapa* var. yellow sarson were used. Among these parents two were of tetralocular type and designated as E_4 and other two, NW (non-waxy) and Binoy (a popular variety of West Bengal), were of bilocular type. Crosses were made under field condition and the F_1 hybrids, F_2 and back cross (BC) generations were grown at the same farm during 2004–05 to 2006–07. The selfed seeds of F_1 plants of each cross were sown in 6-row plots with three replications to grow the F_2 generation. The plants of F_2 and BC generations were grouped on the basis of siliqua locule number, either bilocular or tetralocular. The collected data were analyzed (chi-square analysis) to test the goodness-of-fit of observed genetic ratios to the theoretical ratios and a test of homogeneity was made according to Gomez and Gomez (1984) on F_2 and BC generation data to justify pooling of data.

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Each tetralocular and bilocular group comprised 17 randomly selected homozygous lines and all 34 lines were tested in a group balanced block design with three replications during *rabi* seasons of 2005–06 and 2006–07. Entries of each group were randomized and sown in 2.5 m long single row plots spaced 30 cm apart in two consecutive years. Observations on plant height (cm), length of main raceme (cm), height up to first fruiting branch (cm), number of branches, number of siliqua and seed yield/plant (g) were determined from 10 randomly selected plants in each entry. One siliqua from each of the 10 plants were measured for siliqua length, breadth of siliqua and seeds/siliqua. Thousand seed weight was measured by separating 1000 seeds from each sample of ten plants bulk harvested seeds.

The data were analyzed separately for tetralocular and bilocular group. Correlation co-efficients between all pairs of variables were calculated. The path co-efficient analyses were done according to Li (1975) and Williams *et al.* (1990). To analyze the relationship between variables multiple regression analyses were done with SPSS statistical software (version 16.0 for Windows, SPSS Inc. Chicao, USA). Seed yield/plant was kept as dependent variable and other components as independent variables.

RESULTS AND DISCUSSION

Inheritance of siliqua locule number

The F_1 hybrids of bilocular × tetralocular crosses (NW × E_4 and E_4 × Binoy) were bilocular suggesting the dominance of bilocular trait over tetralocular. The data on segregation of locule number in the two F_2 populations suggested a 3 : 1 ratio for bilocular : tetralocular siliqua. The good-fit of a 3 (bilocular) : 1 (tetralocular) ratio using chi-square test (χ^2 = 6.61; P = 0.05–0.01) indicated that siliqua locule number is governed by a single major gene (Table 1). In the BC generation of F_1 × tetralocular parents, the segregation of bilocular : tetralocular plants fitted well to a 1 : 1 ratio (χ^2 = 0.48; P = 0.05–0.25). No tetralocular plants were observed in the BC generation of F_1 × bilocular parents. These observations in BC generation confirmed the validity of the F_2 data. Varshney (1987) and Salava *et al.* (1996) also reported similar inheritance pattern of siliqua locule number. The simple inheritance of siliqua locule number offers the scope of transferring tetralocular trait into suitable background.

Variability parameters

The means (pooled over two years) and co-efficient of variation values for all the traits are presented in Table 2. Significant differences were observed between bilocular and tetralocular groups for most of the traits except length of main raceme, height up to first fruiting branch and siliquae on main raceme (data not shown). The co-efficients of variation for most of the traits were high for both the groups. The wide variability for the important traits held promise for selection in crop improvement, especially in tetralocular group.

Relationship between seed yield and yield components

Correlation

The correlation co-efficients amongst the traits in bilocular and tetralocular group are presented in Table 3. In both siliqua groups length of main raceme, number of branches, siliquae on main raceme, siliquae on branches and seeds/siliqua showed significant and positive correlation with seed yield/plant. In tetralocular group 1000-seed weight was significantly and positively correlated with seed yield/plant. The height up to first fruiting branch had significant and

Table 1 Observed phenotypes and chi-square test of F_2 populations and backcross generations derived from crosses between tetralocular and bilocular lines of *B. rapa* var. yellow sarson

Generation	Crosses	Phenotypes observed		Expected ratio	χ^2	df	*P*-value
		Bilocular siliqua	Tetralocular siliqua				
F_2	NW × E_4	224	93	3 : 1	3.19	1	(0.10–0.05)
	E_4 × Binoy	206	87	3 : 1	3.44	1	(0.10–0.05)
	Total	430	180		6.63	2	
	Pooled			3 : 1	6.61	1	(0.05–0.01)
	Homogeneity				0.02	1	(0.90–0.75)
BC	*F_1 × tetralocular*						
	(NW × E_4) × E_4	32	27	1 : 1	0.42	1	(0.75–0.50)
	(E_4 × Binoy) × E_4	38	35	1 : 1	0.12	1	(0.75–0.50)
	Total	70	62	-	0.54	2	
	Pooled			1 : 1	0.48	1	(0.50–0.25)
	Homogeneity				0.06	1	(0.90–0.75)
BC	*F_1 × Bilocular*						
	(NW × E_4) × NW	36	0	1 : 0			
	(E_4 × Binoy) × Binoy	29	0	1 : 0			
	Total	65	0				

Table 2 Tetralocular and bilocular group means and co-efficients of variation for yield components and seed yield/plant

Trait	Mean±SE		CV (%)	
	Tetralocular	Bilocular	Tetralocular	Bilocular
Plant height (cm)	105.65±10.38	107.56±10.84	13.89	14.26
Length of main raceme (cm)	32.95±3.99	35.00±3.91	17.15	15.81
Height up to first fruiting branch (cm)	45.50±11.33	35.37±6.83	39.56	27.32
Number of branches	2.19±0.77	6.42±1.11	55.37	24.38
Siliquae on main raceme	26.73±3.66	28.56±3.47	19.35	17.19
Siliquae on branches	8.66±3.89	41.74±8.04	63.62	27.24
Length of siliqua (mm)	37.35±3.76	44.22±5.27	14.22	16.85
Breadth of siliqua (mm)	7.30±0.72	5.66±0.52	13.97	12.98
Seeds/siliqua	35.09±3.48	23.75±3.11	14.05	18.53
1 000-seed weight (g)	3.03±0.31	3.45±0.40	14.59	16.55
Seed yield/plant (g)	3.31±0.65	5.04±0.99	27.75	27.89

Table 3 Correlations of seed yield components and seed yield/plant[a]

Trait	LMR	HFB	NB	SMR	SB	LS	BS	SS	SW	SY
PH	–0.195	0.330	0.189	0.022	0.192	–0.998**	0.023	–0.123	0.247	0.208
	0.661**	–0.245	0.699**	0.744**	0.713**	0.372*	0.735**	0.356*	0.045	0.823**
LMR		0.116	0.661**	0.630**	0.645**	–0.286	–0.069	0.205	–0.416*	0.604**
		–0.463**	0.491**	0.889**	0.424*	0.284	0.379*	0.340*	–0.235	0.552**
HFB			0.148	0.134	0.083	0.240	0.200	0.216	0.816	0.134
			–0.758**	–0.002	–0.593**	–0.246	0.037	–0.483**	–0.250	–0.644**
NB				0.617**	0.888**	–0.831**	–0.416*	–0.139	0.072	0.677**
				0.263	0.897**	0.304	0.284	0.645**	0.103	0.969**
SMR					0.533**	–0.758**	–0.011	0.189	0.148	0.763**
					0.229	0.155	0.446**	0.225	–0.035	0.369*
SB						–0.553**	–0.374*	0.084	0.306	0.755**
						0.113	0.335*	0.489**	–0.151	0.877**
LS							–0.013	0.130	–0.999**	–0.429*
							0.492**	0.598**	0.482**	0.424*
BS								0.461**	0.492**	0.017
								0.428**	0.452**	0.380
SS									–0.362*	0.644**
									–0.300	0.684**
SW										0.428*
										0.185

[a] Upper and lower correlation co-efficients are for tetralocular and bilocular siliqua groups, respectively

$*P = 0.05$, $**P = 0.01$

PH, Plant height; LMR, length of main raceme; HFB, height up to first fruiting branch; NB, number of branches; SMR, siliquae on main raceme; SB, siliquae on branches; LS, length of siliqua; BS, breadth of siliqua; SS, seeds/siliqua; SW, 1 000-seed weight; SY, seed yield/plant

negative correlation with seed yield/plant in bilocular group. Whereas, in tetralocular group this trait showed non-significant correlation with seed yield. In this group length of siliqua had significant and negative correlation with seed yield/plant. While, opposite was recorded in case of bilocular group. The breadth of siliqua did not record significant correlation with seed yield, but it had significant and positive correlation with seeds/siliqua and 1 000-seed weight in both siliqua groups.

Path analysis

The direct and indirect effects of different traits on seed yield/plant are presented in Table 4. Path co-efficient analysis revealed highest direct effect of seeds/siliqua on seed yield/plant in tetralocular group, followed by siliquae on branches, siliquae on main raceme and number of branches. All these traits had significant and positive correlation with seed yield. In the bilocular group, plant height recorded highest direct effect on seed yield, followed by siliquae on main raceme,

Table 4 Path co-efficient analyses of seed yield and its components. Direct (italicized) and indirect effects on seed yield/plant are shown for each component trait in tetralocular and bilocular siliqua groups

Trait	PH	LMR	HFB	NB	SMR	SB	LS	BS	SS	SW	r[a]
Tetralocular											
PH	*–0.125*	0.037	–0.029	0.032	0.005	0.084	0.296	0.000	–0.080	–0.012	0.208
LMR	0.024	*–0.189*	–0.010	0.112	0.115	0.282	0.074	0.001	0.133	0.021	0.604**
HFB	–0.041	–0.022	*–0.087*	0.025	0.033	0.036	0.062	–0.003	0.140	–0.009	0.134
NB	–0.024	–0.125	–0.013	*0.169*	0.152	0.388	0.217	0.007	–0.090	–0.004	0.677**
SMR	–0.003	–0.119	–0.012	0.104	*0.246*	0.233	0.198	0.000	0.123	–0.007	0.763**
SB	–0.024	–0.122	–0.007	0.150	0.131	*0.437*	0.144	0.006	0.055	–0.015	0.755**
LS	0.142	0.054	0.021	–0.141	–0.186	–0.242	*–0.261*	0.000	0.085	0.099	–0.429*
BS	–0.003	0.013	–0.017	–0.070	–0.003	–0.163	0.003	*–0.017*	0.300	–0.025	0.018
SS	0.015	–0.039	–0.019	–0.024	0.046	0.037	–0.034	–0.008	*0.650*	0.018	0.644**
SW	–0.031	0.079	–0.016	0.012	0.036	0.134	0.509	–0.008	–0.235	*–0.051*	0.428*
Bilocular											
PH	*0.908*	–0.645	0.190	–0.148	0.471	0.140	0.070	–0.236	0.076	–0.004	0.823**
LMR	0.600	*–0.976*	0.360	–0.104	0.563	0.083	0.054	–0.122	0.072	0.021	0.552**
HFB	–0.222	0.452	*–0.777*	0.161	–0.001	–0.170	–0.047	–0.012	–0.103	0.022	–0.644**
NB	0.634	–0.479	0.589	*–0.212*	0.167	0.177	0.057	–0.091	0.137	–0.009	0.969**
SMR	0.676	–868	0.002	–0.056	*0.633*	0.045	0.029	–0.143	0.048	0.003	0.369*
SB	0.647	–0.414	0.461	–0.190	0.145	*0.197*	0.021	–0.108	0.104	0.013	0.877**
LS	0.338	–0.277	0.192	–0.064	0.098	0.022	*0.189*	–0.158	0.127	–0.043	0.424*
BS	0.667	–0.370	–0.028	–0.060	0.282	0.066	0.093	*–0.321*	0.091	–0.040	0.380
SS	0.323	–0.332	0.376	–0.137	0.143	0.096	0.113	–0.137	*0.213*	0.027	0.684**
SW	0.041	0.229	0.195	–0.022	–0.022	–0.030	0.091	–0.145	–0.064	*–0.088*	0.185

[a] Correlation co-efficient between seed yield/plant and its components

P = 0.01, ** *P* = 0.05

PH, Plant height; LMR, length of main raceme; HFB, height up to first fruiting branch; NB, number of branches; SMR, siliquae on main raceme; SB, siliquae on branches; LS, length of siliqua; BS, breadth of siliqua; SS, seeds/siliqua; SW, 1000-seed weight; SY, seed yield/plant

Table 5 Multiple regression analysis of yield attributes on seed yield

	Bilocular group		Tetralocular group	
	Beta co-efficient	t	Beta co-efficient	t
Constant	–2.401	–1.572	0.050	0.053
Plant height (X1)	–0.012	–0.035^{ns}	–0.012	–1.226^{ns}
Length of main raceme (X2)	–0.009	–0.100^{ns}	–0.018	–0.569^{ns}
Height up to first fruiting branch (X3)	0.012	0.425^{ns}	–0.006	–0.985^{ns}
Number of branches (X4)	0.406	2.040^{ns}	0.074	0.461^{ns}
Siliquae on main raceme (X5)	0.047	0.688^{ns}	0.057	1.874^{ns}
Siliquae on branches (X6)	0.036	1.659^{ns}	0.067	2.450*
Length of siliqua (X7)	0.007	0.118^{ns}	–0.109	–3.402*
Breadth of siliqua (X8)	–0.305	–1.576^{ns}	–0.087	–0.553^{ns}
Seeds/siliqua (X9)	0.073	0.954^{ns}	0.209	5.036**
1 000-seed weight (X10)	0.829	1.347^{ns}	0.144	0.252^{ns}
R^2	0.977		0.967	

**P* = 0.05, ** *P* = 0.01, ^{ns} non-significant

seeds/siliqua and siliquae on branches.

Tetralocular siliqua bears more seeds, simply inherited and singularly most important primary yield component besides number of siliqua and 1000-seed weight. Further, both number of branches and siliquae on branches have wide variability and positive correlation with seed yield/plant in this group. However, lower mean number of branches and siliquae on branches in comparison with bilocular group might be due to the lack of basal branches. Branches produced at upper level of the main stem are generally fewer in number and bear less number of siliqua. Therefore, the most important objective of breeding high-yielding tetralocular type would be to shorten the height up to first fruiting branch. Selection towards basal branching to enhance seed yield was also proposed by Satyabati *et al.* (2001). In bilocular group the height up to first fruiting branch which actually indicates the position of branches along the main stem, had significant negative correlation as well as high negative direct effect on seed yield/plant. Seed yield could be increased if the height of the fruiting branches is lowered and basal branching type is selected for bilocular siliqua types.

Multiple regression analysis

From the multiple regression analyses (Table 5) it was found that the calculated values of ‘t’ for the partial regression co-efficient of seed yield on number of branches and siliquae on branches were higher than that of other traits. Step-wise multiple regression analysis taking these two traits two traits gave a R^2 value of 0.922 ($Y = 0.657 + 0.660\ X_4^* + 0.004\ X_6^*$; Y, seed yield/plant; X_4, number of branches; X_6, siliquae on branches; * $P = 0.05$), i e these traits together had explained 92% of the variation in seed yield. In the tetralocular group siliquae on branches, length of siliqua and seeds/siliqua were higher than rest of the traits and explained 91% of the variation in seed yield/plant ($R^2 = 0.907$; $Y = 0.389 + 0.088\ X_6^* – 0.013\ X_7^* + 0.196\ X_9^*$; Y, seed yield/plant; X_6, siliquae on branches; X_7, length of siliqua; X_9, seeds/siliqua; * $P = 0.05$). In both bilocular and tetralocular groups siliquae on branches was important in the formation of seed yield. In the present study the results of multiple regression analysis corroborate the results of correlation and path co-efficient analysis. Therefore, breeding objective for higher seed yield in tetralocular and bilocular group should be envisaged choosing parents having wide variation for these traits and practising selection for them in the segregating generations.

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