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BREEDING BRASSICA NAPUS FOR SHATTER RESISTANCE

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ABSTRACT

This paper deals with the application of a laboratory test for shatter resistance in rapeseed to genetic and breeding studies of this character. This test is based on measuring the strength of the siliquae. Siliqua strength is positively correlated with shatter resistance. All the *Brassica napus* lines studied were shatter susceptible while some lines of *B. juncea* had intermediate shatter resistance. Certain lines of *B. campestris* vars Yellow Sarson and Brown Sarson were highly shatter resistant. In the Sarsons shatter resistance was recessive and controlled by two to three loci which showed dominant epistasis. There was considerable variation for siliqua strength in segregating populations of crosses between the Sarsons and *B. napus* and in progenies derived from irradiation of the *B. napus* cv. Midas. These materials provide good potential for incorporating shatter resistance in rapeseed.

KEYWORDS

Brassica juncea, B. campestris, siliqua strength, interspecific hybridisation.

INTRODUCTION

Shattering (dehiscence) of rapeseed siliquae occurs in the field after impact between siliquae and other plant parts, and due to gravitational, inertial, and aerodynamic (wind) loads on the siliquae. Shattering can also be caused by the impact of harvest machinery. Dehiscence of the siliqua occurs along an abscission (separation) layer present in the suture. There is no evidence for dehiscence arising from forces within the siliqua (Kadkol, 1984). Because the mechanism of dehiscence appears to be passive, levels of shattering in the field are largely influenced by environmental factors; this renders selection in the field for low levels of shattering difficult. For this reason we devised a laboratory method for evaluating shatter resistance which involved measuring the strength of the siliqua (Kadkol *et al.*, 1984).

LABORATORY TEST FOR SHATTER RESISTANCE

Strength of ripe siliquae, which was positively correlated with shatter resistance of *Brassica* accessions (Kadkol *et al.*, 1984), was measured using an Instron Universal Testing Instrument (Model 1122) which was linked to an EXIDY Sorcerer Mark II mini-computer, visual display unit and printer (Fig. 1).

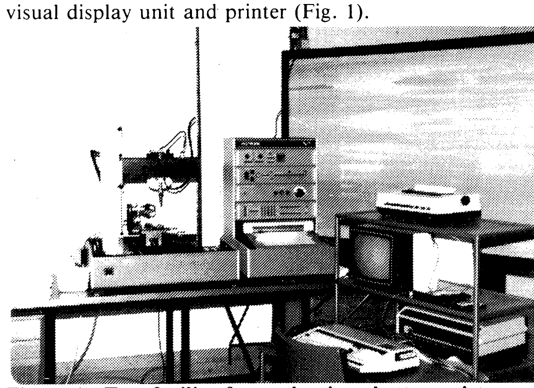

Figure 1. Test facility for evaluating shatter resistance of the siliquae of *Brassica* species.

In this procedure, the rapeseed siliqua is clamped at its junction with the stalk in an air operated clamp at constant pressure such that the plane of replum is horizontal (Fig. 2a and 2b). A steel wedge was fixed to the load cell in the moving cross-head of the instrument and as it moved vertically downwards at a constant speed of 100 mm. min^{-1} it applied a force to the siliqua. The point of loading for all tests was set to be beyond half the length of the siliqua towards the distal end. The chart recorder associated with the Instron Instrument recorded the applied force (paper speed was constant at 100 mm. min^{-1}) producing a force-displacement graph (Fig. 3). Failure of the siliqua occurs at the peak of this graph. Siliqua strength was therefore characterised using the following parameters:

- Bending moment: maximum bending moment (M') = P'x.
- Energy: energy absorbed is the area under the force displacement curve (Fig. 3).

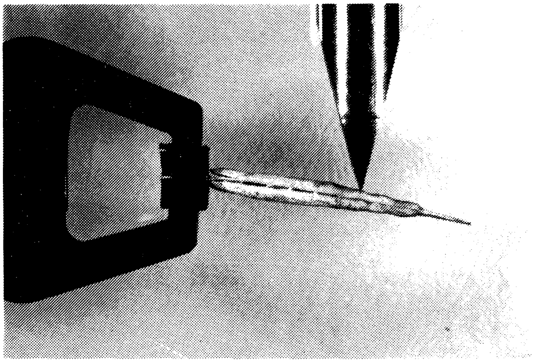

Figure 2. (a) Siliqua on dehiscence in the machine for measuring shatter resistance.

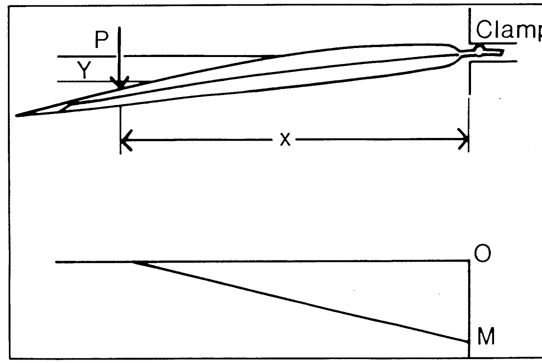

Figure 2. (b) Details of loading of the siliqua in evaluating shatter resistance of *Brassica*.

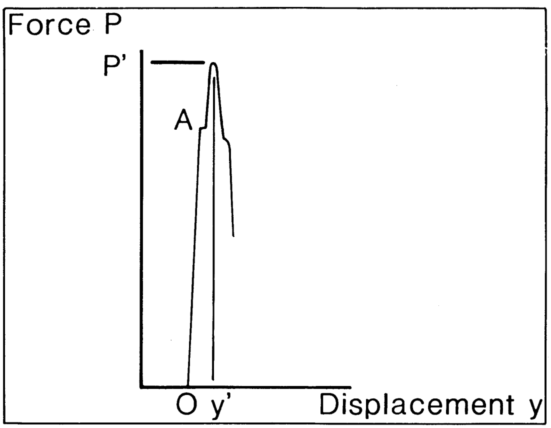

Figure 3. Force-displacement graph of a siliqua of *Brassica napus* before and after dehiscence in the testing machine.

$$E' = \sum_{y=0}^{y=y'} P \Delta y$$

Where,

E = energy absorbed by the siliqua (mJ (millijoules))
M = bending moment at clamp (N mm (Newton millimetres))
P = force on siliqua (N (Newton))
x = distance from the clamp to point of application of force (mm)
y = siliqua displacement at loading point (mm)
Δ = differential
' = indicates value of the parameter at the failure condition

In addition to using the chart recorder, the data were also fed to the mini-computer via an analogue-to-digital converter. A BASIC programme in the computer was used for the above calculations. This increased the speed of operation to about 60 tests per hour. Setting-up the test system takes about 40 minutes.

VARIATION FOR SILIQUA STRENGTH IN BRASSICA OILCROPS

While most *B. napus* lines were found to have siliquae of low strength, some *B. juncea* and *B. campestris* lines had siliquae of intermediate strength. Certain lines of Yellow Sarson (IB-5, B-46, DYS-1) and Brown Sarson (DS-17-D) were found to have very high siliqua strength (Kadkol *et al.*, in press). High siliqua strength of the Sarson lines appeared to be due to the absence of an abscission layer at the junction of the valve with the replum in the suture of the siliqua. The Yellow Sarson lines used have siliquae of four valves; this also could be a factor contributing to their high siliqua strength.

GENETICS OF SILIQUA STRENGTH IN B. CAMPESTRIS

Inheritance of siliqua strength was studied in crosses between *B. campestris* cv. Torch (shatter susceptible) and DS-17-D, IB-5 and B-46 (all shatter resistant). The F_1 plants of these crosses had low siliqua strength, indicating dominance of shatter susceptibility. The F_2 distributions for measures of siliqua strength were classified into phenotypic classes based on

- shape of the distribution;
- normal distribution of the strength parameters (Kadkol *et al.*, in press).

This procedure consisted of fitting a normal distribution to the data, based on the observed mean and standard deviation, to determine significance of the observed peaks in the distribution (Fig. 4). Segregation for siliqua strength in the F_2 generation suggested a two-gene difference between Torch and DS-17-D and a three-gene difference between Torch and each of IB-5 and B-46 for this character (Table 1). These loci appeared to interact in a dominant epistatic manner (Kadkol *et al.*, in press).

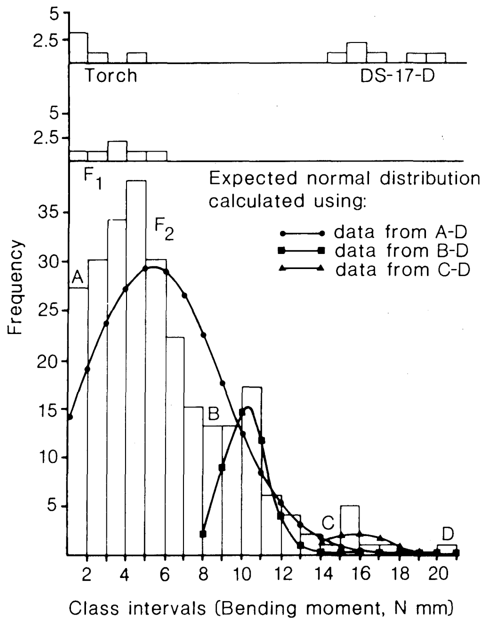

Figure 4. Classification of frequency distribution for bending moment in the F_2 generation of the cross, Torch x DS-17-D into discrete phenotypic classes.

Quantitative genetic analysis of siliqua strength using F_2 plants of the Torch X DS-17-D cross showed significant non-additive genetic variance and high broad sense heritability for this character (Kadkol *et al.*, in press).

INTRODUCTION OF VARIATION FOR SILIQUA STRENGTH INTO B. NAPUS

Selection for higher siliqua strength in the *B. napus* cultivar Midas showed an absence of heritable variation for this character in it (Kadkol, 1984). We therefore attempted to generate variation for this character in *B. napus* by crossing it with the Sarsons (*B. campestris*) and by inducing mutation.

Variation for siliqua strength in crosses of B. napus with B. campestris vars Yellow Sarson and Brown Sarson.

B. napus can be readily hybridised with *B. campestris* because these two species possess the 'A' genome in common. Their F_1 hybrid possesses $2n = 29$ chromosomes which have been reported to form 10 bivalents and nine univalents at meiosis (Morinaga, 1929; McNaughton, 1973). The F_1 hybrid plants were backcrossed with *B. napus* as the male parent and variation in siliqua strength was evaluated in F_2 progenies of the backcrosses grown in the field during 1983-84. Three to six ripe siliquae were tested per plant using the procedure described above. There was considerable variation in siliqua strength in the backcross populations compared with that in the *B. napus* parents (Table 2).

Table 1. Segregation for siliqua strength in the F_2 generation of the crosses between *Brassica campestris* cv. Torch and the Sarsons.

	Observed ratios			
Class	Bending moment	Energy	ERLN[1]	BMLN[2]
(Torch x DS-17-D) F_2				
Weak	196.0	191.0	160.0	
Intermediate	55.0	52.0	—	no discrete
Strong	9.0	17.0	100.0	classes detected
Chi-square	3.48	0.22	2.74	
Probability	0.18	0.90	0.10	
Fitted ratio	12:3:1	12:3:1	9:7	
(Torch x IB-5) F_2				
Weak	819.0	845.0	791.0	
Strong	48.0	22.0	71.0	no discrete
Chi-square	0.64	4.74	1.21	classes detected
Probability	0.42	0.03	0.27	
Fitted ratio	60:4	63:1	58:6	
(B-46 x Torch) F_2				
Weak	539.0	606.0	634.0	646.0
Intermediate	—	44.0	—	—
Strong	117.0	10.0	26.0	14.0
Chi-square	2.27	5.41	22.72	1.00
Probability	0.07	0.13	0.00	0.32
Fitted ratio	54.10	57:6:1	60:4	63:1

[1]ERLN — Energy/siliqua length, [2]BMLN — Bending moment/(siliqua length)

Table 2. Variation in measures of siliqua strength in M_2 population of cv. Midas, interspecific crosses (*Brassica napus* x *B. campestris*) and parent accessions.

Population		Bending moment (N mm)	Energy (mJ)	BMLN (X1000) (N mm mm^{-2})	ERLN (X1000) (mJ mm^{-1})
Midas-M_2	R[1]	0.48-8.88	0.02-0.84	0.39-8.21	0.58-27.63
	CV[2]	35	59	48	65
B. napus	R	0.58-6.90	0.01-0.83	0.45-12.61	0.33-25.34
X DS-17-D	CV	41	75	65	78
B. napus	R	0.77-10.56	0.03-0.58	0.47-6.18	0.63-11.33
X IB-5	CV	48	57	60	56
B. napus	R	0.69-8.24	0.04-0.66	0.61-6.12	0.95-23.99
X B-46	CV	50	77	49	91
B. napus	R	0.76-8.80	0.04-0.43	0.45-17.03	1.13-89.46
X DYS-1	CV	51	58	75	162
Shatter-susceptible *B. napus* parents					
Midas	R	1.25-6.29	0.06-0.73	0.32-3.49	0.94-12.79
	CV	31	57	35	54
76-407-R5	R	1.89-6.98	0.07-0.39	0.85-2.58	1.48-7.48
*10-10-7	CV	40	62	42	65
76-497-R5	R	2.14-5.74	0.07-0.25	0.93-1.84	1.47-4.20
*1-13-5	CV	30	39	22	32
Shatter-resistant *B. campestris* parents					
IB-5	R	8.05-18.91	0.49-3.52	6.12-15.89	12.05-87.87
	CV	28	62	28	60
DS-17-D	R	18.81-37.44	0.78-3.27	7.23-15.56	15.33-67.70
	CV	32	41	30	50
B-46	R	7.97-45.25	1.75-8.70	7.18-18.85	34.23-177.63
	CV	31	41	32	45
	R	10.42-19.00	0.93-1.59	5.20-9.38	21.15-37.81
DYS-1	CV	29	27	20	29

[1]R — range of variation; [2]CV — coefficient of variation (%)

Most of the previous reports of the transfer of characters from *B. campestris* to *B. napus* have been for dominant or co-dominant characters which would be expressed regardless of the alleles at the presumed homoeologous loci for the character in the 'C' genome. It could be postulated that there are dominant genes for shattering on the chromosomes of the 'C' genome of *B. napus* because

- no shatter-resistant forms have been reported in *B. oleraceae,* the donor of the 'C' genome;
- shatter susceptibility is dominant over resistance in *B. campestris* and many other crop plants.

Therefore shatter-resistant plants in such crosses could result most likely from recombination between the 'A' and 'C' genomes involving loci controlling shatter resistance. There is some cytological evidence for limited homoeologous pairing in *B. napus* x *B. campestris* F_1 hybrids but a majority of studies indicate no homoeologous pairing (Prakash and Hinata, 1980).

Induction of mutations for higher siliqua strength in B. napus

The feasibility for inducing mutations for shatter resistance in *B. napus* appeared to be good on the basis of the oligogenic control of this character in *B. campestris.* Six hundred seeds of *B. napus* cv. Midas were irradiated with 122 kR gamma rays at the Genetics School, the University of Melbourne. The irradiated seeds were sown in seed trays and the seedlings were potted at the 2-3 leaf stage. These plants were self-pollinated to give seeds for 270 plant-to-progeny rows which were grown in the 1983-84 season together with an unirradiated control population. Evaluation of the plants was based on 3-6 siliquae per plant. The irradiated population had a higher level of variation than the control population for all parameters of siliqua strength (Table 2 and Fig. 5).

The breeding material from the above experiments offers good promise for incorporating shatter resistance in *B. napus.* Further evaluation of the material to determine

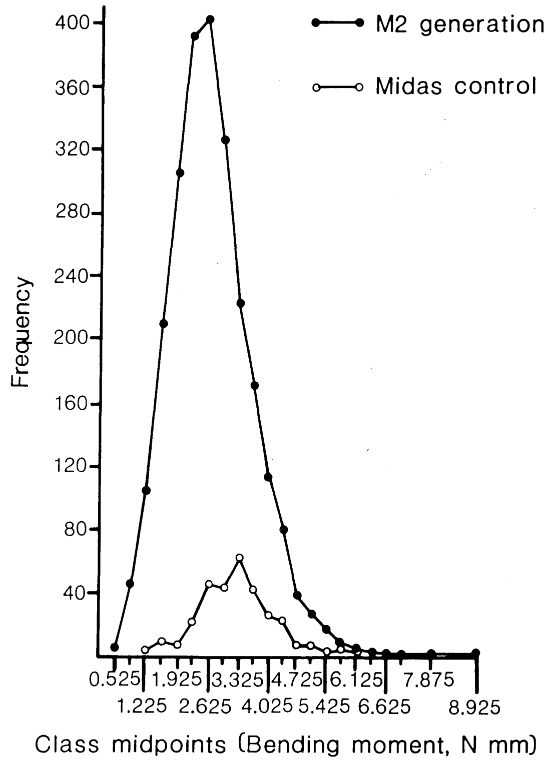

Figure 5. Frequency distributions for bending moment in the M_2 and control populations of *Brassica napus* cv. Midas.

the nature of the observed variation for siliqua strength is in progress.

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