Source of resistance to clubroot (*Plasmodiophora brassicae* Wor.) in triazine-resistant spring canola (rapeseed)

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A total of 31 cultivars and lines of spring canola (rapeseed, ***Brassica napus*** L.) were evaluated for their resistance to clubroot (***Plasmodiophora brassicae*** Wor. race 2) under greenhouse assay conditions. The most resistant selections were swedish lines SV8525952 and SV8525953, Svalof, Sweden and canadian cultivar OAC Triton from Ontario Agriculture College. The resistance appears to be a nuclear phenotype character which is lost in progeny.

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Une evaluation de resistance à la hernie des crucifères (***Plasmodiophora brassicae*** Wor. race 2) a été réalisée sur 31 cultivars et lignées de canola de printemps (colza, ***Brassica napus*** L.) dans des conditions contrôlées en serre. Les lignées les plus résistantes ont été celles d'origine suédoise SV8525952 et SV8525953 de Svalof, Suede ainsi que le cultivar canadien OAC Triton du "Ontario Agriculture College". Le caractère de resistance semble être d'origine nucléique qui disparaît chez les descendants.

Introduction

Spring canola is an oilseed crop increasing in popularity in Eastern Canada and more recently in Quebec where clubroot is one of the most destructive diseases of crucifer crops. The canola trade mark is given in Canada to rapeseed cultivars or lines which have less than 30 micromoles of glucosinolates per gram of oil-free meal and less than 2.0% erucic acid in the oil (10). The disease incidence and severity has been observed to be greater in regions with severe winters when compared to milder winter climates (11).

In Europe, clubroot damage on winter oilseed rape has been observed since 1981 in France (13) where most cultivars produced in that country are very susceptible to the clubroot pathogen (12). Many physiological races of this organism are found, but race 2 or ECD 14/02/31 (1) and race 6 or ECD 16/02/30 predominate in Quebec (5).

There are few economical means of controlling clubroot. Therefore, developing resistance in oilseed rape through breeding appears to be a most promising and effective means of control since resistance to clubroot is quite common in ***Brassica napus*** especially in Sweden (9).

Breeding programs for clubroot resistance in oilseed rape have been undertaken using nonspecific resistance in ***Brassica campestris*** and backcross with existant ***Brassica napus*** containing race-specific genes ***(8).*** The present screening test was aimed at finding the susceptibility of recent canola cultivars to this disease.

The other purpose of the present screening test was to find out the susceptibility of recent canola lines and cultivars to this disease.

Materials and methods

In two greenhouse tests, a clubroot-free soil, mixture of 1:1 perlite and pasteurized mineral soil, was heavily inoculated with a suspension of resting spores of ***P. brassicae*** mainly race 2, at a soil concentration of 5×10^6 spores per dm^3 of soil. The technique of infestation has been previously described (5). The original inoculum source came from ***P. brassicae***- infected roots of cablbage (***Brassica oleracea*** L. var. ***capitata*** L.) obtained from a heavily infested field located on the L'Acadie experimental farm, L'Acadie, Quebec. Rutabaga (***B. napus*** L. ssp. ***rapifera*** L.) clubroot sensitive cv. Laurentian was used as a control. A severity damage index (D.I.) was assessed 45 days after seeding according to the following 4 grades (G.) of severity (6):

G.0 = number of plants with 0% of the root system affected.
G.I = very small clubs on lateral roots (1 to 10%).
G.2 = moderate clubs on lateral roots and/or taproot (11-50%).
G.3 = severe clubbing on lateral roots and/or taproots (51-100%).

The equation used for the calculation of the disease index is the following:

$$D.I.\% = \frac{[(G.0) \times 0 + (G.1) \times 1 + (G.2) \times 2 + (G.3) \times 3] \times 100}{(3 \times \text{total number of plants})}.$$

Data were collected on an average of 32 plants, distributed at the rate of 4 plants per 5 cm-diameter plastic pot (4). A 20-20-20 soluble fertilizer was applied once a week on all plants.

Results and discussion

Of the 31 entries in the first screening test, two Swedish lines, SV8525952 and SV8525953 from Svalöf AB, a private plant breeding company, and the Canadian cultivar OAC Triton, from the University of Guelph, slhowed some resistance to

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Table 1. List of spring canola (*Brassica napus* L.) entries for resistance to clubroot, their origin, number of plants in disease grade and disease indices from two greenhouse tests with race 2 of *P.* brassicae.

Entry	Origin	Disease grade				Disease indices %	Resistant (R) or susceptible (S) to triazine herbicides
		0	1	2	3		
				TEST I			
Plant breeder lines:							
81-17016A	Canada	**0**	1	0	22	97	S
BS-1-87	Canada	**0**	0	2	28	95	S
BS-2-87	Canada	**0**	0	0	33	**100**	S
LD 9922	Canada	**0**	0	1	30	99	S
OAC SC 86-02	Canada	0	**0**	0	28	100	**R**
OAC SC 87-01	Canada	0	**0**	0	27	100	**R**
OAC SC 87-02	Canada	0	**0**	0	31	100	S
S81-2716	Canada	1	**0**	**0**	26	96	S
SEMU DNK 237184	W. Germany	0	0	0	32	100	S
SEMU DNK 244184	W. Germany	0	0	0	32	100	S
SEMU DNK 85/201	W. Germany	0	0	0	34	100	S
SEMU DNK 861224	W. Germany	**0**	1	1	27	97	S
SV02402	Sweden	0	0	0	31	100	S
SV02404	Sweden	0	0	0	33	100	S
SV8323005	Sweden	0	0	2	28	98	S
SV8525952	Sweden	9	3	1	18	63	**R**
SV8525953	Sweden	12	3	4	7	41	**R**
WW 1398	Sweden	0	0	0	30	100	**S**
WW 1427	Sweden	0	0	0	30	100	S
WW 1447	Sweden	0	0	0	31	100	S
WW 1467	Sweden	**0**	**0**	0	28	100	S
WW 1471	Sweden	**0**	**0**	3	23	96	S
Commercial cultivars:							
GLOBAL	Canada	0	0	2	29	98	S
HANNA	Canada	0	0	0	33	100	S
OAC TRIUMPH	Canada	0	0	0	32	100	**R**
OAC TRITON	Canada	14	1	2	16	54	**R**
PIVOT	Canada	0	0	0	32	100	S
TOPAS	Canada	0	1	**1**	30	97	S
TRIBUTE	Canada	1	0	2	29	95	**R**
WESTAR	Canada	0	0	0	32	100	S
LAURENTIEN*	(control)	0	0	0	32	100	S
				TEST II			
Plant breeder lines:							
SV8323005	Sweden	3	1	3	23	84	**S**
SV8525952	Sweden	6	8	1	5	42	**R**
SV8525953	Sweden	6	8	1	7	47	**R**
Commercial cultivars:							
OAC TRITON	Canada	7	10	**5**	1	33	**R**
OAC TRIUMPH	Canada	3	2	2	**9**	69	**R**
TRIBUTE	Canada	0	0	0	7	100	**R**
BIRD'S RAPE**	Canada	14	8	3	0	19	**R**
LAURENTIEN	(control)	0	1	2	31	96	**S**

*Rutabaga (*B. napus* L. ssp. *rapifera* L.);

**_Triatine resistant_ bird's _rape_ (*Brassica campestris* L.).

clubroot (Table 1). The two Swedish lines had an average disease index of 52% while the Canadian cv. had an index of 54%. All three lines exhibiting some clubroot resistance were resistant to triazine herbicides. None of the triazine-resistant lines which also did not exhibit clubroot resistance.

In the second screening test with the best entries found in the first test, both Swedish lines and Canadian cv. OAC Triton had a mean index of 45% and 33%, respectively. The actual number of clubroot infected plants was lower in this test, possibly because several plants were infected by root rot pathogens, including *Rhizoctonia solani* Kuhn.

The triazine resistant parent of OAC Triton (triazine resistant bird's rape (*B. campestris* L. x Tower, backcrossed four times to Tower)) (1) also was investigated to detect the source of the clubroot resistance. Tower had no resistance to clubroot infection (disease index = 97%) in an earlier screening test (7).

Triazine herbicide resistant bird's rape had a disease index of 19%. The triazine-resistance of bird's rape is maternally inherited via a single chloroplast gene. OAC Triton contains the cytoplasmic genetic complement (chloroplast and mitochondria1 genes) of triazine-resistant *B. campestris* and the nuclear complement of *B. napus* (1). With strict maternal inheritance of the triazine resistance, other triazine-resistant lines should also have *B. campestris* cytoplasm. The resistance to clubroot in OAC Triton appeared to be diminished, compared to bird's rape.

Clubroot resistance in SV8525952 and SV8525953, derived from OAC Triton as the original female parent, did not appear to be further diminished, although clubroot resistance in OAC Triumph, a result of crossing OAC Triton with Topas and backcrossing to Topas, did increase. The recently developed University of Guelph lines OAC SC86-02, OAC SC87-01 and OAC SC87-02, which are another cycle of crossing removed from OAC Triton, appear to have lost all resistance to clubroot. The results suggest that, in spring canola, clubroot resistance exhibits nuclear inheritance and that the trait was lost rapidly as progeny lines progressed further from the original source in bird's rape.

According to Chiang and Crete (3), the disease index of an entry is a weighted average of infection. A breeder should look at the frequency of plant distribution in each disease grade rather than depend only on the index to assess the resistance of a particular line or cultivar. The relative high number of plants in '0' grade of the three above mentioned entries indicate truly resistant plants rather than escapes and could be a good source of clubroot resistant germplasm, since all the plants of cv. Laurentian were heavily infected.

Conclusion

The triazine herbicide tolerant canola cultivar OAC Triton (resistant *Brassica rapa* L. x susceptible *Brassica napus* L. cv Tower) appears to have some resistance to the clubroot pathogen race 2, with an average disease index of 33% while its parent, triazine tolerant bird's rape, had a much lower index of 19% compared to its progeny.

Although triazine-resistant bird's rape appears to be a better source of clubroot resistance than the three triazine-resistant spring canolas, using the latter as clubroot resistance sources in canola breeding programs would be desirable because they have low erucic acid and glucosinolate contents.

Further studies are necessary to establish the inheritance of resistance before undertaking a clubroot-resistant canola breeding program.

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