Resistance to *Polymyxa betae* and Beet Necrotic Yellow Vein Virus in *Beta* Species of the Section *Corollinae*

H. Paul, B. Henken, O.E. Scholten, Th.S.M. De Bock and W. Lange

DLO-Centre for Plant Breeding and Reproduction Research (CPRO-DLO), P.O. Box 16, 6700 AA Wageningen, The Netherlands.

ABSTRACT

Seedlings of twenty-one *Corollinae* accessions, of five interspecific hybrids between *Beta vulgaris* and *B. intermedia* or *B. lomatogona*, and of the susceptible sugar beet cultivar Regina were grown in a mixture of sand and soil containing *Polymyxa betae* with beet necrotic yellow vein virus (BNYVV). After four weeks, the level of infection by *P. betae* was measured by counting the resting spores (cystosori) and the level of BNYVV in the roots by enzyme linked immunosorbent assay (ELISA). Resistance to *P. betae* and BNYVV was found in various accessions. Some hybrids had resistance to BNYVV. Low numbers or even the absence of resting spores often did not result in low concentrations of BNYVV.

Additional Key Words: ELISA, rhizomania, sugar beet

Polymyxa betae Keskin, a soil-borne, root infecting fungus, is the vector of beet necrotic yellow vein virus (BNYVV), which causes rhizomania in sugar beet. Resistance to *P. betae* could be an objective in breeding sugar beet with resistance to rhizomania. Wild *Beta* species have been reported to carry resistance to *P. betae* (Fujisawa and Sugimoto, 1979; Asher and Barr, 1990). Paul et al. (1992b) located resistance to *P. betae* in *B. procumbens* Chr. Sm. on chromosomes pro-4 and pro-8, using monosomic chromosome additions of *B. procumbens* in *B. vulgaris* L., and reported on the possible effect of resistance to *P. betae* on the infection with BNYVV. In the present study, *Beta* species of the section *Corollinae* and some of their hybrids with *B. vulgaris* were tested for resistance to *P. betae* and BNYVV and the effect of resistance to *P. betae* on the infection with BNYVV was investigated.

MATERIALS AND METHODS

Twenty-one accessions of the section *Corollinae* were used. The accessions included most species of the section and represented the region of origin. Dr Lothar Frese of the German-Dutch Beta Genebank is acknowleged for sending most of the seed samples. In addition, five interspecific hybrids between *B. vulgaris* and *B. lomatogona* Fisch. & Mey. or *B. intermedia* Bunge (Cleij et al., 1968, 1976) were used; in the description of the hybrids, the letters V, I and L stand for the genomes of *B. vulgaris, B. intermedia* and *B. lomatogona,* respectively. The study consisted of testing this material for resistance to *P. betae* and BNYVV, and cultivar Regina served as control variety. The seed coat of the seeds of the *Corollinae* species was removed mechanically. Seedlings approximately four weeks old were transplanted into a mixture of sand and soil, in a ratio 9:1 (v/v), containing *P. betae* with BNYVV. After four weeks, roots were homogenised in phosphate buffered saline (PBS) in a ratio 1:20 (w/v). Resting spores (cystosori) were counted to estimate the level of infection with *P. betae* and ELISA was applied to determine concentrations of BNYVV in the roots (Paul et al., 1992a; 1992b). Plants with estimated virus concentrations below 4 ng ml^{-1} were considered to be free of virus. Data are presented as $\log_{10}$ of the number of cystosori mg^{-1} of root and $\log_{10}$ of the virus concentration in ng ml^{-1}. Zero values were read as one.

RESULTS

Significant differences among the average numbers of cystosori were found ($P < 0.05$) (Table 1). Various accessions of different species had plants with a few or without cystosori. The latter plants were found in the accessions *B. corolliflora* Zos. 18253, 17822 and 58248, *B. lomatogona* 61241 and *B. macrorhiza* Stev. WB65. All hybrid plants had high numbers of cystosori. Significant differences among accessions for average virus concentration were found. Some plants had low concentrations or no virus. Plants with virus concentrations below the detection limit were found for the *B. corolliflora* accessions 18253 and 61227, the *B. intermedia* accessions 61218, 17913 and 17967, and the *B. lomatogona* accessions WB23, 61191 and WB5. In some plants of the hybrids VLL and VVLL, no virus was detected. Resistance to BNYVV in VLL and VVLL appears to behave as a dominant trait in hybrids with *B. vulgaris*.

Resistance to BNYVV made it difficult to investigate the relationship between the level of infection by *P. betae* and infection with the virus. Low numbers or even the absence of cystosori often did not result in low virus concentrations. Resistance to BNYVV could not be ruled out as being the cause of the low virus concentrations. A significant positive correlation between the number of cystosori and the virus concentration was only found for *B. macrorhiza* WB65 ($r = 0.85$; $P < 0.05$). A significant negative correlation between the number of cystosori and the virus concentration was found for the *B. intermedia* accession 61218 ($r = -0.80$; $P < 0.05$) and the hybrid VVVI ($r = -0.95$; $P < 0.05$).

DISCUSSION

Resistance to *P. betae* was found in *Corollinae* species, which confirms the results of Fujisawa and Sugimoto (1979). The results of Fujisawa and Sugimoto (1979) suggested immunity to *P. betae* in these species, whereas the results of the present study, in which only a few plants without cystosori were found, indicate high levels of partial resistance. Within the *Corollinae* species, resistance to BNYVV was found, which has not been reported before. Fujisawa and Sugimoto (1979) found chlorotic lesions on the leaves of some *Corollinae* species after mechanical inoculation, which indicated susceptibility to BNYVV. In the present study, no virus was detected in only a few plants. Therefore, resistance to BNYVV in *Corollinae* species does not seem to be based on immunity, but on high levels of partial resistance.

Table 1. Average numbers of cystosori of *P. betae* and concentrations of BNYVV, with 95% confidence intervals (log_{10} of the data; original data in cystosori/mg root and ng/ml)(n=6).

Accession	Number of cystosori	Virus concentration
B. vulgaris subsp. *vulgaris*		
Regina	2.35 ± 0.20	2.42 ± 0.18
B. corolliflora		
BGRC 18253	0.44 ± 0.66	1.52 ± 0.96
BGRC 61227	1.10 ± 0.58	1.12 ± 1.12
BGRC 35314	1.32 ± 0.83	2.62 ± 0.22
BGRC 17822	1.42 ± 0.95	2.56 ± 0.29
BGRC 58248	1.43 ± 0.85	2.15 ± 0.48
Ames 4527	1.57 ± 0.86	2.05 ± 0.40
B. intermedia		
BGRC 61218	1.53 ± 0.61	2.21 ± 1.30
WB323	1.82 ± 0.39	2.97 ± 0.21
BGRC 17913	1.86 ± 0.34	0.37 ± 0.33
BGRC 17990	2.28 ± 0.23	2.72 ± 0.11
BGRC 61233	2.32 ± 0.24	1.55 ± 0.90
BGRC 17967	2.46 ± 0.17	0.42 ± 0.53
B. lomatogona		
BGRC 612413	1.63 ± 1.30	2.04 ± 1.40
BGRC 612381	1.87 ± 1.64	2.23 ± 3.50
WB23	2.17 ± 0.89	0.67 ± 0.47
BGRC 611911	2.35 ± 0.27	0.91 ± 0.94
WB52	2.41 ± 0.29	0.70 ± 0.33
B. macrorhiza		
WB65	1.06 ± 1.01	2.22 ± 0.48
BGRC 18242	1.71 ± 0.87	2.17 ± 0.36
B. trigyna		
BGRC 35313	1.33 ± 0.37	2.98 ± 0.27
PI 264352	1.90 ± 0.41	2.13 ± 0.44
B. vulgaris subsp. *vulgaris*		
Regina	2.43 ± 0.20	2.74 ± 0.22
Interspecific hybrids		
VVLL	2.00 ± 0.36	1.41 ± 0.94
VL	2.15 ± 0.24	3.04 ± 0.13
VLL	2.45 ± 0.24	0.37 ± 0.50
VVVI-13	1.97 ± 0.28	2.93 ± 0.19
VVVI	2.19 ± 0.34	2.84 ± 0.20

A positive correlation was found between the number of cystosori and the virus concentration in one accession. Low virus concentrations could be caused by resistance to BNYVV. Since plants with low numbers or even without cystosori were found to have high virus concentrations, there was little evidence for the suggestion that resistance to *P. betae* could have an effect on the level of infection with BNYVV. Such an effect has been reported from a study with chromosome addition plants of *B. procumbens* in *B. vulgaris,* in which the average numbers of cystosori were correlated with the average virus concentrations, but correlations within accessions were not significant (Paul et al., 1992b).

The *Procumbentes* species and their hybrids with *B. vulgaris* had no cystosori, and virus concentrations were low or the virus was absent (Paul *et al.,* 1992b). The results reported here showed that several *Corollinae* accessions had plants without cystosori but with high virus concentrations. It remains to be investigated whether different mechansisms of resistance to *P. betae* are involved in the different beet sections and what their effect is on the transmission of BNYVV. The negative correlations between the numbers of cystosori and the virus concentrations could be explained as a negative effect of the virus on the development of *P. betae,* as was reported by Schlösser (1990).

Although the species of the sections *Corollinae* and *Procumbentes* have high levels of resistance to *P. betae,* the use of these sources of resistance in breeding programmes is hampered by crossing barriers, while also the effect of the resistance on the infection by BNYVV might be limited.

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