Screening for resistance to black rot in a Spanish collection of *Brassica rapa*

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Abstract

Productivity and quality of crops of *Brassica rapa* L. in northwestern of Spain are highly affected by black rot, caused by the bacterium *Xanthomonas campestris* pv. *campestris* (Pammel) Dowson (Xcc). Several races of Xcc have been described in this area, being the race 6 the most frequent in *B. rapa* crops and races 1 and 4 the most frequent in *B. oleracea* crops. The control of the disease can be aided by the employment of resistant varieties. The aim of this work was to find sources of resistance to Xcc in a collection of open-pollinated varieties of *B. rapa* from northwestern Spain. Resistance was evaluated in 191 landraces. Partial resistance to races 6, 1 and 4 and complete resistance to race 4 were identified in several landraces. Several accessions exhibited partial resistance to the three races. Sources of resistance were identified in landraces of different crops of the species (turnips, turnip greens and turnip tops). These landraces could be grown directly after selection for resistance or they can be donors of resistance genes in breeding programs.

Keywords: Bacterial disease, resistant landraces, screening, turnips, *Xanthomonas campestris* pv. *campestris*

Introduction

Brassica rapa L. is grown worldwide as a vegetable and for edible and industrial oil, providing a large proportion of the daily food intake in many regions of the world (Zhao et al. 2005). China is the major producer in the World, accounting for more than 41.1 million t in 2010. In this country and in other Asian countries, *B. rapa* crops are major food, which reflects the importance of this vegetable (Bong et al. 2012, Kim et al. 2013).

Productivity and quality of *B. rapa* are highly affected by several diseases, which result in substantial economic losses. Black rot, caused by the bacterium *Xanthomonas campestris* pv. *campestris* (Pammel) Dowson (Xcc), is considered one of the most serious diseases of crucifers world-wide (Williams 1980). Crop losses due to the disease may exceed 50% in favorable environmental conditions, especially in warm and humid climates (Williams 1980). The pathogen produces V-shaped necrotic lesions from leaf margins, which decrease the quality of the product for fresh-market sale and cause a decrease in the quality trade for the food industry (Williams, 2007). Moreover, this disease weakens the plant tissues, favoring the attack of other bacterial organisms. The seedborne pathogen can survive in crop debris or crucifer weeds ([Alvarez and Cho 1978](#), [Schaad and White 1974](#), [Schaad and Dianese 1981](#), [Dias et al. 2010](#)). In *B. rapa*, the disease can be serious in turnip and turnip greens (Vicente 2004) and it has also been reported in Chinese cabbage (Ignatov et al. 2000, Schaad and Thaveechai 1983).

Crops of *B. rapa* are currently grown in northwestern Spain during the winter. Turnip leaves and turnip tops are used for human consumption in soups and stews, and turnips are mostly used for fodder. Varieties employed as turnips have thickened roots. Commercial varieties grown to obtain turnip tops and turnip leaves have been selected for high production of floral shoots or leaves, [respectively](#). However, in the case of many local landraces grown in northwestern of Spain, the same landrace can be grown for more than one purpose, allowing the existence of local populations with high levels of variability (Padilla et al. 2005). A collection of *B. rapa* crops from northwestern

Spain is currently kept at the Gene bank from the ‘Misión Biológica de Galicia’ (MBG-CSIC, Spain). These Spanish landraces have been characterized based on morpho-agronomical traits (Padilla et al. 2005), molecular data (Soengas et al. 2011) and leaf glucosinolate content (Cartea et al. 2012, Francisco et al. 2009, Padilla et al. 2007). Some landraces were found suitable to be included in breeding programs due to either their good agronomic performance, or their good nutritional composition, but most of them are highly susceptible to several diseases, including black rot. The presence of this disease has been documented in the northwestern Spain, where Xcc strains from this region were isolated and characterized (Lema et al. 2008, Lema et al. 2012a), finding that races 6, 1 and 4 are the most widespread. Race 6 was found to be the most frequent (Lema et al. 2012a) in fields cultivated with *B. rapa*. Race 6 was also found in turnip cultivated in Portugal (Vicente 2004). According to Lema et al. (2012a) breeding programs designed to provide resistance, at least to race 6 in *B. rapa*, must be developed so that new released plant materials with improved resistance to Xcc are available to growers in northwestern Spain. However, races 1 and 4 are the more widespread worldwide in *B. oleracea* crops, accounting for a large part of black rot disease (Vicente et al. 2001) and they can also infect *B. rapa*. The control of black rot is complicated, but it can be aided by the employment of resistant varieties. To improve *B. rapa* varieties for resistance to Xcc, it should be taken into account the existence of different races of the pathogen. Therefore, *B. rapa* cultivars with resistance to these races should be grown in those areas where the disease is present. The objective of this work is to identify sources of resistance to Xcc races 6, 1 and 4 in a Spanish collection of *B. rapa*.

Materials and methods

Accessions

The whole collection of *B. rapa* landraces from the Gene bank of Misión Biológica de Galicia (MBG-CSIC), including turnips, turnip greens and turnip tops from northwestern Spain (191 accessions), was evaluated for their resistance to Xcc in two different experiments. For a detailed description of the landraces, including Xcc reaction for all landraces evaluated, see supplementary Table 1. In the experiment 1, resistance of accessions was tested against race 6, and in the experiment 2, accessions were tested against races 1 and 4. A set of Brassica accessions was originally proposed by Vicente et al. (2001) to conform a Brassica differential resistance series. Afterwards, Vicente et al. (2013) included doubled haploids from several accessions to replace the previous differential ones. The modified Brassica differential series was used as controls in the experiment. This includes doubled-haploid line S×D₁ (*B. oleracea*, susceptible to the three races), the doubled-haploid line Cob60 (*B. napus*, resistant to race 4), the open pollinated Seven Top Turnip (*B. rapa*, resistant to race 4), the inbred line PIC1 (*B. carinata*, resistant to races 1 and 4), the doubled haploid line FBLM2 (*B. juncea*, resistant to races 1 and 4) and the cultivar Wiroso F₁ (*B. oleracea*, susceptible to the three races). All these controls were provided by ~~Warwick~~ [HRI University of Warwick](#), UK except Wiroso F₁ provided by Germisem-Sementes Lda.

Pathogen isolates

Bacterial isolates used were: race 6 type strain HRI6181 (collected on *B. rapa* in Portugal), race 1 type strain HRI3811, synonymous with PHW1205 (collected on *B. oleracea* in USA), and race 4 type strain HRI1279A (collected from *B. oleracea* var. *capitata* in UK) typed by Vicente et al. (2001) and provided by ~~Warwick~~ [HRI University of Warwick](#), UK. Bacterial cultures were grown in

bacterial screening media 523 (provided by Sigma-Aldrich, Inc.) at 30 °C for 48 h. Bacterial cultures were diluted in sterile tap water. Turbidity of the suspension was measured with a spectrophotometer Beckman Coulter DU 62 at a wavelength of 600 nm. ~~and the~~ ~~S~~suspension was diluted to reach an absorbance of 0.5, which corresponds with a concentration of 5×10^8 cfu mL⁻¹

Disease resistance test

Plants were grown in greenhouse, with a photoperiod of 14h light, temperature 18 °C at night and 20 °C during the day. Inoculations were carried on four to five weeks after sowing, in two different experiments. In the experiment 1, plants were inoculated in the third leaf from the base of the stem with race 6. In the experiment 2, the third leaf of each plant was inoculated with race 1 and the fourth leaf was inoculated with race 4. An average of 15 plants per accession was inoculated in the experiment 1 and an average of 10 plants per accession was inoculated in the experiment 2. All the plants of the same experiment were inoculated in the same day. Multiple needles mounted in circles (61 needles inserted in a 3 cm diameter metallic base) were used for inoculation by pressing them through the middle of the leaf onto a sponge submerged in the inoculum, and holding the central midrib. This method has been applied successfully in *B. oleracea* and *B. napus* (Lema et al. 2011, 2012b). After inoculation, greenhouse conditions were set to 14h light, temperature 24 °C at night and 28 °C during the day (with an oscillation of ± 2 °C) and relative humidity above 80%. Plants were rated for disease reaction 21 days after inoculation according to Lema et al. (2011, 2012b). Disease evaluation was made on a visual 1 to 9 rating scale based on the relative lesion size, where 1 = no visible symptoms; 2 = slight chlorosis surrounding the inoculation points; 3 = an isolated, diffuse chlorotic zone around necrotic lesions with blackened veins of <25% of the inoculated area; 4 = chlorotic zones around necrotic lesions with blackened veins occupying <50% of the inoculated

area; 5 = chlorotic zones around necrotic lesions with blackened veins occupying around <75% of the inoculated area; 6 = chlorotic zones around necrotic lesions with blackened veins occupying <100% of the inoculated area; 7 = complete chlorosis with blackened veins and usually necrotic centers of the inoculated area and chlorotic or necrotic lesions extending beyond the inoculated area; 8 = chlorotic or necrotic lesions in the uninoculated areas with a size less than 1 cm²; and 9 = severely diseased with typical V-shaped chlorotic leaf edge lesions presenting blackened veins areas. Accessions with mean disease scores of 1<4 were considered resistant, 4<7 were considered intermediate or partially resistant and 7 to 9 were considered susceptible. A mean disease score was computed for each landrace.

Statistical analyses

Analyses of variance were performed for disease scores by using the GLM procedure of SAS (SAS Institute Inc. 2008). The data were analyzed as a randomized design. Accessions and races were considered as fixed effects whereas replications (plants within accessions) were considered as a random factor. Comparisons of means were performed for mean disease score by using Fisher's protected Least Significant Difference (LSD) at the 0.05 level of probability (Steel et al. 1997).

Results

In the analysis of variance, the source of variation due to landraces was highly significant for the three races (Table 1). The mean disease score for each landrace was computed and their distributions are shown in figure 1. The mean disease score of the whole set of landraces was 7.6 for race 6. Mean landraces scores were classified into two categories ($4 < 7$ and $7-9$) (Figure 1). Mean disease scores for race 1 fell into the category of $7-9$ with a whole mean disease score of 8.5. There were different levels of resistance to race 4 identified in the landraces tested, the entries ranged from highly resistant to highly susceptible, having landraces assigned to all categories from 1 to 9 (Figure 1) with a mean disease score of 6.4. Results about the most outstanding genotypes are presented separately for each race.

Race 6

Around the 57% of accessions tested were uniformly susceptible, which means that all the plants tested within ~~the~~ these accessions were scored within the categories of $7-9$ (Supplementary table 1). Besides, 43% landraces had plants included in the category $4 < 7$. ~~No one~~ None of the landraces had plants included in the category of complete resistance ($1 < 4$). Landrace MBG-BRS0362 showed the lowest mean disease score (6.0), with one plant included in the category $4 < 7$. Fourteen landraces did not significantly differ from it (Table 2). However, ~~only a low number of plants~~ (2 and 3 plants, respectively) were tested for MBG-BRS0362 and MBG-BRS0350 respectively, due to the poor germination of the seed. Therefore, results related to both landraces should be taken cautiously. Landraces MBG-BRS0188 and MBG-BRS0293 stood out among the rest for having the highest number of plants (4), within the category of partial resistance ($4 < 6$).

Race 1

Eighty percent of the accessions were uniformly susceptible, with all the plants included in the category of 7-9 (Supplementary table 1). Hence, we could not find any resistant landrace, or a landrace with a significant number of individual plants that showed complete resistance to race 1. Five landraces (MBG-BRS0215, MBG-BRS0320, MBG-BRS0327, MBG-BRS0440 and MBG-BRS0467) had one plant scored within the category 1<4. This kind of total resistance to race 1 has not been described in *B. rapa*. For this reason, those accessions were re-inoculated and total resistance was not found.

Despite all accessions tested were categorized as susceptible to race 1 based on their mean disease scores, nine of them had plants with partial levels of resistance (Table 2). Among them, landraces MBG-BRS0479, MBG-BRS0507, MBG-BRS0155, MBG-BRS0417 and MBG-0427 stood out for the number of partially resistant plants which were scored in the category 4<7. MBG-BRS0479 had four plants scored within this category, MBG-BRS0507 and MBG-BRS0427 accessions had three plants scored within this category and MBG-BRS0417 and MBG-BRS0155 accessions ~~showed~~ had 2 plants within the category 4<7 (Table 2).

Race 4

Twenty-one landraces tested were uniformly susceptible to race 4 (category 7-9) and the remaining landraces showed plants with variable reactions including resistant and susceptible plants (Supplementary table 1). One landrace (MBG-BRS0259) was uniformly resistant to this race, having the lowest mean disease score (1.3) and eight landraces did not differ significantly from this, showing a high number of resistant plants (Table 2).

Part of the landraces showed intermediate distributions, meaning that most of individuals within these accessions were scored as partially resistant (4<7), although some individuals were also resistant (1<4) or susceptible (7-9). Seven landraces presented this type of distribution (MBG-

BRS0414, MBG-BRS0418, MBG-BRS0420, MBG-BRS0421, MBG-BRS0422, MBG-BRS0431 and MBG-BRS0451), with a mean disease score between 4.9 and 6.2, and included cultivars for turnip green and turnip top production (Supplementary table 1).

Races 6, 1 and 4

Landraces ~~MBG-BRS0215~~, MBG-BRS0155, MBG-BRS0420, and MBG-BRS0550 had plants with partial levels of resistance to races 6, 1 and 4 ($4 < 7$). Besides ~~MBG-BRS0215~~, and MBG-BRS0550 had plants with complete resistance to race 4 (Table 2).

Discussion

Resistance to races 6, 1 and 4 of Xcc has been tested in 191 landraces of *B. rapa* from northwestern of Spain. Race 6 was found to be the most frequent race, in a previous survey carried on in the northwestern Spain (Lema et al. 2012a), in fields cultivated with *B. rapa*. Race 6 was also found in turnip cultivated in Portugal (Vicente 2004). In this work we did not find any landrace completely resistant to race 6. This type of resistance ~~to race 6~~ has not been described before in *B. rapa*. In the gene-to-gene model established by Vicente et al. (2001), there are no R gene conferring resistance to race 6 in the *Brassica* species. However, other types of resistance different of a R gene can be present. Several landraces with partial resistance have been found. Partial levels of resistance to race 6 were found before in *B. rapa* by Taylor et al. (2002). Landraces with partial levels of resistance could be improved and grown in those areas where only race 6 is present~~by selecting those more outstanding individuals within each landrace for resistance to race 6~~. After being improved by their resistance, MBG-BRS0188 would be suitable to produce turnips, MBG-BRS0298 to produce turnip greens and MBG-BRS0225 to produce turnip greens and turnip tops ~~in the conditions of northwestern Spain~~. These accessions can also be used for researchers and breeders in other regions of the world.

Races 1 and 4 are also common in northwestern of Spain (Lema et al. 2012a), mainly in *B. oleracea*, although they can also infect *B. rapa* crops. Accessions of *B. rapa* with resistance to race 1 or 4 can be grown in those areas where these races are present. Based on mean disease scores, race 1 isolate used in the present tests was more aggressive than the race 4 isolate used. Previous findings have also reported similar differences in aggressiveness, based on testing on another set of accessions of *Brassica* (Taylor et al. 2002).

We did not find any source of complete resistance to race 1. As it was previously reported by Taylor et al. (2002), resistance to race 1 is very unusual and it has only been reported in Brassica crops carrying the B genome (*B. carinata*, *B. juncea* and *B. nigra*). In the gene-to-gene model established by Vicente et al. (2001), resistance to race 1 is conferred by the R1 gene, possibly originated from the B genome of *B. nigra*. Since resistance to race 1 is not present in the *B. rapa* genome, partial resistance plays an important role in breeding for resistance to Xcc race 1 and therefore, accessions with this type of resistance could be considered as a promising material. Landraces MBG-BRS0479, MBG-BRS0507, MBG-BRS0155, MBG-BRS0417 and MBG-BRS0427 showed plants with intermediate levels of resistance. MBG-BRS0479 is suitable to produce turnip greens MBG-BRS0507, MBG-BRS0155 and MBG-BRS0027 are adequate to produce both, turnip greens and turnip tops and MBG-BRS0417 has been described as suitable to produce turnips (Cartea et al. 2004). These landraces could be improved for their resistance to Xcc race 1 by selecting those individual plants having the lowest disease score. Improved landraces could be grown to produce turnip greens, turnip tops and turnips in environments where Xcc race 1 is the only race in the area, and causes yield and quality losses. Partial resistance to race 1 has been found before in other crops of the same species. After screening a high number of accessions, Griffiths et al. (2009) found partial resistance to race 1 in five oilseed *B. rapa* accessions and Taylor et al. (2002) found it in six accessions, including broccoletto types. Resistance to race 1 was also found by Dias et al. (2010) in Chinese cabbage and broccoletto crops after screening a collection of 210 accessions. Partial resistance to Xcc race 1 could be conferred to a different mechanism than an R gene, but the nature of the resistance has not been the scope of our study.

Our results suggest that there is race-specific resistance to race 4 in some landraces from NW Spain (i.e. MBG-BRS0259). This type of resistance to race 4 has been described before in different subspecies of *B. rapa*. The majority of the *B. rapa* accessions tested by Taylor et al. (2002) were resistant to race 4, including turnip, Chinese cabbage and broccoletto types, of which some of them were uniformly resistant varieties. Ignatov et al. (2000) studied the resistance to race 4 found

in an inbred line of pak-choi. Resistance to race 4 is most common in *B. rapa* and *B. napus* genome, which suggests an A genome origin (Taylor et al. 2002). Dias et al. (2010) found accessions of broccoleto, choy-sum, and Chinese cabbage with a significative number of resistant plants to race 4. The race-specific resistance found in this work could be controlled by the already described R4 gene (Vicente et al. 2001). Resistance to race 4 found in MBG-BRS0259 could be fixed by producing inbred lines by self-crossing or double haploid production to introduce it in other cultivars. This resistance could be transferred to other cultivars of the same species, or different *Brassica* species by using somatic hybridization or embryo rescue (Hansen and Earle 1995, Tonguc and Griffiths 2004).

Apart from a resistance mechanism conferred by an R4 gene, other mechanisms could also be acting in resistance against race 4. Landraces MBG-BRS0414, MBG-BRS0418, MBG-BRS0420, MBG-BRS0421, MBG-BRS0422, MBG-BRS0431 and MBG-BRS0451 showed intermediate distributions of disease scores. This type of distribution may be a result of a resistance controlled by several genes with additive and moderate effects as it was suggested by Westman et al. (1999).

Landraces ~~MBG-BRS0215~~, MBG-BRS0155, MBG-BRS0420, and MBG-BRS0550 are potentially sources of race nonspecific resistance to races 6, 1 and 4. Race-nonspecific resistance to Xcc races has been reported before. Taylor et al. (2002) found two *B. rapa* accessions resistant to several Xcc races. After screening different crucifer accessions, Griffiths et al. (2009) identified five *B. rapa* accessions with variable resistance to race 1 and uniformly resistant to race 4, all of them having the oilseed plant growth type. Resistance conferred by R genes can be easily broken down by natural selection of those pathogens which carry the dominant allele of the avirulence gene. Pyramiding R genes have been proposed as a strategy to follow in order to obtain durable resistance. Other strategies include the use of quantitatively inherited and race-nonspecific resistance governed by several genes. This type of resistance is usually partial and hard to manage. However, it has the advantage that it may be being durable, ~~race-nonspecific~~ and more difficult to

overcome by pathogens. It is common that various Xcc races are present in a particular Brassica growing area. In Spain, race-typing tests determined the presence of seven (1, 4, 5, 6, 7, 8 and 9) out of nine Xcc races (Lema et al. 2012a). ~~A high number of individual plants of L~~landraces MBG-BRS0215, MBG-BRS0155, MBG-BRS0420, and MBG-BRS0550 should be tested with the six races to ~~select those individuals with e~~confirm that individual plants have race nonspecific resistance.

Quantitatively inherited resistance will be essential to obtain appropriate resistant cultivars, protected against all races of this pathogen. Quantitatively inherited resistance found in the inbred line B162 (Guo et al. 1991) has already been introgressed into *B. oleracea* germplasm aided by linked molecular markers (Soengas et al. 2007). More durable resistance could also be obtained by combining race-nonspecific resistance and race-specific resistance in the same cultivar. We have found these two types of resistance after screening the collection of *B. rapa* kept at the Gene bank of the Misión Biológica de Galicia. ~~Resistance can be used directly by growing the landraces which already possess the resistance or can be transferred into other cultivars.~~

Conclusions

Landraces ~~MBG-BRS0215~~, MBG-BRS0155, MBG-BRS0420, and MBG-BRS0550 exhibited potential race-nonspecific resistance to Xcc. Landrace MBG-BRS0259 was uniformly resistant to race 4 and other eight landraces did not differ significantly from this, suggesting that there is race-specific resistance to race 4 in the accessions from NW Spain. In this work, sources of resistance to black rot were identified in different crops of *B. rapa* (turnips, turnip greens and turnip tops) and they can be grown directly after selection for resistance, or they can be donors of resistance genes to introgress in other germplasm or commercial varieties.

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Figure legends

Figure 1. Distributions of mean disease scores for races 6, 1 and 4 of *Xanthomonas campestris* pv. *campestris* among 191 landraces of *Brassica rapa*

Source of variation	df	Mean square	Pr > F
<u>Race6</u>			
Landrace	190	1.8450954	< 0.01
Error	2659	0.678228	
<u>Race 1</u>			
Landrace	190	4.143	< 0.01
Error	2141	0.609	
<u>Race 4</u>			
Landrace	190	28.933	< 0.01
Error	2114	5.763	

Table 1. Analyses of variance of mean disease scores for 191 landraces of *Brassica rapa* from northwestern Spain tested in greenhouse for resistance to races 6, 1, and 4 of *Xanthomonas campestris* pv. *campestris*.

Table 2. Mean disease score and number of resistant, partially resistant and susceptible plants for differential cultivars and the most outstanding resistant *Brassica rapa* landraces after inoculations of 191 accessions with races 6, 1 and 4 of *Xanthomonas campestris* pv. *campestris*

Accession [§]	Race 6			Mean disease score (1-9)	Race 1			Mean disease score (1-9)	Race 4			Species / Crop type [†]
	Mean disease score (1-9)	PR* (4<7)	S* (7-9)		R* (1<4)	PR* (4<7)	S* (7-9)		R* (1<4)	PR* (4<7)	S* (7-9)	
Differential cultivars												
Cob 60	8.0	0	15	9.0	0	0	16	1.8	16	0	0	<i>Brassica napus</i>
FBLM2	9.0	0	15	1.1	16	0	0	1.2	16	0	0	<i>Brassica juncea</i>
PIC 1	7.8	0	15	1.0	16	0	0	1.1	16	0	0	<i>Brassica carinata</i>
Seven Top Turnip	9.0	0	15	9.0	0	0	16	2.6	13	0	3	<i>Brassica rapa</i>
S x D ₁	9.0	0	15	9.0	0	0	16	8.3	0	0	16	<i>Brassica oleracea</i>
Wirosa F ₁	8.7	0	15	9.0	0	0	16	9	0	0	16	<i>Brassica oleracea</i>
R6 resistant landraces												
0362	6.0	1	1	7.9	0	0	12	6.5	2	2	9	turnip greens
0298	6.4	3	3	8.3	0	0	7	5.3	2	1	4	turnip greens
0441	6.8	2	6	9.0	0	0	13	7.0	2	0	8	turnip greens
0188	6.8	4	13	9.0	0	0	6	7.8	0	1	4	turnips

0183	6.8	3	10	9.0	0	0	15	7.5	2	0	8	turnip greens
0319	6.9	1	6	8.4	0	0	13	5.6	6	0	8	turnip greens
0225	7.0	3	12	8.6	0	0	14	6.1	4	0	7	turnip greens, turnip tops
0293	7.0	4	11	9.0	0	0	15	6.9	3	1	10	turnip greens, turnip tops
0350	7.0	0	3	8.8	0	0	10	3.4	6	2	1	turnip greens, turnip tops
0353	7.0	1	5	7.7	0	0	6	6.0	1	0	4	turnip greens
0354	7.0	1	7	8.5	0	0	14	7.6	1	2	11	turnip greens
0247	7.0	1	13	9.0	0	0	10	8.2	1	0	9	turnip greens
0344	7.0	2	11	9.0	0	0	13	8.8	0	0	13	turnip greens, turnip tops
0327	7.0	3	11	8.8	0	0	11	8.1	0	1	12	turnip greens, turnip tops
0215	7.0	1	9	7.2	0	0	4	5.3	1	2	3	turnip greens, turnip tops
R1 resistant landraces												
0479	7.8	0	16	6.7	0	4	7	3.6	8	2	2	turnip greens
0285	7.6	0	3	6.7	0	1	7	6.1	1	1	5	unknown
0427	7.7	0	12	6.8	0	3	10	6.4	0	4	10	turnip greens, turnip tops
0417	8.0	1	17	6.9	0	2	12	3.9	8	5	2	turnips

[illegible]

0550	7.3	1	13	8.3	0	2	10	5.0	4	1	5	turnip greens
LSD (5%)	0.6			0.6				2.0				

[§] The landrace identification is preceded by the prefix MBG-BRS.

* R: Resistant, PR: partially resistant, S: susceptible

† Taken from Padilla et al. (2005) and Cartea et al. (2012).

| Landraces in bold are potential sources of race-non-specific resistance.

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