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Breeding and development of *Globodera*-resistant potato varieties with long tuber shape and russet skin for production in the western United States

Potato cyst nematode (*Globodera pallida*) with florescent stain (PKH26) observed under the microscope (R Kooliyottil)

Introduction

Two species of potato cyst nematode (*Globodera rostochiensis* and *G. pallida*) have been identified in the U.S. and are under quarantine regulations, with a third newly identified species (*G. ellingtonae*) not categorized as a quarantined pest. Management of *G. rostochiensis* in the state of New York includes the use of resistant potato varieties, but resistance to *G. pallida* is not present in the primary varieties grown in the state of Idaho where *G. pallida* was identified in 2006. The primary market class of potato grown in Idaho and the western U.S. is characterized by varieties having long tuber shape and russet skin (Fig. 1). Potato varieties commercially available having *G. pallida* resistance typically have round tubers and white or yellow skin making them unsuitable for producers in the western U.S. Hybridizations have been conducted between *Globodera*-resistant breeding clones and varieties to generate PCN-resistant progenies with the long tuber type and russet skin desired for fresh-pack and fry processing in the western U.S. Sources of *Globodera* resistance being utilized in our program, the use of marker-assisted selection, and our progress in developing russet-skinned germplasm having long tuber shape with resistance to the three *Globodera* species are described.

Figure 1. Tubers of the potato variety 'Clearwater Russet' representing the russet skin and long tuber type of the predominate market class grown in the western U.S.

Material and Methods

Following identification of *G. pallida* in Idaho, an initial assessment of breeding germplasm maintained in the Aberdeen potato breeding program was conducted (See poster by Whitworth et al: *Host resistance in potato to three Globodera species*). Scottish variety, Eden, was identified as having moderate resistance to the *G. pallida* (Pa2/3) in Idaho, and high levels of resistance to *G. rostochiensis* and *G. ellingtonae*. Successful hybridization was achieved between Eden and PCN-susceptible Western Russet for the generation of progenies in a family designated A10915 (Fig. 2). Subsequently:

- 251 clones of family A10915 established in vitro.
- Screened for infestation response to 3 *Globodera* spp. with nematologists in ID, OR, and NY. Protocol as described in Whitworth et al. (2018).
- Screened using molecular markers associated with resistance to *G. pallida* (Contig237, HC, and 221R) and G. *rostochiensis* (57R associated with *H1* gene).
- Progenies grown in the field and selected for desired type for western U.S. production and nematode resistance based on greenhouse nematode assays and molecular marker data.
- Selected progenies intercrossed with PCN-resistant potato varieties from Europe and New Zealand to pyramid *G. pallida* resistance loci, thereby generating higher levels of *G. pallida* resistance.

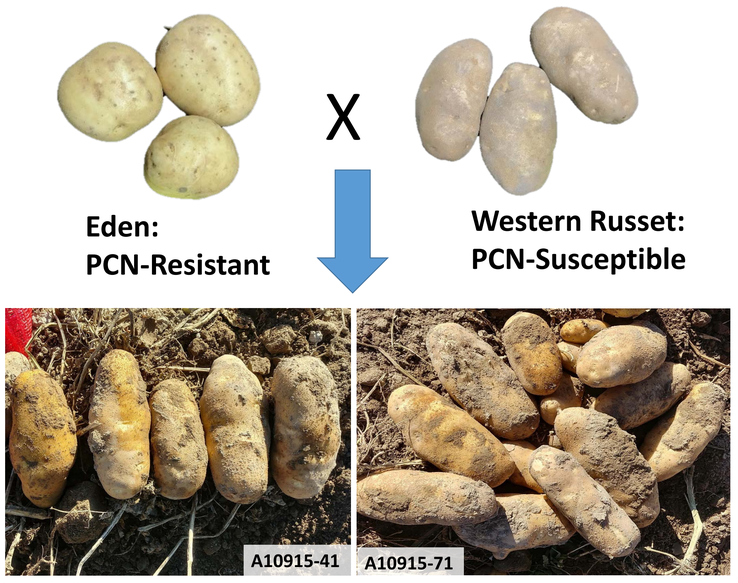

Figure 2. Intercrossing of *G. pallida* resistant 'Eden' with susceptible 'Western Russet' generated progenies (A10915-41 & -71) having the desired market characteristics of long tuber shape with russet skin and resistance to *G. pallida*, as well as resistance to *G. rostochiensis* and *G. ellingtonae*.

Results

Two hundred and fifty-one progeny of Eden and Western Russet (Family A10915) were successfully established *in vitro* and subsequently screened for the presence of known molecular markers associated with PCN resistance (Table 1). Eden, the PCN-resistant parent, had molecular markers Contig 237 and 57R associated with genes for resistance to *G. pallida* and *G. rostochiensis*, respectively. These markers were absent in susceptible parent, Western Russet. Segregation for these two markers among all A10915 progeny is summarized in Table 2. Based on the segregation in its progeny, Eden most closely fits a gene model in which it is simplex for $GpaIV^{s}_{adg}$ and duplex for the *H1* gene.

Two hundred and twenty-four progeny of family A10915 were planted in the field in 2017 with 31 (14%) selected for acceptable tuber type and presence of molecular markers associated with PCN-resistance—emphasis being on *G. pallida* resistance conferred by $GpaIV^{s}_{adg}$. This source of resistance to *G. pallida* effectively reduced the number of cysts in selected progeny relative to the susceptible parent, Western Russet (Fig. 3). Progeny also had the long tuber type and russet skin desired in western U.S production (Fig. 2), as well as the ability to process for French fries following 3.5 months storage at 7.2°C (data not presented).

Table 1. Assessment of parents, Eden and Western Russet, their progenies A10915-41 and -71 (Fig. 1) and the reference potato varieties, Russet Burbank, Innovator, and Tokio for presence (+) or absence (-) of molecular markers associated with PCN resistance.

PCN Resistance Genes/Loci:	$GpaIV^{s}_{adg}$	*Gpa5*	*Gpa2*	*H1*
Associated Markers:	Contig 237	HC	221R	57R
Parents and Progeny				
Eden	+	-	+	+
Western Russet	-	-	-	-
A10915-41	+	-	-	+
A10915-71	+	-	N.A.	+
Reference Potato Varieties				
Russet Burbank	-	-	-	-
Innovator	-	+	-	+
Tokio	+	+	+	+

Table 2. Segregation in family A10915 for molecular markers Contig 237 and 57R associated with $GpaIV^{s}_{adg}$ and *H1*, respectively. Both markers were contributed by parent 'Eden' with those markers being absent in parent 'Western Russet'

Molecular Marker Segregation in Family A10915	Present	Absent	Undetermined
Contig 237 associated with $GpaIV^{s}_{adg}$	**118**	**116**	**17**
57R associated with H1	**194**	**50**	**7**

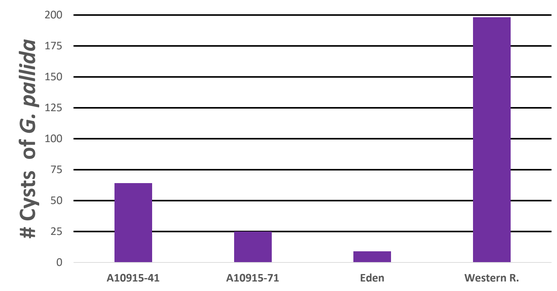

Figure 3. Average number of cysts of G. pallida in greenhouse challenges (2016 & 2017). Six replicates of each clone were challenged in each of the two years.

Discussion

PCN-resistant progeny of Eden and Western Russet were obtained having the long tuber shape and russet skin that characterizes the primary market class grown in the western U.S. The *H1* gene, present in a large percentage of progeny, confers resistance to *G. rostochiensis*, and is correlated with resistance to *G. ellingtonae* as well (Zasada et al. 2013; Whitworth et al. 2018).

Resistance to *G. pallida* was obtained in progeny of family A10915 with $GPaIV^{s}_{adg}$ and *Gpa2* conferring resistance based on Eden having molecular markers associated with both (Table 1). Higher levels of *G. pallida* resistance have been observed when $GPaIV^{s}_{adg}$ is combined with *Gpa5* (Dalton et al. 2013; Rigney et al. 2016). Pyramiding of *G. pallida* resistance loci was undertaken in 2017-18 with selected A10915 progeny being hybridized with thirteen *G. pallida*-resistant varieties requested and obtained from Europe and New Zealand. An assessment of 12 of these varieties for the presence of markers associated with known *G. pallida* resistance loci was conducted. The overwhelming majority (75%), based on the presence of associated molecular markers, had *Gpa5*, 25% had $GPaIV^{s}_{adg}$, 50% had *Gpa2*, with only one variety (Tokio) having the presence of all three *G. pallida* resistance genes (Table 1). Successful hybridizations were made between A10915 progeny and *G. pallida*-resistant varieties with the goal being to further pyramid *G. pallida* resistance genes and increase levels of *G. pallida* resistance. Selection will be made among populations for the long tuber shape, russet skin, and processing characteristics that typifies the primary market class grown in the western U.S.

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