Study of Wild Solanum *Species to Identify Sources of Resistance Against the Green Peach Aphid,* Myzus Persicae *(Sulzer)*

Alireza Askarianzadeh, A. Nicholas E. Birch, Gavin Ramsay & Mehrnoosh Minaeimoghadam

American Journal of Potato Research
The Official Journal of the Potato Association of America

ISSN 1099-209X

Am. J. Pot Res
DOI 10.1007/s12230-012-9277-9

Am. J. Pot Res
DOI 10.1007/s12230-012-9277-9

Study of Wild *Solanum* Species to Identify Sources of Resistance Against the Green Peach Aphid, *Myzus Persicae* (Sulzer)

Alireza Askarianzadeh · A. Nicholas E. Birch · Gavin Ramsay · Mehrnoosh Minaeimoghadam

Abstract The green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae), damages potato worldwide. In this study, we investigated 21 Commonwealth Potato Collection (CPC) accessions from seven wild *Solanum* species in order to identify sources of resistance against the green peach aphid. Test plants of wild potato species were grown from seed. After 4 weeks, 5 wingless adult aphids were put onto each test plant. The number of aphids was counted after 24 h, 7 and 10 days. At the second screening stage, plants were tested after 4 week's growth, using the same aphid bioassay as in the first stage screen. Results showed that the most resistant *Solanum* species to *M. persicae* were *S. trifidum* and *S. palustre* and the most susceptible species tested was *S. sanctae-rosae.* Stability of the detected aphid resistance during plant development was measured by the correlation of repeated tests S. *jamesii* (CPC 7166) and *S. trifidum* (CPC 7123) were significantly more correlated than other accessions tested. The number of glandular hairs on these two resistant species was low and medium respectively. Therefore, resistance of these CPC accessions does not appear to depend on the presence of glandular hairs. Based on glasshouse tests, these two CPC accessions may be useful for novel aphid resistance traits in potato to *M. persicae*.

Resumen El áfido verde del durazno, *Myzus persicae* (Sulzer) (Homoptera: Aphididae), daña a la papa en todo el mundo. En este estudio, investigamos 21 introducciones de la colección de papa de la Comunidad Británica (CPC) de siete especies silvestres de *Solanum* a fin de identificar fuentes de resistencia contra el áfido verde del durazno. Se cultivaron las plantas sujetas a la prueba de las especies silvestres de papa a partir de semilla. Después de cuatro semanas, se pusieron cinco adultos no alados de los áfidos sobre cada planta de prueba. Se contó el número de áfidos después de 24 hs, 7 y 10 días. En la segunda etapa del ensayo, se probaron las plantas después de cuatro semanas de crecimiento, usando el mismo bioensayo de áfidos que en el primero. Los resultados mostraron que las especies mas resistentes de *Solanum* a *M. persicae* fueron *S. trifidum* y *S. palustre*, y la especie mas susceptible probada fue *S. sanctaerosae*. La estabilidad de la resistencia al áfido detectada durante el desarrollo de la planta se midió mediante la correlación de pruebas repetidas. *S. jamesii* (CPC 7166) y *S. trifidum* (CPC 7123) estuvieron mas significativamente correlacionadas que otras introducciones probadas. El número de pelos glandulares de estas dos especies resistentes fue bajo y medio, respectivamente. De aquí que la resistencia de estas introducciones de la CPC no parece depender de la presencia de los pelos glandulares. Con base a pruebas de invernadero, estas dos introducciones de la CPC pudieran ser útiles para caracteres de resistencia novedosa a áfidos en papa a *M. persicae*.

A. Askarianzadeh (✉)
Plant Protection Department, College of Agricultural Sciences,
Shahed University,
Tehran, Iran
e-mail: askarianzadeh@shahed.ac.ir

A. N. E. Birch · G. Ramsay
The James Hutton Institute,
Dundee DD2 5DA, UK

A. N. E. Birch
e-mail: Nick.Birch@hutton.ac.uk

G. Ramsay
e-mail: Gavin.Ramsay@hutton.ac.uk

M. Minaeimoghadam
Plant Protection Department, Agricultural College,
Chamran University,
Ahwaz, Iran
e-mail: Minaei_mehrnoosh@yahoo.com

Published online: 24 October 2012

Keyword *Myzus persicae* · Resistance · *Solanum* species · Glandular hairs

Introduction

The potato, *Solanum tuberosum* L. (Solanaceae) ranks as the fourth most important food crop in the world after wheat, rice and maize. It is grown from 55° N to 50° S at altitudes between sea level up to 5,000 m and under a wide range of temperature and humidity regimes (Mendoza 1994; Pandey and Kaushik 2003). The potato is an annual herbaceous dicotyledonous plant that reproduces asexually by tubers, the only edible part of the plant. The plant also flowers and forms small green or purplish-green berries in which the true potato seeds (TPS) are produced. True potato seeds are used for breeding and in recent years also for propagation. Over 2,000 species have been described in the genus *Solanum* (Gopal et al. 2003). There are many wild species of potato, of which a sub-sample was tested in this experiment (Table 1).

The genus *Solanum* is vulnerable to attack by a large number of pests and pathogens that individually and in combination can cause severe reductions in the yield and quality of *Solanum* crops. In each region and production system, however, there are certain key pests that need to be monitored for control. In seed tuber production systems, for instance, the most important of pests are usually aphid vectors of potato viruses, particularly the green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae) (Raman and Radcliff 1992). Plant viruses are comprise an important group of potato infecting pathogens of which some, such as *potato leaf roll virus* (PLRV), *potato virus Y* (PVY) and *potato virus X* (PVX) are among the most significant biotic yield constraints of potato crops (Mendoza and Sawyer 1985).

Aphids damage crops both directly by their feeding and by spreading viruses. In the case of *M. persicae*, the damage it does directly is minor compared to the damage due to the viruses it transmits. Aphicides have proved very effective at protecting crops against aphids and preventing the spread of some aphid-borne viruses. However, the constant and increasing use of pesticides has caused new problems such as ecological side-effects, the danger of selection for insecticide-resistant aphids and destruction of predators. Moreover, the success of aphicides in controlling aphids has overshadowed the value of plant resistance against aphids. Therefore, the use of plant genotypes resistant against either viruses or vectors or against both viruses and vectors can reduce their effects on crops without having the problems resulting form the repeated application of pesticides. When there are only one or few vector species and several viruses, breeding for resistance to the vector is simpler and more advantageous than to viruses (Gibson and Plumb 1977). It should be noted that aphid resistance is not an effective management tool for viruses such as PVY

Table 1 Accessions of wild *Solanum* species used in this study

Species	Accession	Shared origin with USDA accessions
S. jamesii	CPC 3850	From a cross with CPC 1439 (PI 195190) [a]
S. jamesii	CPC 7166	PI 275169
S. jamesii	CPC 5845	
S. ehrenbergii(*S. cardiophyllum*)	CPC 5908	
S. ehrenbergii(*S. cardiophyllum*)	CPC 7507	
S. chomatophilum	CPC 3558	
S. chomatophilum	CPC 5855	
S. chomatophilum	CPC 5861	
S. chomatophilum	CPC 7139	
S. sanctae-rosae	CPC 3269	
S. sanctae-rosae	CPC 7204	
S. sanctae-rosae	CPC 7325	
S. palustre (=*S. brevidens*=*S. etuberosum*)	CPC 1576	
S. palustre (=*S. brevidens*=*S. etuberosum*)	CPC 2451	
S. palustre (=*S. brevidens*=*S. etuberosum*)	CPC 7034	
S. palustre (=*S. brevidens*=*S. etuberosum*)	CPC 7134	
S. trifidum	CPC 7123	PI 255536 [1.]
S. trifidum	CPC 7125	PI 283104 [1.]
S. infundibuliforme	CPC 2479	
S. infundibuliforme	CPC 7051	
S. infundibuliforme	CPC 7249	

[a] PI accessions have been recorded in the USDA database as possessing possible resistance to *M. persicae*

that are mechanically transmitted by multiple aphid species, including many species that do not colonize potatoes at all.

In this study, several wild *Solanum* species were investigated to identify sources of resistance against the green peach aphid, *M. persicae*.

Materials and Methods

Rearing M. Persicae In order to rear aphids, several pots of the susceptible potato cv Desiree were put in two insect rearing cages and adult aphids placed on leaves. The cages were maintained in a constant environment room at 20 °C and 16L8D hour photoperiod respectively for the population of aphids increased. During the screening program, adult aphids were taken from these stock plants for inoculation onto test plants.

List of Commonwealth Potato Collection (CPC) Accessions A set of accessions were assembled from the CPC held at the James Hutton Institute in the UK using species which have had putative resistance recorded previously (Table 1). In some cases CPC accessions could be linked to accessions in the United States Department of Agriculture collection at the same locality and time from a comparison of collector numbers of accessions in both collections.

Rearing Material Plant For the first screen, about 25 seeds from each CPC accession were sown in 10 cm pots. Control seeds from self-pollinated cv Desiree were also sown. After 2 weeks, seedlings were transferred individually to single pots. At the second screen, accessions that showed segregation for resistance were re-sown in batches of 100 seeds.

The First Aphid Resistance Screen Screening was delayed until plants were about 4 weeks old. Ten healthy plants were selected and transferred into another glasshouse for screening. The distance between pots was 20 cm. Five wingless adult aphids were put on each plant at day 0. After 24 h, the number of settled aphids was counted aphids on each plant. Plants that had less than 5 aphids were re-inoculated so that the total of aphids on each plant became 5. After 24 h the plants were carefully watered by hand daily to avoid disturbing feeding aphids. After 7 and 10 days, the following measurements were recorded: Number of winged adults, number of wingless adults, number of winged nymphs, number of wingless nymphs (all aphids were counted), and plant development stage (number of leaves each plant).

The Second Aphid Resistance Screen Selected CPC lines from the first screen were re-screened using the same procedure (e.g. five aphids put on each plant and after 24 h were checked then after 7 and 10 days were measured the same variables above on 10 plants) (Table 2).

Statistical Analysis Data were analyzed using ANOVA and means were compared using Duncan's test in the SPSS statistical program (Green et al. 2000). For investigating the stability of genetic resistance in the tested CPC accessions, correlations were calculated between the first and second screening for each CPC accession based on numbers of aphids per plant on day 10 (Table 3).

Status of Leaf Hairs in Selected CPC Accessions For the assessment of this plant trait, 10 fully expanded, healthy leaves from each CPC accession were viewed with a binocular microscope at x50 magnification. A four-stage scale was used to score hair density of short, long and glandular hairs (Nil=without hairs, low=1–10, medium=11–20 and high>21 hairs per viewing area).

Results and Discussion

Screening Experiments The mean number of aphids on 10 plants from each CPC accession at the first and second aphid resistance screening tests is shown in Table 2. The most resistant CPC accessions belonged to the species *S. trifidum* and *S. palustre* (=*S. brevidens*=*S. etuberosum*). The most susceptible CPC accessions screened belonged to the species *S. sanctae-rosae*. Based on the criteria published by Davis (1971), the correlation coefficient analysis showed that only CPC accessions, *S. jamesii* (CPC 7166) and *S. trifidum* (CPC 7123), had significantly very strong (r=0.88, P<0.01) and relatively strong (r=0.68, P<0.05) correlations, respectively. The numbers of aphids in the second trial on *S. jamesii* 7166 and *S. trifidum* 7123 did not differ significantly from numbers on *S. tuberosum*, but only correlations on *S. jamesii* 7166 and *S. trifidum* 7123 between trials 1 and 2 were significant that indicating heritability. In another published study on the characterization of *Solanum chomatophilum* resistance to two aphid potato pests, *Macrosiphum euphorbiae* (Thomas) and *M. persicae* resulted in congruent resistance levels at the accession level for each of the two aphid species, supporting the use of any of them in *S. chomatophilum* resistance screening (Pompon et al. 2010). PI243340 was resistant to both aphid species, while PI365324 and PI310990 were also resistant to *M. euphorbiae* and *M. persicae*, respectively. A comprehensive field and greenhouse study was undertaken to assess 49 commercial potato cultivars (*S. tuberosum* including: All Blue, All Red, Alturas, Aracy, Atlantic, Augsberg Gold, Bannock Russet, Cribe, Carola, Cascade, Chieftain, Dark Red Norland, Denali, Early Ohio, Epicure, Gem Russet, German,

Table 2 Results of data analysis and mean (± SD) number of aphids on CPC lines after 24 h, 7 days and 10 days

Species	CPC	Mean of no. aphids in screening 1			Mean of no. aphids in screening 2		
		24 h	7 Day	10 Day	24 h	7 Day	10 Day
S. palustre	1576	4.8 ± 0.4	15.9 ± 10.1	11.5 ± 11.8a[a]	3.8 ± 1.3	11.8 ± 14.3	5.9 ± 4.6a
S. palustre	7034	4.6 ± 3.7	9.7 ± 4.2	14.8 ± 12.5ab	4.3 ± 0.8	16.7 ± 18.5	21.0 ± 22.9ab
S. palustre	2451	4.6 ± 0.7	16.3 ± 8.2	17.0 ± 14.1a	3.5 ± 1.1	4.3 ± 3.4	5.6 ± 5.3ab
S. ehrenbergii	5908	1.8± 1.3	13.2 ± 6.2	18.1 ± 12.6a	4.2 ± 1.5	40.3 ± 35.6	51.3 ± 41.8cd
S. jamesii	3850	3.6 ± 1.0	13.8 ± 8.7	18.3 ± 15.5a	4.2 ± 1.4	35.1 ± 19.6	56.5 ± 22.3d
S. ehrenbergii	7507	3.1 ± 1.4	16.4 ± 6.6	19.1 ± 7.3a	0.8 ± 1.2	0.2 ± 0.4	0.3 ± 0.7ab
S. trifidum	7125	2.9 ± 1.3	13.0 ± 4.6	19.8 ± 8.0a	0.4 ± 0.7	1.2 ± 1.5	0.8 ± 1.2ab
S. sanctae-rosae	7325	3.5 ± 1.0	10.4 ± 6.0	20.8 ± 11.4d	4.8 ± 0.6	68.5 ± 33.1	112.2 ± 56.8ab
S. palustre	7134	3.4 ± 1.3	14.5 ± 8.9	21.2 ± 16.2a	3.1 ± 1.1	14.7 ± 9.7	10.2 ± 5.6ab
S. infundibuliforme	2479	2.3±1.4	19.1 ± 8.6	21.6 ± 11.5a	3.9 ± 1.4	11.3 ± 10.3	18.9 ± 21.4ab
S. jamesii	7166	2.7 ± 0.8	17.2 ± 9.4	24.0 ± 16.7ab	3.1 ± 1.8	15.5 ± 21.9	28.1 ± 28.3ab
S. infundibuliforme	7249	3.7 ± 1.3	20.0 ± 8.3	25.9 ± 10.7a	-	-	-
S. trifidum	7123	3.8 ± 1.2	16.1 ± 8.4	26.0 ± 15.6a	3.1 ± 1.4	4.1 ± 6.7	2.6 ± 5.0ab
S. sanctae-rosae	7204	4.2± 0.8	15.8 ± 6.9	28.9 ± 19.5bc	-	-	-
S. chomatophilum	3558	3.7 ± 1.3	18.1 ± 7.6	31.0 ± 19.5c	4.4 ± 0.8	31.8 ± 16.4	63.1 ± 44.5ab
S. tuberosum	-	4.1 ± 1.1	28.6 ± 13.9	34.9 ± 21.4bc	4.1 ± 1.3	21.3 ± 16.5	42.4 ± 29.5bc
S. chomatophilum	5855	3.5 ± 1.0	16.6 ± 5.8	38.9 ± 13.0e	-	-	-
S. sanctae-rosae	3269	4.3 ± 0.7	24.0 ± 6.8	41.2 ± 19.1e	-	-	-
S. chomatophilum	5861	4.2 ± 1.0	21.6 ± 6.6	43.1 ± 17.2e	-	-	-
S. infundibuliforme	7051	3.1 ± 1.6	16.0 ± 10.4	47.4 ± 25.6f	-	-	-
S. chomatophilum	7139	3.5 ± 0.7	18.0 ± 17.0	48.0 ± 19.1f	-	-	-
S. jamesii	5845	4.1 ± 0.7	23.6 ± 12.3	49.1 ± 27.4f	-	-	
F (df)				16.7 (21)**			4.6 (13)**
P- value				0.001			0.001

[a] Based on Duncan's test, means within a column followed by the same letters are not significantly different ($P<0.05$)

Butterball, Gold Nugget, Goldrush, Green Mt, Inca Gold, Irish Cobber, Ivory Crisp, Katahdin, Kennebec, King Edward, Loman, New Leaf (RB), Pimpernel, Pink Pearl, Princess Laraette, Red La Soda, Red Pontiac, Red Thumb, Red Warba, Reda, Rose Gold, Ruby Crescent, Russet Burbank, Russet Norkottah, Sebago, Shepody, Sieglinde, Snowdrift, Sto Amor, Summit Russet, Triumph, Yellow, Finn, Yukon Gold cultivars), primarily of North American origin, for resistance to green peach aphid, *M. persicae*, and potato aphid, *M. euphorbiae* (Thomas). Cultivars were found to show considerable differences in resistances to each aphid species, but these resistances were not significantly correlated ($r=0.032$) (Jeffrey et al. 2007).

Status of Hairs in CPC Lines Glandular hairs are one of the aphid resistance factors in *Solanum*. However, the genetic basis of glandular hair formation is complex and difficult to select for in breeding programs (Alvarez et al. 2006). Our results indicated that the species *S. palustre* had the highest number of glandular hairs and species *S. ehrenbergii* and *S. chomatophilum* lacked glandular hairs. The number of

Table 3 Correlation coefficients number aphids (after 10 days) between the first and the second screening of selected CPC's

Species	CPC No.	P-value	Correlation coefficients
S. palustre	1576	0.45	0.27
S. palustre	7034	0.44	0.27
S. palustre	2451	0.07	0.59
S. ehrenbergii	5908	0.56	0.21
S. jamesii	3850	0.16	0.48
S. ehrenbergii	7507	0.20	−0.43
S. trifidum	7125	0.66	−0.16
S. sanctae-rosae	7325	0.31	0.35
S. palustre	7134	0.99	−0.007
S. infundibuliforme	2479	0.19	0.45
S. jamesii	7166	0.001	0.88**
S. trifidum	7123	0.029	0.68*
S. chomatophilum	3558	0.93	0.032
S. tuberosum (Desiree seedlings)	-	0.89	−0.05

Correlation coefficients with ** and * ($P<0.01$ and $P<0.05$, respectively) are significantly different from zero

Table 4 Status of hairs in CPC lines (nil=without hairs, low=1–10, medium=11–20 and high>21 hairs)

Species	CPC. No.	Short hairs	Long hairs	Glandular hairs
S. palustre	1576	High	High	High
S. palustre	7034	Medium	Medium	Medium
S. palustre	2451	Medium	Medium	High
S. ehrenbergii	5908	Medium	Nil	Nil
S. jamesii	3850	Low	Nil	Moderate
S. ehrenbergii	7507	Low	Low	Nil
S. trifidum	7125	High	Low	Nil
S. sanctae-rosae	7325	Nil	Medium	Medium
S. palustre	7134	High	High	High
S. infundibuliforme	2479	Medium	Medium	Medium
S. jamesii	7166	Nil	Low	Low
S. infundibuliforme	7249	-	-	-
S. trifidum	7123	Nil	Medium	Medium
S. sanctae-rosae	7204	-	-	-
S. chomatophilum	3558	Nil	Nil	Nil
S. tuberosum (Desiree)	-	Low	Low	Low
S. chomatophilum	5855	-[a]	-	-
S. sanctae-rosae	3269	-	-	-
S. chomatophilum	5861	-	-	-
S. infundibuliforme	7051			
S. chomatophilum	7139	-	-	-
S. jamesii	5845			

[a] They were not tested

glandular hairs for the two most resistant CPC accessions, *S. jamesii* (CPC 7166) and *S. trifidum* (CPC 7123), were low and medium respectively (Table 4).

Based on resistance to aphids, *S. palustre* was also more resistant than *S. ehrenbergii* and *S. chomatophilum.* This suggests that in *S. palustre,* the presence of glandular hairs may be a resistance factor for *M. persicae.* The stability of resistance during plant growth (young and older plants) for *S. jamesii* (CPC 7166) and *S. trifidum* (CPC 7123) was greater than for the other wild *Solanum* species assessed. The number of glandular hairs for these two recent CPC accessions was low and medium respectively. This result indicates that the detected aphid resistance of these CPC accessions is not related to the presence of dense glandular hairs and may be due to a resistance mechanism based on an R-gene of use in future plant breeding. Therefore, these two wild *Solanum* species are potentially useful in studies to identify molecular markers of potato for novel mechanisms of resistance to *M. persicae* in potato. In tomato for example, the *Mi-1* gene is a nucleotide-binding LRR-type R gene conferring resistance to both the nematode *Meloidogyne incognita* and the potato aphid *M. euphorbiae* (Vos et al. 1998). Future work should focus on the possibility that similar genes exist in wild potato species and that they could confer resistance to the main virus-transmitting aphid pest *M. persicae*.

Acknowledgments This work was conducted at James Hutton Institute/Dundee, UK. The authors thank the Scottish Government's RESAS and the Iranian Ministry of Agriculture (Sugarcane Development & Industrial By-Product Co.) for funding.

References

Alvarez, A.E., W.F. Tjallingii, E. Garzo, V. Vleeshouwers, M. Dicke, and B. Vosman. 2006. Location of resistance factors in the leaves of potato and wild tuber-bearing *Solanum* species to the aphid *Myzus persicae*. *Entomologia Experimentalis et Apllicata* 121(2): 145–157.

Davis, J.A. 1971. *Elementary survey analyses*, 325. Englewood cliffs: Prentice-Hall.

Gibson, R.W., and R.T. Plumb. 1977. Breeding plants for resistance to aphid infestation. In *Aphids as virus vectors*, ed. K.F. Harris and K. Maramorosch, 473–500. London: Academic.

Gopal, J., V. Kumar, and S.K. Sandhu. 2003. Biosystematics and genetic resources of potato. In *The potato: production and utilization in sub-tropics*, ed. S.M.P. Khurana, P.S. Naik, J.S. Minhas, and S.K. Pandey, 31–47. New Delhi: Mehta Publishers.

Green, S.B., N.J. Salkind, and T.M. Akey. 2000. *Using SPSS for windows: analyzing and understanding data*, 2nd ed. USA: Prentice Hall.

Jeffrey, A., D. Edward, B. Radcliffe, and D.W. Ragsdale. 2007. Resistance to green peach aphid, *Myzus persicae* (Sulzer), and potato aphid, *Macrosiphum euphorbiae* (Thomas), in potato cultivars. *American Journal of Potato Research* 84(3): 259–269.

Mendoza, H.A., and R.L. Sawyer. 1985. The breeding program at the international potato center. In *Progress in plant breeding*, ed. G.E. Russell, 117–137. UK: Butterworths.

Mendoza, H.M. 1994. Development of potato with multiple resistances to biotic and abiotic stresses: the international potato centre approach. In *Advances in potato pests biology and management*, ed. G.W. Zehnder, R.K. Powelson, and K.V. Raman, 627–642. St. Paul: APS Press.

Pandey, S.K., and S.K. Kaushik. 2003. Origin, evolution, history and spread of potato. In *The potato: production and utilization in sub-tropics*, ed. S.M.P. Khurana, P.S. Naik, J.S. Minhas, and S.K. Pandey, 15–24. New Delhi: Mehta Publishers.

Pompon, J., D. Quiring, P. Giordanengo, and Y. Pelletier. 2010. Characterization of *Solanum chomatophilum* resistance to two aphid potato pests, *Macrosiphum euphorbiae* (Thomas) and *Myzus persicae* (Sulzer). *Crop Protection* 29(8): 891–897.

Raman, K.V., and E.B. Radcliff. 1992. Pest aspects of potato production, part 2, insect pests. In *The potato crop, the scientific basis for improvement*, ed. P. Harris, 477–506. London: Chapman & Hall publishers.

Vos, P., G. Simons, T. Jesse, J. Wijbrandi, L. Heinen, R. Hogers, A. Frijters, J. Groenendijk, P. Diergaarde, M. Reijans, J. Fierens-Onstenk, M. de Both, J. Peleman, T. Liharska, J. Hontelez, and M. Zabeau. 1998. The tomato *Mi-1* gene confers resistance to both root-knot nematodes and potato aphids. *Nature Biotechnology* 16: 1365–1369.