Pak. J. Phytopathol., Vol. 31 (02) 2019 – 147-154 DOI: 10.33866/phytopathol.031.02.0514

Official publication of Pakistan Phytopathological Society
Pakistan Journal of Phytopathology
ISSN: 1019-763X (Print), 2305-0284 (Online)
http://www.pakps.com

AGGRESSIVENESS AND HOST ADAPTATION OF SOME ALGERIAN *PHYTOPHTHORA INFESTANS* CLONAL LINEAGE ON POTATO AND TOMATO

[a]Sihem Belkhiter*, [b]Lyes Beninal, [a]Hassiba Khedidji, [a]Amira Krimi, [a]Zouaoui Bouznad

[a] Laboratoire de Phytopathologie et Biologie Moléculaire, Département de Botanique, Ecole Nationale Supérieure Agronomique (ENSA) – 16200 El Harrach – Algiers-Algeria.
[b] CNCC El Harrach, Algiers, Algeria.

A B S T R A C T

Late blight caused by *Phytophthora infestans* (Mont.) de Bary is one of the most important biotic constraints to Solanaceae crops. This investigation was carried out to study host adaptation of some *P. infestans* clonal lineages present in Algeria. A total of 36 isolates from different clonal lineages were tested, including EU_23_A1 (n=28), EU_2_A1 (n=3) and EU_13_A2 (n=5), cross inoculation were carried out on potato and tomato leaflets, aggressiveness components such as incubation period, latency period, lesion area and sporangia production were assessed. The results indicated that isolates of EU_23_A1 and EU_2_A1 clonal lineage showed no significant differences in lesion size on both hosts, but sporulated more abundantly on tomato than on potato. However, EU_13_A2 isolates were more aggressive on potato than on tomato, these results suggest that the *P. infestans* population in Algeria is subdivided into potato specialist isolates such as the EU_13_A2 lineage, which attacked only potato under field conditions and generalists such as EU_23_A1 and EU_2_A1 lineages which are more adapted to tomato, but attack potato under field conditions. This study is the first in Algeria to identify host adaptation among *P. infestans* clonal lineages. These data can be useful in developing sustainable control strategies to treat both hosts, especially tomato, which contribute to the production of secondary inoculum in order to reduce the risk of major late blight epidemics.

Keywords: Host specialization, Late blight, *Solanum lycopersicum, Solanum tuberosum*

INTRODUCTION

Potato *Solanum tuberosum* (L.), and tomato *Solanum lycopersicum* (L.), occupy an important place in Algerian agricultural economy. Potato is grown during three seasons in 156 thousand ha with an annual production of 5 million tons (FAOSTAT, 2016). Whereas, tomato is grown all year-round in 22 thousand ha, in plastic house and in open fields with an annual production of 1 million tons (FAOSTAT, 2016); most part of its production is located in the northern regions, including Biskra in the south.

Phytophthora infestans is the major biotic constraint to these crops in Algeria. Since 2007, severe late blight epidemics have been recorded annually, in northern regions where climatic conditions are very favourable for late blight development, infection can occur at any time during the growing season. This Oomycete pathogen is heterothallic with two mating types A1 and A2, which can induce sexual reproduction and oospores formation (Mizubuti and Fry, 1998). The pathogen infects all above ground parts of the plant, even tomato seeds and potato tubers. Under favourable conditions black lesions develop on leaves and stems; the underside of leaf is covered with a fine white mycelium with sporangiophores and sporangia which are rapidly disperse by wind or rain (Akhtar *et al.,* 2012; Nowicki *et al.,* 2012). The infected field can be destroyed in seven to ten days due to the pathogen's ability to spread rapidly (Fry, 2008).

Potato and tomato are the main hosts infected by *P. infestans* (Seidl Johnson and Gevens, 2014), this specific ecological situation in which two or more potential hosts are grown in the same environment leads to important

Submitted: September 01, 2019
Revised: December 01, 2019
Accepted for Publication: December 19, 2019
* Corresponding Author:
Email: belkhitersihem@gmail.com

epidemiological consequences; the inoculum can move easily from one host to the other and vice versa (Erselius *et al.,* 1997). It is essential to determine the host adaptation among new *P. infestans* clonal lineages in order to have an optimal integrated late blight management (Seidl Johnson and Gevens, 2014).

Some specific *P. infestans* lineages are usually associated with only a single host. In Brasil and Ecuador, the BR_1 lineage (A2 mating type) and EC_1 lineage (A2 mating type) were associated only with potato; while US_1 lineage (A1 mating type) with tomato, respectively (Oyarzun *et al.,* 1998; Reis *et al.*, 2003; Maziero *et al.,* 2009; de Miranda *et al.,* 2010). However, some clonal lineages in USA, infect both potato and tomato, such as US_11 (A1 mating type), US_22 (A2 mating type), and US_23 (A1 mating type) (Blandón-Díaz *et al.,* 2012; Danies *et al.,* 2013).

Most of *P. infestans* genotypes present in Algeria originate from Europe. The EU_ 13_ A2 is the current highly aggressive lineage; which had been detected in many potato fields in Europe, Africa and Asia (Naveed *et al.,* 2017). It has been reported in Europe since 2004 (Cooke *et al.,* 2012). While, EU_2_A1 was the main genotype in France until 2006 (Corbière *et al.*, 2015). However, EU_23_A1 has been reported on tomato crops in Great Britain (Stroud et al., 2016). It seems that this clonal lineage has the same SSR profile as the US_23 genotype, which is very aggressive on potato and tomato crops in USA. In Algeria, isolates of EU_13_A2 clonal lineage were detected only on potato (Beninal *et al.,* 2008; Corbière *et al.,* 2015; Rekad *et al.*, 2017). However, isolates widely found on tomato belong to A1 mating type such as EU_2_A1 and EU_23_A1 (Corbière *et al.,* 2015).

The purpose of this study is to clarify the possibility of host adaptation of some Algerian *P. infestans* clonal lineages by aggressiveness tests on detached leaflets of potato and tomato using cross-inoculation under controlled conditions. The aggressiveness components such as incubation period, latency period, lesion area and sporangia production were quantified which revealed the effect of the original host on isolate aggressiveness.

MATERIALS AND METHODS

Plant material: Commercial seeds of tomato cv. Marmande and potato cv. Spunta have been used in this study. Those were provided by the Vegetables Institute (ITCMI) located at Staoueli (Algiers) Both cultivars are very susceptible to late blight. Plants were grown in pots filled with a mixture of 50% disinfected soil and 50% compost, under glasshouse with regulated temperature between 25°C during day and 20°C during night. Leaflets of the same stage were harvested after nine weeks for pathogenicity tests.

***Phytophthora infestans* isolates:** In total, 36 isolates were used in this study (Table 1), collected from the main tomato and potato production regions around Algiers and other areas such as Tipaza, Boumerdès, Mascara, Guelma, Medea, Bouira, Tizi ouzou during 2013 to 2016. Isolates were obtained from infected potato and tomato stems, by isolation technique, small pieces of infected fresh samples (leaf, stem and fruit) were placed on potato slices, these were put in closed Petri dishes and incubated at 18°C in the dark. After 4 or 5 days, mycelium formed was purified by repetitive transfers in pea agar medium amended with antibiotics (30 mg of Rifamycine and 200 mg of Ampicillin); pure cultures were maintained at 18°C.

The isolates have been characterized genotypically using 17 SSR loci (Belkhiter *et al.,* 2017). The clonal lineages were named according to the classical European nomenclature established by Cooke *et al.,* (2012). We used 5 isolates of EU_13_A2 clonal lineage, 3 isolates of EU_2_A1 clonal lineage and 28 isolates of EU_23_A1 clonal.

Inoculation: Sporangial suspensions were prepared by flooding 3-weeks old *P. infestans* cultures with 5 ml of sterilized distilled water. The concentration of sporangia was adjusted to 5 x 10^4 sporangia ml^{-1} and kept at 4°C for 3 h to promote zoospores release. All detached leaflets were inoculated with a 20 µl sporangial suspension on the abaxial side. Six leaflets were inoculated for each isolates and placed on a moist sterilized filter paper in Petri dishes and incubated at 20°C in a growing chamber during a 16 h light, 8h dark period.

Aggressiveness evaluation: Aggressiveness components such as incubation period expressed by daily observation of the first symptoms; latency period was determined by daily observation of the first sporangia production were assessed. Lesion area was measured five days post inoculation, using the formula reported by Vleeshouwers *et al.* (2000) as follows: the lesion area =1/4 x π x length x width of necrosis. Sporangia production was scored seven days post inoculation, infected leaflets were washed with 10 ml of stzed distilled water and sporangia were counted using Malassez cell, expressed as the number of sporangia ml^{-1}.

P. infestans is an oomycete that has the ability to produce sporangia. Under microscope the sporangia have an ovoid shape containing swimming cells called zoospores. This asexual form is responsible for inoculum spread.

Table 1. Characteristics of isolates used in this study, collected during 2013 - 2016 from different Algerian regions on infected potato and tomato.

Region	Locality	Year of Sampling	Number of isolates	Original host	Clonal lineages
Algiers	Staoueli	2014,2015	4	Tomato	EU_23_A1
		2015	2	Potato	EU_13_A2
		2014	1	Tomato	EU_2_A1
	El Harrach	2014	1	Potato	EU_2_A1
		2016	2	Tomato	EU_23_A1
	Bab Ezzouar	2016	1	Potato	EU_23_A1
	Zeralda	2014	4	Tomato	EU_23_A1
Tipaza	Chenoua	2014,2015	14	Tomato	EU_23_A1
		2015	1	Potato	EU_23_A1
Boumerdès	Khemis el khechna	2015	1	Potato	EU_23_A1
Mascara	_	2015	1	Potato	EU_23_A1
Guelma	_	2013	1	Potato	EU_13_A2
Medea	Galb el kebir	2015	1	Potato	EU_13_A2
Bouira	Ain bessam	2015	1	Potato	EU_13_A2
Tizi ouzou	Soumaa	2014	1	Potato	EU_2_A1

DATA ANALYSIS

The data for aggressiveness components were subjected to an analysis of variance (ANOVA) and the mean values were compared using the Tukey HSD test with $\alpha = 0.05$. All Statistical analyses were performed using the software R v.3.3.2. (The R Foundation for Statistical Computing, 2016).

RESULTS

Symptoms assessment: All isolates tested were pathogenic to both potato and tomato. However, *P. infestans* clonal lineages don't produce the same kind of symptoms (Figure 1). EU_23_A1 isolates were very biotrophic on tomato and showed lesions difficult to delimit on leaflets with abundant sporulation after five days post inoculation (Figure 1A). On potato, this lineage produced dark lesions with less sporulation. In contrast, EU_13_A2 produced a darker necrosis; with less abundant sporulation on tomato leaflets. Unlike potato leaflets, EU_13_A2 isolates showed large lesions with abundant sporulation (Figure 1B).

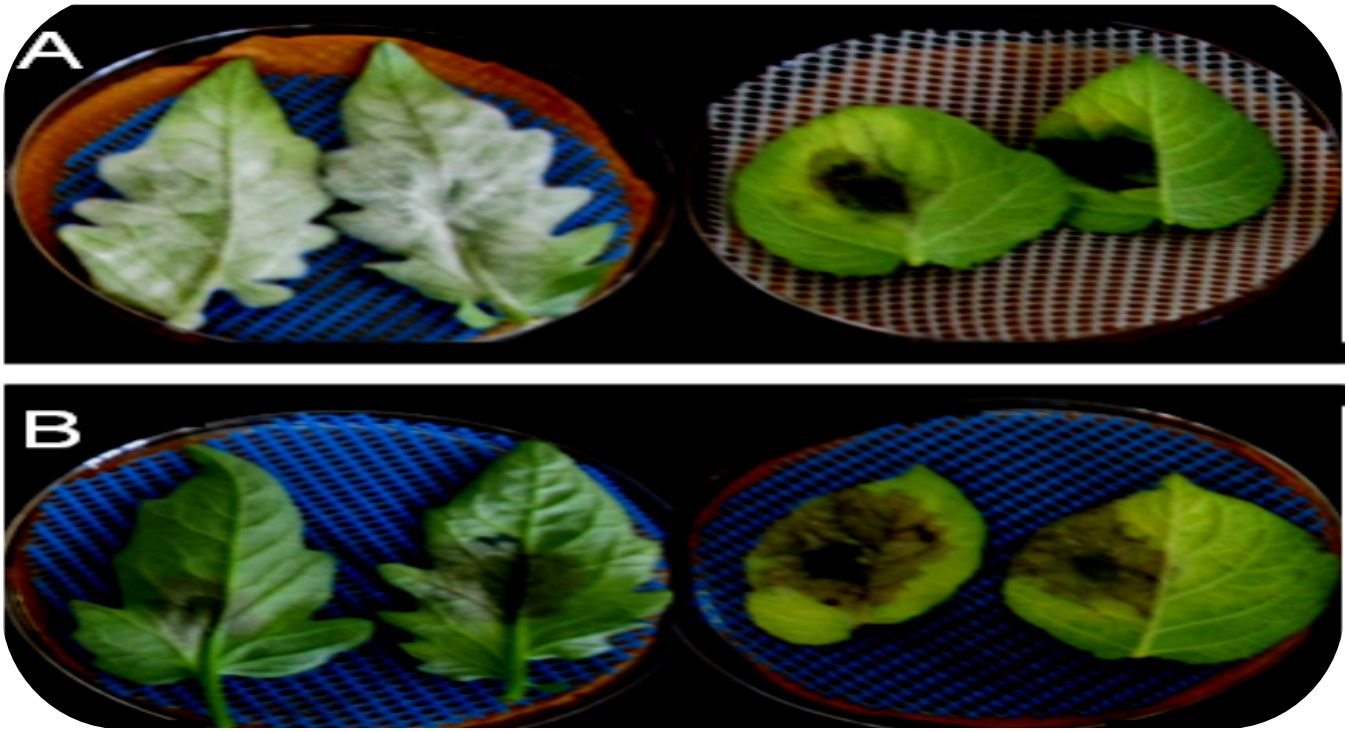

Figure 1. Symptoms of tomato and potato isolates on detached leaflets of both hosts. (A) Lesions produced by isolate of EU_23_A1 clonal lineage. (B) Lesions produced by isolates of EU_13_A2 clonal lineage.

Aggressiveness of *P. infestans* clonal lineages on potato and tomato: Incubation period showed no significant interaction between *P. infestans* clonal lineages and hosts (Table 2), it ranged from 3.5 days (EU_13_A2, on tomato) to 4.73 days (EU_2_A1, on tomato). However, on potato this period was ranged from 3.6 days with EU_13_A2 isolates to 4.53 days with EU_2_A1 isolates.

Latency period was shorter on tomato than on potato, ranging from 4.39 days (EU_13_A2, on tomato) to 6 days (EU_2_A1, on potato). It was statistically significant between hosts and EU_23_A1 and EU_2_A1 clonal lineages (P≤0.001). While, no significant difference was noticed with EU_13_A2 lineage and both hosts (P=0.15).

Lesions area ranged from 357.57 mm^2 (EU_13_A2, on tomato) to 629.44 mm^2 (EU_23_A1, potato), it's been significantly larger on potato than on tomato with EU_13_A2 isolates (P≤0.001). Both EU_23_A1 and EU_2_A1 lineages had slightly larger mean lesions area on potato than tomato, these differences were not significant (P = 0.32 and P = 0.58, respectively) (Table 2, Figure 2).

Sporangia production ranged from 4.1 $x10^4$ sporangia ml^{-1} (EU_2_A1, on potato) to 48.86$x10^4$ sporangia ml^{-1} (EU_13_A2, on potato). EU_23_A1 and EU_2_A1 isolates sporulated more abundantly on tomato than on potato (P≤0.001). In contrast, EU_13_A2 isolates sporulated more profusely on potato than on tomato (Table 2, Figure 2).

Table 2. Mean values of aggressiveness components; thirty six isolates were inoculated on potato cv. Spunta and tomato cv. Marmande.

Components	Cultivars	EU_13_A2 (n=5)	EU_2_A1(n=3)	EU_23_A1(n=28)
Incubation period	Marmande	3.5 a	4.73 a	3.73 a
(days)	Spunta	3.60 a	4.53 a	3.77 a
	Pr(>F)	0.67	0.33	0.63
Latency period	Marmande	4.39 a	5.2 a	4.44 a
(days)	Spunta	4.88 a	6 b	4.86 b
	Pr(>F)	0.15	0.0049 **	7.96e-08 ***
Lesion area (mm^2)	Marmande	357.57a	455.88 a	588.77 a
	Spunta	549.06 b	533.85 a	629.44 a
	Pr(>F)	0.00551 **	0.58	0.32
Sporangia production	Marmande	21.99$x10^4$ a	21.56$x10^4$ b	43.53$x10^4$ b
(Sporangia x 10^{-4}) ml^{-1}	Spunta	48.86$x10^4$ b	4.1$x10^4$ a	15.35$x10^4$ a
	Pr(>F)	0.0107 *	0.000241 ***	<2e-16 ***

The mean aggressiveness components are expressed using Tukey's HSD test with α=0.05.The statistic significant are expressed using asterisk (*P < 0.05; **P < 0.01; ***P < 0.001).

Specific virulence of isolates on their respective and alternative host: Incubation period showed no significant interaction between potato and tomato isolates and their hosts (P=0.94, P=0.85, respectively). It ranged from 3.73 days (tomato isolates, on tomato) to 3.91 days (potato isolates, on potato).

Latency period was shorter on tomato than on potato with all isolates ranging from 4.44 days (Tomato isolates, on tomato) to 5.11 days (Potato isolates, on potato). Tomato isolates showed significant results between hosts (P≤0.001). While, potato isolates showed no significant hosts interaction (P= 0.085). Lesion areas ranged from 364.64 mm^2 (Potato isolates, on tomato) to 625.89 mm^2 (Tomato isolates, on potato), values were not significant between tomato isolates and both hosts (P = 0.65). While, potato isolates showed a larger lesion on potato than on tomato (P≤ 0.05).

Sporangia production of tomato isolate was important on tomato than on potato leaflets (P≤0.001). In contrast, potato isolates sporulated more abundantly on their original host than on the tomato (P≤ 0.05) (Table 3).

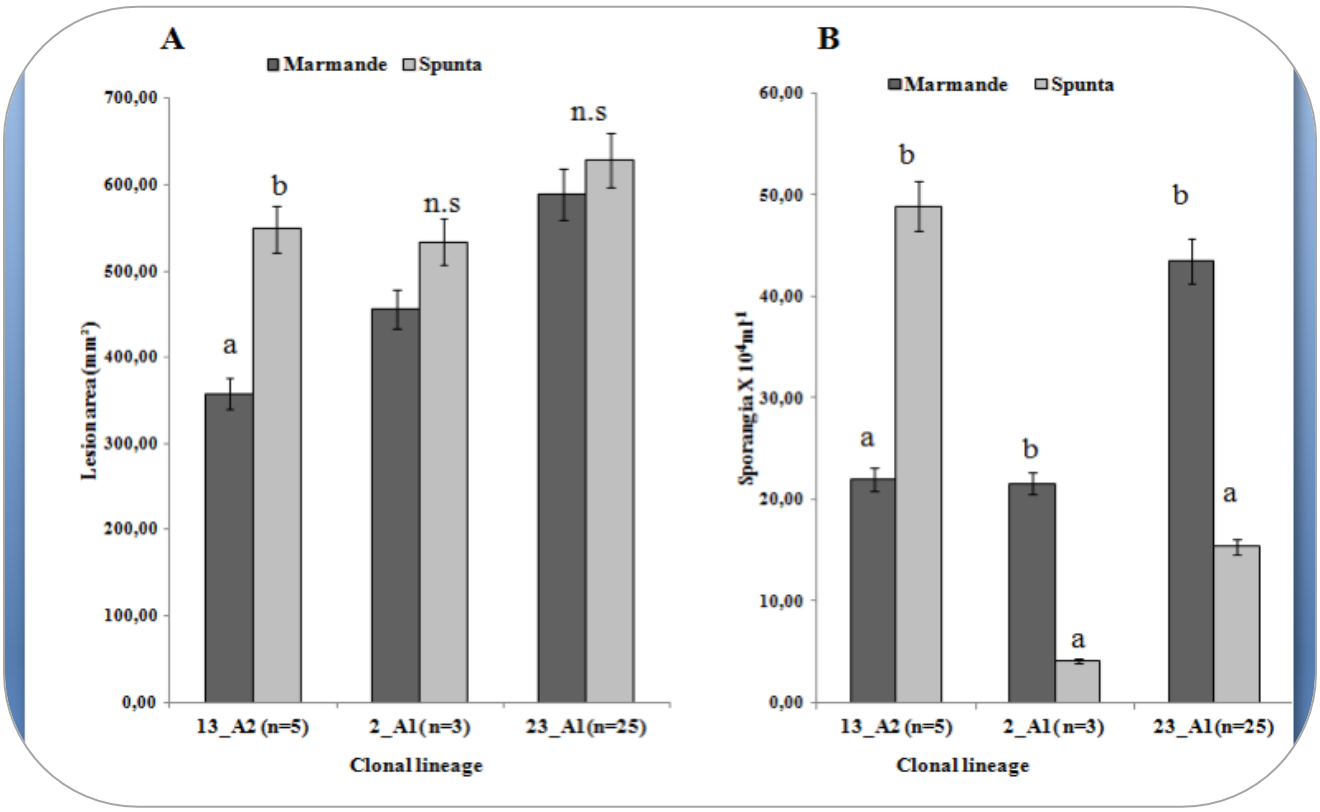

Figure 2. Pathogenicity of each clonal lineage on tomato cv. Marmande and potatocv. Spunta. (A) Lesion area expressed in mm^2. (B) Sporangia production expressed by the number of sporangia x $10^4 ml^{-1}$.The means of lesion area and sporangia production are separated using Tukey's HSD test with α=0.05. n.s= no significant.

Table 3. Mean values of the aggressiveness components of isolates on tomato and potato.

Components	Cultivars	Tomato isolates n= 25	Potato isolates n=11
Incubation period	Marmande	3.72 a	3.80 a
(days)	Spunta	3.73 a	3.91 a
	Pr(>F)	0.94	0.85
Latency period	Marmande	4.44 a	4.56 a
(days)	Spunta	4.83 b	5.11 a
	Pr(>F)	1.96e-07 ***	0.085
Lesion size (mm^2)	Marmande	615.19 a	364.64 a
	Spunta	625.89 a	549.73 b
	Pr(>F)	0.654	0.0263 *
Sporangia production	Marmande	46 ab	22.02 a
(Sporangia x 10^{-4}) ml^{-1}	Spunta	14.46a	30.69 b
	Pr(>F)	<2e-16 ***	0.0483 *

The mean aggressiveness components are expressed using Tukey's HSD test with α=0.05. The statistic significant are expressed using asterisk (*P <0.05; **P < 0.01; ***P < 0.001).

DISCUSSION

In Algeria, potato and tomato crops are grown all year round and often in close proximity under the same environmental conditions. Investigations on *P. infestans* have shown that isolates of the EU_13_A2 clonal lineage have been detected only on potato at all sites (Beninal *et al.,* 2008; Corbière *et al.,* 2015; Rekad *et al.,* 2017). While EU_23_A1 and EU_2_A1 clonal lineages were found on tomato and little on potato under field conditions. These observations theoretically showed the presence of host adaptation among *P. infestans* populations, confirmed by aggressiveness tests carried out carried out during the

present study on potato and tomato leaflets under controlled conditions. The symptoms exhibited by *P. infestans* clonal lineages were very different on potato and tomato. The EU_23_A1 isolates were highly biotrophic on tomato and showed the same symptoms described by Vega-Sanchez et al (2000), and Danies *et al.* (2013).

With regard to sporulation, the EU_23_A1 clonal lineage sporulated two times more than both EU_2_A1 and EU_13_A2 lineages on tomato leaflets. While, EU_13_A2 lineage sporulated profusely on potato than on tomato leaflets. However, EU_2_A1 sporulated less than the other lineages, but sporulated profusely on tomato than on potato. Abundant sporulation on the foliage suggests that these host plants are more likely to contribute to epidemics through the production of secondary inoculums and to increase the inoculum amount of the same genotype, which contributes to the maintaining of separate *P. infestans* populations (Suassuna *et al.*, 2004; Seidl Johnson and Gevens, 2014).

The adaptation of *P. infestans* population on both potato and tomato is also derived from their original host (Michalska *et al.,* 2016). In our data, we found that isolates collected from tomato produced almost lesion of the same size on potato and tomato leaflets. Usually, lineages detected on tomato are more generalist than those found on potato (Kröner *et al.,* 2017). Vega-Sanchez et al (2000); suggests that *P. infestans* adaptation to tomato is not always associated with reduced fitness on potato. As the case in Algeria, it would appear that isolates of EU_23_A1 and EU_2 _A1 lineages are well adapted to tomato plants and have the ability to switch from tomato to potato under field conditions. In the other hand, potato isolates are more aggressive on their original host than on tomato. As in Europe, some lineages such as EU_13_A2 and EU_6_A1 are considered as potato specialists (Kröner *et al.,* 2017). Consequently, they do not adapt well to a substrate other than potato and lose their performance on another host plant (Michalska *et al.,* 2016).

According to our results, the Algerian EU_13_A2 lineage may also be considered as a specialist potato lineage. However, in southern India, this lineage causes serious outbreaks in potato and tomato fields (Chowdappa *et al.,* 2013, 2015). The population structure of *P. infestans* is different in each country and influenced by several factors such as environmental conditions: presence of potential host in the region, cultural practices and the introduction of new lineages by infected seeds from other countries.

This research should be continued and extended to other host ranges of Solanaceae outside potato and tomato in Algeria. Indeed, it is important to monitor the evolution and adaptation of *P. infestans* populations on host plants to better control this potentially destructive pathogen by taking into account appropriate rotation and an effective fungicide treatment schedule.

ACKNOWLEDGEMENTS

This work was supported by the PoH-MED project, Potato Health – Managed for Efficiency and Durability, funded under the ARIMNet (Agricultural Research in the Mediterranean Area) ERA-Net (KBBE 219262) and the Ministry of higher education and scientific research of Algeria for allowing for awarding to S. Belkhiter a scholarship for her stay at (INRA, UMR IGEPP, and 35653 Le Rheu, France).The authors thank R. Mabon (INRA, UMR IGEPP, and 35653 Le Rheu, France) for isolates genotyping, *R. Corbière* (INRA, IGEPP) for providing advices and constructive discussions during experiments and D. Andrivon for his orientations.

REFERENCES

Akhtar, K.P., M.Y. Saleem, M. Asghar, S. Ali, N. Sarwar and M.T. Elahi. 2012. Resistance of Solanum species to *Phytophthora infestans* evaluated in the detached-leaf and whole-plant assays. Pakistan Journal of Botany, 44:1141-1146.

Beninal, L., R. Corbiere, A. Kedad, D. Andrivon and Z. Bouznad. 2009. A2 mating type, metalaxyl resistance and complex virulence profiles: common features in some *Phytophthora infestans* isolates from Algeria. PPO-Special Report no. 13.237.

Blandón-Díaz, J.U., A.K. Widmark, A. Hannukkala, B. Andersson, N. Högberg and J.E. Yuen. 2012. Phenotypic Variation Within a Clonal Lineage of *Phytophthora infestans* Infecting both Tomato and Potato in Nicaragua. Phytopathology. 102:323-330.

Chowdappa, P., N.B. Kumar, S. Madhura, M.S. Kumar, K.L. Myers, W.E. Fry, J.N. Squires and D.E. Cooke. 2013. Emergence of 13_ A 2 Blue Lineage of *Phytophthora infestans* was Responsible for Severe Outbreaks of Late Blight on Tomato in South-West India. Journal of Phytopathology. 161:49-58.

Chowdappa, P., B. Nirmal Kumar, S. Madhura, S. Mohan

Kumar, K. Myers, W. Fry and D. Cooke. 2015. Severe outbreaks of late blight on potato and tomato in South India caused by recent changes in the *Phytophthora infestans* population. Plant Pathology. 64:191-199.

Cooke, D.E.L., L.M. Cano, S. Raffaele, R.A. Bain, L.R. Cooke, G.J. Etherington, K.L. Deahl, R.A. Farrer, E.M. Gilroy, E.M. Goss, N.J. Grünwald, I. Hein, D. Maclean, J.W. Mcnicol, E. Randall, R.F. Oliva, M.A. Pel, D.S. Shaw, J.N. Squires, M.C. Taylor, V.G.a.A. Vleeshouwers, P.R.J. Birch, A.K. Lees and S. Kamoun. 2012. Genome Analyses of an Aggressive and Invasive Lineage of the Irish Potato Famine Pathogen. PLoS Pathogens. 8:e1002940.

Corbiere, R., L. Beninal, S. Belkhiter, R. Mabon, N. Mariette, D. Andrivon and Z. Bouznad. 2015. Do the Algerian *Phytophthora infestans* populations show genotypic structuration on potato and tomato? PPO-Special Report no. 17.155.

Danies, G., I.M. Small, K. Myers, R. Childers and W.E. Fry. 2013. Phenotypic Characterization of Recent Clonal Lineages of *Phytophthora infestans* in the United States. Plant Disease. 97:873-881.

Erselius, L., H. Hohl, M. Ordoñez, P. Oyarzun, F. Jarrin, A. Velasco, M. Ramon and G. Forbes. 1997. Genetic diversity among isolates of *Phytophthora infestans* from various hosts in Ecuador. Impact on a Changing World. Program Report. 1998:39-48.

Faostat. 2016. Food and Agriculture Organization of the United Nations, Agricultural Statistics.

Fry, W. 2008. *Phytophthora infestans* : the plant (and R gene) destroyer. Molecular Plant Pathology. 9:385-402.

Kröner, A., R. Mabon, R. Corbière, J. Montarry and D. Andrivon. 2017. The coexistence of generalist and specialist clonal lineages in natural populations of the Irish Famine pathogen *Phytophthora infestans* explains local adaptation to potato and tomato. Molecular Ecology. 26:1891-1901.

Maziero, J.M.N., L.A. Maffia and E.S.G. Mizubuti. 2009. Effects of Temperature on Events in the Infection Cycle of Two Clonal Lineages of *Phytophthora infestans* Causing Late Blight on Tomato and Potato in Brazil. Plant Disease. 93:459-466.

Michalska, A.M., S. Sobkowiak, B. Flis and E. Zimnoch-Guzowska. 2015. Virulence and aggressiveness of *Phytophthora infestans* isolates collected in Poland from potato and tomato plants identified no strong specificity. European Journal of Plant Pathology. 144:325-336.

Miranda, B.E.C.D., N.D. Suassuna and A. Reis. 2010. Mating type, mefenoxam sensitivity, and pathotype diversity in *Phytophthora infestans* isolates from tomato in Brazil. Pesquisa Agropecuária Brasileira. 45:671-679.

Mizubuti, E.S.G. and W.E. Fry. 1998. Temperature Effects on Developmental Stages of Isolates from Three Clonal Lineages of *Phytophthora infestans*. Phytopathology. 88:837-843.

Naveed, K., N.A. Rajputt, S.A. Khan and A. Ahmad. 2017. Population structure of *Phytophthora infestans* on worldwide scale: a review. Pakistan Journal of Phytopathology. 29:281.

Nowicki, M., M.R. Foolad, M. Nowakowska and E.U. Kozik. 2012. Potato and Tomato Late Blight Caused by *Phytophthora infestans*: An Overview of Pathology and Resistance Breeding. Plant Disease. 96:4-17.

Oyarzun, P.J., A. Pozo, M.E. Ordoñez, K. Doucett and G.A. Forbes. 1998. Host Specificity of *Phytophthora infestans* on Tomato and Potato in Ecuador. Phytopathology. 88:265-271.

Reis, A., C.D. Smart, W.E. Fry, L.A. Maffia and E.S.G. Mizubuti. 2003. Characterization of Isolates of *Phytophthora infestans* from Southern and Southeastern Brazil from 1998 to 2000. Plant Disease. 87:896-900.

Rekad, F.Z., D.E.L. Cooke, I. Puglisi, E. Randall, Y. Guenaoui, Z. Bouznad, M. Evoli, A. Pane, L. Schena, G. Magnano Di San Lio and S.O. Cacciola. 2017. Characterization of *Phytophthora infestans* populations in northwestern Algeria during 2008–2014. Fungal Biology. 121:467-477.

Seidl Johnson, A.C. and A.J. Gevens. 2014. Investigating the Host Range of the US-22, US-23, and US-24 Clonal Lineages of *Phytophthora infestanson* Solanaceous Cultivated Plants and Weeds. Plant Disease. 98:754-760.

Stroud, J.A., D.S. Shaw, M.D. Hale and K.A. Steele. 2015. SSR assessment of *Phytophthora infestans* populations on tomato and potato in British gardens demonstrates high diversity but no evidence for host specialization. Plant Pathology. 65:334-341.

Suassuna, N.D., L.A. Maffia and E.S.G. Mizubuti. 2004. Aggressiveness and host specificity of Brazilian isolates of *Phytophthora infestans*. Plant

Pathology. 53:405-413.

Vega-Sanchez, M.E., L.J. Erselius, A.M. Rodriguez, O. Bastidas, H.R. Hohl, P.S. Ojiambo, J. Mukalazi, T. Vermeulen, W.E. Fry and G.A. Forbes. 2000. Host adaptation to potato and tomato within the US-1 clonal lineage of *Phytophthora infestans* in Uganda and Kenya. Plant Pathology. 49:531-539.

Vleeshouwers, V.G.a.A., W. Van Dooijeweert, F. Govers, S. Kamoun and L.T. Colon. 2000. The hypersensitive response is associated with host and nonhost resistance to *Phytophthora infestans*. Planta. 210:853-864.

Contribution of Authors:

Sihem Belkhiter	:	Layout experiment
Lyes Beninal	:	Provide research facilities
Hassiba Khedidji	:	Researcher
Amira Krimi	:	Researcher
Zouaoui Bouznad	:	Supervisor of the whole research