Review Article

www.dergipark.org.tr/en/pub/mediterranean

MEDITERRANEAN AGRICULTURAL SCIENCES
(2024) 37(1): 23-26
DOI: 10.29136/mediterranean.1428267

Solanum americanum: An alternative model crop in plant pathology

Abdul Razak AHMED, Abdellahi GALLEDOU, Utku DEMIRTAS, Hakan FIDAN, Ozer CALIS

Akdeniz University, Faculty of Agriculture, Plant Protection Department, 07059, Kampüs, Konyaaltı, Antalya, Türkiye

Corresponding author: O. Calis, e-mail: ozercalis@akdeniz.edu.tr
Author(s) e-mail: abdulairazakahmed89@gmail.com, galledou4@gmail.com, utkudemirtas0748@gmail.com, hakanfidan@akdeniz.edu.tr

ARTICLE INFO

Received: January 30, 2024
Received in revised form: February 27, 2024
Accepted: March 25, 2024

***Keywords*:**

Nightshade plant
Model plant
Resistance
Solanum americanum

ABSTRACT

The *Solanum americanum*, possesses valuable features that earn it a deserved addition to the expanding list of model plants that are utilized in the fields of plant genetics, plant breeding and biotechnology. This review attempts to comprehensively highlight the crucial role of this model plant and its genetic diversity in terms of resistance against biotic pathogens. In summary, we recommend the use of this plant in future studies focused on plant-pathogen interactions.

1. Introduction

Plant pathogens have become a major global concern, especially among crop farming communities. This concern is aggravated by significant changes in climate patterns, which have informed the importance of identifying, researching, and effectively addressing these pathogens and their economic impact. This poses a significant struggle for plant pathologists, who strive to bring to light the complete array of effects caused by these pathogens and find lasting solutions to them. In the pursuit of complete understanding and the scrutiny of viable alternatives, researchers and plant pathologists have turned to the utilization of model crops as indispensable tools in their research endeavors.

Model plants are pivotal in phytopathology as they are used in research on plant-pathogen interactions, disease resistance mechanisms, and genetic variability of plants. Plants such as *Arabidopsis thaliana* (Padole and Ingle 2017), maize (Gaut et al. 2000; Strable and Scanlon 2009), tomato (Meissner et al. 1997), wheat (Feldman et al. 2012), rice (Izawa and Shimamoto 1996) and others have been reported to be used as model crops. These crops, by virtue of valuable characteristics such as genetic tractability, and rapid growth, provide a controlled environment to investigate the complexity of plant diseases and other agronomic features. They offer insights into host responses, pathogen virulence, and underlying molecular pathways involved in resistance or susceptibility. The understanding of these interactions helps researchers gain fundamental knowledge applicable to diverse crops, aiding in the development of disease-resistant varieties.

Aside from their role in plant pathology, they also serve as valuable tools for assessing the evolutionary trajectories of plant genomes. For example, maize, as a model plant, has been used to decipher complex subjects of heterosis, epigenetics, and quantitative inheritance, thereby enhancing our comprehension of these complex phenomena (Strable and Scanlon 2009). Amongst other reported model plants, *A. thaliana* has been investigated the most and has been widely used in research studies. The preference of this plant for research studies can be attributed to its short life cycle, ability to produce a multitude of seeds, small genome size (about 143 Mbp) and the ability to generate mutants using simple agrobacterium transformation systems such as the flower dip method (Meyerowitz 2001). Despite the popularity of *A. thaliana*, another interesting crop group that are used in the understanding of plant pathogen interactions are the *Solanaceae* group. In a review paper by Arie et al. (2007), the importance of tomato (*Solanum lycopersicum* L.) in understanding the interaction between tomato and its viral, bacterial, fungal and nematode pathogens were highlighted. Also, they listed resistance and susceptibility genes discovered in tomato plants. Nevertheless, recent attention has shifted towards another member of this botanical family, *Solanum americanum* Mill., Black nightshade (Fig. 1), which is emerging as a promising candidate for plant-pathogen studies. Consequently, this paper aims to comprehensively review current research on *S. americanum*, particularly focusing on its morphology and role in plant-pathogen interaction studies.

2. *S. americanum* morphology

Solanum americanum is commonly known as Black nightshade. Despite its importance and diversity within the *Solanum* group, it has been classified as a weed and of less usage in most countries (Vandeventer et al. 1982). Often mistaken for *S. nigrum, S. americanum* is a diploid whilst *S. nigrum* is a polyploid. Moreover, the seeds of *S. americanum* are smaller and range from 1.2 - 1.6 mm in length, contrasting with the larger seeds of *S. nigrum* (1.8 - 2.2 mm). Phenotypically, *S. americanum* can be distinguished by its umbellate inflorescence, purplish-

© Akdeniz University Faculty of Agriculture

blackish shiny fruits (Fig. 2), 1 - 2 mm long anthers and pollens with diameter between 19 - 27 µm (Schilling et al. 1992).

3. S. americanum as a model plant

When comparing *S. americanum* with established model plants such as *A. thaliana*, distinct differences and potential advantages emerge. *A. thaliana* has been a cornerstone in plant research due to its well-characterized genome and extensive genetic tools, but *S. americanum* offers a unique perspective. Numerous studies have reported and documented various genes conferring resistance to plant pathogens in this emerging model plant. For instance, Moon et al. (2021) identified *RipAZ1* in *S. americanum*, which serves as an avirulent factor against *Ralstonia solanacearum*, the causal agent of bacterial wilt in most crops. In addition, two resistance genes (*Rpi-amr1* and *Rpi-amr3*) to late blight (*Phytophthora infestans*) resistant - potato plants were reported by Lin et al. (2023). The integration of these genes into vegetable and other crop species could confer resistance against these pathogens. Other analogous investigations focusing on pathogen-microbe interactions in *S. americanum* have also been conducted, as outlined in Table 1. However, there is insufficient knowledge on other important plant pathogens. Notably, the impact of *Rhizoctonia solani* infection on *S. americanum* remains unknown. However, research on *S. nigrum* extract had proven to have high fungicidal (88%) properties against this pathogen (Pathak et al. 2020). Similar instances were observed for *Fusarium solani* and *Pseudomonas syringae* where a 10% concentration of *S. nigrum* extract were effective in inhibiting these pathogens' growth (Opande et al. 2017). These findings underscore the potential for uncovering possible resistance gene resource in *S. americanum* since these pathogens are of serious economic importance.

Beyond studies on plant pathogens, liquid and aqueous extracts from *S. americanum* have exhibited efficacy against diverse pathogens, offering potential applications in clinical studies (Afolabi et al. 2008; Cáceres et al. 1998).



Figure 1. *Solanum americanum* plant.



Figure 2. Morphology of *S. americanum* plant. A) *S. americanum* flowers (white, small, star-shaped), B) *S. americanum* flowers and leaves (leaves are ovate, arranged alternately along the stems), C) colour (initially green and may darken as it ripens), shape, and size (pea-sized) of *S. americanum* fruits.

© Akdeniz University Faculty of Agriculture

Table 1. List of research conducted on *S. americanum*

Pathogen	Research findings	Recommendations	References
Ralstonia solanacearum	1.*RipAZ1* was discovered to be an *avirulent* gene against *Rastolnia solanacearum* 2. The 213-amino acid central region of RipAZ1 was reported to induce programmed cell death in *R. solanacearum*-infected *S. americanum* *3*. The gene can initiate early defense mechanism in the cytoplasm of the host cell.	The *S. americanum R* gene recognizing RipAZ1 offers potential for creating potato varieties resistant to both *P. infestans* and *R. solanacearum* in breeding programs	(Moon et al. 2021)
Phytophthora infestans	Nine (9) *Rpi-amr1* genes which offers broad spectrum resistance against different isolates of *P. infestans* were successfully identified and isolated from *S. americanum* Rpi-amr recognized the effectors *of Phytophthora parasitica* and *Phytophthora cactorum*	Combination of these genes and other R*pi* genes may help in the development of other crop varieties that are resistant to late blight disease	Witek et al. (2021)
Xanthomonas perforans	*X. perforans* was isolated from wild *S. americanum* on tomato fields.	*S. americanum* weed plants on tomato fields should be eliminated since they are favourable hosts for *X. perforans*.	Araújo et al. (2015)
Cariogenic *Streptoccoccus* mutants	Extracts from *S. americanum* together with *Hibiscus subdariffa*, and Garcinia kola in addition to methanol were analyzed for their role as growth inhibitors of Cariogenic bacteria. 2.5 g ml^{-1} of *S. americanum* extracts were ineffective in inhibiting growth of *Streptococcus* mutants	*S. americanum* liquid extracts should not be used in the treatment of cariogenic *Streptococcus* mutants	Afolabi et al. (2008)
Artemia salina	50 mg kg^{-1} of *S. americanum* extracts inhibited the growth of *A. salina*	*S. americanum* extracts can be used in the treatment of A. *salina.*	Cáceres et al. (1998)

4. *S. americanum* and plant viruses

Plant viruses are responsible for severe losses in the yield of economic crops. Plant viruses pose significant threats to crop production worldwide, impacting both quantity and quality of agricultural yields. Cao et al. (2020) estimated that more than 1500 viruses belonging to 26 families negatively affect plants. With the advent of new detection and sequencing methods, these numbers are expected to increase. Viruses infect crops, causing a range of detrimental effects with symptoms manifesting as leaf discoloration, distorted growth patterns, stunted growth, reduced yields, and in severe cases, plant death. Viruses are regularly transmitted through insect vectors, contaminated seeds, and agricultural tools.

Weeds and natural hosts within plant ecosystems serve as active reservoirs for these viruses. For instance, studies conducted in Poland revealed significant coinfections in weeds belonging to the *Asteraceae* family, including *Achillea millefolium*, *Sonchus oleraceus*, and *Crepis tectorum*, with pathogens such as Tomato spotted wilt virus (TSWV), Tobacco mosaic virus (TMV), Potato virus Y (PVY), Cucumber mosaic virus (CMV), and Tobacco ringspot virus (*TRSV)* (Korbecka-Glinka et al., 2021) . Additionally, in a survey conducted in Saudi Arabia by Al-Shahwan et al. (2017), *Sonchus oleraceus* was found to be infected with Alfalfa mosaic virus (AMV), Bean common mosaic virus (BCMV), Bean leaf roll virus (BLRV), Bean yellow mosaic virus (BYMV), Cucumber mosaic virus (CMV), Lucerne transient streak virus (LTSV), Pea streak virus (PeSV), Red clover vein mosaic virus (RCVMV), Tobacco streak virus (TSV), and White clover mosaic virus (WCMV).

Weeds of the Solanaceae family have been identified as significant reservoirs for numerous plant viruses in a review by Hančinský et al. (2020). The review highlighted Carolina horse nettle as a natural host for Peach rosette mosaic virus (PRMV), and petunia as a host of Potato virus B (PVB) and Tomato ringspot virus (ToRSV). Various viruses have been observed and documented on *S. americanum* across different global locations. For instance, in 2016, Potato yellow mosaic virus was recorded on both *S. americanum* and *S. pimpinellifolium* in Venezuela (Romay et al., 2016). Similarly, in the United States, Tomato chlorotic spot virus was reported on *S. americanum* (Badillo-Vargas et al. 2015), while in South America, Tomato chlorosis virus was also reported on *S. americanum* and *S. sisymbriifolium* (Arruabarrena et al. 2015). Although Tomato spotted wilt virus has not been officially reported on *S. americanum*, it has been found on other weed species such as *Amaranthus hybridus*, *S. nigrum*, *Tagetes minuta*, and *Datura stramonium* (Macharia et al. 2016). The confirmation of TWSV infection on *S. nigrum*, a close relative of *S. americanum*, prompts research questions regarding the potential for this virus to infect *S. americanum* as well.

Presently, within our research facility, there are ongoing research to investigate the susceptibility of *S. americanum* to TSWV and Tomato brown rugose fruit virus (ToBRFV). The prospect of identifying inherent resistance genes within this plant against these pathogens will serve as a roadmap in engineering resistant crop varieties. Since there are limited research studies

© Akdeniz University Faculty of Agriculture

on the susceptibility or resistance of the plant against important plant viruses (for example Tomato leaf curl new Delhi virus-ToLCNDV, and Tomato yellow leaf curl virus- TYLCV), future research directions can be tailored to that.

Acknowledgements

The authors would like to thank Prof Dr. Jonathon D.G. JONES (The Sainsbury Lab, United Kingdom) and Dr. Volkan CEVIK (The Bath University, United Kingdom) for providing seeds of *S. americanum*.

References

Afolabi OC, Ogunsola FT, Coker AO (2008) Susceptibility of cariogenic Streptococcus mutans to extracts of Garcinia kola, Hibiscus sabdariffa, and *Solanum americanum*. West African Journal of Medicine 27(4).

Al-Shahwan IM, Abdalla OA, Al-Saleh MA, Amer MA (2017) Detection of new viruses in alfalfa, weeds and cultivated plants growing adjacent to alfalfa fields in Saudi Arabia. Saudi Journal of Biological Sciences 24(6): 1336-1343. doi: 10.1016/j.sjbs.2016.02.022.

Araújo ER, Costa JR, Pontes NC, Quezado-Duval AM (2015) *Xanthomonas perforans* and *X. gardneri* associated with bacterial leaf spot on weeds in Brazilian tomato fields. European Journal of Plant Pathology 143(3): 543-548. doi: 10.1007/s10658-015-0705-9.

Arie T, Takahashi H, Kodama M, Teraoka T (2007) Tomato as a model plant for plant-pathogen interactions. In Plant Biotechnology 24(1): 135-147. doi: 10.5511/plantbiotechnology.24.135.

Arruabarrena A, Rubio L, González-Arcos M, Maeso D, Sánchez-Campos S, Fonseca M. DN, Boiteux LS (2015) First report of *Solanum sisymbriifolium* and *S. americanum* as natural weed hosts of Tomato chlorosis virus (genus Crinivirus) in South America. Plant Disease 99(6): 895.

Badillo-Vargas IE, Roe N, Funderburk, JE, Adkins S (2015) First Report of Tomato chlorotic spot virus in Scarlet Eggplant (*Solanum aethiopicum*) and American Black Nightshade (*Solanum americanum*) in the United States. Plant Disease 99(10): 1450.

Cáceres A, López B, González S, Berger I, Tada I, Maki J (1998) Plants used in Guatemala for the treatment of protozoal infections. I. Screening of activity to bacteria, fungi and American trypanosomes of 13 native plants. Journal of Ethnopharmacology 62(3): 19-202. doi: 10.1016/S0378-8741(98)00140-8.

Cao Y, Zhou H, Zhou X, Li F (2020) Control of plant viruses by CRISPR/Cas system-mediated adaptive immunity. Frontiers in Microbiology 11: 593-700. doi: 10.3389/fmicb.2020.593700.

Feldman M, Levy AA, Fahima T, Korol A (2012) Genomic asymmetry in allopolyploid plants: wheat as a model. Journal of Experimental Botany 63(14): 5045-5059. doi: 10.1093/JXB/ERS192.

Gaut BS, D'Ennequin MLT, Peek AS, Sawkins MC (2000) Maize as a model for the evolution of plant nuclear genomes. *P*roceedings of the National Academy of Sciences 97(13): 7008-7015.

Hančinský R, Mihálik D, Mrkvová M, Candresse T, Glasa M (2020) Plant viruses infecting *solanaceae* family members in the cultivated and wild environments: A review. Plants 9(5): doi: 10.3390/plants9050667.

Izawa T, Shimamoto K (1996) Becoming a model plant: The importance of rice to plant science. Trends in Plant Science 1(3): 95-99. doi: 10.1016/S1360-1385(96)80041-0.

Korbecka-Glinka G, Przybyś M, Feledyn-Szewczyk B (2021) A survey of five plant viruses in weeds and tobacco in poland. Agronomy 11(8). doi: 10.3390/agronomy11081667.

Lin X, Jia Y, Heal R, Prokchorchik M, Sindalovskaya M, Olave-Achury A, Makechemu M, Fairhead S, Noureen A, Heo J, Witek K, Smoker M, Taylor J, Shrestha RK, Lee Y, Zhang C, Park SJ, Sohn KH, Huang S, Jones JDG (2023) *Solanum americanum* genome-assisted discovery of immune receptors that detect potato late blight pathogen effectors. Nature Genetics 55(9): 1579-1588. doi: 10.1038/s41588-023-01486-9.

Macharia I, Backhouse D, Wu SB, Ateka EM (2016) Weed species in tomato production and their role as alternate hosts of Tomato spotted wilt virus and its vector Frankliniella occidentalis. Annals of Applied Biology 169(2): 224-235. doi: 10.1111/aab.12297.

Meissner R, Jacobson S, Melamed S, Levyatuv S, Shalev G, Ashri A, Elkind Y, Levy A (1997) A new model system for tomato genetics. Wiley Online Library 12(6): 1465-1472. doi: 10.1046/j.1365-313x.1997.12061465.x.

Meyerowitz EM (2001) Prehistory and history of Arabidopsis research. Plant Physiology 125(1): 15-19. doi: 10.1104/pp.125.1.15.

Moon H, Pandey A, Yoon H, Choi S, Jeon H, Prokchorchik M, Jung G, Witek K, Valls M, McCann HC, Kim MS, Jones JDG, Segonzac C, Sohn KH (2021) Identification of RipAZ1 as an avirulence determinant of *Ralstonia solanacearum* in *Solanum americanum*. Molecular Plant Pathology 22(3): 317-333. doi: 10.1111/mpp.13030.

Opande GT, Musyimi DM, Cherono KL, Jiveri BK, Buyela DK (2017). Antimicrobial Activities of Crude Leaf Extract of *Solanum nigrum* on *Fusarium oxysporum* and *Pseudomonas syringae* Cultures in Maseno (Kenya). Journal of Asian Scientific Research 7(7): 271-278. doi: 10.18488/journal.2.2017.77.271.278.

Padole D, Ingle KP (2017) Arabidopsis-A Model Plant. Trends in Biosciences 10(2): 557-559.

Pathak N, Prajneshu M, Ahmad S, Kumar L, Bhaduri A, Dhandapanı A, Sharma OP (2020) Phytochemical Analysis and Antifungal Activity of Weed Extracts against Rhizoctonia Root Rot in Buckwheat (*Fagopyrum tataricum*). Biopesticides International 16(2): 125-131.

Romay G, Chirinos DT, Geraud-Pouey F, Torres M, Bragard C (2016) First report of Potato yellow mosaic virus infecting *Solanum americanum* in Venezuela. New Disease Reports 34(1): 20-20. doi: 10.5197/j.2044-0588.2016.034.020.

Schilling EE, And QM, Andersen RN (1992) Common Names and Species Identification in Black Nightshades, Solanum sect . *Solanum* (*Solanaceae*). Economic Botany 46(2): 223-225.

Strable J, Scanlon MJ (2009) Maize (*Zea mays*): A model organism for basic and applied research in plant biology. Cold Spring Harbor Protocols 4(10). doi: 10.1101/pdb.emo132.

Vandeventer JW, Meggitt WF, Penner D (1982) Morphological and physiological variability in black nightshade (*Solanum* spp.). Pesticide Science 13(3): 257-262. doi: 10.1002/ps.2780130306.

Witek K, Lin X, Karki HS, Jupe F, Witek AI, Steuernagel B, Stam R, Van Oosterhout C, Fairhead S, Heal R, Cocker JM, Bhanvadia S, Barrett W, Wu CH, Adachi H, Song T, Kamoun S, Vleeshouwers VGAA, Tomlinson L, Jones JDG (2021) A complex resistance locus in *Solanum americanum* recognizes a conserved Phytophthora effector. Nature Plants *7*(2): 198-208. https://doi.org/10.1038/s41477-021-00854-9.

© Akdeniz University Faculty of Agriculture