**Research Proposal Submitted to the Northwest Potato Research Consortium**

**Fiscal Year 2023-24**

**Proposal Title**: **Automated identification of plant-parasitic nematodes of potato at genus level**

**Principal investigator and co-PIs:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Address** | **Phone number** | **Email address** |
| Timothy Paulitz | USDA-ARS | 509-335-7077 | [paulitz@wsu.edu](mailto:paulitz@wsu.edu) |
| Cynthia Gleason | Washington State University | 509-335-3742 | [cynthia.gleason@wsu.edu](mailto:cynthia.gleason@wsu.edu) |
| Inga Zasada | USDA-ARS |  | [inga.zasada@usda.gov](mailto:inga.zasada@usda.gov) |
| Sam Chavoshi | AGNEMA |  | [sam@agnema.com](mailto:sam@agnema.com) |

**Total Funds Requested**: $73,863

Principal investigator portion: $28,506

Co-PI portion(s): $45,357

Second, third or more year funding request? x Yes No

**If Yes**, prior year(s) amount(s) funded:

2022-23: $ 67,784

2021-22:

**Research Plan (**2 page with three components**)**

**Summary of problem**

Effective management of plant-parasitic nematodes require early and accurate identification and quantification. Current nematode diagnosis relies heavily on morphology-based identification methods which demand highly skilled personnel and are time consuming. Similarly, molecular marker-based methods tend to be cost and resource intensive and are not available for all plant-parasitic nematodes. To help resolve this problem, a fast, accurate and efficient nematode identification tool is needed. Currently labs that provide nematode identification services do not possess the resources to produce fast and accurate results at scale. According to PI Chavoshi, who runs a nematode diagnostic clinic, one of the main bottlenecks in nematode identification is that it requires skilled personnel to look at nematodes individually and identify it. This process is not only time consuming and expensive in terms of labor costs, but also prone to inevitable human error. As such, automated tools that do not demand taxonomic expertise and generate reproducible results are needed. Such tools have been reliably developed with machine learning algorithms in various domains, from biomedicine to entomology ([Martineau et al. 2017; McKinney et al. 2020](https://docs.google.com/document/d/1AIU3Ve4R6-CSBYSVoQW3URErWOvV4YyACLp5Twgwks0/edit)). Most recently, a research group in Florida has begun to develop an identification tool for plant-parasitic nematodes that affect citrus ([Buck 2021](https://docs.google.com/document/d/1AIU3Ve4R6-CSBYSVoQW3URErWOvV4YyACLp5Twgwks0/edit)). This illustrates that nematologists in high value fruit crops realize the value of using machine learning algorithms to provide faster, cheaper, and more accurate nematode identification. Unfortunately, the nematode problems of citrus in Florida are not the same as potato in the PNW. The goal of this research proposal is to develop an automated method that would recognize key genera of plant-parasitic nematodes based on photos taken of extracted nematodes. We propose to develop our tool for nematodes that affect potato, such as root lesion (*Pratylenchus* spp.)*,* root knot (*Meloidogyne* spp.)*,* and stubby root (*Paratrichodorus* and *Trichodorus* spp.) nematodes([Hills et al. 2020; Zasada et al. 2018](https://docs.google.com/document/d/1AIU3Ve4R6-CSBYSVoQW3URErWOvV4YyACLp5Twgwks0/edit)).

For this project, machine learning algorithms will be developed to identify common plant-parasitic nematode genera associated with potato production. Models will be built and trained on a large number of raw images of different nematode genera. The algorithms will learn to associate diagnostic features, such as their morphology (length, width, shape), texture in order to make accurate predictions. Once trained, model performance will be validated on previously unseen images. The first year of the project has been completed, but an additional year of funding is needed in order to acquire enough images and test the performance of algorithms on unseen images. Our goal in this proposal is to generate the baseline of data and validate the system. This research sets the stage for our long-term goal, in which these models will be developed into an automated detection and quantification system of plant-parasitic nematodes that threaten the potato industry that can be used by the industry. Such a tool will enable stakeholders to make faster and more informed nematode management decisions.

**Research Objectives**

The goal of this project is to enhance the accuracy, efficiency, and reproducibility of nematode identification for potato growers in the Pacific Northwest. To accomplish this goal, we propose to build and validate machine learning algorithms that can quickly and accurately identify three plant-parasitic nematodes associated with potato production in the Pacific Northwest. The objectives of this study are to i) capture microscopic images of common plant-parasitic nematodes, ii) confirm the identify of our three nematode genera with traditional and molecular methods to validate our photo library and iii) build and validate machine learning models that can identify nematodes.

[**Experimental Approach**](https://docs.google.com/document/d/1AIU3Ve4R6-CSBYSVoQW3URErWOvV4YyACLp5Twgwks0/edit)

**For objective 1,** pure cultures of each nematode genus already maintained in the Chavoshi, Gleason and Zasada laboratories will be used. To supplement our collection with nematodes other than the target nematodes, nematodes will be extracted from field soils or pot cultures with standard procedures (**Fig 1a**). Individual nematodes from pure cultures and soil samples will then be imaged with 200/100X magnification (**Fig 1b**). Objective 1 will be completed by Zasada, Gleason, and Chavoshi.

**For objective 2,** nematodes will be identified to genus with morphological features like shape of head, body length and shape, stylet length, shape of stylet knob etc. In total, images from four nematode genera including root lesion (*Pratylenchus* spp. (n = 1,000)), root knot (*Meloidogyne* spp. (n = 1,000)), and stubby root (*Paratrichodorus* spp. (n = 500) and *Trichodorus* spp, (n = 500)) nematodes will be captured (**Fig 1b**). Non-parasitic nematodes (n = 2,000) will also be imaged and serve as a control group. Different life stages of the nematodes including juveniles and adults (both male and female) will be included in image dataset. Captured images will include both full and partial (head and tail) body parts of juvenile/adult nematodes (**Fig 1c**). Like objective 1, objective 2 will be completed by Zasada, Gleason, and Chavoshi.

**For objective 3,** the labelled images from objective 2 will be used to build and validate machine learning algorithms. At least two separate machine learning algorithms will be developed and validated for genus level classification problems (**Fig 1d**). First, a subset of the images collected from objective 2 will be used to train the algorithms to associate the pixels in each image with the label or taxa within each image. If necessary, image augmentation will be completed to introduce variance into dataset. Mainly, convolution neural network (CNN), a type of machine learning algorithm which takes raw images as an input file, will be used. Several architecture types of CNN including ResNet, AlexNet, VGG etc. will be implemented to train the algorithms and their predictive performance will be evaluated. To test the accuracy of each algorithm, new images that have not yet been “seen” or learned will be presented to each algorithm. The models with the best accuracy will be selected for future use (**Fig 1e**). An accurate model is one that, for example, labels an image of a root lesion nematode as such. An inaccurate model will label and image of a root lesion nematode as a stubby root or root lesion nematode. Altogether, the labelled images from Objective 1 will be compiled, and using the machine learning algorithms we develop, we will be able to scan the images and predict the genera of nematode present. The image analysis pipeline will be developed in the open-source programming languages, Python and R, and will be published online. Objective 3 will be completed by Paulitz and GC Upadhaya.

Diagram

Description automatically generated with medium confidence

Figure 1. Flow chart of experiment. (a) The collected nematodes will be identified at genus level and (b) imaged under a compound microscope. (c) Images including sample nematode images to be used to train machine learning algorithms. (d) The multilayered machine learning algorithm will be developed and optimized to extract and learn important features from each image. (e) Model performance will be evaluated using a confusion matrix. Finally, the best performing model will be selected for nematode identification in future (e-bottom picture).

**Budget:** Please provide the following in a table format as shown, listing only the budget items appropriate for your project. Add columns or tables as needed to accommodate all scientists/labs seeking funding under this project. Add or subtract footnotes or addenda to the budget table as needed to fully explain your plans or needs. More detail is better than less. Personalize the budget table with the names of each funded scientist at the tops of the columns, delete unneeded rows/columns, and delete these instructions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Paulitz | Gleason | Zasada | Chavoshi | **Total** |
| **1Salaries:** Faculty |  |  |  | 11,094 | 11,094 |
| Graduate student | 26,095 |  |  |  | 26,095 |
| Other students |  |  |  |  |  |
| Other labor |  | 8,754 | 4,616 | 7,350 | 20,720 |
| **2Employee Benefits (OPE):** Faculty |  |  |  |  |  |
| Graduate student | 2,411 |  |  |  | 2,411 |
| Other students |  |  |  |  |  |
| Other labor |  | 893 | 471 | 4,344 | 5,708 |
| Computing |  |  |  |  |  |
| Equipment |  |  |  |  |  |
| Travel: |  |  |  |  |  |
| Operating Expenses |  |  |  | 1,296 | 1,296 |
| Other Expenses |  | 500 | 500 | 5,539 | 6,539 |
| **Total** | 28,506 | 10,147 | 5,587 | 29,623 | 73,863 |

|  |
| --- |
| ¹Salary is to support graduate student for 0.86 FTE of 9 months at Paulitz's lab. |
| ²Benefits for graduate student are 15.4% of salary |

**Other Support of Project, Anticipated Supporting Grant Applications:** NA

**Progress Report**: (one page or less)

For objectives 1 and 2, Cynthia Gleason will provide images ofroot-knot (*Meloidogyne)*, Inga Zasada will provide images of root lesion (*Pratylenchus*) and *Trichodorus* (stubby root), and Sam Chavoshi will provide an assortment of images from his diagnostic service. We discussed the formatting and resolution of captured images to obtain high-quality images. We also met by zoom with Peter DiGennaro and Alina Zare at University of Florida, to discuss the approaches being used by this researcher in Florida. Images for each group of nematodes are being captured and deposited to the common repository. In addition, we have a collection of non-plant parasitic nematode pictures from Dr. Hassan Mayad. This includes all the trophic groups.

For objective 3, Tim Paulitz and Sudha GC Upadhaya will work to develop deep learning algorithms to classify nematode genera. A simple pipeline for the image-based analysis has been developed in TenserFlow framework of Python, a programming language. Several architectures type and size, regularization methods and other parameters will be tested and adjusted during the model training process to develop best performing model. We expect to capture all images and complete algorithm development and validation by the end of year 2023.

A close-up of a feather

Description automatically generated with low confidence

Figure 1. Sample image of *Meloidogyne hapla* captured by Dr. Gleason to be used for classification

**Timothy C. Paulitz**

**Research Plant Pathologist**

USDA-ARS Wheat Health, Genetics and Quality Research Unit

Washington State University, Pullman, WA 99164-6430

**ORCID:** **0000-0002-8885-3803.**

**EDUCATION**

University of California, Riverside, PhD in Plant Pathology 1984

California State Polytechnic University, Pomona, BS in Botany and Plant Pathology, 1979

**RESEARCH AND PROFESSIONAL EXPERIENCE**

2000-present. GS 15. USDA-ARS Wheat Health, Genetics, and Quality Research Unit, Pullman, WA. Research Plant Pathologist. Soilborne fungal and nematode diseases of wheat, barley, canola, legumes and other rotation crops. Epidemiology, ecology, detection and quantification of soilborne pathogens. Microbiome of wheat and rotation crops, soil health, soil microbiomes

1989-2000 Dept. Plant Science, Macdonald Campus of McGill University, Ste. Anne de Bellevue, Quebec, Canada. Assistant and Associate Professor. Plant pathology of cereal, fruit, vegetable crops and greenhouse crops. Mycology, ecology, epidemiology.

1987-1989. USDA-ARS Horticultural Research Laboratory, Postdoctoral Research Associate. Biological control of fungal diseases with antagonistic bacteria and interactions with vesicular-arbuscular mycorrhizal fungi.

1984-1987. Department of Plant Pathology and Weed Science, Colorado State University. Visiting assistant professor. Biological control of greenhouse crops.

**Relevant Professional Experience and Synergistic Activities**

2019-present Section Editor, Canadian Journal of Plant Pathology

2007-2016 Editor-in-Chief, American Phytopathological Society Press

2009 Fellow, American Phytopathological Society

2007-2012 Associate Editor-in-Chief, American Phytopathological Society Press

2004-2007 Senior Editor, American Phytopathological Society Press

2005-present Collaborator with CIMMYT Global Initiative on Wheat Root Health in Rainfed System, teaching workshops in Turkey and hosting Turkish, Moroccan and Tunisian scientists.

2002-present Member, secretary, and chair of W-3147 Biological Control of Soilborne Pathogens Multistate CSREES project

1999-2002 Member of U.S. Wheat and Barley Scab Initiative Review Panel

2001-present Section Editor, Canadian Journal of Plant Pathology

1998-2002 Section Editor, Plant and Soil

1994-1997 Senior Editor, Phytopathology

1991-1994 Associate Editor, Phytopathology

From 1990-2000, I supervised to completion 18 MSc students, 4 PhD students, and 5 postdoctoral researchers. From 2000-2022, as an adjunct professor in the Dept. of Plant Pathology at Washington State University, I have supervised or co-supervised 9 PhD and 3 MSc students.

**PUBLICATIONS** (**More than 175 refereed publications over career, 17 book chapters and over 80 abstracts). Refereed publications for the last year are presented.**

Yin, C., Casa Vargas, J.M., Schlatter, D.C. *et al.* Rhizosphere community selection reveals bacteria associated with reduced root disease. *Microbiome* **9,** 86 (2021). <https://doi.org/10.1186/s40168-020-00997-5>

Yin C, Schlatter DC, Kroese DR, Paulitz TC, Hagerty CH. Responses of Soil Fungal Communities to Lime Application in Wheat Fields in the Pacific Northwest. *Front Microbiol*. 2021;12:576763. Published 2021 May 20. doi:10.3389/fmicb.2021.57676342. <https://doi.org/10.3390/agriculture10100447>

Bozoglu, T., Ozer, G., Mustafa, I, Paulitz, T. and Dababat, A. 2021 First report of crown rot caused by Fusarium redolens in Kazakhastan. Plant Disease <https://doi.org/10.1094/PDIS-01-21-0015-PDN>

Imren, M. Ozer, G., Paulitz, T. and Dababat, A. 2021. Plant-parasitic nematode communities associated with wheat-growing areas in central,eastern, and south-eastern Kazakhstan. Plant Disease: https://doi.org/10.1094/PDIS-11-20-2424- SR.

Wang, Z, Schlatter, D., Glawe, D., Edwards, C., Weller, D., Paulitz, T., Abatzouglou, J. and Okukara, P. 2021. Native yeast and non-yeast fungal communities of Cabernet Sauvignon berries from two Washington State vineyards, and persistence in spontaneous fermentation, International Journal of Food Microbiology,

<https://doi.org/10.1016/j.ijfoodmicro.2021.109225>.

Schlatter, D. C, Hansen, J, Carlson, B., Leslie, I. N. Huggins, D. R. and Paultiz, T. C. 2022. Are microbial communities indicators of soil health in a dryland wheat cropping system? Applied Soil Ecology 170: 10.1016/j.apsoil.2021.104302

Yin, C. T., Schlatter, D. C., Kroese, D. R., Paulitz, T. C. and Hagerty, C.H. 2021. Responses of Soil Fungal Communities to Lime Application in Wheat Fields in the Pacific Northwest. Frontiers in Microbiology 10.3389/fmicb.2021.576763

Gargouri, S., Boutrous, A., Murray, T. D., Paulitz, T. C., Khemir, E., Souissi, A. Chekali, S. and Burgess, L. W. 2021. Occurrence of eyespot of cereals in Tunisia and identification of *Oculimacula* species and mating types. Canadian Journal of Plant Pathology 10.1080/07060661.2021.1995501

Hagerty, C., Gardner, S., Kroese, D.R., Yin, C., Paulitz, T.C., Pscheidt, J.W. 2022. Occurrence of mummy berry associated with huckleberry (*Vaccinium membranaceum*) caused by *Monilinia* spp. in Oregon. Plant Disease. 106(2):357-359. https://doi.org/10.1094/PDIS-04-21-0691-SC.

Ahmadi, M., Mirakhorli, N., Erginbas-Orakci, G., Ansari, O., Braun, H., Paulitz, T.C., Dababat, A. 2022. Interactions among cereal cyst nematode *Heterodera filipjevi,* dryland crown rot *Fusarium culmorum*, and drought on grain yield components and disease severity in bread wheat. Canadian Journal of Plant Pathology. 44(3):415-431. https://doi.org/10.1080/07060661.2021.2013947.

**Cynthia Gleason**

**Associate professor**

**department of Plant pathology**

**Washington state university**

[**cynthia.gleason@wsu.edu**](mailto:cynthia.gleason@wsu.edu)

**Education and Training**

2003 Ph.D. University of California, Davis Biochemistry & Molecular Biology

1995 B.S. Santa Clara University, CA Biology

**Research and Professional Experience**

2022- present Associate Professor, Plant Pathology Department, Washington State University

2016-2022 Assistant Professor, Plant Pathology Department, Washington State University

2011-2016 Jr. Professor, Georg-August University, Goettingen, Germany

2006-2011 Post-doctoral fellow, Plant Industry, CSIRO, Perth, Australia

2003-2006 Post-doctoral fellow, Disease and Stress Biology, John Innes Centre, Norwich, UK.

**Professional Activities/Service**

**Trade publications:**

1) Cynthia Gleason and Sagar Sathuvalli “Genetic Diversity in Columbia Root-Knot Nematode, and a Request for Help in Research,”Potato Progress**,** Vol XX, No. 13, 2020

2) Zhang and Gleason, “Loop-Mediated Isothermal Amplification for the Diagnostic Detection of *Meloidogyne chitwoodi,”* Potato ProgressVol XX, No. 1, 2020

**Tools & Products:** Patent Application Number: 6302464, Application Filing Date: May 12, 2021;Title: Bacterial secreted immunostimulants to protect plants against pathogens

**Invited Talks in Past Four Years:**

1. 7th International Congress of Nematology, Antibes, France May 2022

2. 57th Annual Meeting of the Society of Nematologists, Gulf Shores, AL September 2021

2. Plant pathogen effectors- the nematode perspective. The Cluster of Excellence on Plant Sciences, zoom, June 1, 2021.

3. UC Riverside Plant Pathology Seminar, UC Riverside, October 2020

4. Washington*-*Oregon Potato Conference, Kennewick, WA January 2020

5. Plant Pathology Department, University of Wisconsin, Madison, WI. October 2019.

6. Entomology and Nematology Department,Florida State University, Gainesville, FL, 2019

**Synergistic Activities**

**Reviewer of Professional Journals (2020-2022):** Molecular Plant; Phytopathology; Frontiers in Plant Science; PLOS One; Molecular Plant-Microbe Interaction; Plant Physiology, Journal of Nematology; Scientific Reports; Physiological and Molecular Plant Pathology; The Plant Cell; Current Opinion in Biotechnology, BMC Genomics, Plant Disease, Frontiers in Plant Science, Plant Physiology, International Journal of Molecular Sciences, New Phytologist

**Reviewer for Grant Proposals:** US-Israel Binational Agricultural Research and Development Fund (BARD) (2019), USDA-National Science Foundation Plant Biotic Interactions (2020), Israel Science Foundation (2020), German DFG Walter Benjamin Programme (2020)

USDA NIFA (2017, 2019), USDA NSF (2022).

**Refereed Publications (last four years)**

Anderson, S.D., **Gleason, C. “**A Molecular Beacon Real-Time Polymerase Chain Reaction

Assay for the Identification of *M. chitwoodi*, *M. fallax*, and *M. minor.”* Frontiers in Plant Science, under review.

Hu, S., Franco, J., Bali, S., Chavoshi, S., Brown, C., Mojtahedi, H., Quick,R., Cimrhakl, L.,

Ingham, R., **Gleason, C.,** Sathuvalli, V. “Diagnostic molecular markers for identification of different races and a pathotype of Columbia Root-Knot Nematode.” Phytofrontiers, under review.

Baker, H.V, Ibarra Caballero, J.R., **Gleason, C.,** Jahn, C.E., Hesse, C.N., Stewart, J.E. Zasada, I.A. "NemaTaxa: A new taxonomic database for analysis of nematode community data.” Phytobiomes, under revision.

Rutter, W.R., Franco, J., **Gleason, C.** (2022) “Rooting out the mechanisms of plant-nematode

interactions.” Annual Review of Phytopathology 2022 60:1.

Zhang L. and **Gleason, C**.,(2021)“Transcriptome analyses of pre-parasitic and

parasitic *Meloidogyne Chitwoodi* Race 1 to identify putative effector genes.” Journal of Nematology, 53:e2021-84.

Bali, S, Zhang, L., Franco, J., **Gleason, C.** (2021) “Biotechnological advances with applicability

in potatoes for resistance against root-knot nematodes.”Current Opinion in Biotechnology,70: 226-233.*DOI:*https://doi.org/10.1016/j.copbio.2021.06.010

Bali, S., Shengwei, H., Vining, K., Brown, C., Mojtahedi, H., Zhang, L., **Gleason**, **C.,** Sathuvalli, V. (2021) “Nematode genome Announcement: Draft genome of *Meloidogyne chitwoodi,* an economically important pest of potato in the Pacific Northwest.” Mol Plant Microbe Interact Mar 29. doi: 10.1094/MPMI-12-20-0337-A.

Zhang, L. and **Gleason C**. (2020) “Enhancing potato resistance against root-knot nematodes

using plant elicitors delivered by bacteria.” Nature Plants, **6**, pages 625–629.

Bali, S., Vining, K., **Gleason, C**., Majtahedi, H., Brown, C.R., Vidyasagar Sathuvalli, (2019)

“Differential gene expression analysis provides insights into salicylic acid mediated resistance response to *Meloidogyne chitwoodi* derived from Mexican wild potato species *Solanum bulbocastanum*.”BMC Genomics, 20(1):907, DOI: 10.1186/s12864-019-6257-1.

Aharen, I., Habash, S.H., **Gleason, C**., Inada, M., Grundler, F.M.W., Elashry, A. (2019)

“*Heterodera schachtii* glutathione peroxidase (HsGPx) is a parasitism protein.” Journal of Plant Disease and Protection, 1-8, DOI 10.1007/s41348-019-00256-2.

Vieira, P. and **Cynthia Gleason** (2019) “Plant-parasitic nematode effectors – insights into their

diversity and new tools for their identification.” (2019) Current Opinion in Plant Biology, 50:37-43.

Zhang, L. and **Cynthia Gleason** (2018) “Loop-Mediated Isothermal Amplification for the

Detection of *Meloidogyne chitwoodi* and *M. fallax*.” Plant Disease, DOI:10.1094/PDIS-01-18-0093-RE

Leelarasamee, N., Zhang, L., **Gleason**, **C.** (2018)“The root-knot nematode effector MiPFN3 disrupts plant actin filaments and promotes parasitism” PLOS Pathogens 14(3): e1006947. <https://doi.org/10.1371/journal.ppat.1006947>.





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**EDUCATION**

1999 M.Sc., Agronomy, IA University, Isfahan, Iran

1995 B.Sc., Agronomy and Plant Breeding, IA University, Isfahan, Iran

**RESEARCH AND PROFESSIONAL EXPERIENCE**

2015 – Present Founder & Director, AGNEMA LLC, The Phytopathology & Research Laboratories. Pasco, WA.

2012 – 2015 Associate in Research, Washington State University, NW Sweet Cherry Breeding Program. Prosser, WA.

2012 (Apr – Dec) Technical Laboratory Associate, USDA-ARS, Dr. Charles Brown Lab. Prosser, WA.

1999 – 2012 Senior Agronomist – Seed Production & Certification Program. Department of Agricultural, Isfahan, Iran.

**PUBLICATIONS**

* Hu, S., Franco, J., Bali, S., Chavoshi, S., Brown, C., Mojtahedi, H., Quick, R., Cimrhakl, L., Ingham, R., Gleason, C., Sathuvalli, V. “Diagnostic molecular markers for identification of different races and a pathotype of Columbia Root-Knot Nematode.” Phytofrontiers, under review.
* Fu, Z., S. Chavoshi, H. Mojtahedi, S. Sathuvalli, K. Swisher Grimm, I. Zasada, Z. Cheng. 2019. Stubby root nematodes and associated corky ringspot disease. Potato Progress XIX(1).
* Zasada, I., M. Kitner, C. Wram, N. Wade, R. Ingham, S. Hafez, H. Mojtahedi, S. Chavoshi, N. Hammack. 2018. Trends in occurrence, distribution, and population densities of plant-parasitic nematodes in the Pacific Northwest of the United States from 2012-2016. Plant Disease. PDIS-09-18-1691-RE
* Oraguzie, N.C., C. Watkins, S. Chavoshi, and C. Peace. 2017. Emergence of the Pacific Northwest sweet cherry breeding program. Acta Hortic. 1161, 73-78, DOI: 10.17660/ActaHortic.2017.1161.12
* Chavoshi, S., C. Watkins, B. Oraguzie, Y. Zhao, A. Iezzoni, and N. Oraguzie. 2014. Phenotyping Protocol for Sweet Cherry (Prunus avium L.) to Facilitate an Understanding of Trait Inheritance. Journal of the American Pomological Society 68(3): 125-134 2014