**Full Proposal Submitted to the NW Potato Research Consortium**

**Title:** Comparison of potato yields, soil health, and pathogen loads in virgin and non-virgin soils.

**Year Initiated:** 2021-22. **Current Year:** 2021-22. **Terminating Year** 2023

**Personnel & Cooperators:**

PIs involved include David Linnard Wheeler ([david.wheeler@wsu.edu](mailto:david.wheeler@wsu.edu); 215-880-3024), Deirdre Griffin LaHue ([d.griffin@wsu.edu](mailto:d.griffin@wsu.edu); 360-848-6127), and Cynthia Gleason ([cynthia.gleason@wsu.edu](mailto:cynthia.gleason@wsu.edu); 509-335-3742) from Washington State University and Kenneth Frost ([kenneth.frost@oregonstate.edu](mailto:kenneth.frost@oregonstate.edu); 608-556-9637) from Oregon State University. Sudha G.C. Upadhaya ([sudha.gcupadhaya@wsu.edu](mailto:sudha.gcupadhaya@wsu.edu); 701-303-0630) serves as a research associate in the first PI’s lab. Teal Potter serves as a postdoctoral scholar in the second PI’s lab. All PIs will request funding.

**Funding Request for 2021-22:** **$63,053**

**Introduction: Problem Statement, Research Question(s) & Justification:**

Since potatoes were first grown, growers have noticed that the history of a field influences both yield and quality. Fields previously planted with potatoes generally yield less than field soils not previously farmed (virgin soils) or fields never planted with potatoes. Indeed, recent conversations with growers indicated that 14-26% greater yields can be achieved from virgin soils compared to nearby non-virgin soils. These observations corroborate results from several empirical studies (de Boer et al. 2001; Lamers, 1989). The purpose of this proposal is to determine what is responsible for these observations.

Over a century of research efforts on the impacts of virgin soils on crop health have painted a rich but somewhat complicated picture. For example, despite the yield increases often achieved in virgin soils, potential fungal, bacterial, and nematode pathogens can be recovered from these soils (de Boer et al. 2001; López-Fando and Bello 1995; Pratt 1916, 1918). Interestingly, not all crops planted in pathogen-infested virgin soils develop symptoms. Verticillium wilt symptoms, for example, may not be expressed within the first year in infested virgin soil (Davis, 1985), but may arise instead after subsequent plantings (Powelson and Rowe 1993). For other diseases, like common scab, black scurf, silver scurf, and Fusarium wilt and rot, symptoms can arise within the first year in virgin soils (de Boer et al. 2001; Lutman 1923; Pratt 1916, 1918).

Several sources of variation may account for these discrepancies between the expected and observed levels of disease in virgin soils. For example, other differences in soil physical, chemical, and biological properties, may be associated with virgin soils and influence crop health. In fact, differences in nematodes, bacteria, and fungal diversity have been detected between virgin and non-virgin soils (Chen et al. 2020;Gómez-Acata et al. 2014; López-Fando and Bello 1995; Werner and Zadworny 2002). Similarly, differences in soil physical and chemical properties have been detected between virgin and non-virgin soils (Blank and Fosberg 1989; Gómez-Acata et al. 2014; Zhang et al. 2018). Hence, numerous factors likely contribute to plant health in virgin soils. Unfortunately, the authors are not aware of any studies that have quantified the influence of all of these potential factors on crop health.

To identify factors associated with the greater yields observed when potatoes are grown in virgin soil, we propose to conduct a common garden experiment with virgin and non-virgin soils collected from fields in the Pacific Northwest. To capture the physical, chemical, and biological factors often associated with changes in land-management practices (Chen et al. 2020;Blank and Fosberg 1989; Gómez-Acata et al. 2014; Zhang et al. 2018), we have assembled a team of soil scientists and plant pathologists.

Ultimately, the results from this research will (i) document differences in soil physical, chemical, and biological properties that contribute to increases in potato yields and reductions in disease suppression in virgin vs non-virgin soils and (ii) foster future research efforts aimed towards reproducing and maintaining the observed benefits of virgin soils in non-virgin fields.

**Goal(s), Hypothesis & Objectives:**

The goal of this project is to determine the factors that contribute to potato yield increases in virgin soils. To achieve this goal, we will test the null hypotheses (i) there are no differences in potato yield, pathogen inoculum, and disease expression between virgin soils and non-virgin soils and (ii) there are no differences in soil properties between virgin soils and non-virgin soils that are associated with differences in potato performance. Both hypotheses will be supported by the objectives below. All objectives will be completed in the 2021-2022 funding year and repeated in the 2022-2023 funding year.

**Objectives:**

1. Sample soils from virgin and non-virgin fields.
2. Characterize soil physical, chemical, and biological properties.
3. Quantify potato performance in microplots.
4. Learn from data.

**Procedures:**

For objective 1, we will collect soil samples and cropping history records from a total of 10 pairs of fields (n=20) with virgin and non-virgin soils (**Figure 1.1**). To capture environmental differences present in the Northwest, we will sample in central Washington and Oregon, as well as western Washington during winter of 2020 or spring of 2021. This objective will be completed by D Griffin LaHue, DL Wheeler, and K Frost.

To complete objective 2 (**Figure 1.2**), each soil sample from objective 1 will be characterized for:

* soil physical, chemical, and biological properties following the suite of Tier 1 indicators used by the Soil Health Institute (Norris et al., 2020) and in the Comprehensive Assessment of Soil Health (CASH; Moebius-Clune et al., 2017) (to be completed by D Griffin LaHue);
* free living and plant-parasitic nematodes with DNA sequencing (to be completed by C Gleason);
* soilborne potato pathogen presence and abundance by culturing soils on semi-selective media (to be completed by K Frost);
* bacterial and fungal community structure with 16S rRNA and ITS amplicon sequencing, respectively (to be completed by D Griffin LaHue).

For objective 3, Russet Burbank potatoes will be planted in common garden microplots

containing the sampled soil (**Figure 1.3**). Russet Burbank potatoes will be used because they are susceptible to common soilborne plant pathogens. More specifically, after soils are characterized in objective 2, they will all be transferred to a common location and used to fill microplots. The location of these microplots has yet to be determined but the PIs plan to install them on a farm in Pullman, WA. The treatment structure of the trial will be a two-way design where 5 replicates of the soil factor (virgin and non-virgin) are nested within the location factor (Skagit Valley and the Columbia Basin). Microplots will be arranged in a randomized complete block design along the predominant environmental gradient at the site of installation. Overall plant senescence will be assessed at least five times throughout the growing season. Senescence will be estimated weekly by visual quantification of both chlorosis and necrosis. Yields and tuber quality will be determined for each experimental unit (plant in microplot). Objective 3 will be completed by DL Wheeler.

Finally, for objective 4, associations between virgin and non-virgin soils and soil properties will be visualized (**Figure 1.4**). Ordination methods (e.g. non-metric multidimensional scaling, principal components analysis, etc.), boxplots, and scatterplots will be used to visualize data from objective 2. Boxplots and dotplots will be used to visualize data from objective 3. (**Figure 1.4**). Differences between soil properties, potato yields, and disease expression will be investigated with standard statistical procedures like analysis of variance (ANOVA) and permutational multivariate analysis of variance (PERMANOVA). The soil factor will be treated as a fixed effect and nested within the location factor, which will be treated as a random effect. Relationships between soil properties, potato yields, and disease expression will further be elucidated with various classical and machine learning models. Models will be compared and results from the models that perform the best will be presented. Assumptions required for the analyses described above will be inspected visually and tested empirically. Objective 4 will be completed by all PIs.

Diagram

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**Figure 1.** Flow chart of objectives 1 through 5. Circles in objective 3 represent microplots. The arrow represents the primary environmental gradient against which blocks (pairs of virgin and non-virgin soil samples) will be arranged.

**Collaboration:**

DL Wheeler and SGC Upadhaya will collect soils from central WA, establish microplots, collect yield and disease data, and analyze data. D Griffin LaHue and T Potter will collect soils from western WA and conduct analyses of soil physical, chemical, and biological properties with support from M Kleber and D Myrold. K Frost will collect soils from OR, quantify soilborne pathogens from soils. C Gleason will conduct community analysis of nematodes with support from I Zasada (USDA-ARS/OSU).

**Anticipated Benefits/Expected Outcomes/Information Transfer:**

In the short term, we will describe how differences in virgin and non-virgin soils contribute to potato health. More specifically, we will identify the soil physical, chemical and biological (including plant pathogens and nematodes) properties associated with the observed yield increases when potatoes are grown in virgin soils. This work will also contribute toward evaluating the usefulness of soil health indicators in the CASH and establishing a soil health assessment framework that is most relevant for potato systems in the PNW. Results from this research will be disseminated through a peer-reviewed manuscript, Potato Progress report, field days, and conference presentations.

In the longer term, results from this research will inform future efforts to reproduce and maintain the benefits of virgin soils on potato yield and quality at commercial scales. After the factors that contribute to yield increases in virgin soils are identified, the authors will apply for additional funding to study management strategies that can reproduce these effects in commercial potato fields with non-virgin soils.

**Project Timeline:**

The PIs will identify fields and start collecting soils for objective 1 during winter of 2020 and spring of 2021. Similarly, time-sensitive components of objective 2 will begin during the winter of 2020 and spring of 2021. Objective 3 will formally begin during the summer of 2021 but the selection of the location for the microplots and plot preparation will begin as soon as possible. Finally, objective 4 will begin as early as summer of 2021 and end in the winter of 2021. A similar timeline will be used for 2022.

**Literature Cited:**

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| 1. Blank RR, and Fosberg MA. 1989. Cultivated and adjacent virgin soils in northcentral South Dakota: I. chemical and physical comparisons. Soil Sci. Soc. Am. J. 53:1484-1490 |
| 1. Chen LF, He ZB, Zhao WZ, Liu JL, Zhou H, Li J, Meng YY, and Wang LS. 2020. Soil structure and nutrient supply drive changes in soil microbial communities during conversion of virgin desert soil to irrigated Cropland. Eur J Soil Sci. 71:768–781. <https://doi.org/10.1111/ejss.12901> |
| 1. Davis, JR. 1985. Approaches to control of potato early dying caused by *Verticillium dahliae.* American Potato Journal. Vol 62. |
| 1. de Boer R, Petkowski J, Wicks T, Harding R, Watson A. 2001. Influence of rotation and biofumigation on soil-borne diseases of potato. Horticulture Australia Project PT96032 |
| 1. Gómez-Acata ES, Valencia-Becerril I, Valenzuela-Encinas C, Velásquez-Rodríguez AS, Navarro-Noya YE, Montoya-Ciriaco N, Suárez‐Arriaga MC, Rojas‐Valdez A, Reyes‐Reyes BG, Luna‐Guido M, and Dendooven L. 2014. Deforestation and cultivation with maize (*Zea mays* L.) has a profound effect on the bacterial community structure in soil. Land Degrad. Devel*.* 27:1122–1130. [https://doi:10.1002/ldr.2328](about:blank) |
| 1. Lames JG, Hoekstra O, Scholte K. 1989. Relative performance of potato cultivars in short rotations. In ‘Effects of Crop Rotation on Potato Production in the Temperature Zones’. (Eds J Vos, C van Loon, and G Bollen) pp. 57-75. (Kluwer Academic Publishers: Dordrecht, The Netherlands) |
| 1. López-Fando C, and Bello A. 1995. Variability in soil nematode populations due to tillage and crop rotation in semi-arid Mediterranean agrosystems. Soil and Tillage Research. 36: 59-72. |
| 1. Lutman BF. 1923. Potato scab in new land. Phytopathology. 13:241-244. |
| 1. Norris CE, GM Bean, SB Cappellazzi, M Cope, KLH Greub, D Liptzin, EL Rieke, PW Tracy, CLS Morgan, CW Honeycutt. 2020 Introducing the North American project to evaluate soil health measurements. Agronomy Journal. 112:3195-3215. 2. Powelson ML, and Rowe RC. 1993. Biology and management of early dying of potatoes. Annu Rev Phytopathol. 31:111-126. |
| 1. Pratt, OA. 1916. Experiments with clean seed potatoes on new land in southern Idaho. Journal of Agricultural Research. Vol VI, No. 15 |
| 1. Pratt, OA. 1918. Soil fungi in relation to diseases of the Irish potato in southern Idaho. Journal of Agricultural Research. Vol XIII, No. 2 |
| 1. Rowe RC. 1985. Potato early dying – a serious threat to the potato industry. American Potato Journal. Vol. 62. |
| 1. Werner A, Zadworny M. 2002. Interaction between microfungi from arable and fallow land soils and *Heterobasidion annosum in vitro*. Dendrobiology. 47:51-58. |
| 1. Zhang H, Zhang S, Meng X, Li M, Mu L, Lei J, and Sui X. 2018. Conversion from natural wetlands to forestland and farmland alters the composition of soil fungal communities in Sanjiang Plain, Northeast China. Biotechnol. Biotechnol. Equip. 32:951-960. [https://doi:10.1080/13102818.2018.1459208](about:blank) |

**Budget:**

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| --- | --- | --- | --- | --- | --- |
| **FY 2021-22** | **Wheeler lab@WSU** | **Gleason lab@WSU** | **Griffin lab@WSU** | **Frost lab @OSU** | **Total** |
| **Salaries: Faculty** | 12,000 | 7,475 | 10,080 |  | 29,555 |
| Other students | 3,000 |  |  |  | 3,000 |
| **Employee Benefits (OPE): Faculty** | 3,636 | 2,670 | 3,052 |  | 9,358 |
| Travel: | 3,000 |  |  |  | 3,000 |
| **Operating Expenses** |  |  |  |  |  |
| Sampling | 1,500 |  |  |  | 1,500 |
| Lab and microplot supplies | 4,000 | 655 |  |  | 4,655 |
| Culturing pathogens from soil |  |  |  | 2,000 | 2,000 |
| DNA extraction and sequencing |  | 500 | 5,715 |  | 6,215 |
| Soil properties analysis |  |  | 3,570 |  | 3,570 |
| Shipping |  | 200 |  |  | 200 |
| **Total** | 27,136 | 11,500 | 22,417 | 2,000 | **63,053** |

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| ¹Salary is to support employee for 0.25 FTE of 12 months at Wheeler's lab, for 0.15 FTE at Gleason's lab, and for 0.2 FTE at Griffin's lab. |
| ²Benefits for Post-Doc/Research Associate are 30.3% of salary |

**Anticipated Total Requests in Coming Years: 2022-2023: $65,000 2023-2024: $0**

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

This project will serve to generate preliminary data for larger grants, like USDA Sustainable Agriculture Research and Education and Specialty Crop Block Grants.