**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:** 2022-23. **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) is a graduate student 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 2022-23:** **$63,111**

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

After decades of raising potatoes in the Columbia Basin, producers 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 potato 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 project is to determine what soil and biological factors are responsible for these observations. This study was initiated last year and at least one more year of research is required to corroborate or refute the results from the first year. At least three additional pairs of virgin-nonvirgin soils will be collected both to replicate the experiment under a second growing season’s climate conditions as well as to improve the statistical power needed to detect subtle effects of soil properties on potato yields. For example, microbial community composition varies widely among soils due to many factors (e.g. moisture and pH) and therefore many samples are needed to distinguish virgin soil communities from nonvirgin soil communities.

Many decades of research efforts on the impacts of virgin soils on crop health have painted a rich but somewhat complicated picture. For example, despite the higher yields obtained in virgin soils relative to non-virgin soils, 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 or disease suppressive 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). Thus, pathogen density does not appear to be the only factor that explains the higher yields and lower disease intensity observed in virgin fields relative to non-virgin fields.

Several sources of variation may account for these differences in yields and disease expression between virgin and non-virgin fields. 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 continue our common garden experiment with more 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 maintained 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.

**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.

**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 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 2021 or spring of 2022. 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 composition with 16S rRNA and ITS amplicon sequencing, respectively (to be completed by D Griffin LaHue).

For objective 3, Russet Burbank potatoes will again 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 microplots will be installed at the Tukey Orchard 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). Additionally, yield data will be requested from growers who managed potato crops in the fields selected. These data will be compared to our microplot data and used to test the hypothesis that yields are different between virgin and nonvirgin fields. 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.

**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. 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).

**Project Timeline:**

The timeline for 2022-23 will be similar to the timeline from 2021-2022. The PIs will identify fields and start collecting soils for objective 1 during winter of 2021 and spring of 2022. Similarly, time-sensitive components of objective 2 will begin during the winter of 2022. Objective 3 will begin during the summer of 2022 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 2022 and end in the winter of 2022.

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.

**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.

**Literature Cited:**

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**Budget:**

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| --- | --- | --- | --- | --- | --- |
| **FY 2021-22** | **Wheeler lab** | **Gleason lab** | **Griffin lab** | **Frost lab** | **Total** |
| **1Salaries:** Faculty |  | 7,475 | 10,080 |  | 17,555 |
| Graduate student | 13,938 |  |  |  | 13,938 |
| Other students | 3,000 |  |  |  | 3,000 |
| **2Employee Benefits (OPE):** Faculty |  | 2,670 | 3,052 |  | 5,722 |
| Graduate Student | 1,756 |  |  |  | 1,756 |
| 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** | 27,194 | 11,500 | 22,417 | 2,000 | **63,111** |

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| ¹Salary is to support employee for 0.35 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 and graduate student are 30.3% and 12.5% of salary respectively |

**Anticipated Total Requests in Coming Years: 2023-2024: $0**