**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:** **$72,329**

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

Since potatoes were first grown, growers have likely 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, Rhizoctonia scab, 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’s 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’s 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 the 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.

**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 is no difference 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 replicated in the 2022-2023 funding year.

1. Sample soils from virgin and non-virgin soils.
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.

To complete objective 2, each soil sample from objective 1 will be characterized for:

* physical, chemical and biological properties following the Comprehensive Assessment of Soil Health (CASH; Moebius-Clune et al., 2017);
* free living and plant-parasitic nematodes with DNA sequencing;
* soilborne potato pathogen presence and abundance;
* bacterial and fungal community structure with 16S rRNA and ITS amplicon sequencing, respectively (**Figure 1.2**).

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

containing the sampled soil (**Figure 1.3**). The location of these microplots has yet to be determined but the PIs plan to install them in Pullman, WA. The treatment structure of the trial will be two-way factorial design where each level of the first factor (soil: virgin and non-virgin soil) will be replicated 5 times within each level of the second factor (state: Washington and Oregon). Microplots will be arranged in a randomized complete block design along the predominate environmental gradient at the site of installation. Disease expression will be assessed at least five times throughout the growing season. Yields and tuber quality will be determined for each experimental unit (plant in microplot).

Finally, for objective 4, associations between virgin and non-virgin soils and soil properties will be first 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). 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.

Diagram

Description automatically generated

**Figure 1.** Flow chart of experiment

Indicate your approach and procedures to accomplish the objectives. Include as much detail as space allows; it is important to demonstrate to reviewers that the project has been thoroughly planned. Use appropriate language! For example, your writing should be targeted toward college-educated laypeople with little to no knowledge of molecular biology or genetics (if you need help with this, send draft language to Andy Jensen for input well in advance of the deadline). If you intend to follow methods established in published papers, cite the relevant work. Be sure to include in this section information about roles and responsibilities of all collaborators on the project.

**Collaboration:**

DL Wheeler and S GC Upadhaya will collect soils, establish microplots, collect yield and disease data, and analyze data. D Griffin LaHue and T Potter will conduct analyses of soil physical, chemical, and biological properties with support from M Kleber and D Myrold. K Frost will quantify soilborne pathogens from soils. C Gleason will identify and quantify nematodes with DNA sequence data.

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

What specific impacts will result from this project for producers and/or the industry? Be clear and direct, be realistic, and avoid exaggeration.

Ultimately, after the factors that contribute to yield increases in virgin soils are identified, the authors will apply for additional funding to reproduce these effects in commercial potato fields.

**Project Timeline:**

List of activities and stages in the research project for the coming year and/or for the duration of the project.

**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. 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. ~~Huber DM, and Watson RD. 1970. Effect of organic amendment on soil-borne plant pathogens. Phytopathology. 60: 22-26~~ |
| 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. 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:** 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.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Scientist/Lab 1 (specify) | Scientist/Lab 2 (specify) | Scientist/Lab 3 (specify) | **Total** |
| **Salaries:** Faculty |  |  |  |  |
| Graduate student |  |  |  |  |
| Other students |  |  |  |  |
| Other labor |  |  |  |  |
| **Employee Benefits (OPE):** Faculty |  |  |  |  |
| Graduate student |  |  |  |  |
| Other students |  |  |  |  |
| Other labor |  |  |  |  |
| Equipment |  |  |  |  |
| Travel: |  |  |  |  |
| Operating Expenses |  |  |  |  |
| Other Expenses |  |  |  |  |
| **Total** |  |  |  |  |

**Anticipated Total Requests in Coming Years: 2022-2023: 2023-2024:**

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

Please describe other funding and in-kind support that contributes to this work, such as related federal or state grants, internal university grant programs, faculty start-up funds, etc. Also describe plans for submission of federal, specialty crop block grant, or other regional proposals that will support or expand on this project.

Comments from Andy:

1. *Comparison of potato yields, soil health, and pathogen loads in virgin and non-virgin soils.*At the top, the “terminating year” is shown as 2022, which would mean this is a one-year project.  Is that your intention? We suspect that there is more research out there comparing virgin and non-virgin soils than what you cited in the text. To create a strong proposal, I suggest finding, reading, and citing much more relevant literature on such soil comparisons, even if those studies are on crops other than potatoes, in regions outside the Northwest, from the relatively distant past, etc. As you may know, there is some controversy floating around about the relative value of the available soil health assessment methods, including CASH. The proposal will be stronger if you adequately justify the use of CASH as opposed to alternatives. The cartoon on page 2 is good. The project’s cost is relatively high; are all the locations and PIs necessary? Is there enough virgin ground, especially in eastern Idaho, to do this as proposed? Finally, we see that Cynthia Gleason would be leading nematode community analyses. It seems like this is not the strength of her lab. Would she really be doing this, or would it be contracted out to AgNema or Inga Zasada (USDA-ARS Corvallis)?