BC Hazelnut On-Farm Trial Network Research Plan

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Table of Contents

1.0 Introduction

The purpose of this project is to support the resilience of British Columbia's hazelnut industry by developing an on-farm research network to test agronomic performances of hazelnut varieties with resistance to Eastern Filbert Blight (EFB) which is caused by the fungus *Anisogramma anomala*. Recent trials of these cultivars in the Fraser Valley and Hornby Island suggest good potential for the use of EFB-resistant varieties to revitalize hazelnut production in BC; however, these trials also demonstrated a need for better understanding of interactions between climate, management, and cultivars in determining yields, particularly as climate may affect timing of pollen shed and female flower receptivity, and, therefore, pollination and nut yield.[1]

One of the recommendations of the BC Hazelnut Opportunity Assessment Report (Bodnar, 2020) to strategically expand the BC hazelnut sector and domestic hazelnut market is the development of a participatory On-Farm Trial Network[2]. However, while the report mentioned that trees would be provided for growers[2], funding is often limited and growers need to consider different resources available to them. Also, in order to implement an actionable hazelnut network that supports knowledge transfer between growers about new varieties in different climate regions, growers must also be willing to participate and work collaboratively. This involves active grower involvement in data collection and sourcing their own trees to plant across relevant agricultural zones in BC. Governmental and institutional resources will serve as potential sources of funding available to growers to support the on-farm research network.

Currently, approximately half of BC growers have less than 1 acre planted but 33% of these growers plan to increase their plantings within the next 3 years if new hazelnut varieties prove successful[2]. The large number of small hazelnut plantings and an interest in developing plantings outside the Lower Mainland present an opportunity to expand the hazelnut sector and support knowledge mobilization[2]. In addition, larger growers may also support the development of new consumer markets and the viability of hazelnut processing facilities[2].

Furthermore, as newer hazelnut production shifts towards the Okanagan Valley and Vancouver Island due to more favourable land access, better information is needed about the performance of EFB-resistant cultivars in agricultural zones outside the Fraser Valley. Looking towards the future, shifts in weather patterns due to climate change will likely create an even greater need for regional information about the stability and resilience of crop cultivars. Due to the significant damage Eastern Filbert Blight has caused for the hazelnut growers and given that the BC hazelnut industry is only just beginning to recover

from the impacts of this disease, growers may be hesitant to try new varieties or invest significant time into planting and maintaining new hazelnut trees. In order to support the expansion of the hazelnut industry in BC, it is vital to understand where hazelnuts can be grown and which varieties will perform well[2] so that growers know the potential for nut yield for the BC consumer market.

Participatory, on-farm research trials provide a way for farmers to gather and share data about cultivars or other agronomic practices or technology. Typically, farmers work collaboratively in a group, with or without formal researchers, to develop research questions and methods and to analyze and share results[3]. In the case of the BC hazelnut industry, a network of on-farm research trials would provide the opportunity to test EFB-resistant cultivars across a greater array of agricultural zones than has been done previously, while also offering potential to address other agronomic questions of interest to the industry in the future. Cultivar diversification and the use of resilient cultivars is an important strategy for climate change adaptation[4], so developing farmer networks that share information on cultivar performance can also help the BC hazelnut industry adapt to these challenges. In addition, the introduction of new cultivars would diversify current hazelnut orchards by serving as buffers against disease.

This project's objectives consisted of the following:

- Conduct background research and stakeholder conversations to assess priorities, protocols, and most suitable methods for participatory cultivar testing for BC hazelnut growers;
- Create an actionable plan for on-farm testing of EFB-resistant hazelnut varieties across relevant agricultural zones in BC;
- Develop protocols to assist researchers and farmers in the collection of on-site data;
- Suggest options for knowledge mobilization and farmer training.

In British Columbia, there are several existing hazelnut tree plantings in the Chilliwack, Langley, and Abbotsford regions with emerging plantings in the Okanagan Valley (Summerland, Kelowna), Vancouver Island (Courtenay), and Pender Island (Hazelnut Renewal Program 2018-2020, Ministry of Agriculture). There may also be opportunities to encourage growers to diversify and begin planting orchards in unused lands[2].

There are a number of public and licensed hazelnut tree varieties that can be planted depending on the interests of growers and the desired nut yield and quality (**Table 1**). A public hazelnut variety grants growers permission to propagate and sell their cultivar varieties while a licensed variety prohibits these activities. It is important to note that the Canadian Food Inspection Agency (CFIA) currently prohibits whole trees or cuttings for import into Canada and only tissue culture produced plants are exempt[5].

Table 1: Public and Licensed Hazelnut Varieties from the Oregon State University Breeding Program.

Public OSU Hazelnut Varieties	**Hazelnut Varieties Licensed in USA (note: the below varieties are public in Canada)**	**Newest OSU Hazelnut Cultivars to be Planted (licensed in USA & Canada)**
Jefferson	Dorris	McDonald*
Lewis	Felix (Pollinizer)	Wepster*
Sacajewea	York (Pollinizer)	
Yamhill		
Eta (Pollinizer)		
Theta (Pollinizer)		
Gamma (Pollinizer)		

*McDonald (CDN PBRAF# 18-9479) and Wepster (CDN PBRAF# 18-9480) are licensed varieties of Oregon State University and protected both by patents in the US and Plant Breeders Rights in Canada. Purchasers of these varieties are not allowed to propagate for either further sale or expansion of orchards. Illegal propagation will be prosecuted (Thomas E. O'Dell, BCHGA Field Day Presentation, 2019).

2.0 Report Methodology

2.1 Literature Review

We conducted a comprehensive literature review of EFB-resistant hazelnut varieties, traits measured, and previous experimental trials designs in British Columbia, Ontario, Prince Edward Island and Oregon, USA.

2.2 Stakeholder Feedback

Through stakeholder and plant breeder conversations, we established grower priorities and most suitable methods for participatory cultivar testing for BC hazelnut growers and recommendation of EFB- resistant varieties for trialing based on current plant availability and interest of growers. Most growers were enthusiastic about starting a new research trial and some growers have already begun planning to plant more trees. Furthermore, local

nurseries such as Mosterman Plants Inc., have also expressed interest in participating as a trial site.

In addition to 5 phone calls, we also created a *Qualtrics* hazelnut farmer questionnaire which Rita Bruneski from the Agassiz Agricultural and Horticultural Association and BCHGA distributed to grower association members from June 22nd 2020 and closed on July 10th 2020. The survey was sent out to 111 grower members and 25 members completed it with a response rate of 22.5% (**Table 2**).

Our proposed research plan was reviewed by Karina Sakalauskas, Dr. Thom O'Dell and members of the Hazelnut Growers' Association. Further review and research input was provided by UBC faculty member Dr. Thorsten Knipfer. The plan was also reviewed at UBC by Dr. Alex Lyon and Dr. Hannah Wittman.

Table 2: Growers' Association Members' Feedback on trial design based on our *Qualtrics* farmer questionnaire. (x**number**) denotes the number of times that response was repeated by all growers who completed the survey. The 25 grower responses also include partial answers to the 11 questions.

Question	Grower Responses
We have identified Wepster and McDonald the top priorities for trials with new plantings. Are there any other varieties you think should be included as new research plantings?	**From 25 responses:** Cultivars: ● Yamhill (x**11**) ● Jefferson(x**9**) ● PollyO(x**4**) ● Dorris Pollinizers: Felix, York, Eta, Theta, Gamma, Lewis Other responses: varieties that do well in US hardiness Zone 3
In a trial involving new plantings of trees with 2 to 3 varieties, how many trees of each variety would you be interested in planting (provided funding is available)?	**From 25 responses:** ● Small scale range: 2, 5, 5-7(x**2**), 8, 10, 10-20, 12, 15, 25, 30-40, 50 ● Large scale range: up to 100, 100(x**2**), 150, 200/arce, 300 Other responses: No room or 0 (x**4**), already planted, able to dedicate a section, 175 Yamhill, 175 McDonald, 175 Wepster, 75 Gamma

What is the lowest number of trees of each variety that would be feasible in terms of mechanical harvest?	**<u>From 25 responses:</u>** 1 acre (**x2**), 2 acre, 3 acre Number of trees (5, 25, 35, 50, 200-300) N/A (**x12**) Hand harvest only Other responses: cooperate with Fraser Valley Hazelnuts down the road for the trials
Provided compensation is available, would you be willing to harvest up to 5 trees for yield and nut quality assessments? (This would be an alternative for plantings that are too small for a mechanical harvester, and is in line with established sampling procedures for hazelnut trials.)	YES: 18/25 NO: 2/25
How many trees do you have planted and which varieties? (Please list either in area or number of trees)	**<u>From 25 responses:</u>** **<u>Number of trees planted:</u>** ● 7,000 of Yamhill ● 7.5 acres (Yamhill, Sacajawea, Gamma, Jefferson); 12.5 acres (Jefferson, Theta, Eta, Yamhill) ● 45 of each (Lewis, Sacajawea, Yamhill, Jefferson); 5 of each (Dorris, Gamma, Eta, Theta ● 500 total (Yamhill, Jefferson, Gamma, Sacajawea) ● 225 of Jefferson, 75 of Yamhill ● 4 of each (Clark, Dorris, Eta, Felix, Gamma, Jefferson, Lewis, McDonald, Sacajawea, Theta, Wepster, Yamhill, York) ● 30 of Jefferson ● 2 of Jefferson, 2 of Eta, 2 of Theta ● 225 of Jefferson, 40+ of Gamma/Eta/Theta ● 1460 of Jefferson ● 90 of Eta, 80 of Theta, 75 Yamhill ● 32 acre of Yamhill ● 890 of Yamhill, 55 of Gamma, 32 of Jefferson, 25 of Theta (total 9 acres) ● 1200 of Jefferson

	● 400 of Yamhill, 155 McDonald ● 180 of Yamhill, 250 of Jefferson, 50 of Sacajawea, 25 of Wepster ● 100 (Jefferson Yamhill) ● 820 of Barcelona variety ● 1982 of Yamhill, 1982 of Wepster, 146 of Gamma, 73 of Jefferson, 73 of Theta, 72 of McDonald, 72 of York (note: to be planted) ● To be planted: 25-50 of each (Dorris, Felix, Jefferson, Lewis, McDonald, Theta, Wepster, York) Other responses: ● 950 (unknown varieties) ● 28 *Corylus avellana* **<u>Varieties planted:</u>** ● Jefferson(x**18**) ● Yamhill (x**12**) ● Sacajawea (x**5**) ● Gamma (x**8**) ● Theta (x**9**) ● Eta **(**x**6**) ● Wepster (x**5**) ● McDonald (x**4**) ● Lewis (x**3**) ● Clark ● Dorris(x**2**) ● Felix(x**2**) ● York Other responses: *Corylus avellana, Corylus cornuta, Barcelona or Ennis variety*
Do you mechanically harvest your hazelnuts?	YES: 14/25 NO: 11/25
Do you use irrigation on your hazelnuts?	YES: 17/25 NO: 9/25 Method: either surface drip line or underground system irrigation or watering by hand
Which of the following activities would you be willing to do as part of on-farm hazelnut research:	*Note: this data includes growers who gave partial answers only, or did not answer*

a) Monitor female flowers and record timing of receptivity for trees I have already planted b) Monitor male flowers and record timing of pollen shed for trees I have already planted c) Record trunk diameter of trees I have already planted (~5 trees per variety) d) Harvest a sample of nuts from my existing plants in order to measure yield and nut quality (provided feasible methods can be developed) e) Plant new trees for research plots and collect the data listed in a-d	YES: 20/25 NO: 3/25 YES: 21/25 NO: 2/25 YES: 20/25 NO: 3/25 YES: 20/25 NO: 3/25 YES: 15/25 NO: 7/25
Do you already sample soil for pH and moisture content? If yes, what equipment do you use? Do you already get regular soil testing?	YES: 16/25 NO: 9/25 1 response out of 25: soil salinity only Equipment: Hortau soil tension sensors, conductance meter for humidity, soil probe pH, shovel for moisture or send samples to a laboratory for analysis (ie. Terralink)
What do you think are the most important traits to evaluate about a new hazelnut variety?	**<u>From 25 responses:</u>** ● Yield (x**13**) ● Disease resistance (EFB or new) (x**11**) ● Nut flavour, nut quality or nutritional content (x**8**) ● Hardiness (x**6**) ● Resilience (x**5**) ● Flower and pollen shed timing related to BC climate (x**4**) ● Drought resilience and water requirements **(x3**) ● Proportion of kernel to nut size or percentage of blanks (x**2**) ● Timing of nut drop **(x2**) ● Early harvest ● No fungus ● Growth characteristics of tree ● Best ratio of nut production trees to pollinizers

	● Easy management of trees (ie: no suckers at base, less pruning of branches) ● Shell out percentage ● Fill

3.0 Background Research

3.1 Literature Review

We compiled a summary of our literature review (**Table 3**) and summarized traits that have been consistently measured in most studies, conclusions for varieties tested in BC, and recognized gaps in the literature that need further study.

3.2 Common Study Traits

The most common traits in most studies from the literature review were the following: nut and kernel yield and quality, flowering time and timing of pollen shed.

3.3 Varieties That Have Been Tested in BC

Six varieties (Jefferson, Sacajawea, Yamhill, Eta, Gamma, Theta) were tested in BC between 2015 and 2017 in the Fraser Valley and Hornby Island. In this study[1], Sacajawea had low resistance to EFB and lower nut production while Jefferson and Yamhill were highly resistant to EFB and had excellent nut production. Both Jefferson and Yamhill out yielded Sacajawea at each site and had the largest nut yields per farm. However, preventative fungicides were not applied so it was not a good test of yield for Sacajawea without good management. EFB symptoms were not observed on Yamhill or the pollinizers Eta, Gamma and Theta in any of the five sites.

3.4 Gaps in the Literature

Except for the Prince Edward Island experimental study by William M. Glen and Delmar Holmstrom (2012), our literature review found that there has been little research into the relationship between EFB-resistant cultivar performances and climate. This research is critical to understand how a potential EFB-resistant cultivar performs in various climate

zones throughout BC because it may provide reassurance to growers that the cultivars are worth investing into an experiential trial and information about the general resilience of a crop cultivar.

Another gap is the inconsistency of the number of trees used for each trial setup and the lack of reasoning behind the methodology used for the trials. There was a lack of detailed sampling protocols for the Oregon State University hazelnut variety trials.

Table 3: Summary of literature review of previous research trials involving hazelnuts.

Study Location	EFB Hazelnut Tree Varieties Tested	Trial setup	Traits measured
Hornby Island Greendale Agassiz (x2) Chilliwack **(Thomas E. O'Dell, 2019)[1]**	Jefferson, Sacajawea Yamhill Eta(pollinizer) Gamma(pollinizer) Theta (pollinizer)	485 trees per site at "double-density" spacing (2.7 m × 5.4 m–3.0 m × 6.0 m). Each production variety was planted in a block with 15% genetically compatible pollinizers.	1. Female receptivity/flowering time 2. Timing of pollen shed 3. Trunk diameter 4. Nut size, yield & quality 5. Kernel weight, size & defects 6. Leaf tissue nutrient concentration
Oregon State University Vegetable Research Farm **(D.C. Smith, R.L. McCluskey and S.A. Mehlenbacher, 2018)[6]**	*York(pollinizer) *Wepster *McDonald *cross-compatible and recommended to be planted together	7 replicates of each selection were planted at a tree and row spacing of 4.88m.	1. Nut weight, yield & quality 2. kernel size, weight & defects
Corvallis, Oregon **(R.L. McCluskey, S.A. Mehlenbacher, D.C. Smith and A.N. Azarenko, 2009)[7]**	Yamhill Santiam Delta Gamma	8 single tree replicates of each genotype were planted in a randomized complete block design. Trials were planted at 4.6 × 5.5m spacing with a grass strip between the rows.	1. Nut weight 2. Kernel weight & defects 3. Bloom phenology 4. Trunk circumference

Simcoe Research Station(Simcoe, Ontario). **(CFIA, 2014)[8]**	Norfolk C-16 Chelsea C-28 Slate (reference) Butler (reference)	The trial included four replicates with 3 trees of each variety per replicate, establishing a total of 12 trees each of the candidate and reference varieties.	1. Nut width & length
Prince Edward Island **(William M. Glen and Delmar Holmstrom, 2012)[9]**	Car3, Car12, Epsilon, Farris 88BS, Farris G17, Farris GTO, Gamma, Geneva, Grimo 186M, Grimo 208D, Grimo 208P, Het1, Het3, Jefferson, Santiam, Slate, Yamhill, Zeta *Note: The project's objective was to evaluate hybrid hazelnut varieties under Prince Edward Island climatic conditions.*	<u>Total trees planted for 3 sites:</u> Car3(44 trees), Car12(43 trees), Epsilon(73 trees), Farris 88BS(47 trees), Farris G17(114 trees), Farris GTO(42 trees), Gamma(20 trees), Geneva(116 trees), Grimo 186M(117 trees), Grimo208D(62 trees), Grimo 208P(108 trees), Het1(63 trees), Het3(60 trees), Jefferson(47 trees), Santiam(75 trees), Slate(71 trees), Yamhill(45 trees), Zeta(22 trees) ,	1. Mortality 2. Plant height 3. Root collar diameter 4. Stem diameter 5. Air temperature
Simcoe Research Station(Simcoe, Ontario) **(T. Taghavi, A. Dale, et.al)[10]**	Barcelona, Butler, Jemtegaard, Lewis, Clark, Norfolk C-16, Chelsea C-28, Gene (Geneva), Grimo 186M (Alex) and C-409.	10 varieties were tested from different origins; unknown number of trees used; unknown setup.	1. Air temperature 2. Female flowering time stages of flowering 3. Timing of pollen shed

3.5 Feedback from BC Hazelnut Industry Stakeholders

From our conversations with BC hazelnut growers and Qualtrics questionnaire responses, there are varied traits growers would be interested in measuring in a new hazelnut cultivar, such as yield, disease resistance, nut quality (such as proportion of kernel to nut size or percentage of blanks, nut flavour, nutritional content of the nut etc), and the hardiness of the tree.

3.6 Synthesis of Literature Review Results

From the literature, we concluded that the recording and observation of hazelnut female receptivity and timing of pollen shed are the two most significant traits to measure in a new hazelnut research trial.

4.0 Options for On-Farm Hazelnut Research

4.1 Phase 1: Data collection from Existing Trees

To begin collecting data and developing an on-farm research network as quickly as possible, it may be best to start with farmer data collection from existing plantings. Current varieties in British Columbia include Jefferson, Yamhill, Sacajewea and pollinizer varieties such as Etha, Theta, Gamma (Fraser Valley) and varieties expected to be planted and tested also include Dorris, Wepster and McDonald (Sakalauskas, K. BC Ministry of Agriculture).

4.1.1 Traits to Measure

The following traits and data would be collected on existing trees: monitoring female flowers and recording the timing of receptivity; monitoring male flowers and recording the timing of pollen shed; recording trunk diameter; harvesting a sample of nuts to measure yield and nut quality; and soil data such as pH, nutrient content, moisture and drainage. More details about these traits are listed in **Figure 1**. Soil agricultural capability and drainage class can be obtained from public sources (BC Soil Information Finder Tool).

Figure 1: Type of data feasible for farmers to collect on their farms (see also protocols in **Appendix A**)

Proposed Data to be Collected by Farmers on Site	Equipment Required for Measurements	When to Sample	Approx. Time commitment (hours)
Soil drainage, pH and nutrient content	soil pH meter, soil probe	Seasonal or every few years	1 hour
Flowering time and pollen release timing	None; observation	Seasonal (every 2-3 days - approx. January - early April)	1 hour
Nut yield and nut quality	Machine harvesting, sweeping, backpack harvester, hand harvesting	Seasonal	1 hour

Trunk diameter	Measuring tape, caliper	Seasonal, once every 1-2 years	15 minutes
Suggested: Weather data such as temperature, humidity	Weather station, such as Davis Instruments, or a portable hand held station	Automatic daily setup or seasonally	<15 minute
Optional: Disease and insect monitoring	Suggested: Hand held magnifiers; ID card with hazelnut pest and diseases, sealable plastic bags	Seasonal-once a week	1 ½ hour
Data collection,data entry, and summary communication	PC-or notebook	End of the year-once	1 hour
Recommended: Leaf tissue collection for nutrient assessment	Send to lab for analysis	At end of trial	30 minutes

4.1.2 Number of Farms and Geographical Distribution

In order to produce the most reliable results and collect extensive regional data, it would be ideal for a research trial to include similar number of farms across all BC regions where hazelnuts are grown or could be potentially grown in the future such as the Okanagan Valley, Vancouver island, the Gulf islands and Fraser Valley. However, ultimately the geographical farm distribution will be limited by the growers' ability to participate and the research administrator's capacity to support larger numbers of sites.

4.2 Phase 2: New Trial Plantings

In order to test new varieties across various BC regions, the participatory on farm trial will be open to new and existing growers. Data collection can begin early for new hazelnut growers (such as trunk diameter measurements, early pollination data and soil sampling) and yield measurements would begin once the trees reach 3 years after planting.

4.2.1 Traits to Measure

Based on expert and grower feedback, the most significant traits to measure in a new hazelnut variety include the following based on grower priority:

1) Yield and nut quality (via sampling of nuts from 5 selected trees). High quality nuts have market potential to attract large buyers such as Ferrero[2]
2) Disease resistance and drought resilience (probably in a controlled experimental setting). Growers identity the greatest threats being new diseases and changing climate[2]
3) Timing of pollination (flower receptivity and pollen shed) in relation to BC climate. A study in Ontario[10] demonstrated differences in hazelnut pollination related to climate regions and a similar study in BC would support the understanding between flower receptivity and pollen shed for new varieties to be successful in different regions.

Traits suggested to be measured in the participatory on farm trial has been described in Figure 1. (4.1.1)

4.2.2 Number of Trees to Plant

The number of trees to plant for a trial would depend on grower preference and land capability but growers who are willing to participate will need to have enough trees to collect data from 5 trees per variety. The Oregon State University breeding program considers that 4 to 7 trees are sufficient for yield measurements. Some growers may wish to plant more trees, and it is recommended to plant a few more trees than needed in case some die.

1. **Medium-large scale hazelnut growers**

Based on grower feedback, medium-large scale growers with over 5 acres of land are willing to plant over 100 trees per variety. Growers will only be required to collect data and yield from 5 trees per variety and random sampling methods would need to be in place in order to maintain scientific consistency and to accurately represent the overall hazelnut orchard population. A random sampling method could consist of, for example, choosing hazelnut trees from different locations to represent the overall orchard, or randomly selecting hazelnut trees that can still represent the overall population.

2. **Small-scale hazelnut growers**

Based on grower feedback, small scale growers with under 5 acres of land are willing to plant between 2-50 trees per variety with potential to expand their orchards on new properties to accommodate more hazelnut plantings. Growers will be required to collect data and yield from 5 trees per variety and random sampling procedures will need to be followed.

4.2.3 Sampling Methodology

Based on methods used by the Oregon State University breeding program, 5 trees are sufficient for data collection and yield measurements. A detailed protocol is provided in **Appendix A** which provides more information. In scientific research, it is vital to include random sampling. For example, by harvesting nuts for 5 trees per variety, it is possible to compare the estimated harvest to the actual harvest on an acreage. Flowering data can be performed by a dedicated grower or by a hired regional contractor.

Small scale (less than 5 acres)

- 5 trees per variety are sufficient for data collection and yield measurements. However, a suitable random sampling method should be implemented to represent the orchard population and field harvest
- Collection of data relating to pollination, measurement of trunk diameter, nut yield, soil, and climate data
- Harvesting of nuts by hand only. Nuts left on trees must also be collected. 100 nuts per 5 trees is sufficient to measure nut quality such as size, weight, percentage of blanks, etc
- Nuts collected from the 5 trees per variety should be separated as best as possible

Large scale (more than 5 acres)

- 5 trees per variety are sufficient for data collection and yield measurements. However, due to larger numbers of trees, a suitable random sampling method should be implemented to represent the orchard population and field harvest
- Collection of data relating to pollination, measurement of trunk diameter, soil, nut yield and climate data
- Harvesting of nuts either by hand or by mechanical harvesting if prefered. Nuts left on trees must also be collected. 100 nuts per 5 trees is sufficient to measure nut quality such as size, weight, percentage of blanks, etc
- Nuts collected from the 5 trees per variety should be separated as best as possible

4.3 Data Collection and Analysis

4.3.1 Data Collection and Management

A cloud-based data collection software can be used in order for farmers to enter data on their electronic devices while out in the field which would make their results instantly accessible to researchers or data managers. This would greatly improve data collection management compared to sending farmers paper worksheets or datasheets to fill out and send back to the researchers.

For example, an application such as *Google Forms* is a free and publicly accessible option that could be used by the Growers' Association if they are administering the project. Another option is *Qualtrics* which is a UBC-based application similar to Google Forms that complies with FIPPA regulations and can be used by a UBC-based project administrator to develop input forms for farmers. Yet another software option is *SeedLinked* which has previously been found to be helpful for farmer data entry in participatory vegetable variety trials conducted by UBC, but may not be appropriate for tree crops.

4.3.2 Suggested Data Analysis

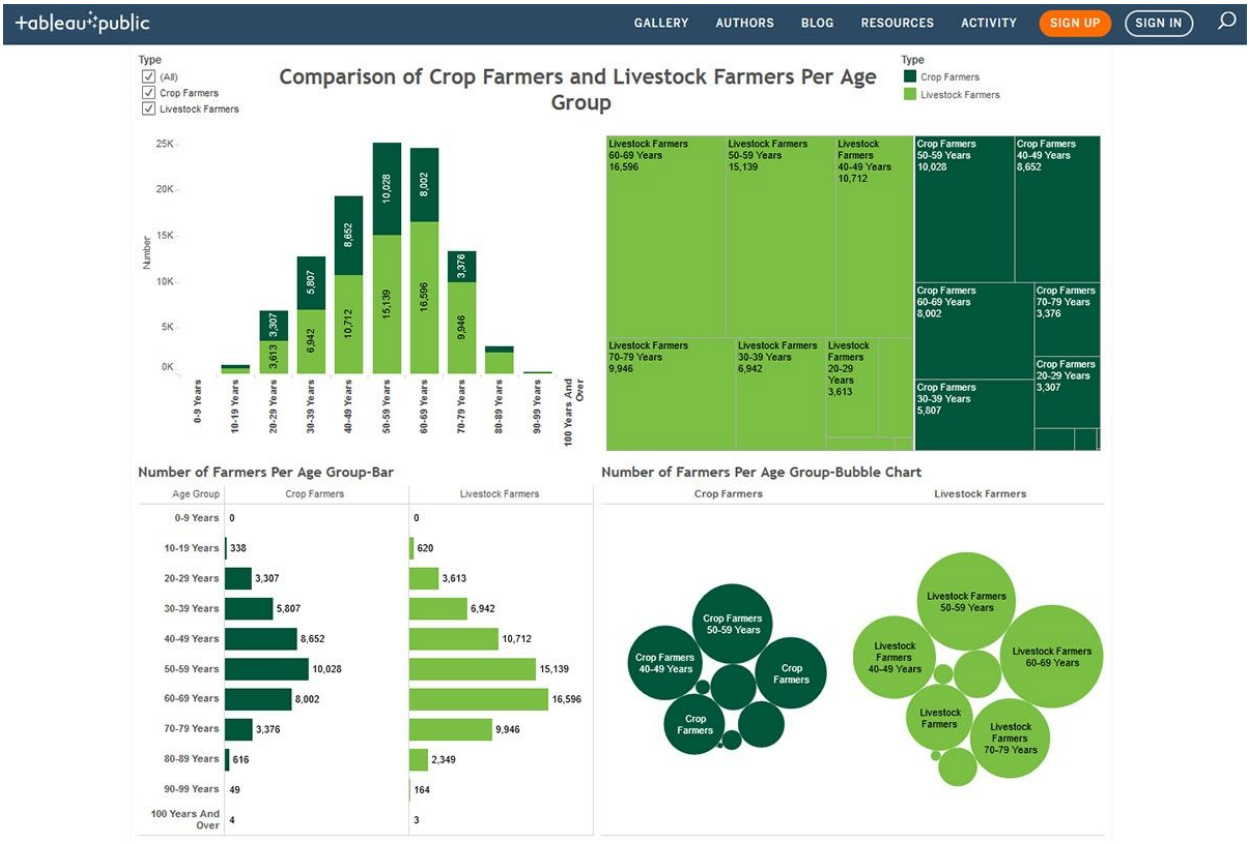
A fundamental research question of this proposed plan is to determine which hazelnut cultivars are suitable for which BC climate regions and help disseminate new varieties and knowledge. There can be two methods to analyze data: 1) based on the number of grower participants and selected regions for trial sites; and 2) based on the varieties planted by growers. Analyses are driven by study goals and constrained by study design. A review of pertinent statistical literature is needed before choosing an approach. Examples of such literature include the following resources:
A-Analyzing Ranking and rating data from participatory on farm trials (https://pdfs.semanticscholar.org/ea8c/b3acd5f1b7295489f926564373bfe2788a11.pdf?_ga=2.104328384.1964810694.1593790048-106769165.1593790048) and B-Analyzing data from participatory on farm trials (https://www.researchgate.net/publication/237309542_Analyzing_Data_from_Participatory_On-Farm_Trials).

4.4 Knowledge Mobilization

4.4.1 Accessibility of Results to Farmers

The On-Farm Hazelnut Trial Network can spark the creation of knowledge mobilization such as the development of an online research platform for farmers to support hazelnut growers. Such online data sharing platforms may include open access databases such as the UBC CSFS Dataverse (https://dataverse.scholarsportal.info/dataverse/UBC_CSFS). The data can be made accessible with Tableau (https://public.tableau.com/en-us/s/), a free data visualization software application (**Figure 2**).

Figure 2: A screenshot example of an agricultural project in Tableau to demonstrate how results could be made accessible to BC hazelnut growers.



Text summaries of results can be posted on the BC FoodWeb website online data sharing platforms (www.bcfoodweb.ca).

In addition, annual written reports and multi-year analysis with freely accessible public research data can be stored on data sharing platforms which will provide valuable knowledge for hazelnut growers and researchers.

4.5 Other Outreach and Training

Farmer training through the creation of in-person workshops (such as through a Horticulture Growers' Short Course), online webinars or courses and mobile apps can support the process of facilitating data collection and basic disease monitoring. Outreach events and farmer field days could further engage and inspire farmers to participate in annual data collection to support the hazelnut industry and become more informed about new EFB-resistant hazelnut cultivars. Findings from on-farm data collection could be presented at the BC Hazelnut Growers' Association annual general meeting. These plans will reflect the preferences expressed by farmers in the stakeholder engagement process.

Social media and email communications may serve as platforms to further inform farmers about upcoming workshops, meetings, and outreach events regarding the Hazelnut Trial Network and these events can be directly advertised on growers' existing social media accounts.

Mitacs internships facilitate connections between university students and industries and applications may be submitted which may provide funding to support on-farm hazelnut research.

4.6 Resources Needed

4.6.1 Personnel Needs

A project manager would be required to recruit farmers, communicate about steps and protocols, organize webinars or training events, and send reminders or phone calls for data collection. In addition, a travel fund for the project manager to conduct site visits and other requirements would need to be considered in the overall budget. A data analyst (could be the same person) would be required to synthesize results from data, and create annual and multi-year evaluation reports.

4.6.2 Estimated Cost for Participation

Farmer compensation would be dependent on potential funding available and the obtention of such funding. If funding is provided, growers would be required to be budgeted accordingly such as payment for time commitments and active participation in the research trial, land property costs, costs of running harvesting equipment (including manually hand picking hazelnuts), and the costs of trees and associated orchard maintenance costs, including pest and disease management of new hazelnut cultivars. See **Section 8.0: Proposed Template Budget** as an example of a possible template that could be used for new growers to calculate these costs.

4.6.3 Equipment

Harvesting equipment for yield measurements may be purchased such as backpack harvesters, machine harvesters such as the Monchiero harvester and miscellaneous harvesters such as the "nut picker upper" (a rolling nut harvester). Other equipment needed would include a soil pH meter, soil probe, measuring tape or caliper (to measure trunk diameter) and climate data recording equipment such as a portable handheld weather station or a stationary weather station.

5.0 Next Steps to Implement a Hazelnut Variety Trial Network

This project can be implemented in a number of ways depending on the capacity and interest of the BCHGA. In order to help identify opportunities and ways forward, below we describe some of the resources available from various regional institutions who might collaborate with the BCHGA to implement the variety trial network.

5.1 Resources at UBC

The Centre for Sustainable Food Systems (CSFS) is a research centre and local-to global food hub that supports cutting edge research on the social, environmental, and economic sustainability of food systems and can support the knowledge translation and research mobilization of the proposed project:

- There is a possibility for UBC faculty members in the Faculty of Land and Food systems to support the future implementation of the BC Hazelnut Variety Trial Network and its applied research components through experimental hazelnut research (see **Section 5.1.1**). In addition, there is also an in-development research proposal which proposes a polyculture at the CSFS involving woody perennials and includes the potential planting of hazelnuts.
- The use of *Qualtrics* online survey software to solicit additional information about growers' practices and challenges and data collection is a possibility (UBC CSFS has already developed a template of such a survey which could be distributed).

There is also potential to connect UBC students with the BC Hazelnut Growers' Association and inspire interest in the hazelnut and food crop industry and research through paid internships such as *Mitacs Accelerate* (https://www.mitacs.ca/en/programs/accelerate) or through Co-op and Worklearn placements for students to gain valuable work experience in an agricultural business setting. Additional sources of funding for UBC students may include support from Agriculture and Agri-Food Canada via partnerships through Canada Summer Jobs.

5.1.1 Proposed UBC Hazelnut Research from Faculty

Thorsten Knipfer
Assistant Professor, Faculty of Land and Food Systems.

In order to support sustainable hazelnut production through water savings and to improve nut quality under the current unprecedented effects of climate change, hazelnut growers in BC will need to have access to (i) elite varieties with improved tolerance to water stress and (ii) precision management strategies that are optimized for water savings. The future goal of growers must be to categorize drought resistance of hazelnut varieties based on their physiological performance under water stress conditions, and in turn, develop varietal-specific irrigation strategies that allow for sustainable production through water savings.

Dr. Knipfer's plant physiology laboratory at UBC-LFS will address these challenges by focusing on three main research aspects:

(1) Phenotyping of hazelnut varieties for resistance to water stress on by drought. Phenotyping for physiological performance provides the foundation for predicting crop water requirements[11,12]. Dr. Knipfer will establish an Automated Growth & screening platform for elucidating crop Water savings (AGroW) that will allow for selections of hazelnut varieties with improved drought resistance.

(2) Drought-induced changes in root water uptake and water delivery to canopy. While previous research has demonstrated that xylem embolism reduces water delivery under severe drought stress[13,14], the impact of root hydraulic dysfunction on crop performance remains largely unknown. Dr. Knipfer will study the impact of water stress on root performance by using fluorescence microscopy, X-ray computed tomography and root-pressure-probing. This will provide the foundation for developing irrigation strategies that prevent drought-induced root dysfunction and dieback.

(3) Monitoring of tree water status for sustainable irrigation management. A Scholander-type pressure chamber provides an affordable and easy solution to determine the stress level of a tree under drought by measurement of plant water potential (xylem pressure)[15]. Dr. Knipfer will establish the water potential method as a crop monitoring tool and for developing sustainable irrigation practice[16].

For more details into Dr. Knipfer's research proposal, please see attached accompanying document, "**Future Hazelnut Research Directions.pdf**."

5.2 Resources at Ministry

Since July 2018, the Ministry of Agriculture (AGRI) has supported the Hazelnut Renewal Program (HRP) by providing the BC Hazelnut Growers' Association (BCHGA) with $300,000 in funding over three years (2018-2020). This initiative is allowing new and existing growers to replace dead and diseased orchards with Eastern Filbert Blight (EFB) resistant varieties and expanding hazelnut acreage in BC with new plantings. During the first two years of the program, 94 acres of new trees were planted, representing approximately 18,844 trees and 43 acres or 4,795 infected trees were removed.

Ministry staff is available and currently working with the hazelnut industry. The following staff is actively involved:

- Plant Pathologist, Siva Sabaratnam;
- Entomologist, Tracy Hueppelsheuser;
- Industry Specialist, Karina Sakalauskas;
- Minor Use Coordinator, Caroline Bedard and personnel of the plant diagnostic lab.

The Ministry is also supporting different initiatives within the hazelnut industry, such as a 3-year (2018-2021) study on emerging diseases and their impact on hazelnuts, and a 5-year (2018-2023) study on emerging pests of concern to BC.

The Ministry of Agriculture will continue to support this initiative through the resources mentioned above.

5.3 Other institutions or Partners

- Agriculture and Agri-Food Canada has research stations in Agassiz and Summerland. The Summerland station could be a key element to determine potential production in the Okanagan[2].

- The University of the Fraser Valley is interested in planting hazelnuts and participating in the BC Hazelnut Variety Trial Network (Sakalauskas, K. BC Ministry of Agriculture).

- Faculty at Kwantlen Polytechnic University (Richmond campus) in the Department of Sustainable Agriculture & Food Systems have expressed interest in supporting the future implementation of the BC Hazelnut Variety Trial Network and its applied research components (Sakalauskas, K. BC Ministry of Agriculture).

- The BC Forage Council (BCFC) provides a useful guide to on-farm demonstration research(https://www.bcagclimateaction.ca/wp/wp-content/media/FI03-On-Farm-Demonstration-Research-Guide.pdf). This includes information about planning, preparing and conducting on-farm trials with examples of data collection worksheets.

5.4 Growers Association Resources

Farmer training through the creation of in-person workshops, online webinars or courses and mobile apps can support the process of facilitating data collection and basic disease monitoring. Outreach events and farmer field days could further engage and inspire farmers to participate in annual data collection. Social media and email may serve as a communications platform to inform farmers about these upcoming workshops, meetings or outreach events.

The BC Hazelnut Opportunity Assessment Report mentions the intention of hiring a part-time coordinator as currently the sector has very little capacity to coordinate its activities[2]. A coordinator could be hired for 15-20 hours a week at a cost of approximately $35/hour or an annual cost of $27,300-36,400. This position could include raising additional funds to support the sector's development through sponsorships and grants[2].

5.5 Potential Grants or Funding Options

At the moment of writing this report there are no specific funding programs available that target this initiative. Participatory on-farm trials seem to be a valuable tool to develop collaborative approaches and partnerships. Some examples could include the following actions:

<u>Potential (near term) actions:</u>

- Host a workshop (or series of workshops) to bring together producer groups, government and post secondary institutions, and academia to identify partners willing to participate in this initiative and commit to a pilot or sustained process
- Develop a funding plan that incorporates the ways in which various partners are able to contribute
- Further explore and develop potential linkages between industry stakeholders with compatible objectives
- Identify, explore and /or apply for funding opportunities such as cost shared funding such as Investment Agriculture Foundation (IAF)

Resourcing the commitment of a number of potential partners would be required to determine what funding model has a better potential. These potential partners include:

1. Agricultural organizations representing the potential areas where hazelnut trees will be planted : Okanagan, Vancouver island, Kootenay and Fraser Valley.
2. Academia: University of British Columbia, Kwantlen Polytechnic University, University of the Fraser Valley, etc.
3. Research centers: AAFC Agassiz Research and Development Centre and Summerland Research and Development Center.
4. Industry stakeholders: private companies, processors, tree nurseries.

6.0 References

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7.0 Appendix A: Protocol Development

7.1 Farmer Protocol for Data Collection

General objectives:

To collect data from <u>existing and new EFB resistant hazelnut cultivars</u> in the Fraser Valley and other regions in BC such as Vancouver Island, the Okanagan Valley and Kootenay.

Learning about important traits from new hazelnut varieties in different climate regions will help you (the grower) determine most suitable cultivars for your needs and will also provide the opportunity for you to share valuable data with other growers and researchers to support the expansion of the hazelnut industry. Dave Losh (USDA-NASS) from Oregon State University is a possible contact to ask for consultation on developing appropriate protocols.

Summary

- For small scale and large scale farms: collect all data from only **<u>5 trees per variety</u>**.
- Use a random sampling method representative of your orchard population. See **Figure 3** for a visual definition.
- Monitor female and male flowering from January to early April (dependent on variety) 2-3 times a week for 10-12 weeks
- Record trunk diameter

- Send soil samples for testing at least once a year
- Record climate data using a portable or stationary weather station in the area
- Harvest nut yield from **5 trees per variety;** separate nuts from each variety
- Use only **100 nuts** to measure nut quality **per 5 trees** (i.e size, weight, percentage of blanks, etc)
- Record separate notes relating to nut development (i.e via use of personal phones), tree behaviour, diseases or pests present)

Project activities:

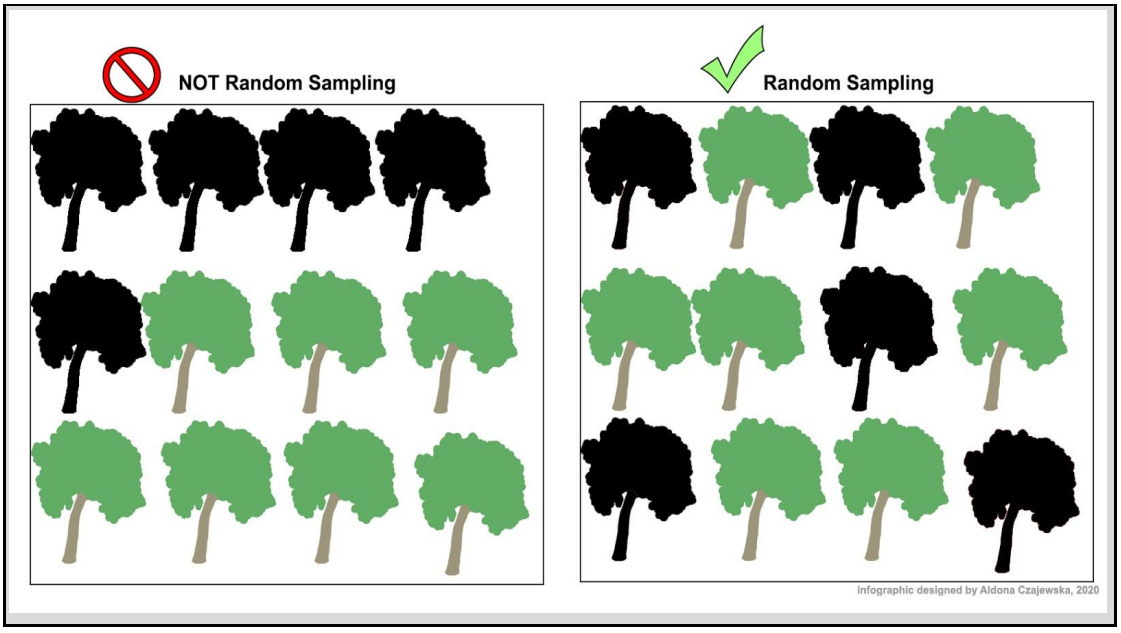
1. **Data collection from already planted trees and new varieties (see accompanying infographic, Figure 5)**

Purpose: to gather information about a new variety's pollination, tree growth, soil composition, climate information and yield output. A metadata example (data that provides information about other data) is given below of the basic data information growers would be required to record in either a *Qualtrics* data survey or in *Google Forms*:

Basic metadata definitions:

- **Date:** Today's date
- **Date_flowering_female:** The date timing of flowering for female flowers was recorded (year/month/day format)
- **Date_flowering_male:** The date timing of flowering for male flowers was recorded (year/month/day format)
- **Collector:** The name of the grower who collected the data
- **Farm:** The name of the farm the data was collected from
- **Location:** The location of the farm the data was collected from; this can be either address or GPS coordinates (preferred)
- **Region:** The region the data was collected from (ie, Vancouver Island, Okanagan Valley, Kootenay, or another region)
- **Variety:** The variety the data was collected from (ie, Jefferson, Yamhill, Wepster, etc)
- **Trunk_Growth:** trunk diameter measurements, reported in centimeters (cm)

Figure 3: How to differentiate between random and non-random hazelnut tree sampling for growers. Black trees in the image represent selected samples.



1.1 Timing of Flowering

Begin flower data collection in January and continue until early April (this may be dependent on your variety as some varieties may flower in December). Flowering requires weekly (2-3 times a week) monitoring and observation.

Monitor female flowers and timing of receptivity every 2-3 days (see **Figure 4**) for 5 trees per variety and use random sampling. Record this data in either Google Forms or Qualtrics.

Figure 4: Flower receptivity and pollen shed of hazelnuts (left, open male catkins; right, open female flowers) (Oregon State University, (https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9074.pdf).

Photo 2: EESC slide collection.
Photo 3: Betsy Hartley.

1.2 Growth
Once every season, record the trunk diameter of trees using either a tape measure or a caliper and record in centimeters (measure 5 trees per variety). Record this data in either Google Forms or Qualtrics. Understanding the growth of a variety can give insight into its water requirements.

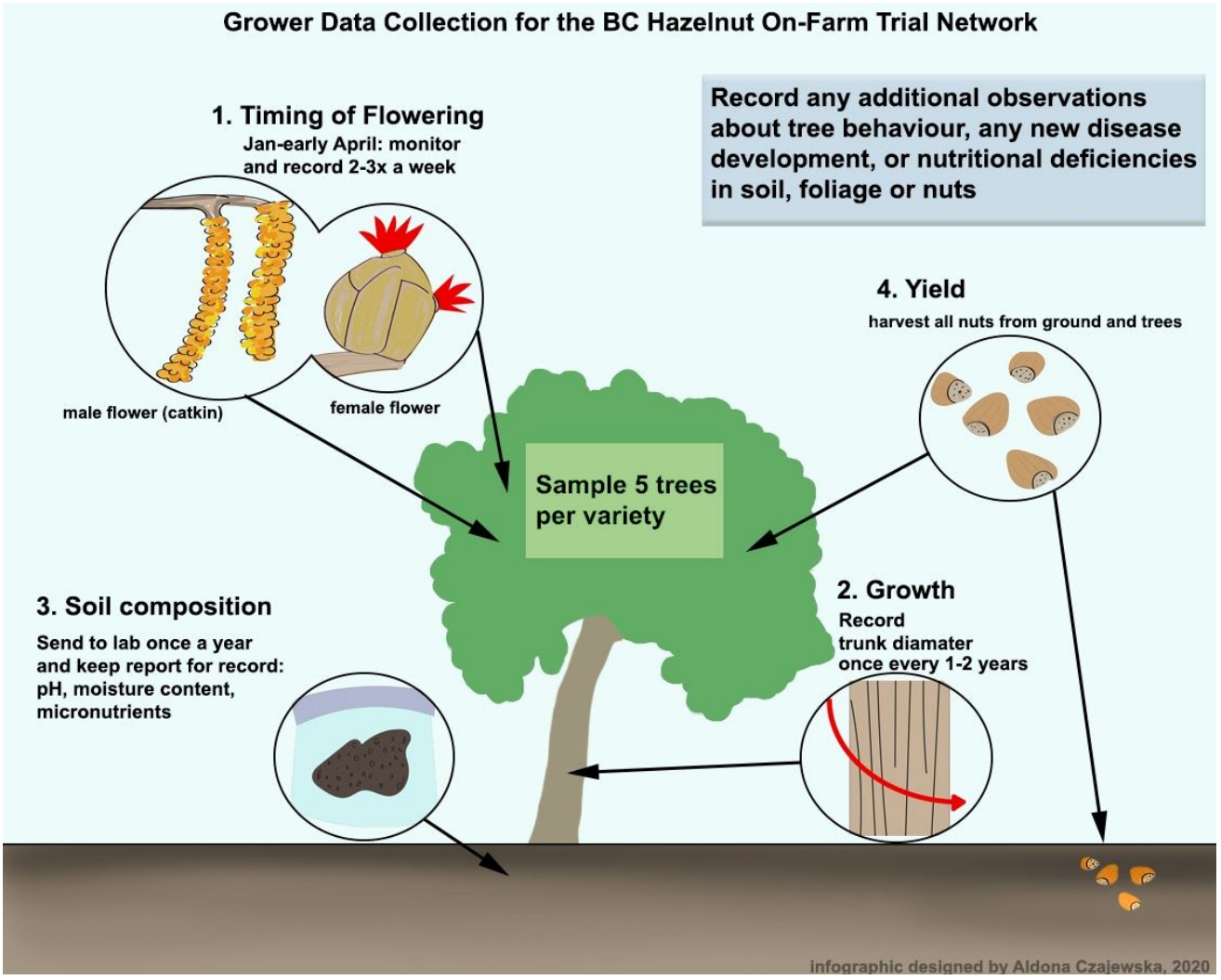
1.3 Soil composition Once every year or more frequently if feasible, send soil samples for lab analysis and request documents for record keeping.

Optional:

- Monitoring nut development using a phone camera
- Send samples of stems for starch composition analysis to understand tree growth (possibility of establishing a method of doing this at UBC)
- Send samples of leaf tissue to analyze nutrient composition

In addition to the above data collection, make observations about **pests**, **tree behaviour**, any **disease development,** or **nutritional deficiencies in soil, foliage or nuts** and record these observations (via a personal designated notebook that can be shared or in Google Forms or Qualtrics). This will give you an idea of the adaptation of different cultivars to diverse regions and how the cultivars are performing in their climate.

Figure 5: Data collection infographic for growers.



2. Climate Data Recording:

Climate data is vital to understanding how a new cultivar performs in its growing region. This data will give you an idea about that cultivar's water requirements and its water usage. If you have a standing or portable weather station in your region, record relevant data such as temperature, barometric pressure, and humidity.

3. Yield Measurements:

A challenge from the prior BC hazelnut research trial was that some farmers were harvesting trees before the research harvest could happen and, thereby, were losing data. Hence, it is essential to collect yield during a research trial. New growers can skip this step until their trees are in years 2-3 and ready to be harvested.

Objectives:
Harvest nuts from **5 trees per variety** of existing plants and new cultivars. Sample **100 nuts** to measure nut quality (this trait will be dependent on a grower's goals).

Small scale and large scale growers: harvest nuts from **5 trees per variety.** Weigh all harvested nuts from 5 selected trees for each hazelnut variety to report yield. **Use only 100 nuts to access quality.** This will serve as a representative of the entire orchard. Send 1 sample per variety to be analyzed in a designated lab for chemical composition or nutritional content if desired.

8.0 Proposed Template Budget

The below budget example (**Figure 6**) could be potentially used as a template for a research trial by growers in order to estimate the necessary costs associated with such a project. More information can be found in the following resources below which provide directions on how to develop a budget for a new or existing hazelnut grower in BC.

1) BC Ministry of Agriculture:
https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/farm-management/farm-business-management/enterprise-budgets/hazelnut-2017_sh_august_2018.pdf

2) BCHGA sample hazelnut production budget website:
https://bchga.ca/grower-resources/#samplebudget

Figure 6: An example of an established hazelnut budget that can be used as a template (BC Ministry of Agriculture, (https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/farm-management/farm-business-management/enterprise-budgets/hazelnut-2017_sh_august_2018.pdf).

Enterprise Budget– Hazelnut

Income					
Product	**Acre**	**Yield– at 5-6**	**7-10 yrs**	**11+ yrs**	**Comment**
Hazelnuts (assume $1.50/ lb; for annual yield)	1 acre	1,250 lb (566kg)	2,000 lb (907kg)	2,500 lb (1,133kg)	2,500 lb Target

Direct Expenses/ acre- vary with # acres planted				
Item	**Quantity**	**Cost**	**1 Acre**	**10 Acres**
Site Prep/ level	Acre	$500	$500	$5,000
Fertilizer	Chicken	$100	$100	$1,000
Lime	Depends	$50	$50	$500
Weeding	Annual	$100	$100	$1,000
Flail/ brush	Annual	$40	$40	$400
Harvesting	lb	$0.20	$500	$5,000
Total Direct Production Expenses	**Annual**	**-**	**$1,290**	**$12,900**
Gross Margin (Income - Direct Expenses)			**$2,460**	**$24,600**

Indirect Expenses - general		
Item	**1 Acre**	**10 Acre**
Accounting/ legal	fixed	$1,000
Bank charges	fixed	$240
Insurance	$100	$1,000
Property tax farm status	$100	$1,000
Utilities	$100	$1,000
Repairs	$100	$1,000
Truck expense	$100	$1,000
Office & Telephone	$60	$600
Tools & equipment	$50	$500
Total General Direct Expenses	**$610**	**$7,340**
Gross Return to Labour (Gross Margin - Direct Expenses– General)	**$1,850**	**$17,260**
Gross Return to Labour (per hour, for 10 acres)	**$26.55**	

**** Estimated at 1 acre of 65 hours per year in production and related time, therefore 650 hours for 10 acres.***