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# POTENTIAL ECONOMIC BENEFITS OF USING CERTIFIED CLEAN HOP PLANTS VS. HOP STUNT VIROID DISEASE

CORNELL UNIVERSITY

Trent J. Davis[†], Miguel I. Gómez[†], Scott Harper[ø], & Megan Twomey[√]

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[†]Charles H. Dyson School of Applied Economics and Management Cornell University
[ø]Clean Plant Center Northwest, Washington State University
[√]Association for the Development of Hop Agronomy

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Abstract
Hop stunt viroid disease (HSVd) is a significant threat to the hops industry in the United States (US). Since it was first discovered in the US in 2004 HSvd has been impacting hop cultivation in the Pacific Northwest and decrease yields by up to 62% in some hop varieties. This study uses a net present value (NPV) approach over a six-year planting/production cycle of one acre of hop plantings to examine the potential economic impact of HSVd, as well as the potential economic benefits of planting certified clean hop plants (CCHPS) to mitigate the risk of HSVd in both aroma and alpha hop varieties. The models indicate for every 1% of expected yield losses the NPV of one acre of aroma hops decreases by $432, and one acre of alpha hops decreases by $400. If a grower expects yield losses of 6% or greater for aroma hops, and 7% or greater for alpha hops, then it would be economically beneficial for said grower to plant CHHPS to ensure HSVd does not impact hop yields. We also find if a grower is experiencing yield losses of 35% for aroma hops and 36% for alpha hops after the first year of production due to HSVd, then it is economically beneficial for them to replant the entire acre of hops immediately as the NPV of replanting using CCHPS over the six-year time period will be greater than continuing hop production at the estimated yield losses. These findings are valuable for growers to understand the potential economic benefits of investing more money upfront to purchase certified disease free plantings to mitigate the risks of HSVd on their farms.

Introduction
From 2012 to 2019 hop acreage in the United States (US) has increased 98.7%, resulting in 58,877 acres dedicated to hops production (George 2020). Aroma varieties are the most commonly grown hops accounting for 75.4% of total acreage while alpha varieties represent 24.6% of acreage in the country (George 2020). The majority of hops in the US are grown in the Pacific Northwest (PNW) with Washington state (WA) as the nation's largest producer. In 2019 hop production in the US grew by 4.7%, while hop acreage increased 2.6% (George 2020). Hop production in 2019 resulted in a new yearly record of an estimated 113 million pounds being produced in the US (George 2020). The industries continued growth is leading to new entrants and current producers to expand their operations. With hop production increasing year-over-year it is imperative producers understand and mitigate potential pests and diseases which may impact their revenues.


*Picture 1: HSVd stunt on trellis system*

One such disease is *hop stunt viroid disease* (HSVd). HSVd is a subviral pathogen belonging to the genus *Hostuviroid*, family *Pospiviroidae* (Flores et al. 1998; Kappagantu et al. 2017). This pathogen can spread easily between plants via injury and sap transfer (Eastwell 2015). Visual symptoms of HSVd vary by hop variety, but common symptoms include stunted plant growth (Picture 1) and yellowing of leaves (Picture 2) (Eastwell 2015).

HSVd presents a potential economic problem for producers as it can reduce hop yields and/or impact both $\alpha$- and $\beta$-acids. Impacts on hop yields and acids may differ by variety. Kappagantu *et al.* (2017) found 'Glacier,' 'Cascade,' and 'Willamette' varieties saw yield losses up to 62%, 14%, and 34% respectively, while 'Nugget,' 'Columbus,' and 'Galena' varieties saw no significant yield

losses when inoculated with HSVd. The same study also found that up to 17% of tested hop plants in central WA may be infected with HSVd, potentially resulting in significant losses for the region. Mitigating the risk of initial HSVd infection is essential to growers given the proven impacts on yields in certain varieties, and thus potential revenues.

*Picture 2: Yellowed leaves from HSVd*

The most common way for the HSVd pathogen to find its way on to farms is by propagation of infected plant stock (Eastwell 2015). Utilizing 'clean plants' may be one way to mitigate the risk of planting HSVd infected stock. Certified clean plants (CCP) are defined by the Clean Plant Center Northwest (CPCNW)[1] as the following:

1) A plant line, variety, or cultivar that has been tested for, and found free of, economically important and/or harmful plant viruses and virus like organisms.
2) A plant line, variety, or cultivar that has been maintained under controlled conditions to prevent (re)infection.

Clean plants go through a rigorous process before being used as new plant stock. The process includes, but is not limited to, initial diagnostics (polymerase chain reaction (PCR), high-throughput sequencing (HTS), and biological indexing assay), virus elimination if necessary, and two more rounds of diagnostics to confirm the plant stock is free of pests and pathogens ("What is a Clean Plant?" 2020). Purchasing CCP stock may reduce the risk of obtaining hop planting stock that is infected with a pathogen, like HSVd, before it is even planted in the ground. Producers may be hesitant to adopt CCP as the initial investment of purchasing CCP is higher than planting non-certified clean plant stock from other third party propagators.

The purpose of this research is to identify the potential economic benefits of utilizing certified clean hop planting stock (CCHPS) for hop production in the PNW compared to non-certified hop planting stock (NCH). Estimates for planting costs, and yearly operating costs were developed, as well as projected yields and receipts. The estimates do not represent the average costs for hop production in the PNW, but represent costs for well-managed hop acreage. The estimates in this study may be used by hop producers to analyze the potential economic benefits of investing in CCHPS when planting their hops.

## Methods

Using data from the *2019 Statistical Report* published by the Hop Growers of America, the *2015 Estimated Cost of Establishing and Producing Hops in the Pacific Northwest* analysis published by Washington State University (WSU) Extension (Galinato and Tozer 2015), and discussing hop management practices with both current producers and the CPCNW, models projecting the net present value (NPV) of a six-year production cycle of one acre of aroma and alpha hops were developed. The models assume different levels of hop yield losses due to HSVd infected NCH and compare the resulting NPV to the NPV of hops planted using CCHPS, which are free from any pests and/or pathogens. We assume the farm is already established and does not need to purchase land or machinery. For this reason, we use only yearly operating costs obtained from the WSU enterprise budget.

[1] Part of the National Clean Plant Network (NCPN) and based at the Washington State University (WSU) Irrigate Agriculture Research and Extension Center in Prosser, WA.

General Production Assumption

For the estimated models we assume a six-year planting cycle for hops. Year one is assumed to be the initial planting year where growers make the choice of planting CCHPS or NCH. In year two we assume the hops produce 80% of expected mature yields. From years three to six we assume the hops are at full maturity and are producing at 100% capacity.

Some producers may expect to need to replant their hops before five years of production, and others may expect to replant their hops after more than five years of production. The estimates used in this model were developed after speaking with producers and may not be fully representative of all potential management practices.

Operating Costs

Yearly operating costs are from the *2015 Estimated Cost of Establishing and Producing Hops in the Pacific Northwest* report. To account for potential increases in operating costs due to inflation we use the CPI information of 0.7%, 2.1%, 2.1%, and 1.9% respectively for years 2015 through 2018. It is important to note these estimates may be lower than the potential real cost increases incurred by hop farmers. The operating costs are shown in Table 1 below:

**Table 1: Yearly Operating Costs of Producing 1 Acre of Hops**

| | NCH[+] | CCHPS[γ] |
|---|---|---|
| Year 1 – planting year | $ 6,933 | $ 9,548 |
| Year 2 – 80% production | $ 8,159 | $ 8,159 |
| Year 3-6 – full production | $ 8,475 | $ 8,475 |

*[+]NCH represents non-certified clean hop planting stock*
*[γ]CCHPS represents certified clean hop planting*

It is assumed when replanting hops the producer does not need to repurchase, or reinstall, any trellising materials. The model assumes 889 hop bines per acre are planted. The cost of CCHPS is assumed to be $5.00/bine while NCH are assumed to cost $2.00/bine, resulting in first year operating total costs of $9,548 for CCHPS and $6,933 for NCH plantings. In *Year 1 – planting year* we see a difference in costs of $2,798, with 100% CCHPS being more costly. These costs are assumed to be constant across all models.

We assume once the initial planting decision is made producers use the same production practices from year two to year six of the planting cycle, resulting in operating costs in year two equaling $8,158 and $8,475/year for years three to five for both NCH and CCHPS planted acreages.

Yield and Sales Assumptions

*Aroma Hops* - In 2019 the average yield of aroma hops on a per-acre basis in the US was 1,981 lbs/acre (George 2020). For simplicity, the model uses 2,000 lbs/acre as the base yield expectations. Aroma hops sold for an average of $5.68/lb in 2019 (George 2020). The base model uses $5.80/lb when calculating sales receipts. It is important to note the sales price is meant to represent a price similar to the 2019 market average. Individual producers may receive more or less per pound when selling their aroma hops, and prices may vary significantly year-to-year. Using these assumptions we estimate sales receipts for the first year of hops production to

equal $9,280/acre, while years two-five of aroma hops production are estimated to result in $11,600/acre each year.

*Alpha Hops* - After consulting with representatives from the *Hop Growers of America* we use an expected yield of 430 lbs/alpha per acre, and an estimated sales price of $25 lbs/alpha. It is important to note the expected yields and sales prices may vary significantly year over year. The sales price producers may receive for alpha hops is especially vulnerable to price variations, with sales prices in 2020 being noticeably lower than other years. Individuals may produce more (fewer) pounds per alpha and/or receive a higher (lower) sales price.

Using the assumptions above, we estimate sales receipts for the first year of alpha hops production to equal $8,600/acre, while years two-five of expected mature production are estimated to equal $10,750/acre.

Net Present Value Analysis

In this section we analyze the net present value (NPV) of NCH and CCHPS plantings of aroma and alpha hop varieties. The NPV is calculated using a six-year planting and production cycle for the tested hops with year one being the planting year, year two resulting in 80% production, and years three through six resulting in full-production. It is assumed the CCHPS plantings are free of HSVd for the entire six-year cycle. Different levels of yield losses due to planting HSVd infected NCH are modelled, and the accompanying NPVs are compared to that of the CCHPS.

*Estimated NPV of Non-Certified Clean Planting Stock with HSVd*

Table 2 indicates the estimated NPV of the six-year planting/production cycle of aroma and alpha hops given different levels of yields losses due to HSVd infection.

**Table 2: NPV of One Acre of Non-Certified Clean Planting Stock - Hops**

| **Estimated Yield Loss** due to HSVd Infection | **Aroma Hops** non-certified clean planting stock | **Alpha Hops** non-certified clean planting stock |
|---|---|---|
| 0% | $4,601 | $1,435 |
| 5% | $2,441 | ($568) |
| 10% | $280 | ($2,571) |
| 15% | ($1,881) | ($4,573) |
| 20% | ($4,042) | ($6,576) |

Aroma hop plantings have a six-year NPV of $4,601/acre at 0% yield loss while one acre of alpha hops has a NPV of $1,435/acre at 0% loss. The results show that for every 1% of expected yield loss the NPV of NCH plantings decreases by $432/acre and $400/acre for aroma and alpha hops respectively.

For aroma hops we estimate the NPV remains positive up until yield losses exceed 10%. Once losses for aroma hops exceed 10% the NPV of the six-year cycle results in negative returns. Our estimates show alpha hops to be more sensitive to yield losses. Estimated yield losses of only 4% or greater result in negative NPV for the six-year planting cycle. These results are heavily dependent on the sales price used in the models. If producers expect to receive a higher sales price then producer may be able incur higher yield losses before the NPV indicates a loss over the six-year cycle.

*Potential Economic Benefits of Certified Clean Planting Stocks vs. Infected NCH*

The NPV of one acre of CCHPS for the full six-year planting and production cycle is estimated to be $2,146/acre for aroma hops and ($1,021)/acre for alpha hops. In Table 2 we see the NPV of the same six-year planting cycle for NCH of aroma and alpha hops equal $4,601/acre and $1,435/acre, assuming 0% yield losses. If a grower of either aroma or alpha hops expects to have 0% yield losses of either varietal then their NPV is expected to be $2,456/acre more by using NCH plantings. However, if the NCHs are not HSVd free upon planting, or if the stock becomes infected with HSVd, expected yields and receipts decrease significantly as shown in Table 2.

Table 3 demonstrates the potential economic benefits of utilizing CCHPS. The results assume that CCHPS plantings are never infected with HSVd, and thus produce at 100% capacity for the entire six-year planting cycle. Column two shows the difference between the NPV of the NCH at the estimated yield loss found in column two of Table 2 and the NPV of CCHP plantings. If the value in column two of Table 3 is red than the NPV of NCH plantings is greater than the NPV of CCHPS by the indicated amount. A value colored black indicates the NPV of planting CCHPS is greater than that of the NCH plantings at the estimated yield loss.

**Table 3: Potential Economic Benefits of Certified Clean Planting Stock**
**One Acre of Planted Hops**

| **Estimated Yield Loss** of non-certified clean planting stock | **Aroma Hops**[ø] Potential economic benefits of CCHPS | **Alpha Hops**[π] Potential economic benefits of CCHPS |
|---|---|---|
| 0% | ($2,456) | ($2,627) |
| 5% | ($295) | ($453) |
| 10% | $1,866 | $1,549 |
| 15% | $4,027 | $3,552 |
| 20% | $6,188 | $5,555 |

*[ø]The NPV for CCHPS of aroma hops equals $2,146/acre*
*[π]The NPV for CCHPS of alpha hops equals ($1,021)/acre*
*Table 3: CCHPS plantings are assumed to produce 100% of expected yields at all times*

The results indicate that even at minimal estimated yield losses the NPV of CCHPS is greater than that of NCH. If a producer is expecting losses equal to or greater than 6% for aroma hops or 7% for alpha hops than the NPV of planting CCHPS is greater than the NPV of the NCH planting by $137/acre and $348/acre respectively. Once yield losses exceed 6% and 7% for aroma and alpha hops respectively, for every 1% increase in expected losses the economic benefits of planting CCHPS increases by $432/acre and $400/acre. The results show that with minimal expected yield losses due to HSVd infection the NPV of CCHPS quickly becomes higher than that of the infected NCH plantings.

Table 3 shows that the greater the expected yield losses of NCH plantings the greater the potential economic benefit of planting CCHPS. This potential benefit is compounded when sales prices for the tested hops increases as well.

*Key Takeaways*

The startup costs of planting certified clean hop planting stock, bought directly from organizations like the CPCNW are roughly $2,456 more per acre than planting non-certified clean planting stock purchased from other third party vendors. If producers of aroma hop are expecting yield losses of their NCH of 6% or greater due to the presence of HSVd they should consider using CCHPS, as the NPV after the six-year cycle is greater. If alpha hop producers are

expecting NCH yield losses of 7% or greater due to the presence of HSVd they should consider using CCHPS, as the NPV after the six-year cycle is greater once yield losses equal or exceed 7%.

Replanting Due to HSVd Infection

The best way to combat HSVd is to use planting material that is certified free of HSVd. The disease spreads easily through mechanical means and may even be transferred through infected root stock. If a farm has confirmed the presence of HSVd, the best way to prevent further spread is to remove and clean the infected area of all potentially infected plants and then replant, as HSVd cannot currently be treated.

Below we analyze the cost-benefit of replanting an entire acre of infected hops with CCHPS due to the presence of HSVd. For these models, we assume the NCH plantings are 100% infected with HSVd when originally planted, and the grower acknowledges this infection after the first year of production (year two of the planting cycle). The grower then decides to replant the entire acre of hops in year three of the six year production cycle. Figure 1 shows the standard six-year planting cycle used in our models (left), and the modified six-year planting cycle when the grower replants their hops in year three (right).

**Figure 1: Standard Six-Year Planting Cycle vs. Replanting in Year 3 Using CCHPS**

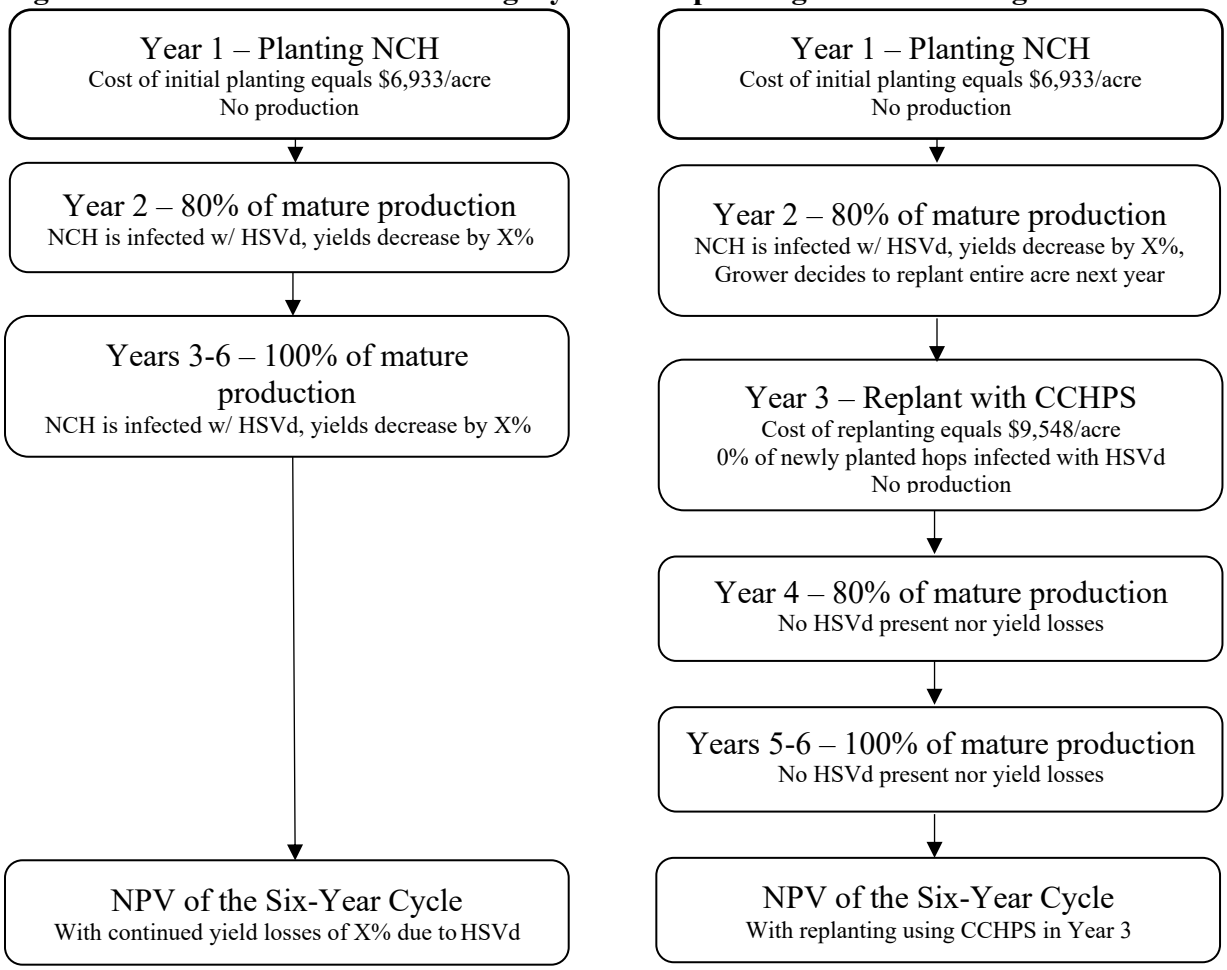


*Figure 1: X% indicates the percent of estimated yield losses due to HSVd*

The models show it takes a moderately high level of estimated yield losses due to HSVd to make replanting the hop acreage in year three with CCHPS have a greater NPV than continuing with the yield losses for the six-year cycle of the infected NCH acreage. The level of yield losses required to result in a higher NPV when replanting for each aroma and alpha hops is below:

- *Aroma Hops* – If a producer is incurring yield losses of 35% or higher in year one of production the NPV of replanting the entire acre of hops with CCHPS is higher than incurring the loss for the entire six-year cycle.
- *Alpha Hops* - If a producer is incurring yield losses of 36% or higher in year one of production the NPV of replanting the entire acre of hops with CCHPS is higher than incurring the loss for the entire six-year cycle.

While the estimated yield losses of both aroma (35%) and alpha (36%) hops may seem high it is important to note yield reductions of up to 62% can be seen in some hop varietals due to HSVd.

Our estimates of when a grower may want to replant may be conservative, as the costs of replanting may not include all of the necessary processes or costs of fully cleaning the previous planting area to remove it of HSVd. Also, if producers are expecting higher sales prices than assumed in our models the yield losses required for the NPV of replanting NCH with CCHPS decreases.

## Conclusion & Discussion

Hop stunt viroid disease is an easily communicable and damaging disease that has taken root in North America and may be impacting the revenues of hop farmers in the Pacific Northwest. HSVd can result in hop yield losses of up to 62% in some varieties, with individual farmers reporting even higher yield losses exceeding 80%. The possible revenue losses due to yield reduction is a potential risk to hop farmers' livelihood.

HSVd commonly spreads to farms when farmers purchase HSVd infected planting stock from third party propagators. One way to mitigate this risk is to buy planting stock that has been certified free of diseases/pests, like HSVd, from organizations like the Clean Plant Center Northwest. While these certified clean planting stocks have a greater upfront cost to farmers, the potential economic benefits they bring may outweigh the initial investment increase.

The results discussed above indicate that even a small yield loss due to HSVd suggests using certified clean planting stock free of HSVd would result in higher returns. The net present value of a six-year planting and production cycle of certified clean planting stock is greater than that of non-certified clean planting stock of both aroma and alpha hop varieties if expected yield losses of the non-certified clean planting stock exceeds 6% and 7% respectively. HSVd may result in hop yields being reduced by 2% to 80% depending on the hop variety. The extreme variation of potential yield losses, and the relatively minimal yield losses necessary for the NPV of certified clean hops being higher over the six-year cycle indicates it may be economically advantageous for growers to pay the upfront premium of investing in certified clean plant stock to mitigate the risk of potential long term losses due to HSVd.

Once HSVd is found on the farm, a producer should consider replanting all of the potentially infected bines with certified clean bines once yield losses are estimated to equal at least 35% for aroma hops and 36% alpha hop varieties. This is a lower bound and may be too conservative as all costs for replanting, and safely eradicating HSVd, may not be included in our models. Ultimately it is at the discretion of the grower to determine when diminishing hop yields outpace revenue and make replanting economically viable.

It is important to note the assumptions used in these models impact these results substantially. If sales prices are expected to be higher than those used in the presented models then the net economic benefits of utilizing certified clean hop plantings, free from HSVd, increase relatively quickly. The models also assume the entire acre of NCH plantings are infected with HSVd. While it is true the pathogen is easily spread through mechanical means it may not always be the case that an entire acre is infected with the pathogen. There is a current lack of research analyzing how quickly HSVd spreads through an acre (or more) of hop plants which limits how we are able to model how an HSVd infection spreads, and thus, how the spread impacts yields. More research should be conducted regarding how quickly and easily HSVd can potentially spread from plant to plant. Our results show the economic benefits of planting CCHPS quickly outweigh the increased costs incurred by planting said hops. That being said, it is ultimately up to the individual grower if they decide they want to utilize such plantings.

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Hop photo, title page. Canva free media.

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