**Determining effect of deficit irrigation regimes on hop yield and quality**

**Project Summary:**

As irrigation water becomes an increasingly limited resource in hop production areas of the Pacific Northwest, it is vital to conserve water where possible. Evaluation of sustainable irrigation methods that utilize lower amounts of water without compromising hop yield and quality are essential. Concerns over environmental contamination due to runoff and deep percolation from over-irrigation have also led to the desire to evaluate more efficient irrigation regimes to limit the amount of water escaping the cropping system. Therefore, improvements in optimizing crop water use efficiency via deficit irrigation techniques may allow for reduced water waste and minimized groundwater contamination of fertilizers and pesticides. The objectives of this study are to compare yield and quality parameters between hops grown under deficit irrigation regimes (80% of full irrigation levels enacted at different time points during the season) utilizing single and double lateral line drip lines with 12” and 24” spacing, respectively, on the hops variety, Citra. The results will provide growers with information on how limiting water use may impact yield and quality, and when water deficits may be put in place to aid in water conservation at time points not critical to hop growth.

**Proposed Duration:** 2 years (Proposal for year 1 of 2)

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| **Project Leader:** | **Co-Project Leader:** |
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**Cooperators:**

|  |  |
| --- | --- |
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Mario Aello

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**Amount Requested:**

Funding for 2023 (first year of two year study) = $38,890

**Other Funding Sources and Support:**

Cooperator donated use of their 14’ row spacing R&D hop yard which is set up with trellis system, drip lines and emitters, use of specialized R&D hops harvester, and use of dedicated R&D computerized irrigation system. This project benefits from cooperator’s knowledge of more advanced irrigation systems for hops production.

**Billing and Contract Management:**

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**Determining effect of deficit irrigation regimes on Citra hop yield and quality**

**Statement of Problem:**

As irrigation water becomes an increasingly limited resource in hop production areas of the Pacific Northwest, it is vital to conserve water where possible: evaluation of sustainable irrigation methods that utilize lower amounts of water without compromising hop yield and quality are essential. Concerns over environmental contamination due to runoff and deep percolation from over-irrigation have also led to the desire to evaluate more efficient irrigation regimes to limit the amount of water escaping the cropping system. Therefore, improvements in optimizing crop water use efficiency via deficit irrigation techniques may allow for reduced water waste and minimized groundwater contamination of fertilizers and pesticides.

**Justification and Importance of Proposed Research:**

Hop quality research for the brewing industry has taken precedence over agronomic research (Turner et al. 2011). Overall, published research on irrigation efficiency and efficacy of irrigation configurations in hops grown in the Pacific Northwest is severely lacking despite the need for this information in light of increased competition for water resources and environmental concerns due to runoff. Water is a limited resource for much of western US agriculture. Mean annual precipitation in Yakima is 8.35 inches (US Climate Data 2019) but water requirements for commercial hops are 700-800 mm (~27-31 in.) throughout the growing season (Turner et al. 2011), therefore commercial hop production is dependent on irrigation in the Yakima Valley. As water demands increase for growing urban areas, other competing agricultural uses, and in-stream flow maintenance for native fish preservation, competition for water resources has increased for hop production (Nakawuka et al., 2017). In addition, environmental concerns of irrigated farms contaminating surface and groundwater are increasing, so pressure is being placed on growers to reduce runoff and deep percolation of irrigation water (Nakawuka et al., 2017).

Improved irrigation efficiency can be achieved by increased management and by upgrading to newer irrigation saving techniques (Evans 2003). Various methods of irrigation have been utilized for hops production, including furrow, sprinkler and drip, but currently, most commercial hop yards in Washington are drip irrigated (George 1999). Drip irrigation methods have advantages over furrow or sprinkler irrigation, which include using significantly less water than furrow or sprinkler irrigation, improving growth and yield of the crop, convenient delivery of fertilizers, potentially lowering the risk of pathogens, and time saving and adaptability of systems (Shock 2013, Wample and Farrar 1983). In addition, deep percolation and runoff can be reduced through carefully monitored drip irrigation systems. Deficit irrigation is another water saving technique that has been widely studied in dryer climates; however, deficit irrigation does not necessarily work for all crops and is not a functional alternative where optimal yields are desired (Geertz and Raes 2009). For example, a study on deficit irrigation in hops indicated that lowered percentage, ie., 60% and 80% less, of water applied may not affect the quality of hops cones, but resulted in lowered yields, thus, economically, deficit irrigation has not been found to be a viable option when water availability is plentiful (Nakawuka et al., 2017).

Utilizing subsurface drip irrigation has been proposed as an improved method to irrigate hops and is listed as one of the priority irrigation methods from the Research Focus Group within the Hop Research Council. Lamm (2002) lists many advantages and disadvantages for subsurface drip irrigation. Although many studies that have been performed on annual crops show that utilizing buried drip lines have advantages, the disadvantages of the use of this system on higher value, perennial crops tends to be unfavorable and adoption has been slow (Lamm 2002). Scott Stephen has had experience working with hops growers who have tried subsurface drip irrigation on hops and most of them have removed the drip irrigation system due to difficulty in repairing lines that have been damaged by root intrusion and rodent damage or cleaning clogged emitters. Also, if salts are present, they tend to move upward in the soil profile in our environment. Due to the lack of popularity of subsurface drip irrigation systems with the hops growers that have tried this method, and the need for more improved equipment to address better ease of use and issues with repairing damage to the buried system, we will focus on improved efficacy of drip methods that may be easily adopted by most current hops growers.

Emitter discharge, placement, and irrigation frequency are important factors of drip irrigation which can determine the variation in soil water potential, root distribution, and plant water uptake patterns (Assouline 2006). Also, accurate irrigation scheduling, based on crop water use, can improve water use efficiency. Utilizing crop evapotranspiration (ETc) calculations can better determine how much water crops need over time. ETc is estimated by multiplying a crop coefficient (Kc) by a reference of potential evapotranspiration (ETo) which is typically based on water requirements for either a grass or alfalfa standard (Allen et al. 1998).

Significant yield advantages have been found for various row crops and berries grown with double lateral drip line systems over those grown with single lateral drip lines (Pits, et al. 1991, Bryla). A survey performed at both the Washington and Oregon Hop Commission meetings in October 2019, indicated that some hops growers have converted, or are in the process of converting, their single lateral line drip systems to double lateral line drip systems. Other survey participants had shown interest in more information regarding double drip line systems. Observational comparisons between single and double lateral drip systems in hops have shown that there is a more even distribution of root growth, better root and plant health, improved yields, and less water loss due to deep percolation and runoff in the double lateral drip systems.

It is therefore proposed to experimentally compare deficit irrigation techniques that may allow for reduced water waste and minimized groundwater contamination of fertilizers and pesticides. Yield and quality parameters will be compared between hops grown under deficit irrigation regimes of 80% of full irrigation levels during the entire season, 80% of full irrigation from late spring to early flowering, 80% of full irrigation levels from flowering through harvest, and no deficit regime (100% irrigation levels based on soil moisture levels) utilizing single and double lateral line drip lines with 12” and 24” spacing, respectively, on hop variety Citra. The results will provide growers with information on how limiting water use may impact yield and quality, and when water deficits may be put in place to aid in water conservation at time points not critical to hop growth. It is also assumed that this project will aid in future decision making for improvements in irrigation scheduling and configurations.

Kaitlin Hadaway, project leader, joined Agrimanagement in 2021 to oversee the company’s contract research program. She specializes in protocol design, data collection, and statistical analysis and reporting. Scott Stephen is a crop consultant with Agrimanagement and has worked with hops growers for 20+ years. He has experience with irrigation monitoring and soil water dynamics within the hop system.

**Objectives:**

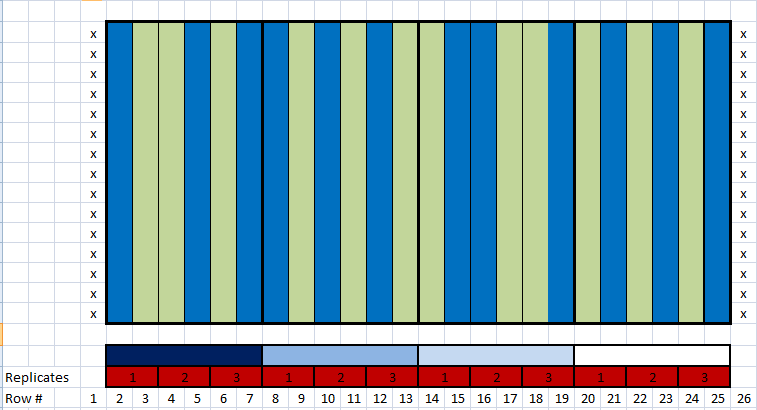
The objectives of this study are to compare yield parameters of wet and dry weight(s) per acre and quality parameters of acids and oils between hop plants grown under deficit irrigation regimes: 80% of full irrigation levels during the entire season, 80% of full irrigation from late spring to early flowering, 80% of full irrigation levels from flowering through harvest, and no deficit regime (100% irrigation levels based on soil moisture levels) utilizing single and double lateral line drip lines with 12” and 24” spacing, respectively.

**Methods:**

A two-year study will be conducted from 2023 through 2024 to test various lateral drip line and emitter spacing configurations on Citra. The study site is a 3.1 acre hops research and demonstration yard located at Roy Farms in Moxee, WA. The experimental hop yard was planted to Cascade in the spring of 2020, but the hop yard will be re-planted to Citra as a previous HRC funded project has worked to determine a Citra hops-based crop coefficient, which will be used in determining crop water requirements. Each year, soil water content, hops yields and hops quality parameters will be monitored and recorded. The grower will manage the experimental hops area, including irrigation construction and management, training the hops, fertilizing, and weed, disease, and pest management.

The experiment will be comprised of four irrigation regime treatments (Factor A) and two drip line configurations (factor B), organized as a Split-Plot design (Figure 1, Table 1). Irrigation regimes will be assigned to six consecutive rows per regime, with three of the rows randomly assigned to be configured with 12” spacing single drip line and the other three configured with 24” spacing double drip line. Therefore, there will be three replicates per drip line spacing configuration within each irrigation regime.

*Figure 1.* Experimental Design, Split-Plot Design



*Table 1.* Experimental Design Key, Split-Plot Design

|  |  |  |
| --- | --- | --- |
| **Factor** | **Treatment** | **Key** |
| A: Irrigation Regime | 80% of full |  |
|  | 80% of full, early |  |
|  | 80% of full, late |  |
|  | 100% full |  |
|  | | |
| B: Drip Line Configurations | Single line, 12” spacing |  |
|  | Double lines, 24” spacing |  |

The single drip line treatments will have the drip line placed along one side of the hops hills and the double drip line treatment will have one line placed on either side of the hills in the spring of 2023 as the drip lines do not remain in the field over winter (or, for option 2, spliced in the center of the 380’ rows to allow for each configuration within each row). Irrigation scheduling for 2023 will be based on crop growth stage of plants, environmental factors, and the current evapotranspiration (ETc) calibration system designed by Allen et al. (1998). Crop evapotranspiration (ETc) will be calculated by multiplying ETo by a variable hops crop coefficient (Kc) derived from the curve developed by the Agrimanagement team from a 2020-2023 HRC funded project. Environmental factors, such as rainfall, mean maximum and minimum air temperature, relative humidity, and evapotranspiration (ETo) data will be obtained from a weather station located at the study site.

The amount of irrigation will be managed by Mario Aello, irrigation manager for Roy Farms, who will consider the data previously described on the full 100% irrigation treatment rows when scheduling irrigation. Zentra soil moisture sensors (METER Group) will also aid in irrigation decision making: if the volumetric water content exceeds field capacity (ie., water loss due to deep percolation) or if moisture levels are below 50% of the total available soil level at the 4 ft. level in the full 100% irrigation regime, then the application rate will be adjusted at the irrigation source. Sensors will be placed within each treatment to monitor irrigation percolation levels, placed horizontally underground within an area influenced by the active root zone and vertically just below the soil surface, from 1- 3.5 ft deep as four feet is at the bottom of the active root zone for hops (Evans 2003).

Vertical water movements of each of the irrigation configurations will be measured with the sensors throughout the season. Plant heights will be estimated in relation to the top of the 18-ft trellis and plant health will be monitored weekly. Stomatal conductance, an indicator of plant water status, will be measured biweekly on five plants per plot to assess potential water stress using the SC-1 leaf porometer (METER Group). To ensure that no outside factors influence yield or quality, the plots will be monitored weekly for the presence of pests. After cone development, cone size will be estimated on five plants biweekly until harvest. Hop harvest and processing will be a joint effort between the researchers and the grower. Twenty plants from each one-row plot will be harvested with a small-scale hops harvester. Cone samples from each plot will be sent to Hollingberry and Son Hops laboratory in Yakima, WA for full chemical analysis including dry matter, alpha and beta acids, hop storage index, cohumulone and colupolone content, moisture, and essential oil profiles.

Results will be analyzed by analysis of variance (ANOVA). Differences in hops yield and quality factors (α and β acids) between treatments will be considered significant when type III sum of squares meet the F-test criteria at p<0.05. When significant differences are found within the ANOVA, means will be separated by Tukey’s HSD test.

**Outcomes:**

The results will provide growers with information on how limiting water use may impact yield and quality, and when water deficits may be put in place to aid in water conservation at time points not critical to hop growth.

**Extension and Outreach Activities:**

A biannual report presentation of the results will be presented at the Hops Research Council summer meeting in August 2023, with final results being presented to attendants of the Washington Hops Growers Convention in January 2024. In addition, final results will be presented as a report to the Hops Research Council to distribute to stakeholders. A field day will be held at the study site during the 2024 season to present the study and all results.

**Time Frame for Objectives:**

2023

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Activity or Goal | J | F | M | A | M | J | J | A | S | O | N | D |
| Meet with grower/order parts |  |  |  |  |  |  |  |  |  |  |  |  |
| Set up irrigation systems |  |  |  |  |  |  |  |  |  |  |  |  |
| Planting, Irrigation of plots |  |  |  |  |  |  |  |  |  |  |  |  |
| Soil water parameter data |  |  |  |  |  |  |  |  |  |  |  |  |
| Present at HRC meeting |  |  |  |  |  |  |  |  |  |  |  |  |
| Yield/quality data collection |  |  |  |  |  |  |  |  |  |  |  |  |
| Analysis of first year data |  |  |  |  |  |  |  |  |  |  |  |  |
| Progress report to HRC |  |  |  |  |  |  |  |  |  |  |  |  |

2024

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Activity or Goal | J | F | M | A | M | J | J | A | S | O | N | D |
| Present at HRC meeting |  |  |  |  |  |  |  |  |  |  |  |  |
| Check irrigation system |  |  |  |  |  |  |  |  |  |  |  |  |
| Irrigation of plots |  |  |  |  |  |  |  |  |  |  |  |  |
| Soil water parameter data |  |  |  |  |  |  |  |  |  |  |  |  |
| Yield/quality data collection |  |  |  |  |  |  |  |  |  |  |  |  |
| Analysis of second year data |  |  |  |  |  |  |  |  |  |  |  |  |
| Final report to HRC |  |  |  |  |  |  |  |  |  |  |  |  |

**Project Budget (2023):**

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| --- | --- | --- |
| **Expenditure** | **Hops Research Council Request** | **Amount Requested** |
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| Billable Hours | Project Leader 120 hr x $75/hr  Co-Project Leader 30 hr x $110/hr  Summer Intern 60 hr x $30/hr | $9,000 $3,300  $1,800 |
| Travel | Meet with cooperator, 4 x 30mi x $0.75/mi  Data collection, 20 visits x 30mi x $0.75/mi  Attend HRC 2023 summer meeting - TBD  Attend 2024 USA Hops Convention – TBD | $90  $450  $700  $1,500 |
| Equipment, services | Zentra sensors, $1,200 x 4 units  Zentra cloud use $200 x 4 units  SC-1 porometer, $200 for unit maintenance | $4,800  $800  $200 |
| Grower compensation | Management of hops yard, including planting, irrigation, pest, disease and weed management, harvest, and technician time. $3,500/ac x 3.1 acres | $10,850 |
| Process Cones | 24 samples (full analysis) x $85/sample | $2,400 |
| Data analysis | Porometer data analysis  Harvest data analysis  Cone chemical analysis | $1,000  $1,000  $1,000 |
|  | **2023 AMOUNT REQUESTED** | **$38,890** |

**Project Budget (2024):**

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| --- | --- | --- |
| **Expenditure** | **Hops Research Council Request** | **Amount Requested** |
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| Billable Hours | Project Leader 100 hr x $75/hr  Co-Project Leader 25 hr x $110/hr  Summer Intern 40 hr x $30/hr | $7,500 $2,750  $1,200 |
| Travel | Meet with cooperator, 4 x 30mi x $0.75/mi  Data collection, 20 visits x 30mi x $0.75/mi  Attend HRC 2023 summer meeting - TBD  Attend 2024 USA Hops Convention – TBD | $90  $450  $700  $1,500 |
| Equipment, services | Zentra cloud use $200 x 4 units  SC-1 porometer, $200 for unit maintenance | $800  $200 |
| Grower compensation | Management of hops yard, including irrigation, pest, disease and weed management, harvest, and technician time. $3,000/ac x 3.1 acres | $9,300 |
| Process Cones | 24 samples (full analysis) x $85/sample | $2,400 |
| Data analysis | Porometer data analysis  Harvest data analysis  Cone chemical analysis | $1,000  $1,000  $1,000 |
|  | **2024 AMOUNT REQUESTED** | **$29,890** |

2023 and 2024 Funds Requested: $38,890 + $29,890 = $68,780

**Literature Review:**

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