AGRICULTURAL RESEARCH FOUNDATION
FINAL REPORT
FUNDING CYCLE 2018 – 2020

TITLE: Reducing Water and Nitrate Losses in Onion Production Systems of the Lower Umatilla Basin

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COOPERATORS: n/a

EXECUTIVE SUMMARY:

Agricultural production in the Lower Umatilla Basin (LUB) is under pressure as a potential contributor to nitrate pollution in the groundwater system. A recent action plan has identified key strategic steps to reduce nitrate leaching by managing soil moisture in irrigated cropping systems. In this region, sandy loam is the major soil type with low organic matter, which presents irrigation and nutrient management challenges. Onions are the second largest crop produced in the region and are primarily irrigated with center pivot systems. Previous research from other regions with different soil types has demonstrated that Subsurface drip (SSD) irrigation systems can produce higher onion yields with total reduced water and nutrient losses. Along with the increases in water use efficiency, it is hypothesized that nitrate leaching in sandy soils will be reduced when irrigation is tailored for maximum crop efficiency. Water use efficiency with SSD irrigation and nitrogen indexing methods need to be evaluated to correlate irrigation methods with nitrate losses in the region. Research is currently underway at the Oregon State University (OSU) Hermiston Agricultural Research and Extension Center (HAREC). Results indicate that onion growth is optimized when irrigation onset values of soil tension are set to irrigate at 10 kilopascals (kPa) (1 kPa=1 cb). By using a SSD irrigatoin flow rate of 0.13 gallons per hour (compared to 0.07 g/h), data indicated that greater lateral spread of water within the onion bed was accomplished. The 0.13 g/h flow rate saturated the onion root zone and reduced water percolation past 16 inches in depth, as seen in the 0.07 g/h flow treatment, which percolated past the onion roots. Less infiltration may be optimal for onion root uptake and could minimize excess water loss and potential nitrate leaching.

OBJECTIVES:

1. Evaluate drip irrigation flow rate and irrigation onset based on soil moisture to optimize onion yield in coarse textured soil (Atkins fine sandy loam).
2. Model subsurface drip applied irrigation water distribution throughout the soil profile to determine optimal irrigation parameters.
3. Determine vertical nitrate leaching in the soil profile and correlate leaching with drip irrigation treatments.

PROCEDURES:

The in-field evaluation was conducted over two years at the OSU HAREC from 5/13/2018 – 9/17/2019. The experimental field was located in Hermiston, Oregon (45°48'60.0"N 119°17'27.7"W), with a soil type classified as Atkins Sandy Loam (mesic Fluvaquentic Endoaquepts). Throughout the field trial, meteorological data was collected 1000 ft. from the field site using a Pacific Northwest Agrimet weather station (U.S. Department of the Interior, 2019). Three-month daily mean, minimum and maximum temperatures were 24℃,14.5℃,and 30℃,respectivly. Mean relative humidity was 46% with an average wind velocity of 6.3 mph at a 207°-azimuth bearing.

The experimental field was setup as a random complete block design with eight irrigation treatments, replicated five times. Treatments consisted of four levels of soil tension (cb) irrigation onset values of 5, 10, 15 and 20 cb at each of the low (L) (0.17 gal per min per 100 ft) and high (H) (0.34 gal per min per 100 ft) flow irrigation rates, set to deliver 1/10th of an inch of water at each irrigation event. Irrigation was monitored using Watermark granular matrix sensors that were located within the onion planting beds. Nine sensors were in each treatment bed in a grid pattern to model soil moisture vertically and laterally and to determine when to initiate irrigation events. Onions were direct seeded with a custom fabricated onion seeder built for the project (Fig.1). The onion variety Swale, which is a yellow fresh market onion that is regionally grown was used. The bed configuration of the SSD irrigated plots is indicated in figures 2 and 3. Plots were managed according to growers' standards for crop protection, fertilization and weed control.

Figure 1. Custom fabricated small plot onion seeded built for this project.

Fertilizer applications

Starter broadcast fertilizer was applied at planting, in which 70 lbs. nitrogen (N) per acre was applied in a starter band over the two onion rows, composed of (70N- 80P-200K-53S-10Mg-1Zn-2B-96Cl lbs. per acre). In season applications of Urea Ammonium Nitrate (UAN 32) were applied through the SDI system four times throughout the growing season, to achieve 20 lbs. N / acre at each date. Total in N applied by the granular base fertilizer and injected fertigation totaled 150 lbs. N per acre.

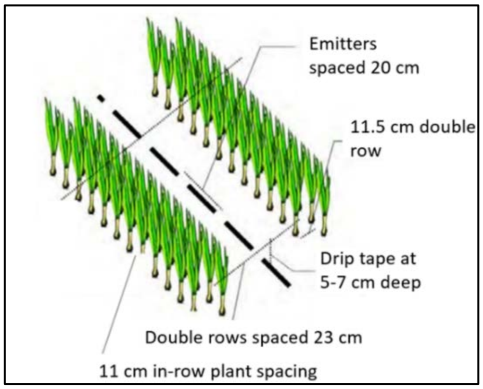

Figure 2. Onion planting bed configuration

Data collection

Data for soil moisture were continually tracked at intervals of one hour for the entirety of the cropping season in each respective treatment plot. Onion data were collected for plant establishment, plant vigor, plant counts and plant height at five times in-season, and final onion graded yield and counts data were collected at harvest on 9/17. Soil sampling and lysimeter solution collections occurred approximately two weeks after each fertilization, totaling four collection events. Soil and lysimeter samples were taken from depths of 6, 12, 24, and 36 inches at each sample date. Data collected on plant measures were analyzed using a random complete block design analysis of variance (ANOVA) with the statistical program Statistix 10.0. When significant treatment effects were detected, means were separated using Fisher's Least Significant Different (LSD) test at ∝=*0.05*.

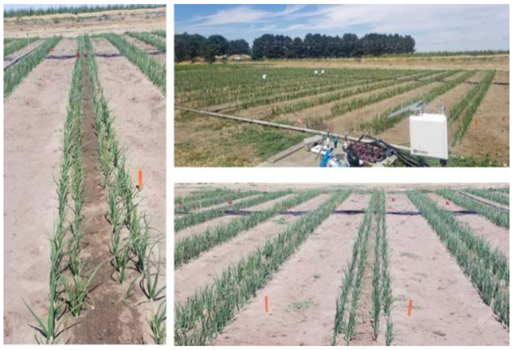

Figure 3. Representative photos of the experimental plot taken 7/2/2019.

SIGNIFICANT ACCOMPLISHMENTS TO DATE:

The results of the ANOVA for in-season data collected on June 21st and July 12th did not indicate significant differences in the data parameters of plant establishment, counts, vigor, or height. As the season progressed and moisture demand and stress increased, data collected on July 31st resulted in the significantly greatest plant height (*p*=0.001) found in the treatments irrigating at 5 cb moisture onset at the high flow rate, 10 cb at the high flow rate, and 10 cb at the low flow rate (Fig. 4). At the final data collection point on 9/10, significant treatment effects were detected in the measures of onion plant vigor (*p*=0.0002) and onion plant height (*p*=0.0008). Plant vigor was greatest in treatments that were maintained at 5 and 10 cb of soil moisture at both flow rates, with the exception of the high flow rate at 15 cb (Fig. 5). Results of plant height indicated the significantly tallest plants were found at the soil moisture onset of 5, 10, and 15 cb at the high flow rate (Fig. 6).

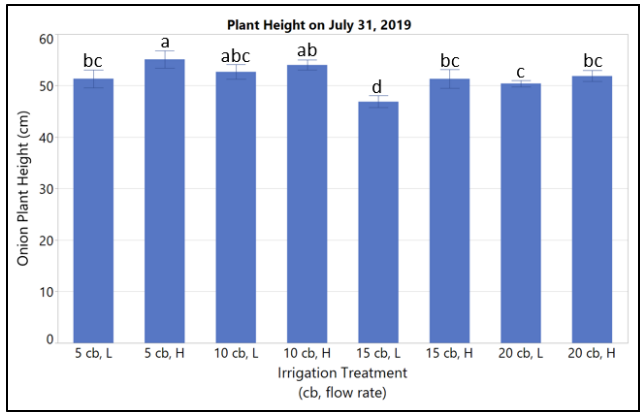

Figure 4. Onion plant height on July 31, 2019. Treatments consisted of four levels of soil moisture (cb), with low (L) and high (H) flow rates of SDI irrigation. Different letters indicate statistical differences between treatment means. Each error bar is constructed using 1 standard error from the mean.

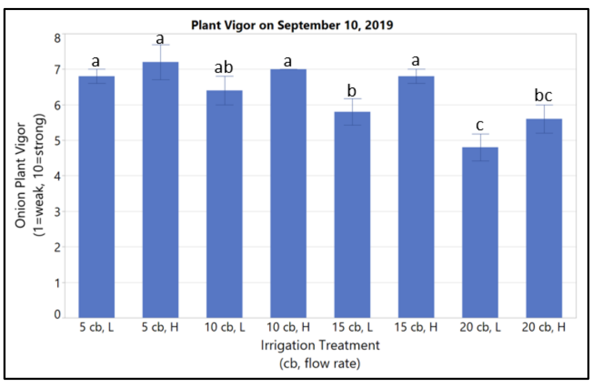

Figure 5. Onion plant vigor on Sept. 10, 2019. Treatments consisted of four levels of soil moisture (cb), with low (L) and high (H) flow rates of SDI irrigation. Different letters indicate statistical differences between treatment means. Each error bar is constructed using 1 standard error from the mean.

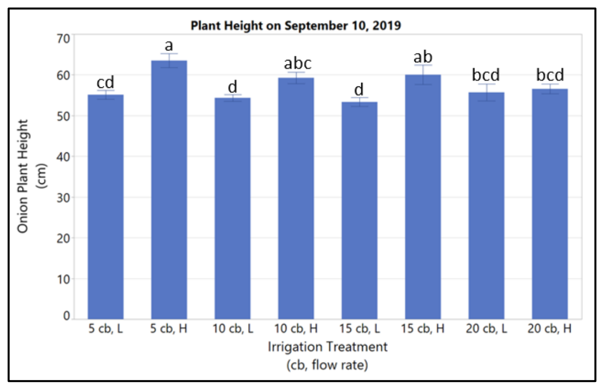

Figure 6. Onion plant height on Sept. 10, 2019. Treatments consisted of four levels of soil moisture (cb), with low (L) and high (H) flow rates of SDI irrigation. Different letters indicate statistical differences between treatment means. Each error bar is constructed using 1 standard error from the mean.

Results of the ANOVA for marketable onion yield (large, jumbo, colossal, and super colossal grades) (*p*=0.0001) and counts (*p*=0.017) indicated significant treatment differences in both categories. Onion counts were significantly greatest in the 10 cb high flow rate treatment, which were not significantly greater than the 15 cb high flow rate, 10 cb low flow rate, or the 5 cb high flow rate (Fig. 7). Onion yield was optimized with the 10 cb high flow treatment which was numerically highest but significantly similar to the 5 cb high flow treatment, but greater than all other treatments (Fig. 8).

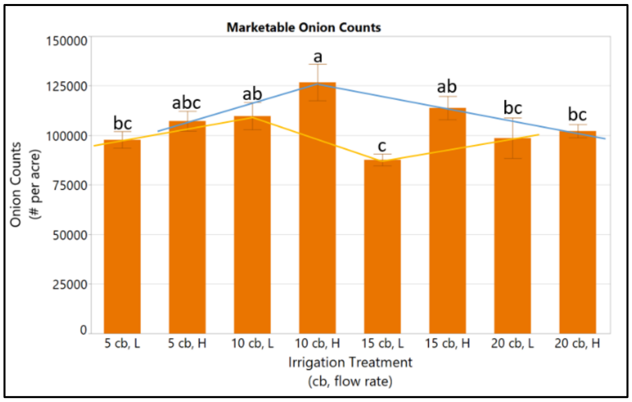

Figure 7. Marketable onion counts per acre at harvest on Sept. 17, 2019. Treatments consisted of four levels of soil moisture (cb), with low (L) and high (H) flow rates of SDI irrigation. Different letters indicate statistical differences between treatment means. Each error bar is constructed using 1 standard error from the mean

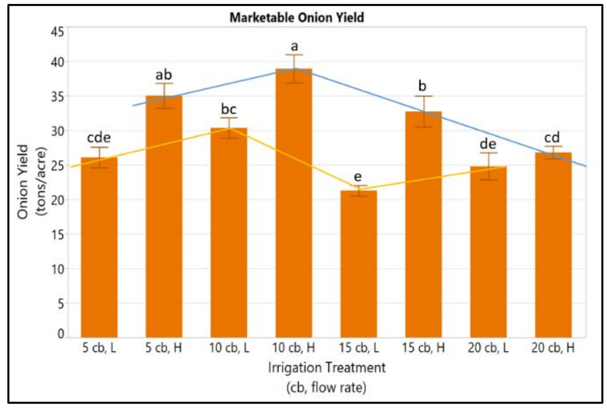

Figure 8. Marketable onion yield per acre at harvest on Sept. 17, 2019. Treatments consisted of four levels of soil moisture (cb), with low (L) and high (H) flow rates of SDI irrigation. Different letters indicate statistical differences between treatment means. Each error bar is constructed using 1 standard error from the mean

Soil moisture

Soil moisture models indicated both irrigation flow rates (L and H) at 5 cb onset resulted in heavy saturation within the onion root rhizosphere (Fig. 9). The 5 cb low flow treatment resulted in more vertical movement of the water compared to the high flow treatment which provided greater saturation laterally towards the onion rows. Within both of the 5 cb treatments, it is evident that excess moisture is moving past the onion roots (~8 inches). At the 10 cb irrigation onset, the low flow treatment resulted in uniform irrigation moisture within the onion root rhizosphere, the moisture moved laterally then vertically to move beyond the onion root zone. Within this treatment, excess moisture loss was not excessive (Fig 10). The high flow treatment irrigating at 10 cb provided soil moisture laterally to the onion rows more rapidly than the low flow treatment. Less moisture was detected past the onion roots at a depth greater than 12 inches. At 15 cb moisture onset level, the high flow treatment maintained soil moisture within the onion root rhizosphere laterally with minimal vertical movement beyond 15 inches (Fig. 11.). The low flow treatment at 15 cb, displayed greater vertical movement of water within the bed, with minimal lateral flow to the onion rows. Soil moisture and infiltration in both treatments irrigating at 20 cb is not sufficient to support onion growth (Fig. 12).

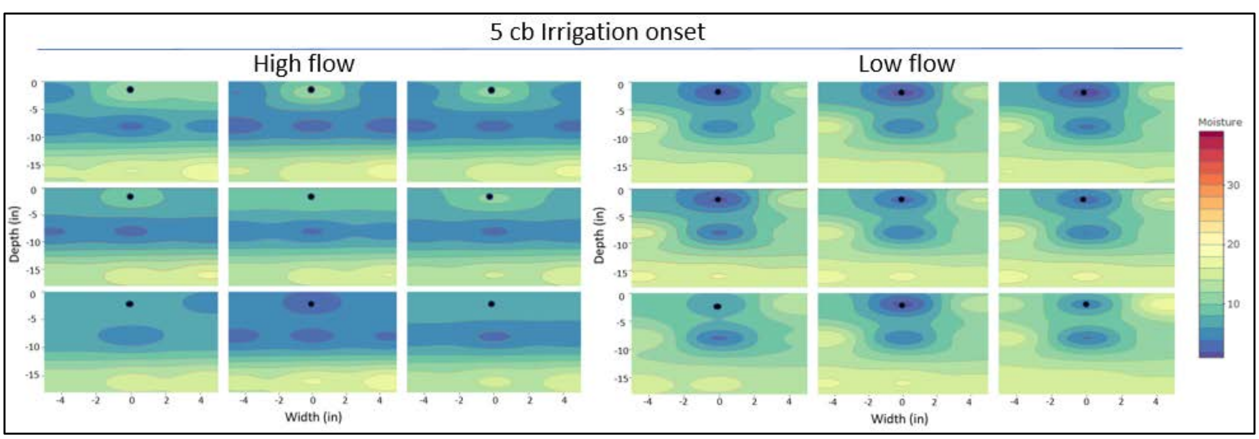

Figure 9. Soil moisture (soil tension) throughout the soil profile with irrigation onset of 5 cb at high flow (left) and low flow (right). Data is presented over a 36 hour time span of irrigation. Block 1 (top left) representing onset with proceeding blocks (left to right) representing hours 1,2,3,4,8,16,24, and 36 after initial onset.

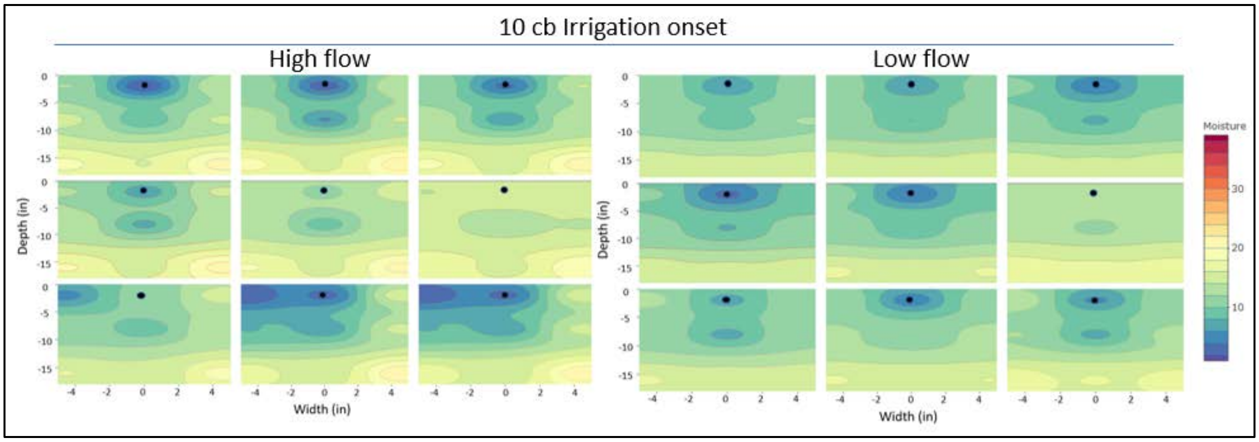

Figure 10. Soil moisture (soil tension) throughout the soil profile with irrigation onset of 10 cb at high flow (left) and low flow (right). Data is presented over a 36 hour time span of irrigation. Block 1 (top left) representing onset with proceeding blocks (left to right) representing hours 1,2,3,4,8,16,24, and 36 after initial onset.

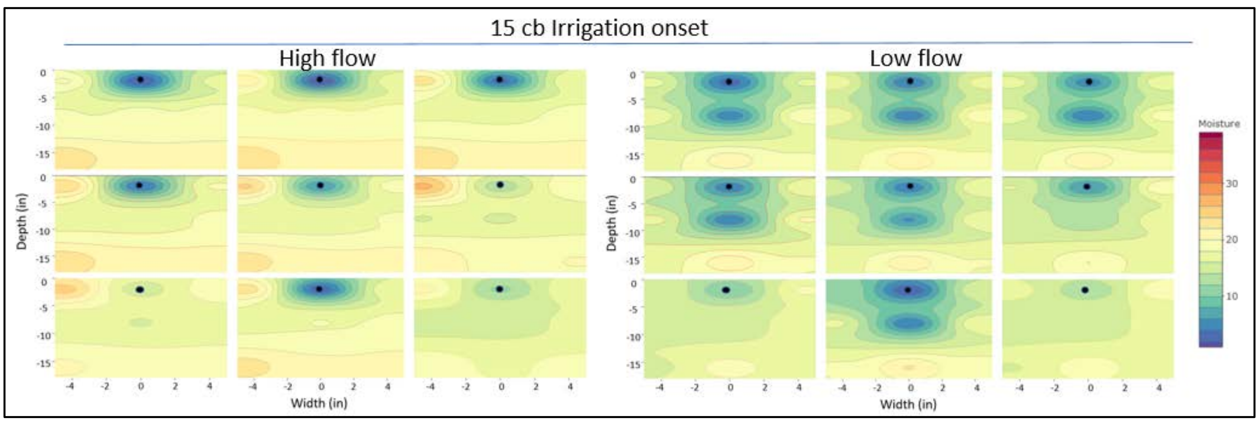

Figure 11. Soil moisture (soil tension) throughout the soil profile with irrigation onset of 15 cb at high flow (left) and low flow (right). Data is presented over a 36 hour time span of irrigation. Block 1 (top left) representing onset with proceeding blocks (left to right) representing hours 1,2,3,4,8,16,24, and 36 after initial onset.

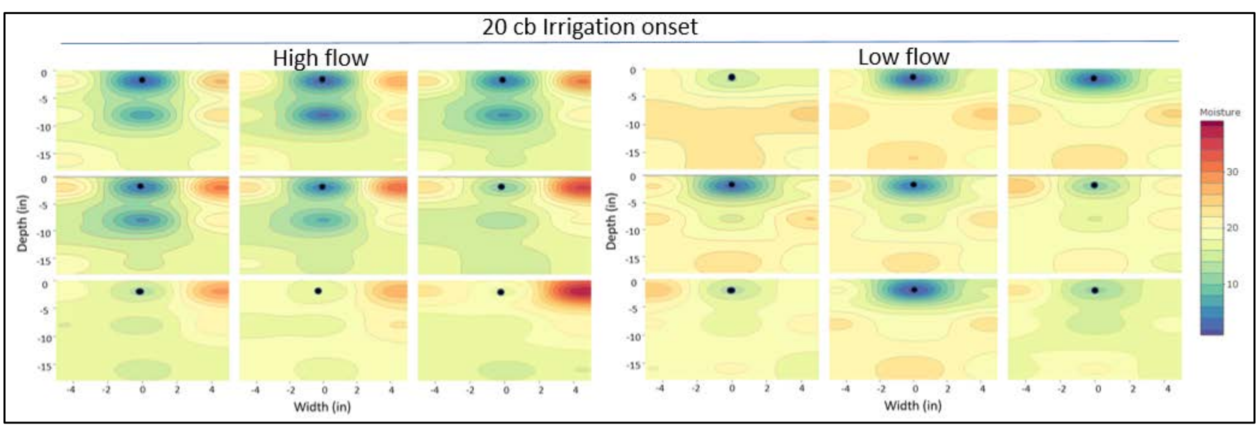

Figure 12. Soil moisture (soil tension) throughout the soil profile with irrigation onset of 20 cb at high flow (left) and low flow (right). Data is presented over a 36 hour time span of irrigation. Block 1 (top left) representing onset with proceeding blocks (left to right) representing hours 1,2,3,4,8,16,24, and 36 after initial onset.

Soil Nitrogen
Results of the NO3-N (nitrate) found within the soil profile indicate that treatments of higher moisture retained less nitrate within the soil column than low moisture treatments (Fig. 13). This is likely due to the correlation between nitrate leaching and water infiltration. Within the 5 cb treatments, soil nitrate remained within the lowest values when compared to other higher moisture treatments, likely due to increased nitrate leaching beyond the sampled soil depths (>3 ft.). In contrast, the 20 cb treatments retained a higher rate of nitrate within the profile, especially at the 6 inch depth. Solution samples collected from the lysimeters at all depths resulted in unexplainable and unreliable data when compared to the corresponding soil sample analyses. Due to the lack of pattern, trend, or correlation to the soil sample data, the lysimeter solution data is considered unusable.

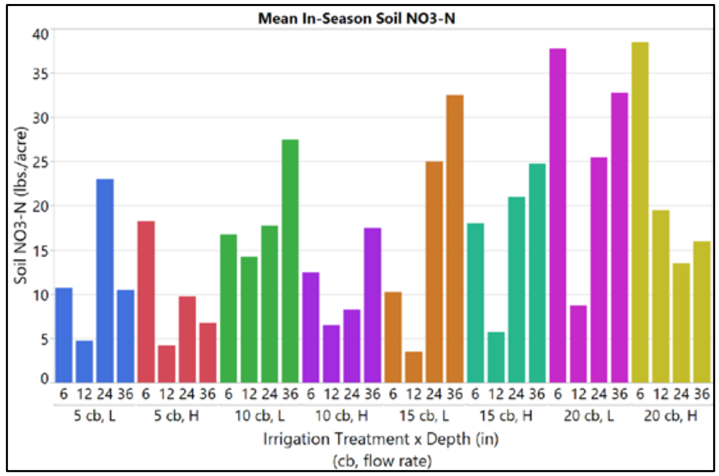

Figure 13. N03-N soil profile values averaged over four sampling events two weeks post- fertigation with 20 lbs.N /acre. Samples were collected from each plot at depths of 6, 12, 24, and 36 inches and composited into one sample for each treatment at each sample duration.

Discussion:
Overall, the results of in season plant health parameters and onion yield data support the use of the 10 cb soil moisture onset threshold with the high flow SDI. Soil moisture at this treatment was ideal to optimize onion growth.
A common trend with the low flow treatments was increased vertical water infiltration with decreased lateral spread to the onion rows. This moisture distribution resulted in an increased amount of irrigation onset events because the moisture sensors (placed in the onion rows at 8 inches) responsible for initiating irrigation were not receiving the threshold moisture treatment value. The increased amount of onset times resulted in more flow through the SDI lines, which led to increased plugging (algae) of the emitters compared to the high flow treatment. Based on the tendency for increased vertical water movement (past the onion roots) and the issues to related to clogging, it is not suggested at this time to use the low flow irrigation line.
Soil sampling to assess nitrate within the soil profile indicated that with increased moisture, there was less nitrate identified. Unfortunately, the most plausible explanation for this is due to moisture leaching the nitrate past the root zone, especially in the 5 cb treatments. It is not recommended to exceed 10 cb of soil moisture, because of excess moisture infiltration and the potential for increased nitrate leaching. Despite the lysimeters being easier to utilize to obtain samples from, compared to soil sampling methods, the validity of the data produced is unreliable and thus is not a practical method at this point. Further evaluation of these results will be completed next season (summer 2020, not supported by OSU ARF) to confirm the findings.

BENEFITS & IMPACT:
The results of the research and dissemination over both years have led to the increased adoption of Subsurface drip irrigation in onion production in the Umatilla Basin. The transition from a grower standard practice takes many years to facilitate, and throughout the duration of this trial, we have identified the expansion from 400 acres of SSD onions (2017) to 800 acres (2019). While this doubling of

acreage cannot be solely attributed to this research, the primary company producing onions on SSD has been engaged through this trial from the inception and has been receiving research updates as they occur.
Impacts in relation to water and yield potential have been evidenced through this research. Water use applied by SSD irrigation is approximately 15% less compared to a center pivot system (most common type of irrigation). Onion yield achieved through SSD is on average 20% greater than with center pivot irrigated onions. Fertilizer usage is also reduced but a quantification of the savings is not available due to differences in producer fertilization methods. Overall, the research demonstrates that the utilization of SSD irrigation is feasible in sandy soil onion production and can reduce inputs and produce greater yields compared to current grower standard practices. With the reduction of inputs and the increased precision of inputs we are able to reduce nitrate leaching from onion producers into the groundwater of the region.

Outreach and Education:
The project and results have been presented at the National conference of the American Society of Horticultural Science (ASHS), in Las Vegas, Nevada on July 22nd, 2019. Regionally, results from this research were presented at the Pacific Northwest Vegetable Association Onion session on November 20th, 2019, the Hermiston Farm Fair on December 5th, 2019, and the North Willamette Horticultural Society annual meeting in January 29th 2020. The OSU intern (Jared Farber) who was supported by this project presented his work at the OSU Experiential Expo on 10/24/2019 and received the award for best poster presentation (Fig. 14). One Oregon State University (OSU) research assistant has worked directly on this project to assist coordination of data collection and plot maintenance.

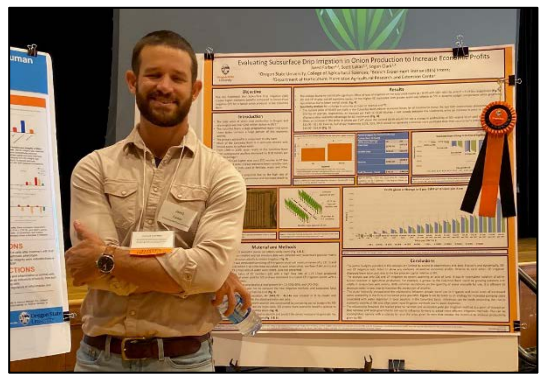

Figure 14. Jared Farber (Intern supported by the project), with his research poster related to the economics of SDI irrigation in onion production. He was awarded the best project statewide over all 2019 OSU interns.

ADDITIONAL FUNDING RECEIVED DURING PROJECT TERM:
Funds provided by the Agricultural Research Foundation have been leveraged as seed funding to secure an additional two years funding from the Oregon Department of Agriculture, totaling $67,000. As a result of my engagement and extension in projects to optimize water and nutrient usage, a grower cooperative has funded future research in my program to focus on utilizing wastewater for crop production over a five year period (2020-2024), totaling $456,825.

FUTURE FUNDING POSSIBILITIES:
Future funds opportunities will continue to be evaluated, such as private, state, and federal sources. I am optimistic that the preliminary results of this trial will lead to securing more funding in future years.