A. Project Information

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Project title: Assessing Drip Irrigation and Nitrogen Management of Fresh Onions Produced in California Low Desert
Project leaders:

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B. Abstract

California has the largest water appropriation of the Colorado River Basin - CRB. Agriculture is the largest offstream use of water in the CRB. Over two decades of persistent drought in the CRB has brought the attention of all water users to adapt to future shortages of water. Excess water and related chemicals from agricultural fields in Imperial County, CA and Mexicali Valley, Mexico end in the largest and most pollutant lake in California, Salton Sea. The main goal of this project was to evaluate the effects of irrigation management and nitrogen fertilization rates on yield and quality of fresh onion bulb production in arid regions using slightly saline water. Field assessments were performed at the University of California Desert Research and Extension Center, Holtville, CA during three growing seasons (2019-2020, 2020-2021, and 2021-2022). Four irrigation levels and four nitrogen rates were established. Assessments were carried out with four replicates in a split-plot design with drip irrigation treatments in the main plot and four N-fertilization rates at the subplot level. Onion size, yields, and total soluble solids (brix) were influenced by irrigation rates. Onion size distribution and total yield did not respond to nitrogen rates when total nitrogen available in the top foot of the profile ranged from 104 to 353 lb/ac. However, onion size distribution and total yield responded to nitrogen rates in a field with only 54 lb/ac of total nitrogen available in the top foot.

C. Introduction

California has diverse agroecosystems throughout the state including low desert irrigated areas in Imperial County. California is the largest onion producer in the nation. The 2018 farm gate value for onions in California was estimated at $611.75 million. In 2018, onion production in Imperial County generated $98.64 million in farm gate value, equivalent to 16% of total gross value in California. For over 100 years, the Colorado River has been the sole water source of a highly productive agricultural sector in Imperial County, one of the top ten agricultural counties in the nation. Agriculture is the largest water user in the Imperial County. The two largest reservoirs in the Colorado River system are reaching historical low water levels due to a persistent drought and over allocations. The US Bureau of Reclamation (USBR) declared water shortages on the Colorado River in 2022 and 2023. Arizona, Nevada, and Mexico have experienced water cuts affecting mostly agriculture water users. The USBR is working with basin users to develop a strategy that may reduce water usage between 2 and 4 million acre-feet per year. Another issue facing agriculture water users in the Colorado River basin is salinity. To prevent soil salinization and enhance agricultural production, agricultural fields in Imperial County have subsurface drainage systems and excess irrigation water is applied to leach salts from the root zone. Although salt leaching improves soil conditions, drainage water dissolves chemicals and carries them into the drainage system. Irrigation excesses as well as municipal and industrial discharges from the Imperial, Coachella and Mexicali valleys flow into California's largest lake, the Salton Sea. Currently, the Salton Sea has high nutrient, salinity, and toxic compound concentrations. Adoption of improved irrigation and nutrient management practices by growers is needed to reduce water pollution from excess nutrients in California's low desert region.

Growers in the Imperial Valley are adopting more efficient irrigation systems (sprinkler and drip) and science-based irrigation scheduling methods (soil moisture, weather-based techniques) motivated by themselves and through the IID On-Farm Efficiency Conservation Program. The current water transfer agreement between IID and the San Diego County Water Authority (SDCWA) calls for transfer of up to 303,000 acre-feet annually of Imperial Valley-Colorado River water to San Diego. From 2018 to 2026, most of the water available for transfer will have to come from on-farm water conservation programs. The purpose of this project was to enhance sustainability through evaluation of irrigation and nutrient management strategies that conserve water and minimize nutrient export. The use of irrigation technology based on plant needs along with soil moisture indicators can help create a healthy environment for crops and minimize the risk of nitrate losses to the groundwater.

D. Objectives

The main goal of this project was to evaluate the effects of irrigation management and nitrogen fertilization rates on yield and quality of fresh onion bulb production in arid regions using saline water. Specific objectives were:
Objective 1. Evaluate the response of onion to drip irrigation and regimes and compare onion production under different N fertilizer application rates.
Objective 2. Communicate findings directly to growers, as well as to crop advisors, academics, regulatory bodies, and agriculture industry.
Objective 3. Provide training opportunities to college students.

E. Methods

Field assessments were performed at the University of California Desert Research and Extension Center -UCDREC, Holtville, CA. The assessment was carried out with four replicates in a split-plot design with drip irrigation treatments in the main plot and four N-fertilization rates at the subplot level. Research plots were 50 ft long and comprised 4 rows on 40-inch beds. Sixty-four plots were established (16 treatments and 4 replicates) during three growing seasons (2019-2020, 2020-2021, and 2021-2022). Sprinklers were used for germination and establishment in all treatments. Four irrigation levels were established: 40, 70, 100, and 130% of crop evapotranspiration (ETc). Irrigation scheduling was based on weather data from the UCDREC's CIMIS station and crop coefficients published by UN FAO for 100% crop evapotranspiration. Watermark soil water tension meters were installed in each of the irrigation treatments at 6-, 12-, and 24-in.

Four in-season nitrogen treatments were assessed: pre-plant; pre-plant plus 75 lbs N per acre; pre-plant plus 150 lbs N per acre; and pre-plant plus 225 lbs N per acre. Three biweekly nitrogen applications through drip after bulbing start were scheduled. Soil samples were collected (pre-planting, during season, and post-harvesting) at different depths (from 0 to 36 in depth) and analyzed for NH_4 and NO_3. Furthermore, bulbs and leaves were analyzed for their N concentration during the growing season to determine N uptake and removal in the different treatments. Biomass data were collected four times after starting bulb formation until harvesting. Onion quality parameters of jumbo sizes, including bulb firmness and total soluble concentration (brix) were measured after onion harvest and curing. Analysis of variance was performed with SAS. Duncan test at 5% level was used to find any significant difference between treatment means. Soil, water, and biomass data was analyzed using appropriate correlation and assessment procedures.

Water use efficiency (WUE) was computed for each irrigation treatment. The WUE included rain and irrigation amounts. The WUE was computed as the total fresh onion yield divided by the total water use. Apparent nitrogen recovery efficiency (NRE) was calculated using the difference method (Crasswell and Godwin, 1984):

$$NRE = \frac{NF-NC}{R}$$

NF = total crop N uptake from fertilized plots
NC = total crop N uptake from unfertilized plots
R = rate of fertilizer N applied

The following proximal optical sensors evaluated the effects of irrigation treatments during the 2020-2021 growing season:

- MultispeQ measures fluorescence base parameter for plants, records abiotic factors, and contactless leaf temperature. Measurements were carried out between 11:00 am and 2:00 pm on the middle section of a well-developed leaf per repetition.
- CCM-300 uses fluorescence ratio technique for chlorophyll content measure. Data collected similar to MultispeQ.
- GreenSeeker detects wavelengths of reflected light from the crop canopy and produces a normalized difference vegetation index value called NDVI. Average values recorded from a 3-m bed per repetition. Data were collected five times during the growing season.

Analysis of variance was performed with SAS. The Least Significant Difference (LSD) test at 5% level was used to find any significant difference between treatment means.

We used field experiments and laboratory analyses to train college students attending local and regional colleges in irrigation and nutrient management methods. A survey was performed to assess student's internship program.

F. Data/Results

The fresh market onion growing season in Imperial County starts in October with harvesting schedules in May or June. This study used sprinkler irrigation for crop emergence and until beginning of bulbing to ensure an adequate establishment. This is a normal practice in our region. Irrigation treatments using drip system were established in January of every season. Water amounts delivered through drip irrigation system were computed using a daily water balance approach (irrigation needs = crop evapotranspiration (ETc) – rainfall). Crop evapotranspiration was computed using potential evapotranspiration from the California Irrigation Management Information Systems -CIMIS station at DREC (Meloland station #87) and adjusted by stage-specific crop coefficients (Table 1) developed by Montazar (2019) for Imperial County onion production. Drip irrigation treatments (130%, 100%, 70%, and 40% ETc) started at bulb initiation (about 8 leaves and bulb diameter was twice that of the neck). Table 2 shows total water use (rain, sprinkler, and drip irrigation) by irrigation treatment during each season.

Table 1. Growth stage onion crop coefficient values used in this study (Montazar, 2019).

Growth stage	Days after planting	Crop coefficient
Emergence	0-30	0.40
Two/three leaves to bulb development	45-165	0.84
Bulb fully developed to dry leaf stage	170-harvest	0.62

Table 2. Total water use by irrigation treatment and season

Season	130% ETc (in)	100% ETc (in)	70% ETc (in)	40% ETc (in)
2019 - 2020	23.57	20.61	17.65	15.41
2020 - 2021	25.89	22.70	19.47	16.36
2021 - 2022	26.32	22.48	18.76	14.83

We collected hourly soil water tension (SWT) data at 6-, 12-, and 24- in. Average SWT values during germination and establishment periods were near field capacity in the top one foot. Average SWT data by irrigation treatment and depth are shown in Table 3. These values show that SWT data increased (soil gets drier) in the top one foot as irrigation levels were reduced. Average records at 6- and 12-in from 40% and 70% ETc treatments indicated dryness and lack of available water.

Table 3. Average hourly soil water tension (cb) during irrigation treatments (drip irrigation).

Season	Depth (in)	130% ETc	100% ETc	70% ETc	40% ETc
1/28/2020 to 4/28/2020	6	-45	-46	-50	-121
	12	-30	-27	-42	-91
	24	-17	-18	-18	-18
2/9/2021 to 4/25/2021	6	-57	-47	-77	-95
	12	-22	-37	-57	-112
	24	-1	-4	-8	-4
2/1/2022 to 4/21/2022	6	-31	-45	-49	-106
	12	-23	-31	-67	-128
	24	-13	-18	-24	-24

During our trials, the following commercial onion varieties were available: Terena (2019-2020), Hornet (2020-2021), and Sweet Agent (2021-2022). Onion variety was not a factor in our experiment design. Onion yields and bulb size distribution responded to irrigation rates (Table 4). Maximum yields were obtained in the 130% ETc treatment. The highly stressed irrigation treatment (40% ETc) had the lowest yield. In general, higher yields of mediums and lower yields of jumbo, colossal and super colossal were obtained with the lowest irrigation rate (40% ETc). The two highest irrigation rates (100% and 130% ETc) had the highest jumbo, colossal, and super colossal yields. Prepack yields increased significantly with reduction in irrigation amounts.

Table 4. Effect of irrigation rates on fresh market onion size distribution[x] and total yield.

Season	Treatments	Prepack	Medium	Jumbo	Colossal	Super Colossal	Total
				ton/acre			
2019 - 2020	130% ETc	0.6c[y]	4.8c	31.2a	12.6a	3.1a	52.4a
	100% ETc	0.6c	5.8bc	32.4a	9.7ab	2.0ab	50.6a
	70% ETc	1.2b	9.0b	26.2ab	4.0bc	0.3b	40.7b
	40% ETc	1.6a	13.7a	17.6b	1.3c	0.2b	34.4c
2020 - 2021	130% ETc	0.8b	7.4b	18.2a	5.8a	4.8a	36.9a
	100% ETc	0.9b	9.2ab	12.5b	6.0a	4.7a	33.3b
	70% ETc	1.1b	8.9ab	12.6b	3.1b	2.5a	28.2c
	40% ETc	2.0a	10.8a	4.8c	2.0b	0.8a	20.4d
2021-2022	130% ETc	2.4c	7.8b	14.6a	5.7a	4.1a	34.6a
	100% ETc	2.9bc	9.0ab	13.0a	3.5a	0.6b	29.0b
	70% ETc	3.9ab	10.5a	6.7b	0.4b	0.0b	21.6c
	40% ETc	4.8a	7.4b	3.0c	0.0b	0.0b	15.3d

[x]Onion bulbs were categorized as prepack (less than $2^{1/2}$ in), medium ($2^{1/2}$-$3^{1/4}$ in), jumbo ($3^{1/4}$-4 in), colossal (4-$4^{1/4}$ in), and super colossal (greater than $4^{1/4}$ in) based on bulb diameter. [y]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$ according to the Duncan's multiple range test. ETc = crop evapotranspiration.

Onion size distribution and total yield did not respond to nitrogen rates in the two first seasons (Table 5). In the 2021-2022 growing season, onion yield production increased with increasing nitrogen rates. The maximum yield in the 2021-2022 season was reached at the second largest nitrogen rate (pre-plant nitrogen plus 150 lb/ac). During this season, no pre-plant nitrogen was applied. Colossal and super colossal fractions showed a similar trend as total yields during the 2021-2022 season.

Table 5. Effect of nitrogen rates on fresh market onion size distribution[x] and total yield.

Season	Treatments	Prepack	Medium	Jumbo	Colossal	Super Colossal	Total
				ton/acre			
2019 - 2020	PN + 225 lb/ac	1.2a	8.9a	25.6a	7.2a	0.9a	43.8a
	PN +150 lb/ac	0.9a	9.3a	26.3a	6.1a	1.9a	44.3a
	PN + 75 lb/ac	1.1a	7.3a	27.9a	7.4a	1.2a	44.9a
	PN + 0 lb/ac	0.9a	7.9a	27.7a	6.9a	1.7a	45.0a
2020 - 2021	PN + 225 lb/ac	1.5a	9.3a	11.1a	4.7a	3.1a	29.7a
	PN +150 lb/ac	1.1a	9.2a	12.6a	4.3a	3.3a	30.5a
	PN + 75 lb/ac	1.1a	9.3a	12.3a	3.7a	2.9a	29.4a
	PN + 0 lb/ac	1.1a	8.7a	11.2a	4.0a	3.3a	28.3a
2021-2022	PN + 225 lb/ac	3.0b	8.6ab	10.9a	2.4ab	1.1b	26.1ab
	PN +150 lb/ac	3.2b	8.7ab	10.6ab	3.1a	2.5a	28.0a
	PN + 75 lb/ac	3.5b	9.6a	8.6bc	2.6ab	0.9b	25.2b
	PN + 0 lb/ac	4.3a	7.9b	7.2c	1.5b	0.3b	21.2c

[x]Onion bulbs were categorized as prepack (less than $2^{1/2}$ in), medium ($2^{1/2}$-$3^{1/4}$ in), jumbo ($3^{1/4}$-4 in), colossal (4-$4^{1/4}$ in), and super colossal (greater than $4^{1/4}$ in) based on bulb diameter. [y]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$ according to the Duncan's multiple range test. PN = pre-plant nitrogen.

There were no significant irrigation rate x nitrogen rate interactions for total yield and size distribution except for super colossal sizes yielded in the 2021-2022 season. It was noticed that super colossal sizes in the 2021-2022 season were not yielded in the 70 and 40% ETc treatments and potentially affected the statistical analysis.

The initial residual nitrate content in the top 3 ft of the soil profile ranged from 140 to 254 lb/ac (Tables 6-8). The highest values were measured in the 2020-2021 field, which was previously under alfalfa. Because of the high residual nitrate concentration, total input was higher in the second year, even though the pre-plant nitrogen application was skipped. The pre-plant nitrogen application was also skipped in the third year, which together with a relatively low residual nitrate content in the profile, resulted in much lower levels of nitrogen availability compared to the first two years.The lower nitrogen availability in the third year resulted in the significant differences in yield shown in Table 5.

Total nitrogen in the biomass averaged 195 lb/ac in the first two years, with only small differences across treatments and years. In the third year, biomass nitrogen responded strongly to nitrogen fertilization level, ranging from 86 to 202 lb/ac. The difference between nitrogen input and output tended to decrease with increasing irrigation water applications, suggesting that nitrogen was either leached below 3 ft or lost through denitrification. In the absence of losses, the difference between output and input is expected to be positive and related to the mineralization of soil organic nitrogen during the growing season. However, some values were very high, especially in the low irrigation treatment, due to high post-harvest soil nitrate levels. It is possible that capillary rise of nitrate-rich water from the subsoil contributed to the high nitrate levels in the top 3 ft of the profile.

Table 6. Nitrogen balance by irrigation and nitrogen treatments, 2019-2020.

Treatment[1]	Initial residual N (lb/ac in 3 ft)	N fertilization (lb/ac)	Total input (lb/ac)	N in biomass (lb/ac)	Final residual N (lb/ac in 3 ft)	Total output (lb/ac)	Output – Input[2] (lb/ac)
I1-N1	165	56	222	184	88	272	51
I1-N2	165	131	297	183	210	393	96
I1-N3	165	206	372	173	381	554	182
I1-N4	165	281	447	188	489	677	231
I2-N1	165	56	222	180	88	268	47
I2-N2	165	131	297	184	107	291	-6
I2-N3	165	206	372	208	200	408	36
I2-N4	165	281	447	184	301	484	38
I3-N1	165	56	222	196	56	252	30
I3-N2	165	131	297	199	92	291	-5
I3-N3	165	206	372	236	122	359	-13
I3-N4	165	281	447	234	129	363	-84
I4-N1	165	56	222	175	48	223	1
I4-N2	165	131	297	196	110	306	10
I4-N3	165	206	372	215	110	326	-46
I4-N4	165	281	447	233	142	375	-72

[1]Irrigation treatments I1 to I4 correspond to water applications of 40, 70, 100, and 130% of ETc, while N treatments N1 to N4 correspond to in-season N application rates of 0, 75, 150, and 225 lbs per acre; [2]positive values mean that there was some input not included in this budget, negative values indicate that N was lost.

Table 7. Nitrogen balance by irrigation and nitrogen treatments, 2020-2021.

Treatment[1]	Initial residual N (lb/ac in 3 ft)	N fertilization (lb/ac)	Total input (lb/ac)	N in biomass (lb/ac)	Final residual N (lb/ac in 3 ft)	Total output (lb/ac)	Output – Input[2] (lb/ac)
I1-N1	254	0	254	157	114	271	17
I1-N2	254	75	329	196	412	608	279
I1-N3	254	150	404	201	229	430	25
I1-N4	254	225	579	160	577	737	258
I2-N1	254	0	254	174	159	333	79
I2-N2	254	75	329	186	161	347	18
I2-N3	254	150	404	194	287	481	77
I2-N4	254	225	579	244	504	747	268
I3-N1	254	0	254	157	130	287	33
I3-N2	254	75	329	189	240	429	100
I3-N3	254	150	404	210	266	476	71
I3-N4	254	225	579	210	439	650	170
I4-N1	254	0	254	185	144	329	74
I4-N2	254	75	329	192	182	374	45
I4-N3	254	150	404	183	355	538	134
I4-N4	254	225	579	224	379	604	124

[1]Irrigation treatments I1 to I4 correspond to water applications of 40, 70, 100, and 130% of ETc, while N treatments N1 to N4 correspond to in-season N application rates of 0, 75, 150, and 225 lbs per acre; [2]positive values mean that there was some input not included in this budget, negative values indicate that N was lost.

Table 8. Nitrogen balance by irrigation and nitrogen treatments, 2021-2022.

Treatment[1]	Initial residual N (lb/ac in 3 ft)	N fertilization (lb/ac)	Total input (lb/ac)	N in biomass (lb/ac)	Final residual N (lb/ac in 3 ft)	Total output (lb/ac)	Output – Input[2] (lb/ac)
I1-N1	140	0	140	110	132	241	101
I1-N2	140	75	215	127	419	545	330
I1-N3	140	150	290	115	639	754	463
I1-N4	140	225	365	130	933	1063	698
I2-N1	140	0	140	99	64	164	23
I2-N2	140	75	215	148	218	366	151
I2-N3	140	150	290	160	301	461	171
I2-N4	140	225	365	165	560	725	360
I3-N1	140	0	140	86	64	150	10
I3-N2	140	75	215	144	64	208	-7
I3-N3	140	150	290	186	126	312	22
I3-N4	140	225	365	158	173	331	-34
I4-N1	140	0	140	106	54	160	19
I4-N2	140	75	215	140	78	218	3
I4-N3	140	150	290	161	134	295	5
I4-N4	140	225	365	202	105	307	-58

[1]Irrigation treatments I1 to I4 correspond to water applications of 40, 70, 100, and 130% of ETc, while N treatments N1 to N4 correspond to in-season N application rates of 0, 75, 150, and 225 lbs per acre;

[2]positive values mean that there was some input not included in this budget, negative values indicate that N was lost.

Water use efficiency (WUE) is displayed in Figure 1. The trial in 2019-2020 (Terena onion variety) showed the highest WUE. Trials conducted using Hornet (2020-2021) and Sweet Agent (2021-2022) varieties showed the lowest WUE at the lowest irrigation level (40% ETc). Variations of WUE by irrigation levels and season were less than 0.2 lbs/ft^3.

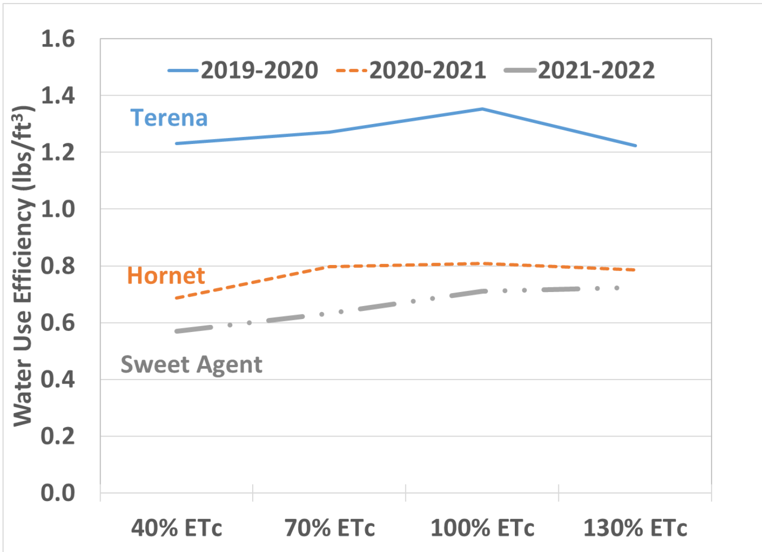

Figure 1. Water use efficiency.

Nitrogen recovery efficiency (NRE) was affected by fertilizer treatment (Figure 2), and values raged from 9 to 12, 18 to 30, and 28 to 52% for Terena (2019-2020), Hornet (2020-2021), and Sweet Agent (2021-2022), respectively. Fertilizer N recovery was low because N availability was relatively high in the unfertilized control. Because of that, N uptake did not increase much with fertilization.

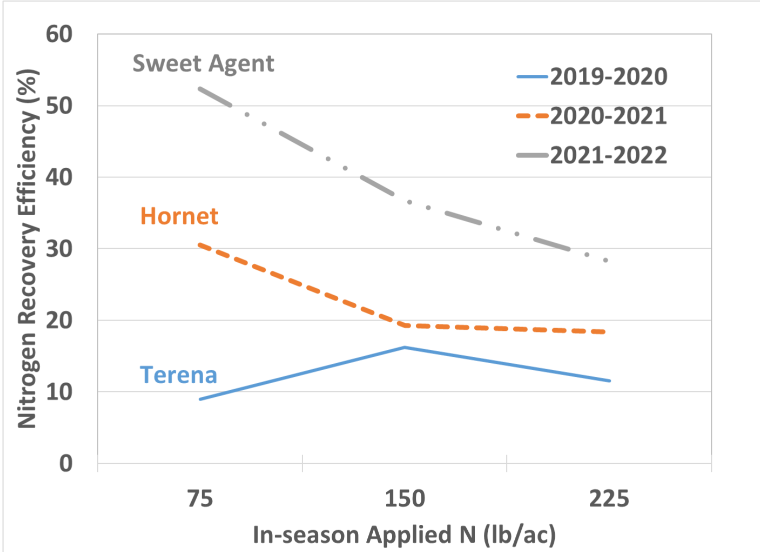

Figure 2. Nitrogen recovery efficiency

Jumbo sizes were used for onion quality analysis (Table 9). Irrigation and nitrogen rates affected onion bulb firmness in the 2021-2022 season (Sweet Agent). Brix values responded to irrigation rates during seasons 2020-2021 (Hornet) and 2021-2022. Nitrogen rates had significant effect on brix in seasons 2019-2020 (Terena) and 2021-2022. There was no significant interaction between N application and water regimes.

Table 9. Effect of irrigation and nitrogen rates on onion quality.

Treatments	**Firmness (lbs)**			**Brix (%)**		
Irrigation rate (I)	2019-2020	2020-2021	2021-2022	2019-2020	2020-2021	2021-2022
130% ETc	9.6a[y]	14.9a	12.5a	6.9a	7.9ab	7.9a
100% ETc	9.7a	14.9a	12.0a	7.6a	8.1a	7.6ab
70% ETc	8.2a	14.4a	10.5b	7.8a	7.8b	7.6b
40% ETc	9.2a	13.3a	10.1b	8.4a	7.2c	7.2c
Nitrogen rate (N)						
PN + 225 lb/ac	9.3a	13.7a	10.5b	7.5ab	7.8a	7.4b
PN +150 lb/ac	9.4a	13.8a	10.7b	7.2b	7.7a	7.9a
PN + 75 lb/ac	8.8a	15.1a	11.3b	7.4b	7.8a	7.4b
PN + 0 lb/ac	9.1a	14.8a	12.5a	8.5a	7.7a	7.5b
Interaction (IxN)						
P	0.439	0.026	0.533	0.487	0.117	0.295

[y]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$ according to the Duncan's multiple range test.

Drought stress had a significant effect on relative chlorophyll content (RCC). RCC mean value recorded under I1 conditions were 35 units higher than the average of I4 treatment (Table 10). The lowest irrigation treatment presented the lowest leaf temperature differential (LTD) and highest non-photochemical quenching of chlorophyll fluorescence (NPQ_t). LTD increased as irrigation increased (Figure 3). LTD increased as crop seasons progressed reaching a peak on 3/29/2021. The last readings of LTD collected on 4/13/2021 shows reduced values compared to the previous readings as crop reached maturity and leaves started fall over.

Table 10. Means (n=20) of optical sensors traits by irrigation treatment (2020-2021).

Trait[x]	I1	I2	I3	I4
RCC (mg m^{-2})	388ab	374b	370b	353b
NDVI	0.52a	0.52a	0.52a	0.52a
LTD (°C)	-4.41b	-5.60c	-5.76c	-6.35c
φII	0.52a	0.54a	0.54a	0.53a
Fv'/Fm'	0.71a	0.73a	0.75a	0.74a
NPQ_t	1.08b	0.87b	0.60b	0.76b

[x]Traits: relative chlorophyll content (RCC), normalized difference vegetation index value (NDVI), leaf temperature differential (LTD), quantum yield of PSII (φII), maximum quantum efficiency (Fv'/Fm'), and non-photochemical quenching (NPQ_t). [y]Means within a sensor followed by same letter are not significantly different by LSD.

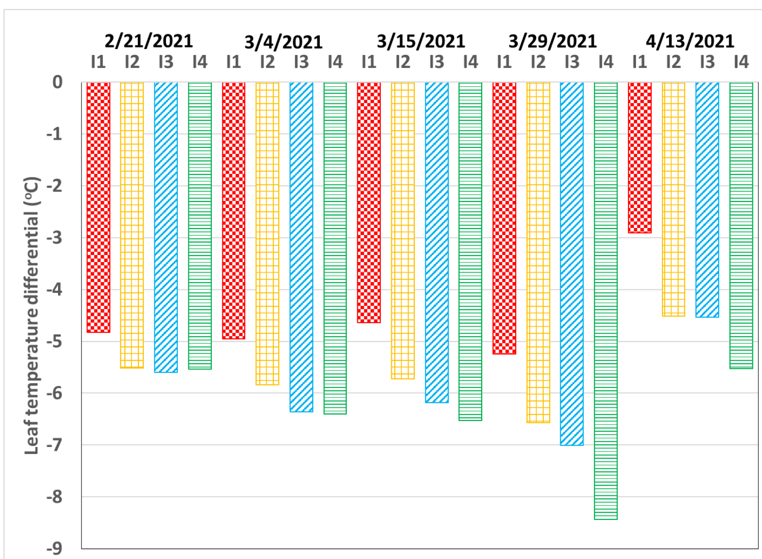

Figure 3. Leaf temperature differential (LTD) by sampling date and irrigation treatment.

Four students were trained during the course of this project:

- Dianely Alba, Universidad Autonoma de Baja California, major in Agronomy, 2022
- Bryan Aguilar: Imperial Valley College, major in Agriculture Plant Science, 2021
- Joseph Leonardo Vega Chacon: Universidad Autonoma de Baja California, major in Agronomy, 2021
- Donald Benedict: Imperial Valley College, major in Agriculture Plant Science, 2021

Student answers of their experience during the internship program are in Table 11.

Table 11. Internship post-program student survey

Questions	Dianely Alba	Bryan Aguilar	Joseph L. Vega Chacon	Donald Benedict
Briefly note new skills, techniques, and knowledge gained during the internship	Better understanding of plant physiology, how to use a variety of sensors, proper techniques for data collection, knowledge about drip irrigation	Data entry skills, soft skills (working with others), exposure to an ag system that requires growing, harvest, sorting, testing, and processing.	The use of UAN32, the irrigation in the onion, manage of groups of work and laboratory equipment.	Learned about plant fertilizer plans, as well as water conservation
What was a time that you felt proud during your internship?	When I was able to apply the knowledge taught to me by Dr. Jairo to properly calculate the estimated time to reach the desired gallons of water.	Most proud I felt was after the harvest. We started early cut bagged and moved the onions. I felt very proud once we finished sorting them by size.	I could say always, because I learn something everyday, and that's something than I like and I feel proud.	I loved the whole internship it was a fantastic experience. I was most proud when I helped complete the end of that season's research with Dr. Jairo Diaz
Do you feel that you received the proper training to complete your duties?	Yes	Yes most tasks were easy and it was good exposure for me.	Always.	Yes, I feel that I did receive proper training to complete my duties. I appreciated how much the staff was more than willing to help me whenever I had a question.
Will you continue to pursue career opportunities in the specific field your internship was in?	Yes	Yes, I want a career involved in growing crops, doing research, and working outside.	Of course.	Yes, I work at Helena Agri Enterprises as a field scout checking crops for fertilizer deficiencies, pest damage, and irrigation. Working at the

				university gave me a great foot into the door to continue my career path further to become a Pest Control Advisor/ Salesman
Did Dr. Diaz and/or DREC staff provided support throughout the internship? Were they available to answer questions when necessary?	Everyone was very supportive and we're willing to help whenever necessary.	Yes, I made sure to ask many questions and Dr. Diaz gladly answered them all.	Yes, they always were available to answer and provided support.	Yes, Dr. Diaz and the staff helped me tremendously with any questions I had. There was support from Dr. Diaz and the whole staff throughout my internship. They were great about the help!
Any suggestions/feedback?		More internships more types of exposure for students that need experience and connections.	No	

G. Discussion and Conclusions

Onion size, yields, and total soluble solids (brix) were influenced by irrigation rates. Fresh market onions reached maximum yields with 100% and 130% ETc treatments. Higher yields of high-value bulbs (jumbo, colossal and supper colossal) were obtained with 100% and 130% ETc treatments. Onion size distribution, total yield, and firmness did not respond to nitrogen rates when total nitrogen available in the top foot of the profile ranged from 104 to 353 lb/ac. However, onion size distribution, total yield, firmness, and brix responded to nitrogen rates in a field with only 54 lb/ac of total nitrogen available in the top foot.

Under water stress conditions leaves were significantly hotter than those of well irrigated plants. In this study, leaf temperature differential measures detected early water stress responses. Water deficit regimes did not significantly affect photosynthesis activity.

College internship opportunities provided new knowledge and career pathways to borderlands, first generation, and underrepresented students in agriculture.

H. Challenges

Global pandemic affected scheduled activities including lack of recruitment of college students for internships, reduction of field data collection and laboratory analysis, and cancelation of in-person outreach activities. We successfully adjusted data collection and laboratory analysis following COVID19 guidelines to reduce the risk of infections.

I. Project Impacts

Our drip irrigation study showed that high yields and large high-value sizes can be produced using 24 to 26 in of water. Assuming 80% of fresh market onions fields (2,786 ac harvested in 2021) use this technology instead of furrow irrigation (that use about 5 ft of water), growers could potentially save about 8,000 ac-ft of water per season.

Reduction of nitrogen fertilization applications is achievable using drip irrigation technology and measuring pre-plant mineral nitrogen in the top foot of the profile. Nitrogen applications can be reduced at least 50% by using drip irrigation and performing soil nitrogen tests in the active root zone compared to onion production under furrow irrigation management.

Hand-held devices that measure leaf and ambient temperature are promising tools that have the potential to provide science-based information and guidance on irrigation management.

Collaborations with local and regional colleges were strengthen. Four college students developed skills in irrigation and nutrient management research methods. All students gained better understanding of onion production, handled research equipment and got exposed to research protocols. All students will continue to pursue a career in agriculture.

Student interns said:

- I have a “better understanding of plant physiology, how to use a variety of sensors, proper techniques for data collection, knowledge about drip irrigation.”
- “Working at the university gave me a great foot into the door to continue my career path further to become a Pest Control Advisor/Salesman.”
- “I learned something everyday, and that's something than I like and I feel proud.”
- “I want a career involved in growing crops, doing research, and working outside.”

We donated about 750 lbs of onions to Imperial Valley Food Bank in May 2020. This donation helped our local communities in need during the mist of COVID19 restrictions and challenges.

J. Outreach Activities Summary

Several in-person meetings were carried out with local onion growers discussing agricultural practices. Our presentations reached 327 participants. Most of the workshops and conferences were delivered virtually. Here is list of the nine presentations we delivered:

Diaz, J., R. Soto, and D. Geisseler. 2022. Irrigation and nutrient management of drip irrigated onions in Imperial County. Vegetable Crops and IPM Workshop, UCCE Imperial County, March 10, 2022. Videoconference. 52 participants.

Diaz, J., R. Soto-Ortiz, and D. Geisseler. 2022. Assessing Drip Irrigation and Nitrogen Management of Fresh Onions Produced in California Low Desert. CDFA/FREP/WPH Nutrient Management Conference. October 26-27, 2022, Visalia, CA.

Diaz, J., R. Soto-Ortiz, and D. Geisseler. 2022. Improving sustainable irrigation practices in onion production in Imperial County, California. Soil and Water Conservation Society International Annual Conference. July 31 – August 3, Denver, Colorado.

Diaz, J., R. Soto-Ortiz, and D. Geisseler. 2022. Measuring onion water stress using proximal optical and soil moisture sensors in California Low Desert Region. Frontiers in Hydrology: Future of Water. Meeting co-sponsored by the American Geophysical Union and Consortium of Universities for the Advancement of Hydrologic Science, Inc. June 19-24, San Juan, Puerto Rico. Poster.

Diaz, J., R. Soto-Ortiz, and D. Geisseler. 2022. Onion response to irrigation and nitrogen rates. California Plant and Soil Science. American Society of Agronomy, California Chapter. February 1-3, Virtual Conference. 105 participants.

Diaz, J., R. Soto, and D. Geisseler. 2021. Nitrogen and irrigation studies in drip irrigated fresh market onions. Vegetable Crops and IPM Workshop, UCCE Imperial County, February 25, 2021. Videoconference. 43 participants.

Diaz, J. 2021. Tecnologías para un riego más eficiente: aplicaciones en regiones húmedas y áridas. Sixth annual Latino Farmer Conference, January 14, 2021. Videoconference. [Invited Speaker]. 70 participants.

Diaz, J. 2020. Update on Irrigation and Nutrient Management of Onion Research: 2019-2020 season. Monthly meeting of the Imperial Vegetable Growers Association, December 16, 2020. Videoconference. 22 participants.

Diaz, J. 2020. Update on Irrigation and Nutrient Management of Onion Production in Imperial County. UC ANR Vegetable Crops Program Team meeting, December 4, 2020. Videoconference. 35 participants

K. References

Crasswell, E.T. and Godwin D.C. 1984. The efficiency of nitrogen fertilizer applied to cereals in different climate. Adv Plant Nutr 1:1–55.

Montazar, A. 2019. Preliminary estimation of dehydrator onion crop water needs in the Imperial Valley. Agricultural Briefs 22(7):131-135. University of California Cooperative Extension – Imperial County.

L. Appendix

M. Factsheet/Database Template

1. **Project Title**: Assessing Drip Irrigation and Nitrogen Management of Fresh Onions Produced in California Low Desert
2. **FREP grant number**: 18-0592-000-SA
3. **Project leaders**:
Jairo Diaz, Director, University of California - Desert Research and Extension Center, (760)-356-3065, jdiazr@ucanr.edu.
Roberto Soto, Professor, Universidad Autónoma de Baja California - Instituto de Ciencias Agrícolas, 52-1-686-121-6934, roberto_soto@uabc.edu.mx.
Daniel Geisseler, Cooperative Extension Specialist in Nutrient Management, University of California - Land, Air and Water Resources, (530)-754-9637, djgeisseler@ucdavis.edu.
4. **Start Year/End Year:** 2019/2022
5. **Location:** Holtville
6. **County:** Imperial
7. **Highlights**: Our drip irrigation study showed that high yields and large high-value sizes can be produced using 24 to 26 in of water. Assuming 80% of fresh market onions fields (2,786 ac harvested in 2021) use this technology instead of furrow irrigation (that use about 5 ft of water), growers could potentially save about 8,000 ac-ft of water per season. Reduction of nitrogen fertilization applications is achievable using drip irrigation technology and measuring pre-plant mineral nitrogen in the top foot of the profile. Nitrogen applications can be reduced at least 50% by using drip irrigation and performing soil nitrogen tests in the active root zone compared to onion production under furrow irrigation management. Hand-held devices that measure leaf and ambient temperature are promising tools that have the potential to provide science-based information and guidance on irrigation management. Collaborations with local and regional colleges were strengthen. Four college students developed skills in irrigation and nutrient management research methods. All students gained better understanding of onion production, handled research equipment and got exposed to research protocols. All students will continue to pursue a career in agriculture.
8. **Introduction**: California has diverse agroecosystems throughout the state including low desert irrigated areas in Imperial County. California is the largest onion producer in the nation. The 2018 farm gate value for onions in California was estimated at $611.75 million. In 2018, onion production in Imperial County generated $98.64 million in farm gate value, equivalent to 16% of total gross value in California. For over 100 years, the Colorado River has been the sole water source of a highly productive agricultural sector in Imperial County, one of the top ten agricultural counties in the nation. Agriculture is the largest water user in the Imperial County. The two largest reservoirs in the Colorado River system are reaching historical low water levels due to a persistent drought and over allocations. The US Bureau of Reclamation (USBR) declared water shortages on the Colorado River in 2022 and

2023. Arizona, Nevada and Mexico have experienced water cuts affecting mostly agriculture water users. The USBR is working with basin users to develop a strategy that may reduce water usage between 2 and 4 million acre-feet per year. The purpose of this project was to enhance sustainability through evaluation of irrigation and nutrient management strategies that conserve water and minimize nutrient export.

9. **Methods/Management**: Field assessment were performed at the University of California Desert Research and Extension Center -UCDREC, Holtville, CA. The assessment was carried out with four replicates in a split-plot design with drip irrigation treatments in the main plot and four N-fertilization rates at the subplot level. Research plots were 50 ft long and comprise 4 rows on 40-inch beds. Sixty-four plots were established (16 treatments and 4 replicates) during three growing seasons (2019-2020, 2020-2021, and 2021-2022). Sprinklers were used for germination and establishment in all treatments. Four irrigation levels were established: 40, 70, 100, and 130% of crop evapotranspiration (ETc). Irrigation scheduling was based on weather data from the UCDREC's CIMIS station and crop coefficients published by UN FAO for 100% crop evapotranspiration. Watermark soil water tension meters were installed in each of the irrigation treatments at 6-, 12-, and 24-in. Four in-season nitrogen treatments were assessed: pre-plant; pre-plant plus 75 lbs N per acre; pre-plant plus 150 lbs N per acre; and pre-plant plus 225 lbs N per acre. Three biweekly nitrogen applications through drip after bulbing start were scheduled. Soil and biomass samples were collected during the growing season and analyzed for nitrogen content. Onion quality parameters of jumbo sizes, including bulb firmness and total soluble concentration (brix) were measured, after onion harvest and curing. Analysis of variance were performed with SAS. Duncan test at 5% level were used to find any significant difference between treatment means. Water use efficiency (WUE) was computed for each irrigation treatment. Apparent nitrogen recovery efficiency (NRE) was calculated using the difference method. Three proximal optical sensors (MultispeQ, CCM-300 and GreenSeeker) were used to assess the effects of irrigation treatments during the 2020-2021 season.
   We used field experiments and laboratory analyses to train college students attending local and regional colleges in irrigation and nutrient management methods. A survey was performed to assess student's internship program.
10. **Findings**: Onion size, yields, and total soluble solids (brix) were influenced by irrigation rates. Fresh market onions reached maximum yields with 100% and 130% ETc treatments. Higher yields of high-value bulbs (jumbo, colossal and supper colossal) were obtained with 100% and 130% ETc treatments. Onion size distribution, total yield, and firmness did not respond to nitrogen rates when total nitrogen available in the top foot of the profile ranged from 104 to 353 lb/ac. However, onion size distribution, total yield, firmness, and brix responded to nitrogen rates in a field with only 54 lb/ac of total nitrogen available in the top foot. Under water stress conditions leaves were significantly hotter than those of well irrigated plants. In this study, leaf temperature differential measures detected early water stress responses. Water deficit regimes did not significantly affect photosynthesis activity. College internship opportunities provided new knowledge and career

pathways to borderlands, first generation, and underrepresented students in agriculture.

N. Copy of the Product/Result

Peer-reviewed article

Geisseler, D., R. Soto Ortiz, and J. Diaz. 2022. Nitrogen Nutrition and Fertilization of Onions (Allium cepa L.) – A Literature Review. Scientia Horticulturae 291, 110591. https://doi.org/10.1016/j.scienta.2021.110591

Extension articles

Diaz, J., R. Soto, and D. Geisseler. 2020. Toward Improving Irrigation and Nitrogen Management in Fresh Market Onions in California Low Desert Region. The National Onion Association, October/November 38(8).

Diaz, J., R. Soto, and D. Geisseler. 2020. Assessing Drip Irrigation and Nitrogen Management of Fresh Onions Produced in California Low Desert. University of California, Agriculture and Natural Resources, Imperial County Agricultural Briefs, September, 23(8).

Media articles

De la Vega, N. 2023/01/13. El Riego Por Goteo Ofrece Varias Ventajas En La Producción De Cebollas De Bola, Según Un Nuevo Estudio. UCANR Spanish Noticias. https://ucanr.edu/sites/Spanish/Noticias/?blogpost=55988&blogasset=112167

Researchers study onion crop's nitrogen needs. 2/18/2021. Western Farm Press https://www.farmprogress.com/soil-health/researchers-study-onion-crops-nitrogen-needs