A. Project Information

Report Type: Final

FREP Grant Number: 17-0515-000-SA

Time Covered by the Grant Period: 01/01/2018 - 12/31/2023

Project Title: Evaluation of Nitrogen Uptake and Applied Irrigation Water in Asian Vegetables Bok Choy, Water Spinach, Garlic Chives, Moringa, and Lemongrass

Project Leaders: Aparna Gazula, Advisor UCCE Santa Clara, San Benito, and Santa Cruz Counties; Ruth-Dahlquist Willard, Advisor UCCE Fresno and Tulare Counties; Daniel Geisseler, UCANR Cooperative Extension Specialist, UC Davis

B. Abstract

A recent survey of nitrogen (N) fertilizer use in some of the Asian vegetables was found to be as follows: bok choy up to 140 lb/acre, garlic chives up to 500 lb/acre, water spinach up to 400 lb/acre. With proposed regulations under the Irrigated Lands Regulatory Program, it's important to understand N uptake in crops that have significant acreage but do not have commodity board support. Therefore, the overall goal of this project is to provide detailed measurements of total N uptake and the N uptake pattern of bok choy, water spinach (ong choy), garlic chives, moringa and lemongrass. Total N is crucial for viable crop production, but irrigation efficiency is vital to retaining the applied N within the crop root zone. This project will also evaluate the current irrigation management practices of these crops, compare it with their water requirements, and identify potential practices that may help reduce nitrate leaching. Together, the information collected will provide the basic information necessary for growers to better manage N inputs to these crops and protect water quality.

Field sampling and data collection was completed for bok choy, water spinach, and garlic chives in Santa Clara and for bok choy, moringa, and lemongrass in Fresno. The data for greenhouse grown bok choy has been incorporated into CropManage. Data integration into CropManage is ongoing for moringa, water spinach, lemongrass and garlic chives.

C. Introduction

Asian specialty vegetables are grown intensively in open field and protected agricultural systems. In protected agricultural systems, some of the vegetables are grown 6-7 times per year in continuous rotations with a 15-day gap between each rotation. Grown primarily in Fresno, Monterey, Riverside, San Bernardino, Santa Clara, San Luis Obispo, and Ventura counties on around 7026 acres, Asian vegetables are valued at $79 million per year (California County Crop Reports, 2015).

In Fresno and Santa Clara Counties, these crops are grown primarily by limited-resource, small-scale, socially disadvantaged Chinese, Hmong, and other Asian immigrant farmers. Information is currently lacking on nitrogen uptake in many of these crops. With proposed regulations under the Irrigated Lands Regulatory Program (ILRP) by the Central Coast Regional Water Quality Control Board (CCWQCB) and the Central Valley Regional Water Quality Control Board (CVRWQCB) to control N losses, it is important to understand N uptake and removal in crops that have significant acreage but do not have commodity board support. Asian growers producing specialty vegetables and herbs are required to fill out the N management plan as part of the ILRP. However, they lack the information to complete this form accurately as there is no information on N fertilizer recommendations or N uptake for most of their crops.

The overall goal of this project is to provide detailed measurements of total N removal, N uptake, and the N uptake pattern of bok choy, water spinach (ong choy), garlic chives, moringa, and lemongrass.

D. Objectives

Information on N uptake is crucial for viable crop production, but irrigation efficiency is important to retaining the applied N within the crop root zone. This project will also evaluate the current irrigation management practices of bok choy, water spinach, garlic chives, moringa, and lemongrass, compare them with the crops' water requirements and identify potential practices that may help reduce nitrate leaching. Together, the information collected will provide the basic information necessary for growers to better manage N inputs to these crops and protect water quality. Specifically, the following two objectives shall be addressed with the work proposed for this project:

1 Evaluate N uptake, N availability, canopy development and water application of bok choy, water spinach, garlic chives, moringa, and lemongrass.
2 Extend the findings of this research to Chinese and Hmong growers in the Central Coast and Central Valley regions to increase their understanding of N uptake and publish results to provide documentation of the findings.

E. Methods

In Santa Clara County 2 and 3 high yielding fields of bok choy were selected in years 1-2 of the trial, and 2 high yielding fields each year for edible chrysanthemum and garlic chives. During the growing season, above ground biomass, biomass N and soil nitrate evaluations were conducted 3 times for bok choy, 7 times for edible chrysanthemum[1] and garlic to generate N uptake curve. From each field data was collected from three discrete blocks. Separate samples were taken from each block. At harvest, samples were collected from at least 4 additional fields per crop and analyzed for fresh and dry

[1] Edible chrysanthemum (tong ho) was also studied during this project, although it wasn't included in the objectives.

weight, as well as N content to obtain a more robust estimate of the amount of N removed with the harvested portion of the crops (expressed in lbs/ton fresh weight).

To conduct crop canopy evaluations and irrigation application evaluations, flow meters and tensiometers were installed in the above-mentioned fields. Also, using an infra-red camera, canopy photos of the crop were taken every two weeks and up to three harvests for multiple harvest crops.

Moringa was planted in the spring of 2021 at the Kearney Agriculture Research and Extension Center in Parlier, California. Three varieties were planted: Kuli Kuli, Kaying, and Moringa Farms. The trees were planted in a randomized block design in four rows. Two of the rows were designated as control plots and unfertilized, while the other two rows were fertilized with NPK fertilizer (20-20-20).

Lemongrass was planted in late spring of 2022 at the Kearney Agricultural Research and Extension Center. The lemongrass was subjected to two different fertilizer treatments: 66.5 lbs N/acre (deficit) and 132 lbs. N/acre (standard) and an unfertilized control. Fertilizer was applied in granular form (20-20-20) at pre-plant, with two post-planting applications (34 and 67 days after planting). Biomass samples were collected seven times throughout the growing season and analyzed for total nitrogen content
Bok choy was planted in early spring of 2022 at the Kearney Agricultural Research and Extension Center. Bok choy was subjected to one fertilizer treatment (48 lbs N/acre) and an unfertilized control. Fertilizers were applied at pre-plant (rate of 16 lbs. N/acre) with two post-plant applications. Biomass samples were collected three times throughout the growing season and analyzed for total nitrogen content.

Because the first bok choy planting bolted before a full season of data could be collected, another round of bok choy was planted in fall of 2022 at the Kearney Agricultural Research and Extension Center. Bok choy was subjected to one fertilizer treatment (32 lbs N/acre) and an unfertilized control. Fertilizers were applied at pre-plant (rate of 16 lbs. N/acre) with one post-planting application. Biomass samples were collected four times throughout the growing season and analyzed for total nitrogen content.

From the total solids calculated from crop dry weight and the percent nitrogen in the biomass of moringa, lemongrass, and bok choy, crop nitrogen removal conversion coefficients were calculated. Canopy photos were taken and % canopy cover was assessed using Pixel Wrench software.

F. Data/Results

Nitrogen Uptake: For open field moringa, nitrogen uptake peaked around 87 days after planting (Figure 1). For lemongrass, nitrogen uptake peaked around 74 days after planting with deficit fertilization, standard fertilization, and unfertilized control taking up 5.8, 5.7, and 6.1 g N/kg lemongrass respectively. For bok choy, nitrogen was taken up early, peaking around our first biomass sampling at 52 days after planting for spring

planted bok choy (3.3 N/kg bok choy for fertilized plot and 2.3 g N/kg bok choy in control plots) and 54 days after planting for fall planted bok choy (9.6 g N/kg bok choy in fertilized plot and 7.3 g N/kg bok choy in control plots). There was a slight late season increase in nitrogen uptake in the unfertilized control spring planted bok choy, but the difference between this control and fertilized plot was not significant.

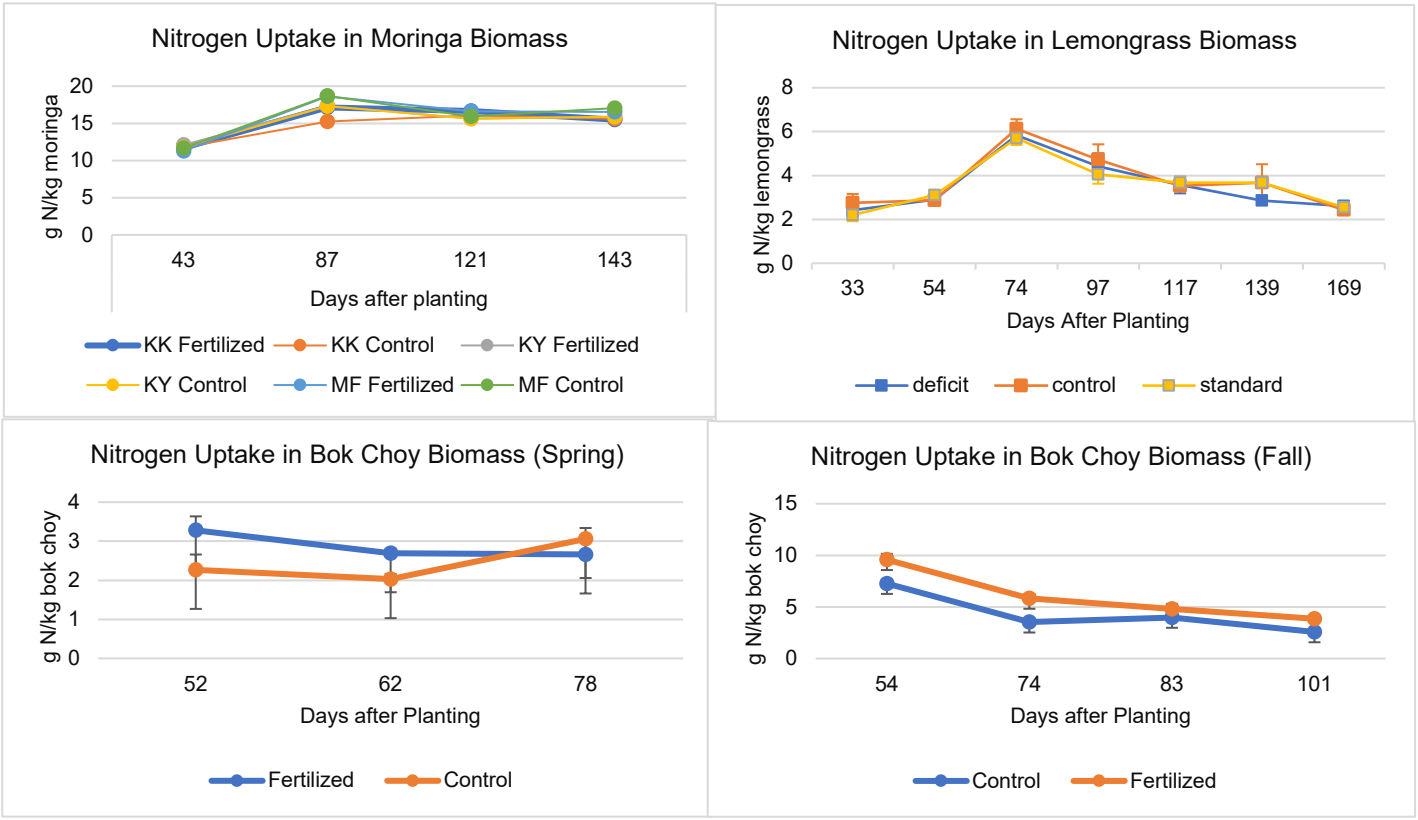


Figure 1. Nitrogen uptake patterns in Kuli Kuli (KK), Kaying (KY), Moringa Farms (MF) varieties of moringa, lemongrass, spring planted bok choy and fall planted bok choy

Crop Nitrogen Removal Coefficients

The crop conversion coefficient is the nitrogen content in the fresh weight of the crop material. The crop conversion coefficient multiplied by the weight of the crop material removed from the field is used to calculate the nitrogen removed from the field through harvest or other removal of crop materials. For moringa (Figure 2), there was no significant difference in crop nitrogen removal coefficients for the control versus fertilizer plots ($p=0.07755$) or among the three different moringa varieties ($p=0.9986$). For lemongrass (Figure 3), our findings indicate that there was no significant difference in crop nitrogen removal coefficients between the deficit fertilization, standard fertilization, and unfertilized control ($p=0.69$). For spring planted bok choy (Figure 5), there was no significant difference of average nitrogen removal conversion coefficient for the control versus the fertilized plots ($p=0.2671$) in the experimental plots. For fall planted bok choy

(Figure 6), the fertilized plots did have a significantly greater average nitrogen removal conversion coefficient than the control plots (p=0.002914).

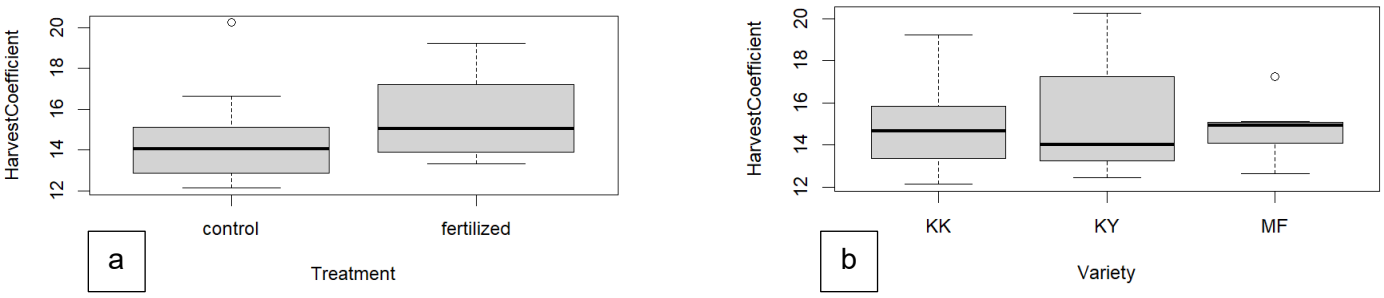


Figure 2a. Harvest coefficients calculated for control plots and fertilized plots for moringa; **2b.** Harvest coefficients calculated for three moringa varieties: Kuli Kuli (KK), Kaying (KY), Moringa Farms (MF).

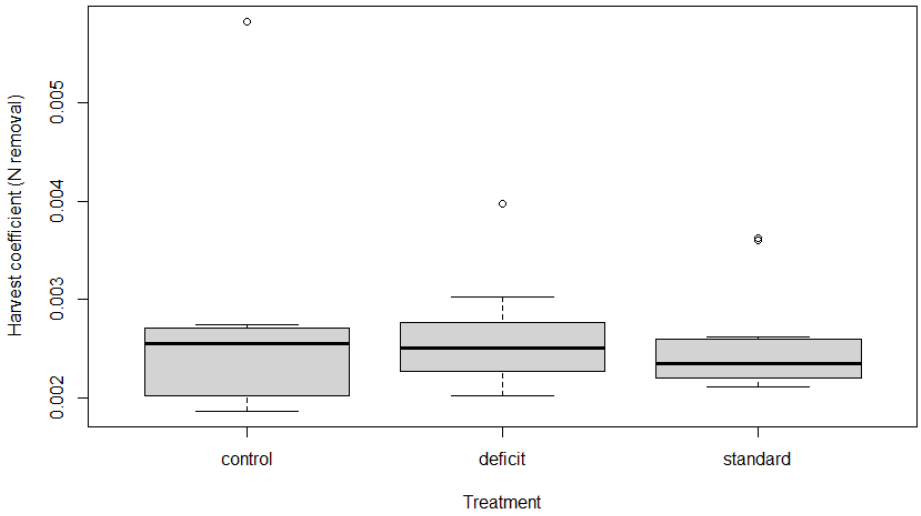


Figure 3. Harvest coefficients calculated for control plots, deficit fertilization plots, and standard fertilization plots in lemongrass.

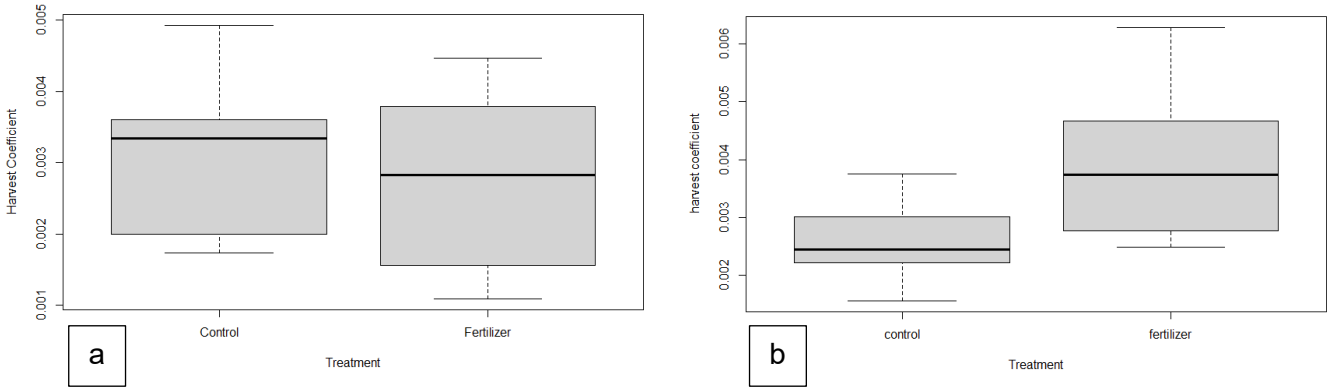


Figure 4a. Harvest coefficients calculated for control vs. fertilized bok choy plots in spring planting, and (**4b**) fall planting.

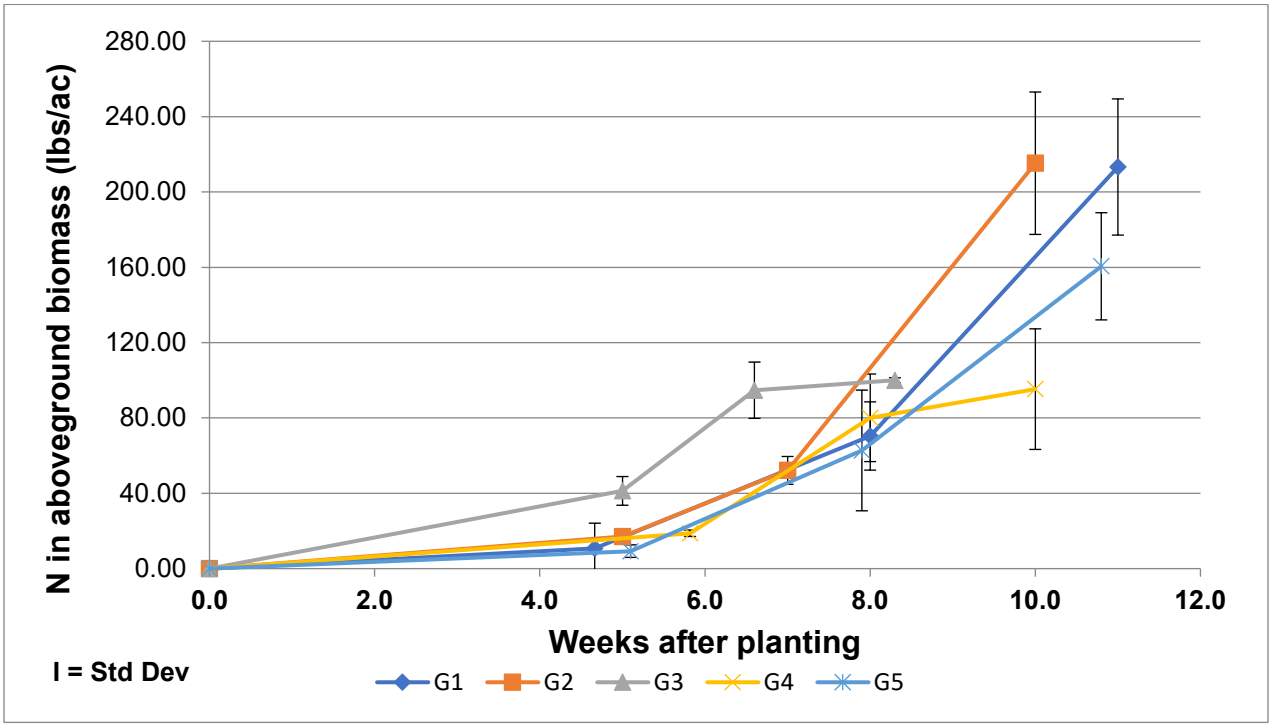


Figure 5: Nitrogen levels in greenhouse grown bok choy crop biomass from seedling to harvest.

Tables 1 and 2: Mean and range of crop coefficients for greenhouse grown bok choy, open field grown moringa, lemongrass, and bok choy developed by this FREP funded project.[2]

Commodity	Product	Pack Type	mean coeff	min coeff	max coeff	mean % solids	min % solids	max % solids	mean %N	min %N	max %N
Bok Choy Greenhouse	Fresh Market	Carton	0.00174	0.00053	0.00308	3.02	1.26	4.71	5.68	3.53	6.94

[2] For a more complete list of crop removal coefficients for a number of Asian specialty crops, including water spinach (ong choy), baby bok choy, and others, see Smith, Cahn, Gazula and Biscaro's FREP project 20-0250.

Commodity	Product	Pack Type	mean coeff	min coeff	max coeff
Bok Choy Greenhouse	Fresh Market	Carton	0.00174	0.00053	0.00308
Bok Choy Spring Open Field Grown Unfertilized Control	Fresh Market	Carton	0.00306	0.00173	0.00492
Bok Choy Spring Open Field Grown Fertilized at 48 lbs N/acre	Fresh Market	Carton	0.00266	0.00109	0.00447
Bok Choy Spring Open Field Grown Local Growers	Fresh Market	Carton	0.00303	0.00274	0.00338
Bok Choy Fall Open Field Grown Unfertilized Control	Fresh Market	Carton	0.00258	0.00157	0.00375
Bok Choy Fall Open Field Grown Fertilized at 48 lbs N/acre	Fresh Market	Carton	0.00386	0.00249	0.00628
Bok Choy Fall Open Field Grown Local Growers	Fresh Market	Carton	0.00138	0.00134	0.00142
Moringa Kaying-Fertilized	Fresh Market	Carton	0.015572	0.013681	0.017317
Moringa Kaying-Unfertilized Control	Fresh Market	Carton	0.014845	0.014932	0.016883
Moringa Kuli Kuli-Fertilized	Fresh Market	Carton	0.015616	0.014491	0.017413
Moringa Kuli Kuli-Unfertilized Control	Fresh Market	Carton	0.014250	0.012795	0.018928
Moringa Moringa Farms-Fertilized	Fresh Market	Carton	0.015241	0.014673	0.019746
Moringa Moringa Farms-Unfertilized Control	Fresh Market	Carton	0.014348	0.015504	0.018866
Moringa Local Farms	Fresh Market	Carton	0.012794	0.012289	0.013387
Lemongrass Unfertilized Control	Fresh Market	Carton	0.002648	0.001868	0.005827
Lemongrass fertilized at 66.5 lbs N/acre	Fresh Market	Carton	0.002612	0.002017	0.003975
Lemongrass fertilized at 132 lbs N/acre	Fresh Market	Carton	0.002550	0.002117	0.003628
Lemongrass Local Farms	Fresh Market	Carton	0.002058	0.001771	0.002296

Canopy Development

Canopy cover was measured by taking overhead photos during the crop cycle using a near-infrared multispectral camera. Photos were analyzed for percent canopy using PixelWrench software (Figure 7). Interpretation of crop canopy development data has been completed for greenhouse grown bok choy (Figure 8), and data analysis and interpretation is currently ongoing for the remaining crops and will be completed in ongoing collaboration with Michael Cahn.

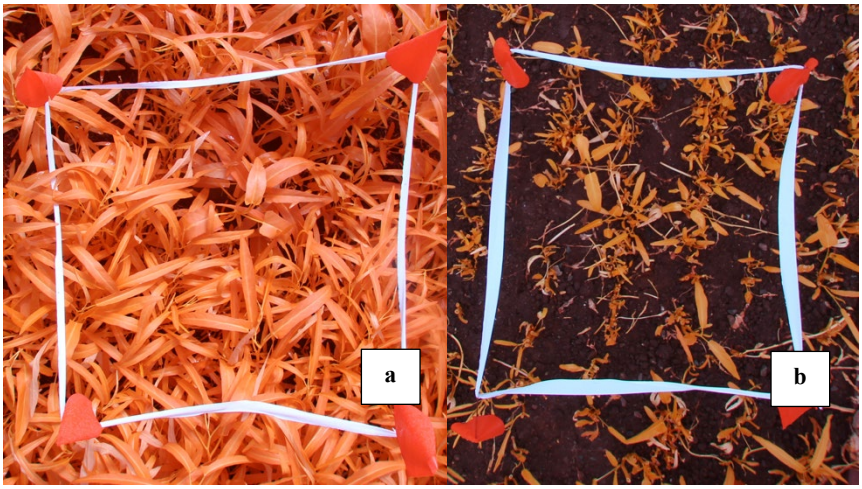


Figure 6a. Infra-red crop canopy cover image of water spinach at 3 weeks after a harvest. **6b.** Infra-red crop canopy cover image of water spinach 1-week after a harvest, the crop is harvested 7-10 times during the growing season.

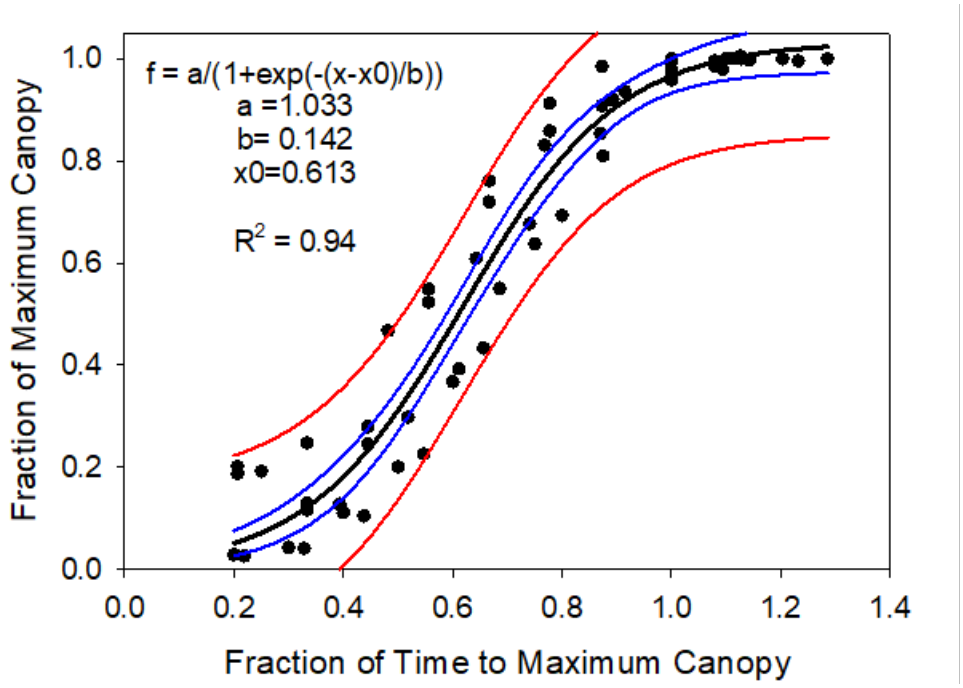
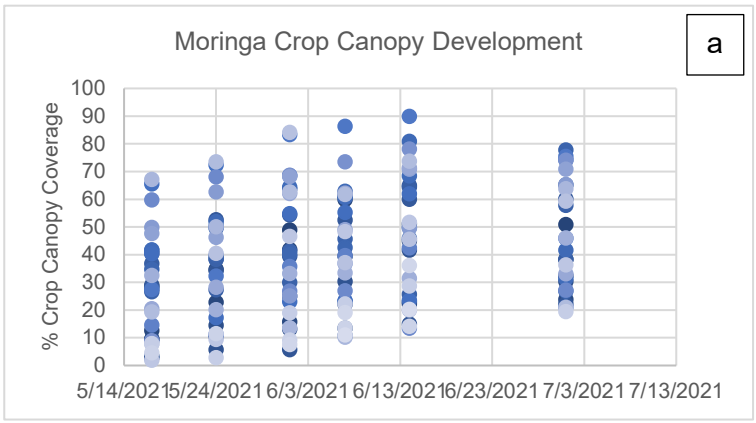


Figure 7: Bok choy crop canopy development. Average maximum canopy at harvest is 82%. Average days from planting to harvest is 65 days. The blue line is the 95% confidence band, and red line is the 95% predicted confidence band.



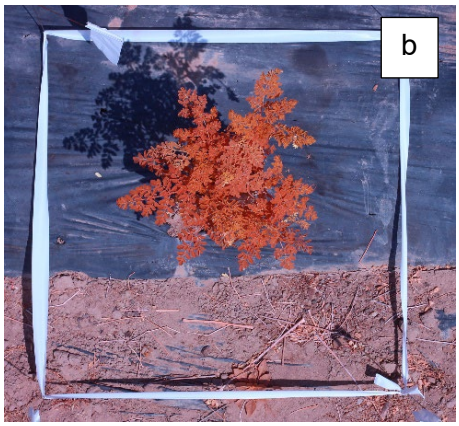


Figure 8a: Moringa crop canopy development. **8b.** Infra-red crop canopy cover image of moringa taken on 5/14/2021.

Table 3. Average canopy cover (%) for moringa in 2021 in control fields and fertilized fields.

Control Fields						
			Date			
	5-17-21	**5-24-21**	**6-1-21**	**6-7-21**	**6-14-21**	**7-1-21**
Red	44.69	44.9	52.51	62.24	62.23	47.62
Yellow	13.00	19.35	22.49	26.86	29.93	37.98
Kuli Kuli	26.61	35.17	37.74	42.66	46.83	43.02
Fertilized Fields						
			Date			
	5-17-21	**5-24-21**	**6-1-21**	**6-7-21**	**6-14-21**	**7-1-21**
Kuli Kuli	24.58	29.45	41.38	39.98	45.9	44.23
Red	34.8	38.04	48.18	44.41	49.505	48.54
Yellow	27.33	34.43	43.74	37.07	42.39	62.27

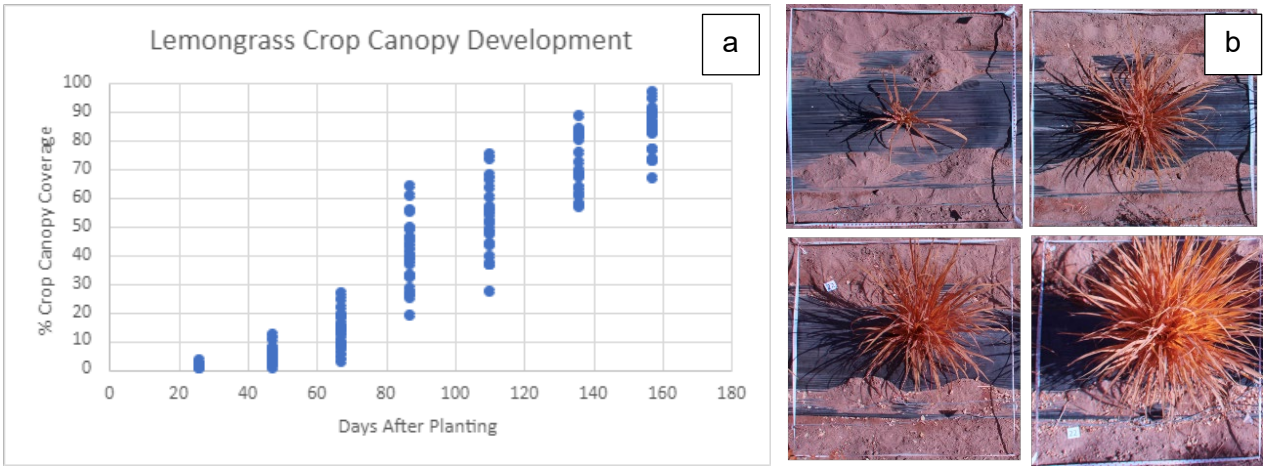


Figure 9a: Lemongrass canopy development. **9b.** Lemongrass canopy photos taken at four different growth time points.

Table 4. Average canopy cover (%) for lemongrass.

	Days after Planting						
	26	**47**	**67**	**87**	**110**	**136**	**157**
Control	1.18	3.60	10.39	33.44	48.05	70.25	83.16
Deficit	2.15	5.12	14.64	42.08	52.66	75.57	83.64
Standard	1.42	5.55	16.02	45.65	49.46	69.00	85.67

Table 5. Average canopy cover (%) for spring planted bok choy.

	Days after Planting		
	21	**32**	**52**
Control	5.22	10.16	30.41
Fertilized	5.33	8.81	29.22

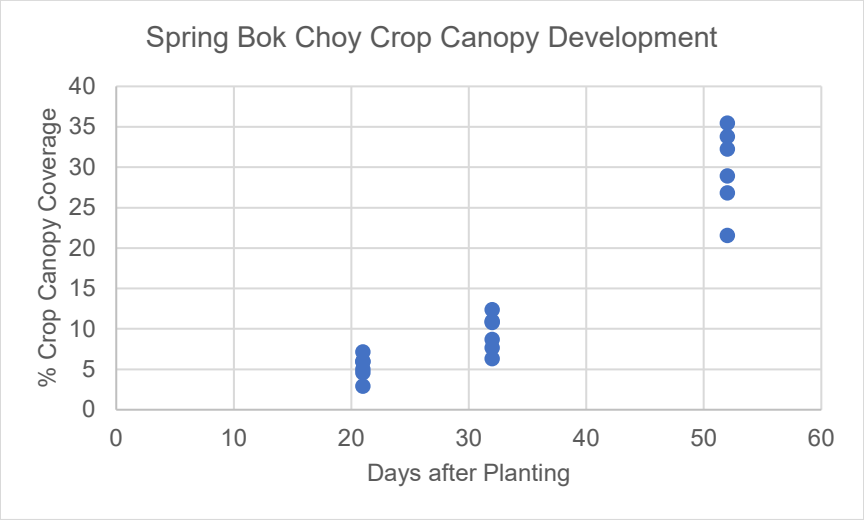


Figure 10. Canopy development for spring planted bok choy.

Table 6. Average canopy cover (%) for fall planted bok choy.

	Days after Planting				
	31	42	63	78	90
Control	1.82	3.03	14.36	32.98	35.31
Fertilized	1.43	2.42	8.16	17.7	21.67

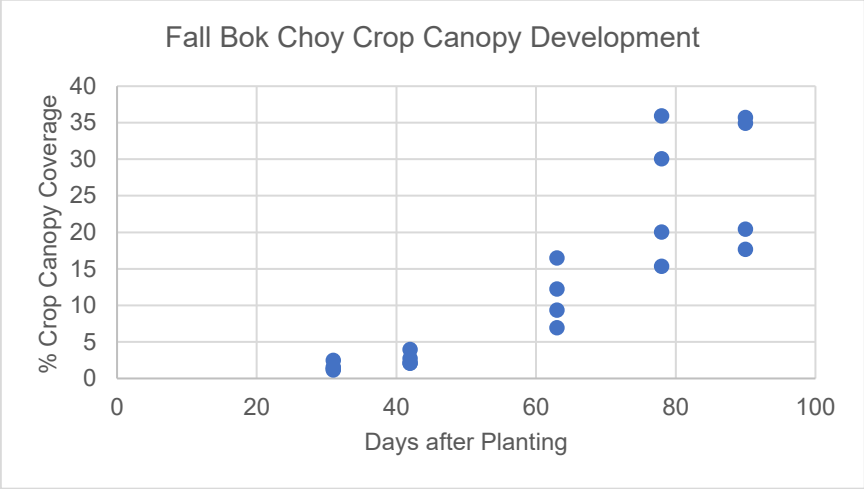


Figure 11. Canopy development for fall planted bok choy.

Applied Irrigation Water

Water applied to plots of moringa, bok choy, and lemongrass was calculated based on flow meter readings and drip tubing emitter rates. Table 6 and 7 show acre-inches per acre and acre-feet per acre applied during the trials. Further analysis will be conducted

to compare flow meter readings with calculations based on emitter rates, to evaluate irrigation water applied to different fertilizer treatments, and to plot irrigation water applied vs. canopy development.

Table 7. Irrigation water applied to experimental plots in Fresno County.

Crop	Dates of Trial	Acre-inches per acre applied
Moringa	5/12/21 – 11/5/21	12.83
Bok choy - Spring	2/4/22 – 4/19/22	10.06
Bok choy - Fall	11/1/22 – 1/30/23	8.92
Lemongrass	5/20/22 – 10/17/22	12.51

Table 8. Average irrigation water applied to greenhouse fields in Santa Clara County.

Crop	Dates of Trial	Acre-inches per acre applied
Bok choy - Fall	November-January	7.5
Ong choy	February-April	9.3
Garlic chives	November-January	6.4

G. Discussion and Conclusion

The objective of this study was to evaluate the uptake of N of lemongrass, bok choy, garlic chives, water spinach and moringa. Based on the data collected, there is not a significant difference between fertilizer treatments for most crops, outside of the fall planted bok choy. Based on this information, it seems that as long as sufficient nitrogen is available in the soil, these crops have a tendency to take up the nitrogen that they need. When nitrogen is in excess, they are not necessarily taking up an excessive amount of nitrogen.

For moringa and lemongrass, a mid-season fertilization is more important than in bok choy. Bok choy appears to take up most of its nitrogen early on, in the first two months of growth. Moringa and lemongrass, on the other hand, see a mid-season increase in nitrogen uptake around 80 and 70 days, respectively. This data can help improve the recommendations we give around split application nitrogen applications and when it is a good time to apply fertilizer for these crops.

H. Challenges

Due to strict shelter-in-place guidelines and restrictions on travel in Santa Clara County (one of the county's most affected by COVID-19 early in the pandemic) that were in effect through end of May 2021 we were unable to collect weekly crop canopy data and regular soil and biomass samples. As such the trials for water spinach and garlic chives had to be abandoned for the 2020-2021 trial years. In Fresno, setup and calibration of

dataloggers and tensiometers was disrupted in March-April 2020 by COVID-19 restrictions on travel and in-person contact. This prevented setup of field trials in 2020. Further, challenges due to COVID-19 restrictions prevented large-group in-person outreach meetings until 2022 and resulted in low turnout for online workshops. Also, continuous staff turnover during the project period was challenging for conducting the field trials and overall data analysis.

I. Project Impacts

Discussions with the Central Valley Regional Water Control Board and the Kings River Water Quality Coalition have resulted in a grant from the Water Board for additional outreach and education on best practices and resources for compliance with the ILRP, including annual reporting of nitrogen fertilizer use and domestic well testing. This grant will leverage and continue the educational activities begun on the FREP project. Data collected and analyzed from research funded by FREP will be used to develop fertilizer recommendations and calculate nitrogen removed at harvest for moringa, lemongrass, and bok choy. These results will be shared with small-scale, diversified growers in the Fresno area on radio programming and in workshops and will also be used in ILRP annual reporting and compliance. Additionally, data are being incorporated into the online web tool CropManage and will be available to growers to make decisions around fertilizer applications for all five crops.

J. Outreach Activities Summary

Several outreach activities and events were conducted throughout the project duration and included 15 events reaching over 650 Asian small farmers. Project staff participated in different types of events including grower meetings, field days, and virtual trainings. When appropriate, outreach participants were surveyed to measure impact. Results were also presented at five scientific conferences.

Conferences:

- Bok choy research results were presented at the 2019 Western Nutrient Management Conference in Reno, Nevada.
- A poster on the moringa study was presented at the FREP conference in San Luis Obispo, California on November 30th, 2021.
- A project report presentation was given at the 2022 FREP conference in Visalia on October 26th, 2022.
- A poster on the lemongrass study was presented at the California Plant and Soil Conference in Fresno, California on February 7th, 2023.
- A poster on the bok choy studies was presented at the FREP conference in Modesto, California on November 8th, 2023.

Outreach events;

- In the Santa Clara County region, a workshop was held about irrigation, nutrient management, and the Irrigated Lands Regulatory Program’s nitrogen fertilizer applied reporting requirements on November 20, 2018, that was attended by 43

Asian growers. Workshop evaluation surveys were collected and 100% of growers stated that the workshop increased their knowledge on nitrogen application limits required by the Irrigated Lands Regulatory Program and why/how to protect underground water and surface water. 100% of attendees intend to monitor and report nitrogen applications on their farm and test and report nitrogen concentration in well water annually. 100% of attendees intend to contact UCCE for future help regarding total nitrogen application (TNA) reporting.

- The initial research findings were presented at the 2019 Irrigation and Nutrient Management Meeting held in Salinas that was attended by over 100 growers.
- In 2020, from January 11th to March 10th, 36 Asian small farmers received technical assistance in Mandarin to complete their annual nitrogen fertilizer use reports. The team also conducted soil and irrigation water nitrate tests to measure nitrate levels in samples.
- In 2021, 15 Asian small farmers received technical assistance in Mandarin to complete their annual nitrogen fertilizer use reports. The team also conducted soil and irrigation water nitrate tests to measure nitrate levels in samples.
- In the Santa Clara County region during two outreach workshops on February 10 and 11, 2022, the project team assisted 43 growers with completing their nitrogen fertilizer use reports. The team also conducted soil and irrigation water nitrate tests to measure nitrate levels in samples. The workshops and technical assistance were conducted in Mandarin.
- 2022 BACGA Continuing Education Meeting was held in San Martin, CA on December 13, 2022. Information was presented on recordkeeping requirements for Total Nitrogen Applied (TNA) and Irrigation and Nutrient Management Plan (INMP) Summary Reporting. The workshop was attended by 60 Asian farmers, 43 male, 17 female.
- September 2022 Santa Clara County Farm Bureau Meeting was held in Morgan Hill, CA on September 6, 2022. Information was presented on A-R research updates and crop coefficients. The presentation was attended by 15 white growers, all male.
- In Fresno, technical assistance to small-scale, underserved farmers with annual reporting of nitrogen fertilizer use for the Irrigated Lands Regulatory Program annually in February 2018 – 2023 (6 events with one-on-one assistance to approximately 30 farmers per year).
- Ongoing conversations with the Central Valley Regional Water Control Board and the Kings River Water Quality Coalition following the approval of alternate reporting requirements for small-scale, socially disadvantaged farmers with diversified farms to develop the alternate forms. An on-farm workshop with Water Board staff and Southeast Asian farmers was held in spring 2022, and the forms were approved for use by qualifying growers in 2023.
- A workshop was conducted on November 28, 2023, to highlight the importance of testing well water for nitrate levels, with a hands-on demonstration of nitrate test strips.

K. References

None provided.

L. Appendix

Not applicable.

M. Factsheet/Database

1. Project Title: Evaluation of Nitrogen Uptake and Applied Irrigation Water in Asian Vegetables Bok Choy, Water Spinach, Garlic Chives, Moringa, and Lemongrass

2. Grant Agreement Number: 17-0515-000-SA

3. Project Leaders: Aparna Gazula, Advisor UCCE Santa Clara, San Benito, and Santa Cruz Counties; Ruth-Dahlquist Willard, Advisor UCCE Fresno and Tulare Counties; Daniel Geisseler, UCANR Cooperative Extension Specialist, UC Davis.

4. Start Year/End Year: 01/01/2018 - 12/31/2023

5. Locations: Kearney, Morgan Hill, San Martin, Gilroy

6. County: Santa Clara and Fresno Counties

7. Highlights

- Open field grown bok choy nitrogen removal crop coefficients ranged between 0.00053-0.00628.
- Greenhouse grown baby bok choy nitrogen removal crop coefficients ranged between 0.00085-0.00344.
- Moringa nitrogen removal crop coefficients ranged between 0.012795-0.019746.
- Lemongrass nitrogen removal crop coefficients ranged between 0.001771-0.005827

8. Introduction: Asian specialty vegetables are grown intensively in open field and protected agricultural systems. In protected agricultural systems, some of the vegetables are grown 6-7 times per year in continuous rotations with a 15-day gap between each rotation. Grown primarily in Fresno, Monterey, Riverside, San Bernardino, Santa Clara, San Luis Obispo, and Ventura counties on around 7026 acres, Asian vegetables are valued at $79 million per year (California County Crop Reports, 2015).

In Fresno and Santa Clara Counties, these crops are grown primarily by limited-resource, small-scale, socially disadvantaged Chinese, Hmong, and other Asian immigrant farmers. Information is currently lacking on nitrogen uptake in many of these crops. With proposed regulations under the Irrigated Lands Regulatory Program (ILRP) by the Central Coast Regional Water Quality Control Board and the Central Valley Regional Water Quality Control Board to control N losses, it is important to understand

N uptake and removal in crops that have significant acreage but do not have commodity board support. Asian growers producing specialty vegetables and herbs are required to fill out the N management plan as part of the ILRP. However, they lack the information to complete this form accurately as there is no information on N fertilizer recommendations or N uptake for most of their crops.

The overall goal of this project is to provide detailed measurements of total N removal, N uptake, and the N uptake pattern of bok choy, water spinach (ong choy), garlic chives, moringa, and lemongrass.

9. Methods/Management: Field trials were conducted during the growing season in Santa Clara and Fresno Counties to evaluate above ground biomass, biomass N and soil nitrate levels in high-yielding fields of bok choy, moringa, lemongrass, edible chrysanthemum and garlic chives to generate N uptake curves. At harvest, samples were collected from at least 4 additional fields per crop and analyzed for fresh and dry weight, as well as N content to obtain a more robust estimate of the amount of N removed with the harvested portion of the crops (expressed in lbs/ton fresh weight).

To conduct crop canopy evaluations and irrigation application evaluations, flow meters and tensiometers were installed in the above-mentioned fields. Also, using an infra-red camera, canopy photos of the crop were taken every two weeks and up to three harvests for multiple harvest crops.

From the total solids calculated from crop dry weight and the percent nitrogen in the biomass of moringa, lemongrass, and bok choy, crop nitrogen removal conversion coefficients were calculated. Canopy photos were taken and % canopy cover was assessed using Pixel Wrench software.

10. Findings: The objective of this study was to evaluate the uptake of N of lemongrass, bok choy, garlic chives, water spinach and moringa. Based on the data collected, there is not a significant difference between fertilizer treatments for most crops, outside of the fall planted bok choy. Based on this information, it seems that as long as sufficient nitrogen is available in the soil, these crops have a tendency to take up the nitrogen that they need. When nitrogen is in excess, they are not necessarily taking up an excessive amount of nitrogen.

For moringa and lemongrass, a mid-season fertilization is more important than in bok choy. Bok choy appears to take up most of its nitrogen early on, in the first two months of growth. Moringa and lemongrass, on the other hand, see a mid-season increase in nitrogen uptake around 80 and 70 days, respectively. This data can help improve the recommendations we give around split nitrogen applications and when it is a good time to apply fertilizer for these crops.

N. Copy of the Product/Result:

Data from the project has been made available to growers at various outreach events and through various modalities.

- https://www.centralcoastfarms.org/crop-management/comprehensive-list-of-nitrogen-removal-coefficients-for-crops-grown-in-coastal-california.
- https://calfruitandveg.com/2025/02/12/comprehensive-list-of-nitrogen-removal-coefficients-for-crops-grown-in-coastal-california/
- https://ccwqp.org/wp-content/uploads/N_Removal_ConversionCoeffsMarch2024Update.pdf