The Impact of Reducing Nitrogen Fertilizer in Iceberg Head Lettuce

A Senior Project
Presented to
The Faculty of the Agriculture Education and Communications Department
California Polytechnic State University, San Luis Obispo

In Partial Fulfillment
Of the Requirements for the Degree
Bachelor of Agricultural Science

By
Jason Acquistapace
Date Submitted
November 30, 2013

Table of Contents

List of Tables and Figures

Abstract

The impact of Nitrogen use in Iceberg lettuce was studied by measuring the weight and size of lettuce heads. A standard nitrogen application based on traditional commercial production was determined and portions of commercial fields (401 and 406) were designated for testing. Based on the standard, three fertilizer treatments (40%, 60%, and 80% of the control) were tested against the control in fields 401 and 406. The results indicated there was no difference in the weight of lettuce heads when treated

with the relative fertilizer percentages. However, the size of lettuce heads decreased as the relative fertilizer percentages decreased. This signifies the impact of using reduced amounts of nitrogen fertilizer in Iceberg lettuce production

Chapter One

Introduction

The Federal Water Pollution Control Act was enacted in 1948, but was significantly reorganized and expanded in 1972 by the U.S. Congress and titled the "Clean Water Act" (EPA, 2012). The Clean Water Act (CWA) is the cornerstone of the United States surface water quality protection. The main goals of the Clean Water Act was to sharply reduce direct pollutants discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. The reasoning behind these goals was to aide in restoring and maintaining the chemical, physical, and biological integrity of the nation's waters (EPA, 2008).

The original Clean Water Act implemented the monitoring from "point sources," but little or no attention was given to wet-weather or "non-point sources" such as farms and construction zones (EPA, 2008) In 1987, Congress added Section 319 to the Clean Water Act which enacted states to establish plans to monitor non-point source pollution. This Section established a three tier system, the first being voluntary controls, the second being conditional waivers, and the third tier being waste discharge requirements (Bagget, 2006).

Due to the U.S. Environmental Protection Agency failing to establish total maximum daily loads (TMDLs) for various bodies of water that were required by the CWA. October 1999, Senate Bill 390 was signed, which revised California's Water Code Section 13269. The bill required regional water boards to review the terms, conditions and effectiveness of the adopted waivers and to renew or terminate waivers every five years. In 2003, the California Water Code Section 13269 was amended again to allow

the State Water Board to establish fees for the waivers, with a particular focus on agriculture statewide. The 2004-2005 fiscal year State Budget for the State Water Quality Board was budgeted at $1.9 million and included up to 22 positions for implementing agricultural waivers that would be funded by the new fees for acquiring the waivers (Bagget, 2006).

California's water is controlled and monitored by the State Water Resources Board that consists of five full-time salaried members that are appointed by the Governor and confirmed by the senate. Their mission is to "…preserve, enhance and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations." The Regional Water Quality Control Boards are in charge of local implementation of policy and regulations, developing long-term plans for the area, issue waste discharge permits, and take enforcement actions against violators (California Water Boards, 2012).

There are nine Regional Water Quality Control Boards in California. The nine boards are as follows: Region 1: North Coast, Region 2: San Francisco, Region 3: Central Coast, Region 4: Los Angeles, Region 5: Central Valley, Region 6: Lahontan, Region 7: Colorado River, Region 8: Santa Ana, and Region 9: San Diego (California Water Boards, 2012).

On July 9, 2004, the Central Coast Regional Water Quality Control Board (CCRWCQB) adopted resolution No. R3-2004-0117 that established a Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands. The adoption of the order was adopted because, the Central Coast Water Board found that the discharge of waste from irrigated lands has polluted the waters of the State and has

impaired the beneficial uses. The Conditional Waiver was not approved entirely until March, 15th 2012 (CRWQCB, 2012).

Statement of the Problem

Order number 74 of the ag waiver requires farms to determine the typical crop nitrogen uptake and report the basis for the determination by citing published agronomic literature or research trials.

The Importance of the Project

The Central Coast Region has approximately 435,000 acres of irrigated land and approximately 3000 agricultural operations which it monitors (CRWQBC, 2012). Imposing new regulations to reduce nitrogen applications without research trials could have a negative effect upon the agricultural operations.

The Purpose of the Project

This experiment is to demonstrate that Acquistapace Farms Inc. uses the minimum amount of nitrogen to produce a marketable product of head lettuce and the proposed reduction of fertilizer in head lettuce will impact the growers.

Important Terms

1. Chlorosis - A botanical term to describe the condition in which leaves of a plant produce insufficient chlorophyll. This reduction of chlorophyll in the leaf will cause it to have a pale, yellow or yellow-white color.
2. Necrosis – A term used to define the death of cells from injury.
3. Nitrate loading – A term used to describe Nitrogen that passed moved down into groundwater.
4. Arizona implement – A cultivating implement that is pulled behind a tractor that pulls apart a row bed and pushes it back together in one pass.
5. Pre-Irrigation – An irrigation practice used before planting. It consists of irrigating bare ground for a period of time in order to bring moisture to the soil for cultivation and also to germinate weed seeds.
6. Lilliston cultivator – An industry term to refer to a Rolling cultivator. It is used to break clods in the beds by running “spiders” along the sides of the beds.
7. Variance –
8. Border effect – An occurrence in row crops that cause the plants on borders of the fields to experience difficult or stunted growth.

Chapter Two

Literature Review

Nitrogen effects in Crop Physiology

Nitrogen (N) is an essential element obtained from the soil. Nitrogen is classified as a macronutrient because of its high concentration (1.5 ppm dry matter concentration) in plant leaves, stems, and roots compared to other essential mineral elements. (Taiz, 2002) Nitrogen is taken up by plants in two different forms; nitrate (NO_3^-) or ammonium (NH_4^+) ions with nitrate being the most common form. (WPHA, 2002) This essential element is mobile in plants and requires further processes such as nitrate assimilation to allow the plant to utilize the element. (Taiz, 2002) From a biochemical perspective nitrogen is a critical constituent in nucleotides and proteins. (Xu, 2012)When plants (excluding legumes) are not supplied with sufficient supplemental nitrogen, deficiencies symptoms begin to show such as chlorosis in older leaves. Due to its mobility, deficiency symptoms in younger tissue are not evident unless severe deficiencies exist. (Taiz, 2002) Other nitrogen deficiencies are slow growth, stunted plants, and necrosis of leaf tips and margins. (WPHA, 2002) In modern cropping system nitrogen is the major limiting factor to crop productivity. (Robertson, 2009)

The high importance of nitrogen in cropping systems results in the need to supplement soils with readily available nitrogen to maximize the use of crop

production. In non-cropping ecosystems, N is replaced by continual production of organic matter year after year. However, in cropping ecosystems yield is removed from the field resulting in a loss of organic matter. (Robertson, 2009) Removal of yield in broccoli and lettuce fields result in approximately .44 lb/cwt and .24 lb/cwt of N removal respectively. (WPHA, 2002) Replenishing the soils with N can be achieved by using nitrogen-fixing crops such as legumes for a rotation, manure, or synthetic nitrogen fertilizers. (Robertson, 2009) For vegetable production on the Central Coast of California the economics of using legumes as a rotation crop has its limitations due to high valued crop land. Manure also has its limitations in fresh produce cropping systems because of biological food safety risks associated with using manure. For vegetable production on the Central Coast of California synthetic fertilizers are most economically with less food safety risks.

Health impacts due to Nitrate in ground water

Nitrate loading to groundwater has been becoming a cause for concern in recent decades. Groundwater is essential to California, and nitrate is one of the state's worst groundwater contaminants. The number one human-generated nitrate source to groundwater is cropland, which is responsible for 96% of the total sources. Cropland includes synthetic fertilizers, animal manure, irrigation source water and food

processing facilities. The other minor sources include such things as domestic septic systems and percolation of wastewater treatment plants. (Harter et al, 2012)

Consumption of nitrates can have adverse health concerns, especially among infants and pregnant women. Concentrations over 45mg/l of nitrate in drinking water have shown cases of methemoglobinemia (blue baby syndrome) in infants. This is the reaction of the nitrate with hemoglobin in the blood to form methemoglobin which reduces the ability of the blood to carry oxygen, because the immature stomach enables the ability to convert nitrate to nitrite. It is for this reason that the maximum contaminant level (MCL) has been set at 45mg/l. Healthy children and adults are at a much lower risk of becoming ill from nitrates in drinking water. There are other health hazards that have been reported related to high nitrate water including cancer and birth defects. Controversy surrounds these claims as these health concerns have been loosely related to nitrate in drinking water. (Anton et al, 1988)

Brief overview of the Conditional Waiver of Waste Discharge Requirements For Discharges From Irrigated Lands (#74 and #78 P. 29, 30)

The Regional Water Quality Control Boards are the principal state agencies with primary responsibility for the coordination and control of water quality pursuant to the Porter-Cologne Water Quality Control Act. On March 15th, 2012 the California Regional Water Quality Control Board Central Coast Region adopted Order no. R3-2012-0011

entitled Conditional Waiver of Waste Discharge Requirements For Discharges From Irrigated Lands. This Order regulates discharges of waste from irrigated lands by requiring individuals subject to the Order to comply with the terms and conditions to ensure that discharges do not cause or contribute to further contamination by fertilizers and pesticides.

The Order entails 88 new regulations that are that can be divided up in a tier system depending on total irrigated acreage. There are two orders that will directly affect the use of nitrogen fertilizer.

> #74 By October 1, 2013, Tier 3 Dischargers with High Nitrate Loading Risk farms/ranches must determine the typical nitrogen uptake for each crop type produced and report the basis for determination (e.g., developed by commodity or industry group, published agronomic literature, research trials, site specific analysis of dry biomass of crop for the nitrogen concentration), per MRP Order No. R3-2012-0011-03. #78 By October 1, 2015, Tier 3 Dischargers with High Nitrate Loading Risk farms/ranches must report progress towards the following Nitrogen Balance ratio or implement and alternative to demonstrate an equivalent nitrogen load reduction. The Nitrogen Balance ratio refers to the total number of nitrogen units applied to the crop (considering all sources of nitrogen) relative to the typical nitrogen uptake value of the crop (crop need to grow and

produce, amount removed at harvest plus the amount remaining in the system as biomass) (CRWQCB, 2012).

Lettuce Packaging

Current standards in the U.S. for head lettuce packaging are a 24 head count per carton with each carton weighing between 42-45 pounds. Consumer demand has driven this standard for head lettuce. The consumer prefers a round shaped head lettuce with a weight of precisely 1.75 pounds. Therefore, this weight and size of this head lettuce will equate to 24 heads fitting comfortable into a carton. Occasionally, there can be a demand for a smaller head lettuce. This demand is filled by packing a 30 head count per carton. These packs are very random, sell for a lower price, and usually will go to lower quality thrift stores or processors. For this project, a 24 head count per carton packaging will be used.

Hypothesis

There is a difference between fertilizer treatments.

Null Hypothesis

There is no difference between fertilizer treatments.

Chapter Three

Materials and Methods

On April 23 and 29, 2013 a lettuce fertilizer trial was started at Acquistapace Farms in Guadalupe California. The ground the trials were planted on were previously turned over from a cauliflower crop, and according to a Fruit Growers Laboratory, an analytical chemists company, soil analysis there was 22.4 PPM of residual nitrogen in the ground. Fruit Growers Laboratory

also classified the ground as a loam soil. The variety of lettuce planted was called Telluride. In the two fields that were planted, there were four rows that were flagged off in each. This allowed for three different treatments, and a control row replicated two times.

Prior to the pre-irrigation, both of the fields were deep ripped at a depth of 16 inches. This was to ensure that there was even and adequate drainage throughout the fields. The fields were then raised up into beds using an Arizona implement that placed the bed spacing at 38 inches. A pre-irrigation of twelve hours was then applied to the field. This was to minimize weed problems and for salt leaching. After twelve days, the field was dry enough to drive thru, and was then cultivated using a Lilliston cultivator. This helped to break apart any clods, and loosen the soil for shaping. The beds were then shaped and planted at the same time. The bed shaper was a steel roller that flattens out the tops of the beds to a width of 22 inches, and a height of 6 inches. The bed shaper also applies a line of Admire® directly below the seed line at 24 ounces per acre and also sprays a band of Kerb® over the seed bed at a rate or 32 ounces per acre. Admire® is a Chloronicotinyl, an acetylcholine receptor agonists for insects, and Kerb® is a selective herbicide to reduce weed growth. Following the bed shaper was a stanhay planter that placed two lines of seed at ½ inch depth, 12 inches wide, and with 2 inch spacings.

The day following seeding, drip tape (#718-12-220) was injected in the center of the seed line of each bed at a depth of 2 inches. The end of the drip tape was connected to a 4 inch oval hose that ran along the end of the rows. The oval hose was then connected to a riser valve with a Nefafim water pressure regulator. Water was sent to this riser by a 120 horsepower well that drew water from the underground aquifer. The date water was placed on the field, was considered the planting date and day 1 of the irrigation schedule.

Plot 401 and 406 plant dates were April 23, 2013 and April 29, 2013. Each planting contained three trials and a control. Each trial, and the control, were different lengths due to the slant of the fields. The lengths of each trial were measured using a Leupold® RX-1000i rangefinder. Once the lengths of each trial were measured, Jason Acquistapace applied a length 'D' in feet to this formula to get the acres. Acres=((D*38)/12)/43,560. The sum of the lengths and distances of the trials for 401 and 406 were 0.126 acres (Table 3.1)

Table 3.1-Trial Acres

Plot-Trial	Length (ft.)	Acres	
401-1	273	0.01985	
401-2	270	0.01963	
401-3	268.5	0.01952	
406-1	306	0.02225	
406-2	309	0.02246	
406-3	312	0.02268	
		0.12639	sum

The fertilizer timing was based on the watering schedule. Fertilizer was applied the day after the irrigation to insure that the fertilizer will be able to move down into the root system, but not be washed away from running irrigation. Both fields followed the same irrigation, fertilizer and cultivation schedule. All of the irrigations were run with the drip tape for a 14 hour period, except the furrow irrigation and the last drip irrigation before harvest. The furrow irrigation was run until the water reached the end of the furrow and the last irrigation with the drip tape was for only 4 hours. Plot 401 was harvested on the 76^{th} day and plot 406 was harvested on the 75^{th} day (Table 3.2).

Table 3.2-Irrigation, Fertilizer and Cultivation schedule

Day	Action	Fertilizer Application
1	Irrigation	

2	Irrigation	
9	Irrigation	#1
14	Knife	
21	Irrigation	#2
23	Thin	
26	Knife	
28	Irrigation	#3
35	Irrigation	#4
42	Irrigation	#5
49	Irrigation	#6
56	Irrigation	#7
63	Irrigation	
68	Furrow Irrigation	
72	Irrigation	
75-76	Harvest	

Acquistapace Farms has a set fertilizer application schedule that it follows for spring, summer and fall. The summer schedule that was used goes as follows: #1-40 units, #2-70 units, #3-75 units, #4-60 units, #5-18 units, #6-18 units and #7-17 units. This was also the control schedule. The trials amounts were based off the unit amounts. Trial #1, such as 401-1 and 406-1, is 80% of these units, trial #2 is 60% and trial #3 is 40% (Table 3.3).

Table 3.3 -Trial Units of Fertilizer

Application	Control Units	Trial 1 Units 80%	Trial 2 Units 60%	Trial 3 Units 40%
#1	40	32	24	16
#2	70	56	42	28
#3	75	60	45	30
#4	65	52	39	26
#5	18	14.4	10.8	7.2
#6	18	14.4	10.8	7.2

#7	17	13.6	10.2	6.8

The amount of fertilizer per trial was different for every application, and to calculate the correct amount for each application use the formula, Fertilizer amount =((AcresxUnits/2.12)x128). The acres are from table 1.1 and the units are from table 1.2. The 2.12 is the pounds per gallon of Nitrogen in the fertilizer used in this experiment, AN-20. The 128 converts gallons into liquid ounces (Table 3.4)

Table 3.4-Fertilizer amounts in ounces

Application	401-1	401-2	401-3	406-1	406-2	406-3
#1	38	28	19	43	32.5	21.9
#2	67	50	33	75.3	57	38.4
#3	72	53.4	35.3	80.6	61.1	41.1
#4	62.3	46.2	30.6	70	52.9	35.6
#5	17.3	12.8	8.4	19.3	14.6	9.8
#6	17.3	12.8	8.4	19.3	14.6	9.8
#7	16.3	12	8.1	18.3	13.8	9.3

The fertilizer was applied by using a custom Nefafim regulator that had ball valves coming off the high pressure end and also the low pressure ends. There was an attachment that connected the ball valves together and also had a hose adapter. When this is connected, and both the valves were opened, suction was created into the drip tape. The hose was attached to the base of a bucket where the fertilizer was placed after being measured with a measuring cup. It is then mixed with water by closing one valve, and opening another. Once the bucket was filled with the water and fertilizer solution, both the valves are opened and the solution was applied to the row. Thirty minutes was given after the bucket became empty to allow time for the fertilizer to flush out of the drip line to ensure that fertilizer was out of the tape and into the soil (Fig. 3.1).

Figure 3.1- Custom Nefafim regulator used to apply fertilizer to each bed.

The control row was applied fertilizer with the rest of the plot by an Ag Solution Master that drew the fertilizer from a tank and injected the fertilizer into the water line at the well to the riser valve.

Santa Maria Valley Crop Service provided the necessary spray applications for the experiment. A PCA from Valley Crop Service walked the fields throughout the duration of the experiment and wrote recommendations for foliar sprays to protect the fields from pests and diseases. The applications were done at night with a tractor that applied the material. The materials sprayed were mixed with 50 gallons of water per acre and sprayed over the foliage of the lettuce (Table 3.5).

Table 3.5- Date, Material Applied and Rates per Acre applied by

Santa Maria Valley Crop Service

401	Date	Material Applied	Rate/AC	406	Date	Material Applied	Rate/AC
	5/13/2013	Endura®	11OZ		5/16/2013	Endura®	11OZ
		Malation 8 Aquamul®	1.2PT			Permethrin 3.2EC Insecticide®	8OZ
		Permethrin 3.2EC Insecticide®	8OZ			First Choice Break-Thru®	1.5OZ
		First Choice Break-Thru®	1.5OZ		5/25/2013	Fontelis®	.18Gal
	5/24/2013	Endura®	11OZ			Malathion 8 Aquamul®	1PT
		Malation 8 Aquamul®	1PT			Manzate Pro-Stick®	2LB
		Manzate Pro-Stick®	2LB			Permethrin 3.2EC Insecticide®	4OZ
		First Choice Break-Thru®	1.5OZ			First Choice Break-Thru®	1.5OZ
	6/8/2013	Malation 8 Aquamul®	1.25PT		6/14/2013	Malathion 8 Aquamul®	1.25PT
		Manzate Pro-Stick®	2LB			Manzate Pro-Stick®	2LB
		Movento®	.15QT			Perm-Up 3.2 EC®	.06GAL
		Exit®	.5PT			Previcur Flex®	.25GAL
	6/17/2013	Coragen®	.15QT			Movento®	.15QT
		Lannate SP®	1LB			Exit®	.5PT
		Movento®	.15QT		6/23/2013	Coragen®	.15QT
		Perm-Up 3.2 EC®	.06GAL			Lannate SP®	1LB
		Previcur Flex®	.25Gal			Movento®	.15QT
		Exit®	.5PT			Previcur Flex®	.25GAL
						Exit®	.5PT
						Perm-Up 3.2 EC®	.06GAL

On July 8th the harvest foreman for Acquistapace Farms determined that the plot 401 was ready for harvest. Starting at one end of a trial row and moving down the row, lettuce heads were

cut, stripped of excess wrapper leaves and placed into a carton box. No lettuce heads were cut within ten feet of the end of the row. This was to ensure that the border effect was minimized. When there were 24 heads in the carton, the box was weighed using a CCI scale (Fig 3.3). The weight was recorded and the boxes were labeled according to their trial or control. Six boxes were recorded from each of the trial rows and also from the control row.

Figure 3.2- A box filled with 24 lettuce heads being weighed

Twenty heads of lettuce were randomly selected from the six boxes of a trial. These heads were then cut in half and the diameter of the lettuce head was measured across with a Stanley Tape Measurer (Fig 3.3). This was done for all the trial rows and the control row.

Figure 3.3- A random lettuce head cut in half for diameter measurement

July 13th the harvest foreman for Acquistapace Farms determined that plot 406 was ready for harvest. The same data collection process that was perform on plot 401 was done to plot 406.

Chapter Four

Results

There was no effect of fertilizer rate on the weight of a box of 24 heads of lettuce. However, as the percentage of fertilizer decreased from 100% to 60%, the weight of the boxes also tended to decrease from a high of 44 lb to a low of 40 lb (Figure 4.1). In contrast, as the percentage was further decreased from 60% to 40%, the boxes of lettuce tended to become heavier.

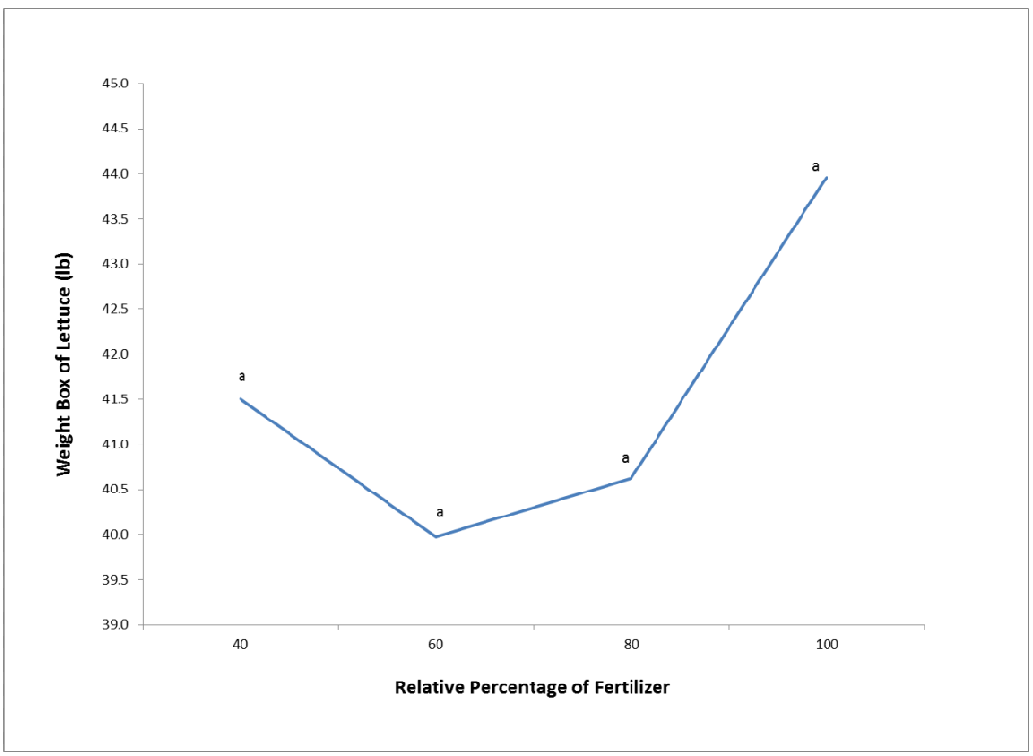

Figure 4.1-Effect of relative fertilizer rate on the weight of lettuce boxes containing 24 Iceberg lettuce heads. Means with the same letter are not significantly different at the 5% confidence level as determined by Duncan's Mean Separation Test.

There was an effect of fertilizer rates on the size of lettuce heads. The size decreased from 6.2 to 5.8 when treated with 100% and 80% fertilizer respectively (Figure 4.2). There was no effect of fertilizer between 80% and 60%, however the head size continued to decrease resulting in an effect of fertilizer rates between the 60% and 40%.

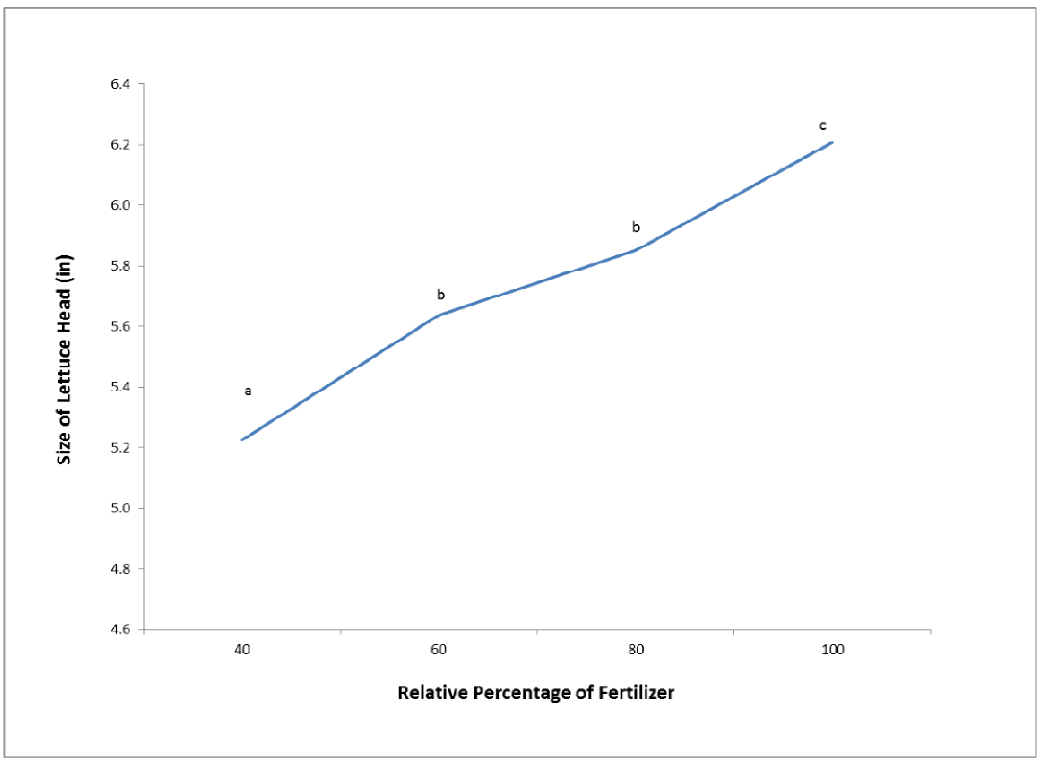

Figure 4.2-Effect of relative fertilizer rate on the size of Iceberg lettuce heads. Means with a different letter are significantly different at the 5% confidence level as determined by Duncan's Mean Separation Test.

Discussion

As previously stated, this trial was designed to test the impact of varying fertilizer rates on the weight and size of head lettue. The null hypothesis states as follows: there was no difference in weight or size of head lettuce when treated with different fertilizer rates. Not accepting the null hypothesis indicated significant difference between the relative percentage of fertilizer used for the trial.

For each fertilizer treatment six boxes packed with 24 Iceberg lettuce heads were weighed. Data was collected from two locations; field 401 and 406. The mean difference in box weight relative to the percent of fertilizer was compared using anlysis of variance (ANOVA). At a 5% confidence level, the null hypothesis was accepted meaning there was no measurable difference in the mean weight of Iceberg lettuce heads when treated with the relative rates of fertilizer. The trial consistented of 6 measurements per treatment for each field. The low number of sampling resulted in large variation among the treatments. Difference between treatments may be detectable with a larger sampling.

In addition to weight, the size (inches) of Iceberg lettuces heads were also measured for each fertilizer treatment. Twenty heads of lettuce per field were collected and measured. The null hypothesis was rejected meaning there was significant difference in the size of Iceberg lettuce heads when treated with different percentages of fertilizer. The mean size of lettuce heads for the fertilizer Control were significantly different from the 40%, 60% and 80% fertilizer treatments at the 5% confidence level as indicated by the letter ‘c’. The mean size of lettuce heads treated with 60% or 80% fertilizer were significantly different from the 40% along with the Control as indicated by the letter ‘b’ in Figure 4.2. Using less than 100% of the fertilizer treatment will

result in smaller heads thus not meeting the industry standards and lowering the price of head lettuce for growers.

The sizes of the lettuce heads were smaller when treated with less fertilizer however the weight remained the same between fertilizer treatments. This difference in results may have been influenced by the water weight as well as the difference in sample size. Although the lettuce heads were smaller with less fertilizer, they may have absorbed the same about of water as the regular sized lettuce resulting in no weight difference between fertilizer treatments.

Chapter Five

Conclusions and Recommendations

The hypothesis for the experiment was varying rates of nitrogen fertilizer impact the size and weight of head lettuce. The trial was designed to test the hypothesis against the null hypothesis to determine any differences. These differences are important because the reduction in size of head lettuce or weight of head lettuce could potentially decrease yield and ultimately profit for growers. The determining factor for lettuce head marketability to a producer is the size of the lettuce head and if it will fit in the carton correctly for shipment. Lettuce heads that are too big become bruised from being packed too tightly and lettuce heads that are too small require more heads than the conventional 24 heads to completely fill the box.

The results indicated there was a significant difference between the sizes of the lettuce heads as the fertilizer rates are decreased. This enforces the purpose of the experiment and gives research trail data to justify the use of the control fertilizer schedule for the time being. The reduction of nitrogen in head lettuce showed no significant difference in weight. However a more extensive trial with more replications and measured water content would help further confirm these results.

The limitations of resources prevented more replications of the experiment. This is because production of head lettuce is a high capital investment and nitrogen trials in a field that is being produced for distributors can cause unmarketability of the trials. It would then be more economically secure to perform another trial similar to this, but apply fertilizer trials with less of a percentage decrease in fertilizer. This would allow for more trials to be replicated and therefore the variance would be decreased.

Works Cited

Anton EC, Barnickol JL, & Schnaible DR. Nitrate in Drinking Water Report To The Legislature. State Water Resources Control Board. Report No. 88-11WQ. 1988

Bagget Arthur Jr. Agricultural Waivers History & Status. California Water Law Symposium. 2006. <http://www.waterlawsymposium.com/papers/images/photos.swf>

California Regional Water Quality Control Board Central Coast Region (CRWQCB). Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands (Order No. R3-2012-0011). 2012.

California Water Boards. State Water Resources Control Board, California. 2012. <http://www.swrcb.ca.gov/>

EPA. Introduction to the Clean Water Act. U.S. Environmental Protection Agency. 2008. <http://www.intellectualtakeout.org/library/primary-sources/introduction-clean-water-act>

EPA. Laws and Executive Orders. U.S. Environmental Protection Agency. 2012.
<http://www.epa.gov/lawsregs/laws/>
<http://www.waterlawsymposium.com/papers/images/photos.swf>
<http://www.intellectualtakeout.org/library/primary-sources/introduction-clean-water-act>
<http://www.epa.gov/lawsregs/laws/>
<http://www.epa.gov/lawsregs/laws/cwahistory.html>

Harter T & Lund JR. Addressing Nitrate in California's Drinking Water With a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Center for Watershed Sciences. UC, Davis. 2012.

Robertson PG & Vitousek PM. Nitrogen in Agriculture: Balancing the Cost of an Essential
Resource. Annu. Rev. Environ. Resour. 34:97-125. 2009.

Taiz L & Zeiger E. Assimilation of Mineral Nutrients. Plant Physiology, 3rd ed. Sunderland, MA: Sinauer Associates. 2002.

Western Plant Health Association (WPHA). Essential Plant Nutrients. Western Fertilizer Handbook, 9th ed. Long Grove, IL: Waveland Press. 2002.

Xu G, Fan X & Miller AJ. Plant Nitrogen Assimilation and Use Efficiency. Annual Review of Plant Biology. 63:153-82. 2012

Appendix

Appendix A. – The Raw Data from Plot 401 (LBS.)

Control	80%	60%	40%
45.5	42.5	41	34.5
45	43	40	35.5
45.5	38	43	41
49	35.5	38	41
45	37.5	39.75	42
44	38	36	44

Appendix B. – The Raw Data from Plot 401 (IN.)

Control	80%	60%	40%
6	6	5.5	5.5
7	5.75	5.5	5.5
6.25	5.75	6.5	5
5.5	6	5.5	4.75
6.25	5.75	5.75	5
6.5	6	6.5	5
6.5	6.25	5.75	4.5
6.5	6	5.75	5.25
5.75	6	5.75	5.75
5.75	6	5	4.75
5.75	5.25	5.5	5.75
6	5.5	5.5	5.25
5.5	5.75	6.25	4.75
5.75	6	5	5.5
6.75	6.25	5.75	5
6	6	5.5	5
6.25	5.75	5.5	4.5
6	6	5.25	5.5
6.75	6.25	5.5	4.75
5.75	6.25	5.25	5

Appendix C. – The Raw Data from Plot 406 (LBS.)

Control	80%	60%	40%
43	44	41	43
45	42.5	40	46
43	43	39.5	42
44	41.5	42	45
43.5	41	36.5	40.5
43	41	43	43.5

Appendix D. – The Raw Data from Plot 406 (IN.)

Control	80%	60%	40%
6.75	6	5.5	5.25
6.5	6	5.5	5
6.75	6.25	5.25	5.5
5.75	6	5.75	4.75
6.25	5.5	5.5	5.75
6.25	5.75	6	5.25
5.75	5.75	5.5	5
6	6.25	5.25	5.5
6	5.5	6	5.5
6	5.75	5.75	5
5.75	5.25	5	5.75
6.75	5.75	6	4.75
6.5	5.5	6	5.25
6.5	6.25	5.25	6
6.5	5.5	6	5.75
6.75	5.25	6	5.5
6.75	6.25	5.5	5.25
6	5.75	5.75	5.75
6.25	5.5	5.75	5
6	5.75	5.75	5.5