A Cost/Benefit Analysis of Soil Test Kits Designed to Improve Fertilizer Management

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To ESSP Faculty, Thursday, May 31, 2001

This project is a cost-benefit analysis of Pre-sidedress Nitrate testing kits produced by EM Quant. The purpose is to show that using these kits farmers can save economic loss and help to slow the leaching of excess soil nitrogen into already saturated water tables.

This project could influence agriculture policy to increase nitrogen loss management. Several groups could benefit from the production of this project, such as the fishing industry, whom can benefit from lower nitrogen levels in their fish habitats and the agriculture production industry, who could benefit from decreased economic loss using the Pre-Sidedress Nitrate Testing kits (PSNT). Excess nitrogen causes some fish habitat to become dead zones from lack of oxygen, which will in turn, decrease fish populations.

During the course of this project I received immeasurable help from Tim Hartz and Shane Breschini from the University of California at Davis. This project is actually a subproject from Shane’s master’s thesis. The two of them were instrumental in setting up and analyzing the data that I collected. I also worked with Tom Lockhart of the Monterey County Resource Conservation District. Tom instructed me on how to use the Pre-sidedress Nitrate Testing kits.

Farmers and ranch owners are the main audience for this project. The information is also directed towards agricultural policy makers who might be able to subsidize the PSNT kits or help in some other way to make these kits more accessible.

This project contains information applicable to the agricultural industry outside of California State University of Monterey Bay. If the ideas from this project were implemented on the fields in Salinas I believe that in a few years we might notice the impact in a positive way. The results from this study show that the use of these kits will decrease nitrogen leaching and would decrease economic loss from nitrogen loss for the farmers of the Salinas Valley.

I believe that I am ethically obligated to fight for other living organisms that have no voice in our political system. The excess nitrogen loss that now occurs in the Salinas Valley could negatively affect fish populations. The excess leached nitrogen could lead to a dead zone in Monterey Bay. The fish have no rights and their aesthetic value make protecting their lives a worthwhile issue. If the agriculture producers used these test kits I believe the amount of soil nitrogen loss could be decreased, which would decrease the chances of a dead zone occurring in Monterey Bay.

When I started this project I was sure that the use of the PSNT kits would result in an immediate change in leaching nitrogen and economic loss. After completing this project I have realized that this process will take an extensive amount of time and effort. I realized that even if every farmer adopted these changes it would still take years for us to see the impact on the nitrogen cycle and that if I believe this policy could work it will take a while to convince everyone else of its effectiveness.

I think that my project should be assessed using MLO 4 and MLO 5. I believe I have covered these two areas extensively for several reasons. I spent my summer of 2000 in the fields of Salinas setting up experiments and collecting data to analyze over the past year. I have analyzed this data and presented it in a scientific manner. I have also used this data to show results that I believe are significant. I have studied the economics of fertilizing extensively as well as the political aspects that govern the economics. I had
the chance to understand every aspect of a farmer’s decision to fertilize the way they chose to. This is why I believe I have covered the two areas of depth.

Thank you,

[Signature]

Matthew Johnson
A COST/BENEFIT ANALYSIS OF SOIL TEST KITS DESIGNED TO IMPROVE FERTILIZER MANAGEMENT
Abstract

Current fertilizer practices are loading the soil of the Salinas Valley with nitrogen. New fertilizer management aimed at slowing nitrogen leached into water tables and reducing economic loss due to excess or lost nitrogen is very important. A study was conducted on four fields growing romaine lettuce in the Salinas Valley of California to test and implement an effective nitrogen fertilizer application. Using Pre-sidedress Nitrate Testing Kits (EMQuat) the soil of each treatment field was tested to determine the amount of fertilizer that should be applied to each site. The control fields were fertilized using conventional farming practices from the preceding year and the farmer’s local knowledge of weather conditions. A t-test comparing percent of plants harvested, carton weights and leaf nitrogen between treatment and control showed that the mean values are not significantly different between control and treatment. Therefore the PSNT kits can be used to reduce fertilizer application without a reduction in lettuce yield or quality. A nitrogen budget analysis was also conducted to assess the amount of nitrogen, referred to as lost nitrogen, left in the soil after harvest. Input and output nitrogen that was calculated with the nitrogen budget was used to run a cost benefit analysis. The cost benefit analysis showed that the benefits from using the PSNT kits outweighed the cost of excess nitrogen over two years. This study suggests that if the testing kits were subsidized, more agriculture producers would use these kits.
Introduction

Role of Nitrogen in Agricultural Production

Nitrogen plays a central role in plant development because it is a major component of amino acids, proteins, nucleic acids and chlorophyll (Haynes, 1986). A protein located at the plasmalemma of plant cells controls the amount of nitrogen that the plant needs. This protein allows only enough nitrogen, as the plant needs to grow and continue photosynthesis. After this threshold, excess nitrogen within the soil will stay in the soil. Organic nitrogen makes up roughly five percent of a plant’s dry weight (Haynes, 1986). Nitrogen is used as a major component of proteins, amino acids, nucleic acids, and chlorophyll (Haynes, 1986). Nitrogen is an essential plant nutrient required to produce food and fiber (Huang et. al., 1999). Essentially nitrogen ensures that plants look green and grow at a constant rate until the time of harvest.

If too little nitrogen is applied during the growing season, the quality and quantity of the product can suffer. Plants under nitrogen stress become wilted, lose their dark green pigment and have less chance of survival. These nitrogen deficient plants become an economic liability for the farmer. It is also important to note that further addition of nitrogen will cause nitrogen to remain in the soil and become susceptible to loss via volatilization and leaching. Volatilization of nitrogen creates a powerful greenhouse gas (N₂O), while leaching of nitrogen pollutes aquatic ecosystems and groundwater.
Negative Effect from Increased Fertilizer Use

Certain amounts of nutrients, including nitrogen, are essential for plant growth and quality, and an excess of these same nutrients can be detrimental to plant life. Ideally the nutrients for plant growth should be found within the soil without the addition of fertilizer. However, some agricultural practices have depleted the soil of these nutrients without letting the natural process of decay replace them (Huang and Uri, 1999). In order to meet the demand of a growing planet’s need for food, agribusiness has been forced to supply these nutrients outside of the natural processes in the form of fertilizer.

Unfortunately several practices in use today result in over-fertilization. It has been estimated that only about 30-70% of nitrogen fertilizer used in U.S. agriculture is recovered by the crop, which leaves the remainder to spread throughout the environment (Legg and Meisinger 1982). While I was working for the Resource Conservation District I realized another disparity that could increase nitrogen loss. Most farmers that use fertilizer on their crops receive their fertilizer application information from the same companies that produce the fertilizers. I believe that the fertilizer companies are encouraged to recommend enough fertilizer for their companies to turn a profit. Another factor contributing the over fertilization and resulting excess nitrogen is the uncertainty in soil nitrate levels that may cause farmers and ranch owners to use excess chemical nitrogen applications as a safeguard against crop failure (Babcock; McSweeney and Shortle 1989; Legg 1991). The lack of efficient fertilizer use could also be accredited to an overall lack of knowledge about nutrient management, which could present barriers for introducing new nitrogen fertilization application practices (Norris and Shabman 1992).
Over fertilization can have several adverse effects on the environment; volatilization of nitrogen creates the greenhouse gas N₂O. Since nitrogen (in the form of nitrate and nitrite) is easily dissolved into water, it follows the flow of water through the hydrologic cycle. Most of the damage done by nitrogen is to the rivers, lakes, groundwater and estuaries that we rely on for potable water and wildlife habitat.

Excess nitrogen can trigger an algal bloom, which accelerates the process of eutrophication; when the algae die in the later stages of eutrophication the oxygen levels within the body of water are significantly depleted (Huang and Uri 1999). The lack of oxygen in the water negatively affects higher order aquatic plants and animals (Huang and Uri). Eutrophication has been observed in Chesapeake Bay, which has contributed to a decline in bay fisheries (Kahn and Kemp 1995). In the Gulf of Mexico, the Mississippi and Atchafalaya rivers actually create a dead zone on a yearly basis (Carlisle, 2000). Every summer the dissolved oxygen levels drop too low to support life and in the summer of 1999 the area of the dead zone was 7,728 square miles (Carlisle, 2000).

**Harmful Effects of Excess Nitrogen Found in the Water Table**

Since nitrate follows water through the hydrologic cycle it is inevitable that excess nitrogen will become stored within the water we use everyday. This nitrogen can have harmful effects if it enters the body. The nitrogen enters the body as nitrate, which bonds easily with hemoglobin producing methoglobin. Unlike hemoglobin, methoglobin does not bond with oxygen and can eventually result in death if not treated immediately (Huang and Uri, 1999). This condition is known as methemoglobinemia or blue baby
syndrome. Nitrites have also been linked to nitrosamine; a compound widely suspected as carcinogenic affecting several organs within many animal species.

Timing of Nitrogen Fertilization

Applying nitrogen when uptake by the plants is the greatest can reduce the amount of excess nitrogen left in the soil and economic losses (Uri, 1999). Also applying nitrogen when environmental factors such as erosion and rainfall are less of a threat is another way to control excess nitrogen loss. According to these ideas there are some farming techniques that could benefit from applying nitrogen fertilizer only after planting, rather than the default of a pre-planting application (Bock, 1984; Kanwar et. al., 1988).

Huang and Uri (1999) analyzed the factors that would cause a farmer to apply nitrogen fertilizer at certain times during the planting process. The authors considered three essential variables that determine when a farmer will apply nitrogen fertilizer; nitrogen loss associated with application time, seasonal variations in nitrogen fertilizer costs and the farmers perceived risk of being unable to apply fertilizer due to environmental conditions. The conclusions of this study reported that moving farmers away from several nitrogen applications would result in an application strategy that was inefficient. Multiple additions of nitrogen fertilizer would allow the plants to absorb as much as possible without leaving as much excess nitrogen. The study also noted that to change the farmer’s application process would take sufficient incentive, such as economic compensation.
Benefits of Using Pre-sidedress Nitrate Testing Kits

The Pre-sidedress Nitrate Testing Kits are used to determine the amount of nitrogen found within the soil before applying nitrogen fertilizer. The kits can be purchased from local Resource Conservation Districts or from the manufacturer, EM Quant online. Some Resource Conservation Districts, including Monterey County, give out replacement strips and solution free. These kits are used to dissolve a soil sample within a 0.01 M CaCl₂ solution. A soil sample is collected in a clean container. This sample should not include the top two inches of soil because nitrate and nitrogen levels are high but too dry for active root growth. The soil sample is placed in a test tube with 30 ml of CaCl₂ solution until it displaces the solution 10-ml. After the sample is shaken vigorously a test strip is placed into the solution for one second then allowed to sit for 60 seconds. After this time, the strip color is used to estimate the nitrate concentration using the provided color chart. These levels are then divided by the correction factor for either dry or wet soil. Levels below 10 PPM of nitrate-nitrogen are considered low; levels above 20 PPM of nitrate-nitrogen are considered adequate to meet immediate crop needs.

Huang and Uri (1999) conducted an analysis of the benefit for the farmer and the benefit of the environment when N-test kits were used to monitor nitrogen fertilizer application practices. Much of their project was based on a carry-over rate. The carry over rate is an estimate of the amount of nitrogen left within the soil following the previous harvest. The analysis used the EPIC model (USDA, 1990) and tested seven management scenarios regarding the use of the PSNT kits.

(1) Annual nitrogen fertilizer applications based on the results of soil nitrogen testing.
(2) An annual fixed application rate of 180 kg/ha.

(3) An annual fixed application rate based on a twenty percent over estimate of the correct carry over rate.

(4) An annual fixed application based on twenty five percent under estimate of the correct carry over rate.

(5) An annual fixed application rate based on a fifty percent underestimate of the correct carry over.

(6) An annual application rate based on yield goals from the past three-year yield average.

(7) An annual application based on an expected plateau yield goal.

The conclusions of this study show that for scenarios 1, 2, 4, 5, and 7, use of the PSNT kits by the farmer will to reduce nitrogen loss and lead to improvement in net farm income. For scenario 3, the soil nitrogen testing will not lead to a reduction in nitrogen losses but may improve the farmer’s net income. Scenario 6, application depending on the average yield goal, the use of soil nitrogen testing will reduce nitrogen losses but will not improve the farmer’s net income. The results of the modeling study suggest that soil nitrogen testing is a beneficial practice when combined with knowledge of the carry over rate.

Salinas Valley

The Salinas Valley is responsible for a great deal of the agriculture produced within the state of California. The Farm Bureau report for Monterey County states that the agriculture production accounted for nearly $2.3 billion in revenue in 1998.
Agriculture producers are faced with the task of producing a massive amount of product while maintaining the viability of agricultural lands. According to the “1999 State of Monterey County” produced by Landwatch, a nonprofit development watchdog organization, agricultural use of water in the Salinas Valley accounts for 92.5% while urban use is only 7.5%. With this disparity, it is the responsibility of agribusiness to maintain the quality of the ground water at standards set forth by state and federal legislation. Unfortunately, according to a report produced in 1995 by the Monterey County Water Resources Agency, 25% of the wells within the Salinas Valley had nitrate concentrations that exceeded the EPA potable water standard of 45 mg/l. A similar report produced in 1998 showed that 40% of the wells had exceeded the potable water standards (Table 1).

<table>
<thead>
<tr>
<th>Location</th>
<th># of Wells</th>
<th>NO₃ (mg/l) 1995</th>
<th>Average Change 1993-95</th>
<th>Percent Change 1993-95</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 Foot Aquifer</td>
<td>78</td>
<td>35</td>
<td>+15.5</td>
<td>+44</td>
</tr>
<tr>
<td>400 Foot Aquifer</td>
<td>116</td>
<td>9</td>
<td>-1.8</td>
<td>-20</td>
</tr>
<tr>
<td>East Side</td>
<td>68</td>
<td>69</td>
<td>-16.1</td>
<td>-23</td>
</tr>
<tr>
<td>Forebay</td>
<td>81</td>
<td>45</td>
<td>+2.5</td>
<td>+5.5</td>
</tr>
<tr>
<td>Upper Valley</td>
<td>35</td>
<td>98</td>
<td>+30.8</td>
<td>+31</td>
</tr>
<tr>
<td>All Locations</td>
<td>378</td>
<td>41</td>
<td>+4.9</td>
<td>+12</td>
</tr>
<tr>
<td>Outside 400</td>
<td>262</td>
<td>55</td>
<td>+1.4</td>
<td>+2.5</td>
</tr>
</tbody>
</table>

Research Question

The purpose of this project is to assess the costs and benefits of using Pre-sidedress nitrogen testing kits to guide efficient application of fertilizer. This project will
attempt a cost-benefit analysis, based on a nitrogen budget analysis, of using these kits in relation to amount spent on nitrogen fertilizer. My hypothesis is that the cost-benefit analysis will determine that economic and environmental losses are greatly reduced by the use of the Pre-sidedress Nitrate Testing kits.

Methods

Study Site
This study was performed during the summer planting and harvest of the year 2000. The fields where this study was performed are all located in Monterey County, within the Salinas Valley. There were two fields located in Pajaro Valley, one field in Castroville and one in Soledad (Figure 1). All of the fields had similar soil types and climate.
The 36 middle rows of five conventionally farmed fields were sectioned off for this project's treatment. (Figure 2) The outer rows of these fields were fertilized in the same manner they had been for the past growing season; these rows were used as the control. The soil nitrogen of the middle 36 rows was monitored using Pre-sidedress Nitrate testing kits. The amount of nitrogen-nitrate was recorded in each field prior to planting. The soil nitrogen levels, according to these test kits, were then used to implement an effective fertilizer application process.
Application of Fertilizer

Pre-sidedress Nitrato Testing kits were used to assess the amount of nitrate-nitrogen in the soil of each treatment field. If these kits showed a value less than 20 PPM of nitrogen-nitrate then more fertilizer was added to ensure quality and quantity of the crop. If the estimate of soil nitrogen-nitrate was above 20 PPM it was considered that there was enough nitrogen in the soil for immediate plant needs.

Under conventional practices, local agriculture fields are usually given a fertilizer sidedress twice during the growing season. The first sidedress is usually applied before the planting season to prepare the soil for the new plants. The second sidedress is applied later in the growing season. The time of application is dependent on the quality and quantity of the crop at that time. The process is similar when using the Pre-sidedress nitrate testing kits. The kits are used to obtain an estimate of soil nitrogen to determine if the sidedress is needed. On the first sidedress date, the first treatment field in Pajaro 1 and the field in Castroville did not require fertilizer, addition of 40 lbs./ac of nitrogen fertilizer were applied to the treatment field in Pajaro 2. The final field in Soledad
applied 68 lbs./ac to the treatment field. Sixty pounds per acre were applied to all of the control fields except the Soledad field where 68 lbs./ac was applied (Table 2).

On the second fertilizer sidedress date the two Pajaro treatment fields received 40 lbs./ac, the Castroville treatment received 60 lbs./ac and the final treatment field in Soledad received 20 lbs./ac of nitrogen fertilizer. The control fields received 60 lbs./ac of nitrogen fertilizer during the second sidedress, except the Soledad field, which received 56 lbs./ac (Table 2). The amount of fertilizer applied on the treatment fields was controlled by the value in parts per million of nitrate-nitrogen within the soil. Any value less than 20 parts per million of nitrate-nitrogen would warrant the use of nitrogen fertilizer. After the second and final sidedress the Pajaro Valley fields were harvested in July while the Castroville and Soledad study sites were harvested in September.

**Table 2. A table of grower practices and amount of fertilizer applied in each treatment throughout the growing season.**

<table>
<thead>
<tr>
<th>Field Location</th>
<th>First Sidedress Application (lbs./ac)</th>
<th>Second Sidedress Application (lbs./ac)</th>
<th>Total Nitrogen Application (lbs./ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pajaro Valley 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-PSNT Treatment</td>
<td>0</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>-Grower Control</td>
<td>60</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td><strong>Pajaro Valley 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-PSNT Treatment</td>
<td>40</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>-Grower Control</td>
<td>60</td>
<td>60</td>
<td>165</td>
</tr>
<tr>
<td><strong>Castroville</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-PSNT Treatment</td>
<td>0</td>
<td>60</td>
<td>146*</td>
</tr>
<tr>
<td>-Grower Control</td>
<td>60</td>
<td>60</td>
<td>206</td>
</tr>
<tr>
<td><strong>Soledad</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-PSNT Treatment</td>
<td>68</td>
<td>20</td>
<td>194*</td>
</tr>
<tr>
<td>-Grower Control</td>
<td>68</td>
<td>56</td>
<td>236*</td>
</tr>
</tbody>
</table>

*Total season applications represents the sum of all fertilizer applications including pre-plant fertilizations and water run applications not appearing in sidedress columns.
Lab Analysis

Upon harvest, wet and dry weights were calculated for the lettuce petiole and leaves. The cartons of 24 romaine lettuce heads were weighed in the field at the point of harvest to compare the quantity between control and treatment. The soil was tested at harvest for the parts per million of nitrate-nitrogen. For quality the percentage of lettuce heads harvested was also noted. When the harvest was delivered to the lab at the University of California, Davis it was analyzed for total percent nitrogen. Nitrogen levels were also analyzed for samples of residual heads of lettuce left on the field. All nitrogen tests were performed in the lab at the University of California at Davis. Nitrogen was tested using kits similar to the PSNT kits used in the field.

The carton weights were used to perform a paired t-test to analyze differences in quantity between control and treatment fields. The nitrogen levels in each of the plant components were then used to design a nitrogen budget analysis. Inputs of nitrogen included the amount of fertilizer applied to each site. The main output of nitrogen that was measured was the nitrogen found in plant tissue at harvest (of plants actually harvested). I assume that the residual nitrogen remaining stayed within the soil and therefore is subject to leaching and volatilization. The amount of nitrogen left in the field and susceptible to loss was calculated and used in a cost benefit analysis to compare the cost of the Pre-sidedress Nitrate Testing kits to the benefit of reducing economic loss due to excess fertilizer use.

Results

Impacts on Lettuce Yield and Quality
A t-test of percent of plants harvested for each field was used to compare the means of the control and treatment crops. This analysis showed that the mean percent of plants harvested for the control and treatment was not significantly different (p<0.05) (Figure 3). T-tests were also performed for the carton weights and the amount of nitrogen found within the leaves. The test was performed on carton weights to show that yield was not significantly impacted by a reduced application of nitrogen fertilizer in the treatment fields (p<0.05) (Figure 4). The leaf nitrogen T-test shows that the lettuce reaches a saturation point of nitrogen uptake and does not exceed that point regardless how much excess nitrogen is found within the soil (p<0.05) (Figure 5).

Figure 3. Comparison of control and treatment fields for percent of lettuce heads harvested.
Figure 4. Comparison of control and treatment fields for cartons of 24 lettuce head weights.
Figure 5. Comparison of control and treatment fields for leaf nitrogen.

<table>
<thead>
<tr>
<th>Field Location</th>
<th>Total Percent Nitrogen</th>
<th>Treatment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pajaro Valley 1</td>
<td>4.5</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Pajaro Valley 2</td>
<td>3.5</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Castrovile</td>
<td>5.0</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Soledad</td>
<td>3.5</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

Nitrogen Budget Analysis

A nitrogen budget was created for the four study sites to assess the amount of soil nitrogen following harvest. This value is important because excess soil nitrogen can be lost through leaching or volatilization. However, it must be noted that this analysis is not a complete and closed budget analysis because soil nitrogen was not analyzed at the start and end of the experiment. The amount of economic loss due to excess nitrogen fertilizer use can be calculated based on a nitrogen budget analysis of inputs and outputs. The fertilizer added during the first and second sidedress were the inputs of the nitrogen. The nitrogen levels derived from the lettuce harvest encompass nitrogen removed during harvest. The residual nitrogen values found within the lettuce left unharvested were also
included in the output because although this organic nitrogen can remain in the soil for a longer period, it too is susceptible to loss. The remaining nitrogen is the change in the soil nitrogen pool from planting to harvest and potentially can be lost. The values for the nitrogen budget on each field are presented in Table 3.

Table 3. Nitrogen Budget Analysis by Study Site

<table>
<thead>
<tr>
<th>Site</th>
<th>Control vs. Treatment</th>
<th>Nitrogen Fertilizer Added (kg/ac)</th>
<th>Harvest Leaf Nitrogen (kg/ac)</th>
<th>Residual Nitrogen (kg/ac)</th>
<th>Change in Soil N Pool (kg/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pajaro Valley 1</td>
<td>Treatment</td>
<td>18.14</td>
<td>40.02</td>
<td>1.90</td>
<td>-23.78</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>54.43</td>
<td>41.08</td>
<td>2.53</td>
<td>10.82</td>
</tr>
<tr>
<td>Pajaro Valley 2</td>
<td>Treatment</td>
<td>36.29</td>
<td>30.92</td>
<td>3.23</td>
<td>2.14</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>74.64</td>
<td>31.80</td>
<td>6.35</td>
<td>36.69</td>
</tr>
<tr>
<td>Castroville</td>
<td>Treatment</td>
<td>66.23</td>
<td>49.76</td>
<td>0.37</td>
<td>16.09</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>93.44</td>
<td>48.53</td>
<td>0.78</td>
<td>44.12</td>
</tr>
<tr>
<td>Soledad</td>
<td>Treatment</td>
<td>88.00</td>
<td>55.81</td>
<td>0.28</td>
<td>31.90</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>104.33</td>
<td>56.59</td>
<td>0.46</td>
<td>47.28</td>
</tr>
</tbody>
</table>

I was able to perform a cost-benefit analysis from the nitrogen budget analysis. The budget shows that the treatment fields had smaller amounts of nitrogen left in the soil after harvest. This difference means potential for less economic loss for the farmer using the PSNT kits. Nitrogen loss in kilograms per acre determined by the budget analysis was multiplied by the price of the nitrogen fertilizer used on each field. This amount was then compared to the cost of purchasing and operating the Pre-sidedress Nitrate Testing kits that were used to implement an effective fertilizer management plan.
Discussion

Impacts on Lettuce Yield and Quality

The t-test analysis of percent plants harvested was used to evaluate not only the quantity of plants harvested on control fields versus treatment fields it was also used to show that the quality of the plants was not significantly different between control and treatment. When the lettuce is harvested there are certain guidelines in accordance with plant quality that the harvest crew must follow; the plants left after harvest are those that do not meet the quality standards. Since the mean values of the percent of lettuce harvested for the control and treatment are not significantly different, the treatment does not reduce amount of acceptable lettuce heads harvested or quality.

The analysis of lettuce leaf nitrogen was used to show that a lettuce crop can use only up to a certain amount of nitrogen excess nitrogen is not taken up but left in the soil. The nitrogen left in the soil is susceptible to leaching and volatiilization. The greater the nitrogen in the soil the greater the loss. The rainy season that usually follows harvest would greatly increase the amount of nitrogen leached into the ground water leading to a number of environmental and social problems mentioned in the introduction. There was not a significant difference between control and treatment of head leaf nitrogen. Using less nitrogen fertilizer did not hinder the amount of nitrogen taken up by the lettuce.

The t-test analysis of carton weights of head lettuce did not show a significant difference in yield between control and treatment. This test was used solely to evaluate the quantity of lettuce harvested between treatment and control. The mean quantity of lettuce harvested from control and treatment was not affected by the difference in
nitrogen fertilizer applied. This information, along with the cost-benefit analysis, can be used to encourage farmers to use less nitrogen fertilizer, in turn, slowing economic loss due to over fertilization.

**Nitrogen Budget Analysis**

The nitrogen budget analysis shows that a larger amount of nitrogen is left within the soil when the amount of fertilizer was applied at conventional rates. When the Pre-sidedress Nitrate Testing Kits were used to allocate an efficient amount of nitrogen fertilizer, the amount of nitrogen found in the soil after harvest is greatly reduced. The reduction in lost nitrogen can be used in a cost-benefit analysis to show that the initial cost and operation of the Pre-sidedress Nitrate Testing kit is outweighed by the economic gain due to reduced use of fertilizer.

This reduction in lost nitrogen is also important from an environmental standpoint. All of the problems that occur when excess nitrogen is leached into ground water are greatly reduced in proportion to the reduction in excess soil nitrogen. Nitrate follows water throughout the hydrological cycle and is easily leached through the fertile soil of an average agricultural field. Since the harvest usually happens before the rainy season it is important that excess soil nitrogen is reduced as much as possible. A cost-benefit analysis that encompasses the environmental costs, although important, was not included in this project because at this time there are no economic policies or incentives for growers to manage nitrogen loss.

**Cost-Benefit Analysis**

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The original cost for the Pre-sidedress Nitrate Testing Kit is $600; since replacement strips and solution can be found free from the local Resource Conservation District, the only other cost is to pay someone to operate the kits. Based on an employee who is paid $8 per hour (this amount was based on personal work experience) for a total of 10 hours (a liberal time estimate spent testing the soil) the total cost for buying and using the PSNT kit is $680. The cost of fertilizer was based on an average price per ton of $250. The cost to have someone apply the nitrogen fertilizer is the same for the treatment and control so it was not included in this cost-benefit analysis. Application costs could be potentially less in the treatment fields because of fewer sidedresses.

For the first growing season on a field of 50 acres, the price for fertilizing a control field is $1125. This cost was based on the average total nitrogen applied on the control fields from the project. For the treatment field the price for fertilization of 115 ($718.75) lbs./ac and use of the PSNT kit ($680) is $1398.75. The first growing season shows that the farmer will not benefit from using the PSNT kits (Table 4).

The second growing season, the initial price of the PSNT kit is not included in the total cost of fertilizing the treatment field because there is no need to buy another kit. The total fertilizer and PSNT kit usage cost over two growing seasons is $1597.50. The cost of fertilizer for the control field over two growing seasons is $2250. While the first season results in a small economic loss due to use of the PSNT kit, by the second season the farmer saves $652.50 when using the PSNT kits to control the amount of fertilizer applied. According to these results, the cost of the PSNT kit would have to be less than $326 dollars for the farmer to break even during the first growing season. Possibly if these kits were subsidized it would encourage their use by the farmers. Over just five
growing seasons a farmer on a 50-acre field has the potential to save a total of $1781.25 by using the PSNT kit to implement an efficient fertilizer application. This cost-benefit analysis does not account for the environmental benefits of using the PSNT kits to create an efficient fertilizer application. If these environmental benefits were put into economic terms the analysis might show considerably more benefit from using the PSNT kits after just the first growing season.

Table 4. Cost-benefit analysis over five growing seasons.

<table>
<thead>
<tr>
<th>Season</th>
<th>Cumulative Control Fertilizer Cost</th>
<th>Cumulative Treatment Fertilizer and PSNT Cost</th>
<th>Cumulative Difference in Fertilizer Cost (savings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season 1</td>
<td>$1,125.00</td>
<td>1398.75</td>
<td>-$273.75</td>
</tr>
<tr>
<td>Season 2</td>
<td>$2,250.00</td>
<td>$1,597.50</td>
<td>$652.50</td>
</tr>
<tr>
<td>Season 3</td>
<td>$3,375.00</td>
<td>$2,396.25</td>
<td>$978.75</td>
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<tr>
<td>Season 4</td>
<td>$4,500.00</td>
<td>$3,075.00</td>
<td>$1,425.00</td>
</tr>
<tr>
<td>Season 5</td>
<td>$5,625.00</td>
<td>$3,843.75</td>
<td>$1,781.25</td>
</tr>
</tbody>
</table>

Suggestions

As mentioned before, there should be a certain incentive to encourage farmers to utilize the PSNT kits. This study suggests that the farmer should either get a tax break for using the PSNT kits or the local and state governments subsidize these kits so that all farmers have access to them. According to the cost benefit analysis the kits would only have to be $274 cheaper for the farmer to break even the first year.
Another suggestion would be to keep a constant record of soil nitrogen levels through a government agency like the Resource Conservation District. These records should be openly available on the Internet or through agency’s files so that when a farmer needed to fertilize he or she could simply find the data and apply fertilizer accordingly. It could be possible to set up permanent monitoring stations much like those used by the USGS for stream discharge that could be linked directly to a database. These numbers could then be extrapolated and placed on the Internet. Then this data could be used to implement an efficient fertilizer application.

Acknowledgements

This project was possible with the collaboration of the U.C. Davis department of Vegetable Crops and Weed Science. Tim Hartz, Ph.D. was the head of the entire project. Tim’s influence was used to start relations with the farmers, produce literature for final analysis and general supervision of scientific methods. Tim Hartz is a qualified extension specialist and agronomist. He has worked on several projects involving nitrogen, agriculture and the Salinas Valley. His expertise was essential in creating and implementing this project.

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Works Cited


