IRRIGATION AND NITROGEN MANAGEMENT WEB-BASED SOFTWARE FOR LETTUCE PRODUCTION

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ABSTRACT

Lettuce growers on the central coast of California are under increased regulatory pressure to reduce nitrate loading to ground and surface water supplies. Two tools available to farmers to improve nitrogen use efficiency of lettuce are the quick nitrate soil test (QNST) for monitoring soil mineral nitrogen levels and weather-based irrigation scheduling for estimating water needs of the crop. We developed a web-based software application, called CropManage (https://ucanr.edu/cropmanage), to facilitate the implementation of both of these tools. The software allows growers to quickly determine an optimal fertilizer N rate based on the QNST and N uptake curves for lettuce. In addition, the software estimates the water requirement of the crop using evapotranspiration data from the California Irrigation Management Information System and models of canopy development. Preliminary field testing of the software in commercial fields demonstrated that growers can significantly reduce N fertilizer and water use without reducing quality and yield of lettuce.

INTRODUCTION

Commercial lettuce production traditionally uses high inputs of nitrogen (N) fertilizer (120 to 200 lbs N per crop) and irrigation water (10 to 18 inches per crop) to maximize yield and quality. Changes in water quality regulations on the Central Coast and spikes in fertilizer prices in recent years have prompted grower interest in increasing efficiency of nitrogen fertilizer use in lettuce. Lettuce growers could potentially use less N fertilizer and address water quality concerns by improving water management and matching nitrogen applications to the N uptake pattern of the crop. Two tools available to growers, the quick nitrate soil test (QNST) and evapotranspiration (ET) data from the California Irrigation Management Information System (CIMIS), have been shown to help better manage water and fertilizer nitrogen in lettuce production (Cahn and Smith 2012, Hartz et al. 2000). However, adoption of these practices has not been wide spread.

One reason is that these techniques can be time consuming to use, and vegetable growers have many fields for which they make daily decisions on fertilization, irrigation, pest control, and tillage. The QNST entails collecting a representative soil sample, extracting the sample, and calculating soil mineral N concentration. When deciding on an appropriate N fertilizer rate, growers also need to consider the N uptake rate of the crop, and mineral N contributions from soil and previous crop residues. Scheduling irrigations based on weather requires retrieving reference ET data from the CIMIS website, and determining an accurate crop coefficient that corresponds to the developmental stage of the crop. In addition, information on the soil water holding capacity and irrigation system performance is needed to determine the optimal irrigation interval and run-time. These calculations can be time consuming and often confusing for growers and consultants to integrate into an irrigation schedule.

To address many of the time constraints in managing water and fertilizer, we developed an online tool that assists growers and farm managers with determining appropriate water and nitrogen fertilizer applications on a field-by-field basis. The software automates steps required to calculate crop water needs from CIMIS ET data, and estimates fertilizer N needs for lettuce using quick N test data and models of crop N uptake. The web application also helps growers track irrigation schedules and nitrogen fertilizer applications on multiple fields and allows users from the same farming operations to view and share records.

METHODS

In collaboration with UC Agriculture and Natural Resources (UCANR), Communication Services, we launched a preliminary version of a web-based software program for managing nitrogen and water in lettuce production on Sept 1, 2011. The software application, named CropManage (ucanr.edu/cropmanage), is hosted and maintained on the UCANR Communications server in Davis, CA. Users can access the software through a web browser on their smart phones, tablet and desktop computers.

CropManage was designed to be intuitive for growers and farm managers to use. The user interface and menu structure were designed and developed under the oversight of collaborating growers, and follows common practices that they use to maintain records of fertilizers, soil tests, and irrigation.

The web application uses a secure login procedure so that only individuals with permission can view and/or edit water and nitrogen fertilizer records of a particular farming operation. After logging on, a screen displays a list of ranches/farms that the user has permission to access. By following the hyperlink for an individual ranch, the user can view a list of all active and/or past plantings associated with the ranch.

A database manages information associated with ranches, fields and plantings, which are used to drive the irrigation and N fertilizer models. The database also facilitates combining and displaying data from multiple sources, such as data from user entries, the CIMIS website, and field sensors. It also minimizes the necessity for reentering information. To establish a new ranch, data must initially be uploaded, which includes lists of field names, associated acres and soil types, as well as a list of nearest CIMIS stations. To add a planting (new crop) to a ranch, one selects the appropriate field, and enters lettuce type, planting/harvest dates, planted acres, bed spacing, and irrigation system characteristics. The planting “home” screen displays summary tables of soil tests, fertilizer applications, and watering schedules. When the user enters intended dates to fertilize and/or irrigate, the summary tables are updated with recommended fertilizer N rates (Table 1) and water volumes (Table 2). Data in tables can be exported into an excel spreadsheet file.

CropManage also has the option of automatically importing, analyzing, and displaying flow meter data, allowing growers to conveniently track the volume of water applied to their fields. Flow meters capable of producing a voltage pulse output proportional to the flow rate are interfaced with a datalogger that records flow at 2 minute intervals. The dataloggers are equipped with internet accessible cell phones, which permit flow data to be downloaded onto a computer in the Monterey County, Cooperative Extension office. The ANR server in Davis is scheduled to upload and analyze flow meter data files from the county computer four times per day.

In addition to storing and displaying records of soil tests, irrigations, and fertilizations, the software algorithms recommend N fertilizer rates and water applications appropriate for the stage of lettuce growth. The N fertilizer algorithm develops recommendations based on an N uptake curve for lettuce, soil mineral N status (QNST data), as well as estimates of N mineralization from the soil and residue of the previous crop. To create a fertilizer recommendation, the user must enter the intended fertilization date, a soil N test value, and estimated days until the next fertilization event. The model uses this information to determine the amount of N fertilizer needed to maintain the soil at a predefined threshold of soil nitrate. The soil nitrate threshold varies from 20 ppm NO_3-N at the early stages of growth to 15 ppm NO_3-N at the late stages.

The irrigation scheduling algorithm uses CIMIS reference ET data, crop coefficient values for lettuce, soil water holding capacity, and the application rate of the irrigation system to estimate the appropriate irrigation interval and volume of water to apply to maximize lettuce growth and minimize deep percolation. The algorithm is based on the crop coefficient model of Gallardo et. al. (1996) for estimating evapotranspiration of lettuce.

To obtain a recommended irrigation volume and interval, the user enters the date of the next irrigation and the software automatically obtains reference ET data from the nearest CIMIS weather station and uses the algorithms described above to estimate the crop coefficient. Historical ET data is used when current data is unavailable. The software also allows the user to select to use reference ET data from spatial CIMIS. Spatial CIMIS reference ET values are partially based on remote sensing estimates of net solar radiation and can provide improved spatial resolution, presumably increasing the accuracy of crop ET estimates for fields located in a different climatic zone than the nearest CIMIS station. The recommended irrigation volume is based on the estimated crop ET adjusted for irrigation system uniformity and leaching fraction, which are initially entered by the user.

Maximum soil moisture tension values known to slow growth of lettuce (-30 kPa) are used to optimize the recommended irrigation interval. The maximum allowable depletion of moisture between irrigations is determined using algorithms relating volumetric soil moisture to soil moisture tension and for estimating rooting depth.

RESULTS AND DISCUSSION

We tested and demonstrating the CropManage software in 10 commercial lettuce during the 2012 season. Portable flowmeters were installed on the main irrigation pipe in each of these fields so that the growers could view the volume of water applied during individual irrigation events, and compare their standard practice with the recommended volumes of applied water (Fig.1). In some cases growers standard irrigation practice appeared to be close to schedule recommended by the software (Fig. 1A.) In other instances, the grower standard practice was in excess of the recommended water volume by as much as 40% (Fig. 1B). Participating growers were responsible for monitoring soil nitrate levels of their fields using the quick nitrate test, and entering these values and fertilizer applications amounts into CropManage. Participants provided assessments of the software application that were used to improve the ease-of-use and the functionality of the online tool. We also conducted 2 demonstration trials comparing yield of lettuce grown under standard and CropManage recommended water or nitrogen management practices. One trial comparing the CropManage fertilizer N recommendation with the grower standard practice resulted in similar commercial yields using almost 30% less N fertilizer (Table

3). The other trial comparing the irrigation recommendation of CropManage with the grower standard practice resulted in a 12% savings in water following the CropManage irrigation schedule during the drip phase of the crop, and equal commercial yields between treatments.

Web-based software appears to be a useful tool for delivering decision support models to growers in a format that they can use for their daily operations, and provides a rapid means to extend new research finds to the agricultural community. Our preliminary work has demonstrated that CropManage could potentially help growers reduce production costs by applying less fertilizer and water, and minimize water quality impacts of vegetable production on surface and ground water supplies. The software tool also provides a convenient means for growers to keep records of their practices, which may help them demonstrate that they are meeting water quality regulatory objectives. Our immediate challenge is to increase the number of commodities included in CropManage so that growers have a tool that can address the full production system on the central coast. As more geo-referenced weather and soil data become available on the web, the accuracy of models for guiding cropping decisions can be improved. We plan to integrate soil survey and remote sensing data into future versions of CropManage. The main limitation of web-based software is that users need internet access, which can be a challenge in remote areas. As cell tower coverage expands, and access and internet speed improves, these types of online tools should become increasingly useful to the agricultural community.

REFERENCES

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Table 1. Fertilization table displayed in CropManage.

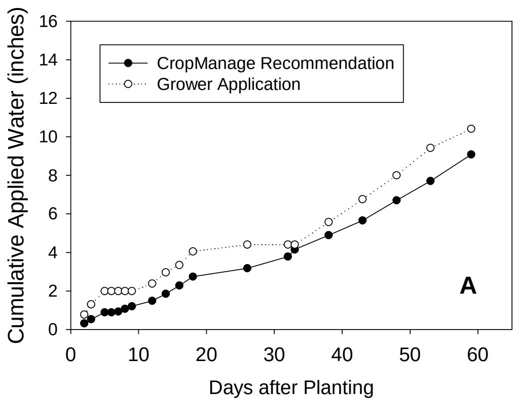
Fertilizer Date	Crop Stage/Event	Soil Nitrate Test Value	N fertilizer recommendation	Fertilizer Type	N applied	Fertilizer Applied
		ppm NO_3-N	lbs N/Acre		lbs/acre	gal/acre
05/06/12	1st sidedress	10	37	15-8-4	78	50
05/24/12	1st drip fertigation	20	5.1	28-0-0-5	46	15
05/29/12	2nd drip fertigation	22	11.2	28-0-0-5	31	10
06/09/12	3rd drip fertigation	26	0.0	28-0-0-5	31	10
06/11/12	4th drip fertigation	26	0.0	28-0-0-5	16	5
06/16/12	5th drip fertigation	20	56.5	AN-20	21	10
Total			110		223	

Table 2. Irrigation summary table displayed in CropManage.

Irrigation Date	Irrigation Method	Recommended Irrigation Interval	Recommend Irrigation Time	Recommended Irrigation Amount	Actual Applied Water	Crop ET
		days	hours	----------------	inches -----------------	
04/19/12	Sprinkler	N/A	N/A	N/A	0.86	--
04/21/12	Sprinkler	1	1.1	0.33	0.53	0.25
04/23/12	Sprinkler	1	1.1	0.34	0.61	0.25
04/27/12	Sprinkler	3	0.8	0.24	0.64	0.20
04/29/12	Sprinkler	1	1.0	0.30	0.51	0.22
05/09/12	Sprinkler	5	1.2	0.37	1.44	0.31
05/24/12	Drip	7	5.3	0.79	1.17	0.72
05/29/12	Drip	7	3.0	0.45	0.76	0.41
06/03/12	Drip	5	5.1	0.77	1.07	0.69
06/09/12	Drip	4	6.4	0.96	1.10	0.98
06/15/12	Drip	4	9.2	1.39	0.76	1.25
06/19/12	Drip	4	6.3	0.94	0.79	0.84
06/23/12	Drip	4	5.5	0.82	0.92	0.74
06/26/12	Drip	4	4.2	0.63	0.52	0.57
Total			50.3	8.3	11.7	7.4

Table 3. Large plot demonstration trial comparing CropManage N fertilizer recommendation during the drip phase of the crop.

Treatment	Applied N Fertilizer	Commercial Cut Product Yield
	------- lbs per acre	--------
CropManage	149	18760
Grower Standard	211	19114



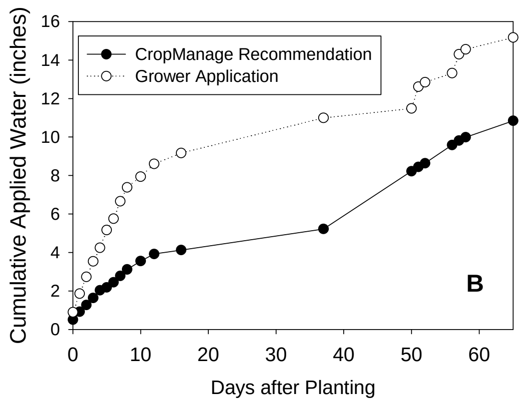


Figure 1. Comparison of actual and recommended irrigation water volumes for 2 commercial lettuce crops.