CROPMANAGE: AN ONLINE DECISION SUPPORT TOOL FOR IRRIGATION AND NUTRIENT MANAGEMENT

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ABSTRACT

Vegetable and berry growers on the central coast of California are under growing regulatory pressure to reduce nitrate loading to ground and surface water supplies. Two tools available to farmers to improve nitrogen use efficiency of these crops are the soil nitrate quick test (SNQT) for monitoring soil residual N concentrations and evapotranspiration (ET)-based irrigation scheduling for estimating crop water requirements. We developed a web-based software application, called CropManage (https://ucanr.edu/cropmanage), to facilitate the implementation of both tools. The software allows growers to quickly determine an optimal fertilizer N rate based on the SNQT and N uptake curves of cool season vegetables and berries. In addition, the software estimates the water requirement of the crop using reference ET data and estimated crop coefficients. Replicated and commercial demonstration trials of the software has shown that growers can significantly reduce N fertilizer and water use without reducing quality and yield of their crops.

INTRODUCTION

Vegetable growers on the central coast of California are under regulatory pressure to reduce nitrate loading to ground water supplies. Additionally, over extraction of ground water for agricultural production has contributed to seawater intrusion into coastal aquifers, which may be accelerated during the current drought. Vegetable growers could potentially use less N fertilizer and address water quality and quantity concerns by improving water management and matching nitrogen applications to the N uptake pattern of the crop. Two tools available to growers, the soil nitrate quick test (SNQT) and evapotranspiration (ET)-based irrigation scheduling, have been shown to help better manage water and fertilizer nitrogen in vegetable production (Cahn and Smith 2012, Hartz et al. 2000).

Although these techniques were introduced to growers more than a decade ago, implementation of the SNQT and ET-based irrigation scheduling into commercial farming operations has been slow. One reason is that both practices can be time consuming to implement, and coastal growers have many small fields to manage during a season. Scheduling irrigations based on weather requires retrieving reference ET data from a website, determining a crop coefficient, as well as information on soil water holding capacity and irrigation system performance. The steps involved in integrating this information into an irrigation schedule can also be time consuming. The SNQT also requires a significant time investment, including collecting a representative composite soil sample and preparing the sample for extraction. In addition to residual soil nitrate, growers also need to consider the N uptake needs of the crop, and future N contributions from the mineralization of soil organic matter and previous crop residues when deciding how much fertilizer N to apply.

To address many of the time constraints in estimating water and N fertilizer needs of coastal vegetable crops, we developed an online tool called CropManage (CM) 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 ET data, and estimates fertilizer N needs 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

Software description and development:

In collaboration with UC Agriculture and Natural Resources (UCANR), Communication Services and Information Technology, the first version of CropManage (ucanr.edu/cropmanage) was launched for lettuce production on Sept 1, 2011. The software application is hosted and maintained on the UCANR server in Davis, CA. Users can access the software through a web browser on their smart phones, tablet and desktop computers. The user-interface and menu structures of CropManage were designed to be intuitive for growers and farm managers to navigate, and were designed and developed under the oversight of collaborating growers. The interface incorporates a structure that growers commonly use to maintain records of fertilizers, soil tests, and irrigation. A structured query language (SQL) database manages information associated with ranches, fields and plantings within fields, which are used to drive the irrigation and N fertilizer decision support models. The database minimizes the necessity for reentering information. CM uses a secure login procedure and only users assigned to specific ranches by a "virtual ranch owner" can add, edit, or delete information. The ranch owner can designate the level of access that users have ranch information. Data from flowmeters and soil moisture sensors can be automatically uploaded into fields on CM and viewed from links in the irrigation table. CM automatically uploads reference ET data from the nearest California Irrigation Management Information System (CIMIS) weather station, and uses models of canopy development to estimate crop water requirements. Fertilizer N recommendations are based on the SNQT and N uptake demand curves for cool season vegetables and berries. Estimates of N mineralization from the soil and crop residues are also used to estimate fertilizer N requirements. Further details about the CM software operations are explained by Cahn and Hartz (2013) and Cahn et al. (2013a, 2013b), including descriptions of the algorithms used to drive the decision-support modules.

Although CM was originally developed for lettuce production, other coastal crops have been added to the software in recent years, including broccoli, cabbage, cauliflower and strawberry. Work is underway to expand CM features and capabilities to handle additional commodities, including spinach, celery, onions, raspberry, alfalfa, and almonds. An application programming interface (API) is also being developed to facilitate interfacing CM with other software applications. The API feature will allow proprietary software to utilize the algorithms developed for CM and to upload or to download data to and from CM. The API will also provide and easier means to link CM to other online software applications.

Field trials:

Replicated trials were conducted for lettuce, broccoli, and strawberry during the past 3 years to validate the accuracy of the algorithms used in CM to recommend fertilizer N and irrigation schedules. Lettuce and broccoli trials were established at the USDA-ARS field station in Salinas CA in 2012 and 2013, and are described by Johnson et al (2014). Treatments compared water management strategies: grower standard practice, CM recommendation, and Satellite Irrigation Management System (SIMS) recommendation. Similar to CM, irrigation recommendations from SIMS are also based on reference ET data. Treatments in these trials were replicated 5 times and plots were harvested at crop maturity following commercial practices. Additional replicated trials were conducted in strawberries at the Driscolls research farm near Watsonville CA during the 2013 and 2014 seasons. Irrigation treatments included the grower standard irrigation practice, 50%, 75%, 100% and 150% of the amount of water recommended by CM.

Nitrogen management trials were conducted in 5 commercial lettuce fields during 2012 and 2013. Treatments were not replicated in these trials but the tests provided an opportunity to evaluate CM under commercial conditions. Adjacent plots, measuring the width of a commercial harvester and the length of the field, were managed under the grower's standard practice or following the N recommendations of CropManage. Large-scale non-replicated trials were also conducted in 2 commercial broccoli fields in 2013 to evaluate if CM irrigation recommendations could reduce water use. Both broccoli fields were planted and established under sprinklers. Irrigation treatments were imposed when the grower had switched to drip irrigation.

Grower outreach and participation:

Both hands-on workshops and field demonstrations of CM have been regularly conducted to introduce and train growers and industry clientele to use the online decision support tool. During 3-hour workshops we provide hands-on training to participants so they can learn step-by-step how to add new ranches and plantings to CM, and how to obtain fertilizer and irrigation recommendations, and update records for plantings.

A blog (http://ucanr.edu/blogs/CropManage/index.cfm) was launched in 2012 which provides users with detailed instructions on how to use CM and keeps users updated on new developments in the software. Links to specific topics in the blog can be found on the CM website under the help menu. We also added the capability to send emails directly to CM users to inform them on updates and educational opportunities.

CM was demonstrated in 6 commercial fields during the 2014 season. The irrigation systems of each field was equipped with a flow meter to record irrigation applications and tensiometers were installed at 3 locations in each field. Irrigation and tensiometer data were automatically uploaded to CM. Soil nitrate was monitored using the SNQT before each fertilizer application. Participating growers entered fertilizer data into the CM, and regularly reviewed data in CM to help with decision making on water and N applications. The SNQT also requires an investment in time, entailing 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.

More than 550 users have accounts on CM and more than 250 ranches have been added to the database as of December 1, 2014. We plan to add capacity to generate reports summarizing user activity so that we can determine the percentage of users that are routinely using the decision support tool.

RESULTS AND DISCUSSION

Replicated trials in broccoli and lettuce conducted at the USDA-ARS research station demonstrated that similar marketable yields could be attained under the CM recommendations compared to the standard grower practice, using 30% to 40% less water (Johnson et al. 2013). Both the ET-based SIMS and CM algorithms provided similar irrigation recommendations with differences generally less than 0.5 inch for the seasonal total applied water. There were no significant differences in yield between the SIMS and CM treatments. Trials evaluating the CM irrigation algorithm for strawberries demonstrated that applying 100% of the water recommended by CM maximized marketable yield and quality.

The 5 large-scale strip trials in lettuce resulted in average reduction in N fertilizer of 57 lbs N/acre, compared to the grower standard practice, by following the CM recommendations during the season (Table 1). Average soil nitrate concentration in the 0-1 foot depth was 32 ppm N less than the grower standard at harvest (Table 1). The lower concentration of N in the top layer of soil reduced the potential for nitrate leaching losses during the pre-irrigation of subsequent crops or during winter rain events. Large-scale non-replicated trials conducted in commercial broccoli fields resulted in 48% less water use under the CM treatment during the drip phase of the crop without affecting marketable yield.

Growers participating in demonstration trials found that CM was useful for comparing recommended irrigation and N management practices with their standard practices. For example, by comparing how much water was actually applied to the recommended amounts, growers could determine if they were over or under irrigating, and if they were potentially leaching nitrate from the root zone of their crops. Soil nitrate data was used to determine if N applications needed to be adjusted from the grower standard practice and to provide evidence of nitrate leaching losses. Participating growers also provided feedback on how to improve CM. Comments ranged from how to improve the user interface, facilitate importing of data, and improve the displaying of data so that it could be quickly understood by the user. All of these suggestions are being incorporated into the next version of CM.

SUMMARY

The current project has demonstrated that web-based applications are useful for delivering accurate decision support to growers, and in a format that they can incorporate into their daily farming operations. Results from replicated and large-scale non-replicated trials suggest that CM could potentially help growers reduce production costs by optimizing fertilizer N and water applications, and minimize water quality impacts to surface and ground water supplies. Growers have also expressed interest in using CM for maintaining records of their practices, which may help them demonstrate that they are meeting water quality regulatory objectives. Web-based tools also provide a rapid means to extend new research findings to the agricultural community. For example, based on the results of field trials conducted by Cahn et al. (2014), we plan to incorporate new algorithms into CM that will estimate the fertilizer value of N in irrigation water. A pressing need is to increase the number of commodities included in CM so that the tool can address the full production system on the central coast. Additionally, we are working on adapting CM for commodities grown in other regions of the state, such as warm season vegetables, field crops, and trees crops. A continuing challenge is to reduce the time commitment for growers that use CM. By providing a more flexible and intuitive interface, and faster computing time, we anticipating the utility of the decision support tool will be improved.

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Table 1. Applied nitrogen fertilizer, soil nitrate, and yields for lettuce strip trials.

Strip Trial #	Management treatment	Fertilizer N	Final soil nitrate-N	Marketable Yield	Yield difference between treatments
		lbs/acre	ppm NO_3-N	lbs/acre	%
	---------------------- iceberg cored 9/5/12 --------------------------				
1	Grower	183	--	64307	
	CropManage	143	17.7	65713	2.2
	---------------------- romaine cored 10/17/12 ----------------------				
2	Grower	211	95.2	19114	
	CropManage	149	71.4	18760	-1.9
	---------------------- romaine cored 9/24/13 -----------------------				
3	Grower	263	87.5	15946	
	CropManage	162	22.5	15644	-1.9
	---------------------- romaine cored 9/19/13 -----------------------				
4	Grower	96	41.7	24903	
	CropManage	71	41.7	27035	8.6
	---------------------- iceberg cartons 10/18/13 ----------------------				
5	Grower	124	62.5	32765	
	CropManage	62	21.0	38434	17.3
	---------------------------- Average ---------------------------------				
	Grower	175	71.7	31407	
	CropManage	118	39.0	33117	4.9

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