VARIABLE APPLICATION OF WATER AND CHEMICALS THROUGH CENTER PIVOT SPRINKLER SYSTEMS

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INTRODUCTION

Increasing concern about the impact of crop production practices on the environment requires improved equipment, systems and management techniques to apply only the necessary amount of water and chemicals while sustaining crop production. Researchers and farmers alike are beginning to recognize that fields are not homogeneous in terms of optimum input requirements and that there are economic and environmental benefits to differential application of water and chemicals rather than a uniform application over the entire field. Soil variability in water holding capacity, texture, horizon depths, weed distribution, and existing fertility levels contributes to different amounts of water and chemicals needed for uniform and near optimum production. Application of chemicals where not needed increases production costs and potential degradation of the environment.

OBJECTIVE

The objective of this research effort is to develop and test a sprinkler irrigation system that can be used for spatially variable application of water and chemicals. There is an increasing desire and need to apply both fertilizers and pesticides more precisely and at reduced rates to reduce the risk of pollution. Using the irrigation system to transport the chemical application system allows the producer to schedule chemical application optimally and reduces exposure to chemicals. Our approach is to make the sprinkler irrigation system be multi-functional, where water and chemicals can be applied independently.

APPROACH

The typical approach for improving crop management to account for spatial variability involves three main steps. Initially, additional data are acquired to sufficiently describe the variabilities of interest. Secondly, these data are analyzed to make better management decisions that can finally be implemented within the crop production system.

Prescription or site-specific farming is an excellent example of this approach. Although it is being adopted and used commercially in rainfed agriculture production, primarily for application of nutrients and mapping of harvest yields, limited attention has been given to the differential application of water and chemicals in irrigated crop production systems.

Producers are very concerned about the cost and time required to adequately sample and characterize the variabilities of interest. Several approaches are being investigated for rapidly assessing actual soil moisture and nitrogen status of corn and thereby reasonably obtaining the necessary additional data. Geographical Information System (GIS) technology is particularly suited to manipulating and analyzing large amounts of spatially variable data. In the past, GIS has focused primarily on management issues over large geographical areas, but it can also be used to map variabilities in smaller geographical areas such as individual fields and manipulate these data to identify areas which could benefit from differentially applied water and chemicals. The final step of implementation is the main focus of this paper, which explains current research on the development of sprinkler equipment that can differentially apply water and chemicals.

Experimental Setup

A system for variable application of water and chemicals is being developed and tested on a replicated water and nitrogen study with two water treatments and three fertilizer treatments at the Agricultural Research, Demonstration, and Education Center of Colorado State University. A linear-move sprinkler is being used to control variable applications of water and chemicals to research plots, but the technology and programming for dealing with spatial variabilities can also be applied to center pivot systems, which are more widely used in commercial applications. The 28 ac field, which includes a 7 ac water-nitrogen study area, is irrigated with a 582 ft linear move sprinkler traveling 2100 ft. The machine is electrically guided with a buried-wire guidance system. Water supply is from underground pipe with two hydrants located at the one-quarter and three-quarters points of the field. Three independent application systems are used for applying water and chemicals. The first system is the primary irrigation system, capable of applying water beneath the corn canopy. The second system is a unique pulsing system for applying chemicals on the crop canopy at very low rates, and the third is a 'washoff' system for applying small amounts of water to wash chemical solutions off the crop canopy if necessary. Each of the four spans of the sprinkler system is divided into two sections, resulting in eight independently controlled segments of each application system. In the direction of machine travel, the 7 ac field is divided into three sets, resulting in 24 separate rectangular plots. Randomization of the 70 ft by 140 ft plots requires the ability to apply water at different rates along the lateral of the linear move as well as in the direction of travel.

Water application system

Water is taken from the mainline through a 1 1/2 in, 24 v electric solenoid valve into a 1 1/2 in PVC pipe manifold with drop tubes spaced every 5 ft. Senniger Quad-IV[1] heads with 6 psi pressure regulators, located approximately 15 in above the soil surface, are used in the spray mode to minimize wind drift and the width of the transition zone when changing application depths. Check valves are installed upstream of each head to provide instantaneous shutoff and prevent drainage from the drop tube when the water is turned off.

A computerized primary control panel, capable of controlling nine output relays, is installed on the cart of the linear move sprinkler and provides the ability to program changes in application depth in the direction of travel. Although each nozzle is the same size and hence has the same instantaneous application rate, by applying water for a fraction of each minute, it is possible to reduce the average application rate, yet maintain a coefficient of uniformity of 94% (Fraisse, 1993; Fraisse et al.,1993).

Since the computerized primary control panel does not have the capacity to control each manifold directly, an auxiliary controller interfaced to the primary control panel is programmed with several predetermined algorithms, each of which pulse each half-span manifold at the desired frequency to obtain the correct average application rate for satisfying the plot randomization requirements. The desired algorithm is selectable by operating the appropriate primary control panel output relays, which specify the input conditions for the auxiliary controller. The primary control panel also communicates via radio with a base station microcomputer to enable remote monitoring, control, data storage, and programming of the plot treatments from the irrigation office. Figure 1 shows the information flow schematically.

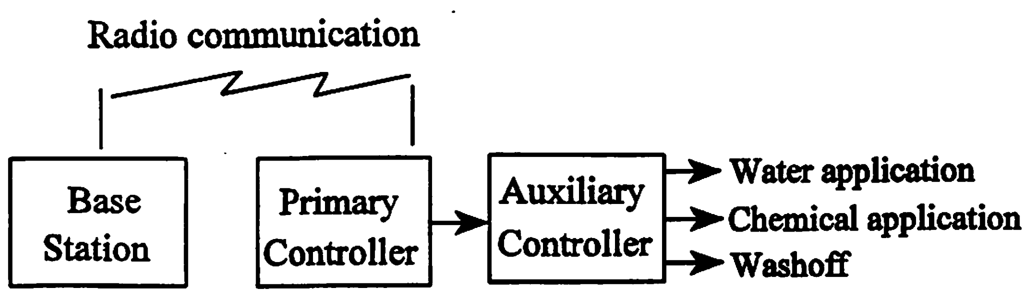

Figure 1. Schematic of information flow.

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[1]Brand names are provided for the convenience of the reader and do not imply endorsement by USDA.

Since no position sensing capabilities are commercially available for the linear-move sprinkler to enable programming operational changes at a particular location, position is calculated either by (1) counting the revolutions of a bicycle wheel mounted on the linear move cart or (2) counting the number of seconds that the cart drive motor runs. The tires on the cart of the linear-move sprinkler are filled with calcium chloride solution to reduce slippage of the drive wheels. Whisker switches contacting small metal posts at known distances along the cart track provide an input signal to the primary control panel, indicating the cart has reached known distances along the edge of the field. Knowledge of when the machine passes these known distances enables periodic correction of the calculated position based on wheel revolutions or cart run time. It appears that sprinkler position can be calculated quite accurately when the appropriate corrections are applied to a sufficient number of points at known distances. Significant variations in actual travel speed were observed when the system was applying water, compared to when the system was moving dry.

Chemical application system

A unique pulsing spray is used to apply liquid nitrogen fertilizer. This technique uses a small diaphragm pump to pressurize a thin-wall polyethylene tubing with spray nozzles at 8.3 ft intervals and attached to an adjustable height boom. When pressure in the tubing is relieved at the first nozzle, a small flap valve diverts the liquid out through the nozzle causing a small burst of spray. This relieves the pressure in successive sections of the tubing, allowing the tube to contract and the next successive valve to open, so that spray pulses progress downstream. Repressurizing the tubing closes the openings to each of the nozzles. The application rate can be varied by varying the time interval when pressure is relieved in the tubing. The application rate ranges from 3 to 200 gal/ac. The third application system, consisting of low discharge, large radius of throw sprinkler nozzles spaced at 20 ft, is designed to apply .20 in of water at the maximum travel speed of the sprinkler (100% control timer setting). This system can operate simultaneously with the chemical application system to wash applied chemicals, such as fertilizers, from the leaves if required to prevent foliar damage.

DISCUSSION AND RESULTS

Corn is planted in 30 inch rows in the direction of machine travel. The Senninger Quad-IV heads in the spray mode are installed on a 60 inch spacing and 15 inches above the ground. They produce a uniform application and minimize wind drift. Application rates and field slopes are sufficiently small that surface translocation or runoff is not a concern. Although not all of the equipment was fully functional for the entire 1994 irrigation season, the application systems performed reasonably well during the first year of testing. Pulsing the spray heads for a fraction of each minute appears to be a viable way of varying water and chemical applications without sacrificing application uniformity or requiring extensive additional hardware and control equipment. Some significant differences in the opening times of the individual control valves to each manifold were observed. The effect of these time differences was minimized by increasing the pressure loss (i.e. partially closing the valve) at some of the manifold inlets to reduce the time delay, and adjusting the on-time in the auxiliary controller to compensate for the remaining difference in time delay.

The auxiliary controller used to pulse the manifold valves is capable of controlling 16 outputs but is expandable by adding more control modules. Although specialized microcomputer software was used to simplify programing the logic in the controller, a working knowledge of control theory is very helpful in developing an efficient control program. There is a tradeoff between the level of control and the complexity and cost of the required equipment. While it is possible to control individual heads, the type of sprinkler package, hardware costs, and the level of management required to realize the full benefit of individual head control, make it difficult to justify economically.

The height of the chemical application system above the ground can be adjusted manually depending on the desired placement of the chemicals but must be above the crop canopy. The chemical application system was not fully tested for different chemicals under a variety of conditions, but limited testing indicates acceptable application uniformity above the crop canopy. Although application uniformity is not as critical , the 'washoff' system also appears to give acceptable uniformity as well.

A cooperative research and development agreement exists between USDA-ARS and the center pivot and linear-move irrigation system manufacturer supplying the equipment for this study. The focus of this agreement is to adapt the variable application systems to commercially available equipment. The goal of the cooperative effort between research and manufacturing is to shorten the production time for making this variable application technology available and adopted on the farm. The reduction of chemicals for fertility and pest control that can be achieved with this technology will help protect the environment and may reduce production costs if the savings in chemicals and/or improved timeliness exceeds the additional application equipment costs.

SUMMARY

A 4-span linear move sprinkler system was modified to apply variable water and chemical amounts on 24 plots in a 7 ac field for a water and nitrogen study. The first of three independently controlled application systems applied irrigation water only. A commercially available computerized control panel controlled the travel speed, hence application depth, in the direction of travel. Variable water application in each half-span along the lateral was achieved by pulsing the flow to individual manifolds with an auxiliary controller interfaced with the primary control panel. The coefficient of uniformity (CU) of

irrigation within each plot exceeded 90%. The second system applied liquid fertilizer by pressurizing thin-wall polyethylene tubing which had spray nozzles at 8.3 ft intervals. When pressure is momentarily relieved at the first nozzle on the inlet side, a small flap valve diverts the liquid out through the nozzle. This relieves pressure in successive sections of the tubing, causing a small burst of spray in each of the remaining nozzles. Application rate can be varied between 3 and 200 gal/ac by varying the time interval for relieving pressure. The third application system, consisting of low discharge sprinkler nozzles spaced at 20 ft, can be operated simultaneously with the chemical application system to wash off applied chemicals, such as fertilizers, which could harm the crop if not washed from the leaves. Although additional testing under various conditions is necessary, the concept of pulsing sprinkler heads to vary application rates appears to be very workable.

REFERENCES

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