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For as long as farming has been practiced, farmers have realized that yield, soil characteristics, and pest infestations vary across fields. Until recently, farmers have dealt with this variation by manually adjusting fertilizer applications according to fertility test results, and have spot sprayed pesticides to control localized pest populations. The technology to increase the ease and precision of such applications has increased tremendously in the past five years. Much of this progress can be attributed to increased computing capacity and speed. Several developments have occurred that will significantly impact the way in which weeds are controlled in the near future, and some of these technologies are already being used in the northern plains states. These new technologies can be broken in two groups, "real-time" weed detection, and what I'll call historic or geographic information systems (GIS) data management of agricultural field information. The "real-time" sensors detect weeds and activate the sprayer based on a threshold criteria, or simply activate the sprayer every time a weed is detected. The GIS approach activates the liquid or dry bulk application based on soil physical and chemical properties, or on weed seedbank numbers.

Because weed populations, and soil physical and chemical properties vary in most fields, pesticide applications could be made according to need, eliminating over- or under- application. The amount of pesticide applied would likely be reduced because it would be applied on an "as needed" basis. The use of such application equipment would also reduce the likelihood of crop injury and off-site movement of pH and organic matter dependent herbicides.

"Real-Time" Plant Detection

"Real-Time" is accomplished by fingerprinting plants based on their light reflectance properties and plant shape. Each plant reflects different amounts of light at different wavelengths. This reflectance data coupled with the plant shape data can be used to create a dictionary of weeds. Sensor systems currently marketed or under development differ in their ability to detect weeds, these differences are largely due to the level of detail the sensor system is capable of processing. For example, a sensing system is currently being marketed that can detect living vegetation (weeds) in soil and crop residue. The sensing device is intended to be used to "spot-spray" foliar active herbicides in an ecofallow or no-till cropping system. The sensor is designed to compare differences in reflectance in the red and near-infrared light regions. Relatively small differences in reflectance occur for soils, while large differences exist for living plants. In this system, the ratio of the two wavebands of light is computed almost

instantaneously. If a plant is detected, a signal is sent to a microprocessor and then on to a solenoid valve. In the current system, one reflectance ratio sensor is mounted in front of each nozzle.

Other real time sensors are under development that rely on machine vision technology. These sensors will not only detect living vegetation but will also distinguish between species. Machine vision is an emerging technology which has the potential for replacing the human eye in some control systems for agricultural machines. Research has developed a background for applications, such as tractor guidance, plant identification, pesticide application, and grading and sorting products.

Most machine vision systems use a version of a video camera. The lens of a video camera projects an image onto a sensitive surface. The circuitry of the camera scans across that surface in a number of closely spaced horizontal scan lines, measuring the light intensity at each point along the line. A signal representing this light intensity is transmitted one line at a time. A full image is called a frame and contains 525 lines, 480 of which contain image information. To prevent perceived flicker, the odd numbered lines are transmitted first, then the even numbered lines. Each of these 240-line sets are called a field. The standard scan rate is 30 frames per second. In order for a computer to interpret this data stream, individual frames or fields must be identified, captured and then interpreted by the computer.

Several promising machine vision developments have occurred in recent years. An insecticide applicator has been developed that applies insecticide in tree orchards based on sensed tree volume. The video sensor turns the sprayer on and off based upon presence or absence of trees and applies active ingredient according to tree volume. This system is in commercial use in Florida. Several researchers are studying ways in which individual weed identification can be accomplished. If this were possible, think of the possibilities, injection systems that spray grass or broadleaf herbicides only when those weeds are present in the field. Long image processing times and high costs of equipment must be overcome before such a system is cost effective.

Geographic Information Systems to Regulate Herbicide Application

Unlike the plant detection sensors outlined above, GIS relies on data previously collected from a field. The data are then managed to regulate the pesticide application process. GIS software and hardware is commercially available to map variations in grain yield, manage data on soil nitrate levels and to regulate nitrogen applications according to fertility maps, soil pH and organic matter content. In addition, herbicide rate can be regulated according to these same soil properties, particularly herbicides whose availability to plants, and carryover potential is influenced by soil pH, texture, and organic matter content. Research is currently under way in which a GIS approach is compared to conventional methods of herbicide application in corn and soybean, and significant reductions in herbicide use have been found. In addition to regulating herbicide application based upon soil physical and chemical properties, GIS field maps

characterizing depth to groundwater, and weed seedbank population data could be used to determine when a herbicide should or should not be applied.

A number of companies, Soil Teq, Micro-trak Systems, Lor-Al, Crop Technology, and Pavelski Enterprises, are already manufacturing and marketing hardware and GIS software to regulate dry bulk fertilizer and herbicide applications based upon the above mentioned soil properties. Because of the cost of retrofitting application equipment and the expertise necessary to interface the GIS software with the application equipment, implementation of this technology will likely occur through adoption by commercial applicators.