Precision Agriculture Technology for Horticultural Crop Production

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SUMMARY. Precision agriculture is a comprehensive system that relies on information, technology and management to optimize agricultural production. While used since the mid-1980s in agronomic crops, it is attracting increasing interest in horticultural crops. Relatively high per acre crop values for some horticultural crops and crop response to variability in soil and nutrients makes precision agriculture an attractive production system. Precision agriculture efforts in the Department of Biological and Agricultural Engineering at North Carolina State University are currently focused in two functional areas: site-specific management and postharvest process management. Much of the information base, technology, and management practices developed in agronomic crops have practical and potentially profitable applications in fruit and vegetable production. Mechanized soil sampling, pest scouting and variable rate control systems are readily adapted to horticultural crops. Yield monitors are under development for many crops that can be mechanically harvested. Investigations have begun to develop yield monitoring capability for hand harvested crops. Postharvest controls are widely used in horticultural crops to enhance or protect product quality.

Precision agriculture can be defined as a comprehensive system designed to optimize agricultural production through the application of crop information, advanced technology, and management practices. To be a truly comprehensive system, it must begin during the planning stages of the crop or commodity and continue through the postharvest processing phase of production. Information, technology and management are the keys to success in this production system (Roberson, 1999).

Information can be the modern farmer's most valuable resource. Precise information is important in every phase of production from initial planning to postharvest. Information requirements include spatial and temporal data on the crop, soil, pests, topography, and weather during the field production phase. During the postharvest phase, temperature, humidity, moisture, and a host of other parameters are of importance. Some of this information can be gleaned from previous crop records. Other data must be acquired in real time for immediate application by the system.

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Technology is the second critical component of the system. Production equipment and systems must be compatible with the operational requirements of precision agriculture. The foundation of precision agriculture, from the mechanization perspective, is traced to the development of precision seeding and chemical application equipment. Equipment designed for accurate control and delivery of crop chemicals makes modern variable rate applications possible. In addition, the global positioning system (GPS), geographic information systems (GIS) and computers are key building blocks in this foundation. GPS, with differential correction, has proven to be an effective tool to georeference features or data in the field. GIS provides the ability of organize data by georeferenced position. Computers have given us the analysis and control capabilities to develop the comprehensive system needed in site-specific and postharvest process management.

Management is the third key to success. Management gives the producer means to analyze information and make timely and sound production decisions. Using the information and technology available to the modern farmer, management practices can be implemented to achieve objectives laid out for precision agriculture. Without effective management practices, the information and technology add very little to the effectiveness of the production system.

Objectives

The objectives of a comprehensive precision agriculture program are summarized as increased production efficiency, improved product quality, more efficient chemical and seed use, energy conservation, and surface and groundwater protection.

These objectives point to two critical concerns which must be addressed before adopting any production system: 1) "Is it cost effective?", and 2) "Is it environmentally responsible?".

Precision agriculture methods

Precision agriculture projects are divided into two arenas at North Carolina State University, site-specific management (SSM) and postharvest process management (PPM). Site-specific management is the field production phase of the system, postharvest process management begins the instant the crop is harvested and continues until final processing or consumption.

Site-specific management

Site-specific management differs from the traditional practice of whole field management. In whole field management, average conditions for a field or a farm are determined and management practices applied accordingly. In site-specific management, fields are divided into management zones, often called grids, where each zone is quantified and managed separately.

To practice site-specific management, producers must have the necessary information and technology at their disposal so that a comprehensive management plan can be executed. Spatial information requirements include soil chemical and physical properties, field topography, pest populations, crop diseases, and available moisture. Technology is necessary to acquire and use this information. Key technologies include GPS / GIS, control systems, and yield mapping systems. However, in order for this technology to be used successfully, it must build upon production equipment: planters, sprayers, spreaders, harvesters, etc., that is compatible with the high level of control and accuracy required in precision agriculture. Equipment that cannot perform adequately in conventional production will not be acceptable in precision agriculture.

Field scouting and mapping are used in precision agriculture to determine georeferenced information on a wide variety of parameters. Georeferenced soil sampling has proven to be an effective tool in defining soil variability within a field. Once critical soil or nutrient properties are identified, steps can be taken to address those problems as needed for each location within a field. In addition, maps can be developed by field scouts for many crop pests. Locating pest populations in limited areas of a field makes site-specific treatment possible. Development of real time sensors to monitor critical parameters can complement map based data. Sensors to measure soil fertility, plant stress, or pest populations could allow management decisions to be implemented automatically with appropriate control technology and management algorithms.

Precision planters are designed to accurately meter and place seeds in the seedbed. Precise control of population, spacing ,and depth are hallmarks of precision planting. Advantages of precision planting over conventional planting include lower thinning costs, reduced seed usage, reduced competition between young plants, and reduced shock to plants during thinning. Disadvantages include protection of stand after emergence, seedbed preparation is more critical and seed treatment is often necessary to improve planter performance. Once the decision to use precision planters has been reached, the opportunity to apply site-specific management principles can be considered. Variable rate controls can be added to the planter to give the

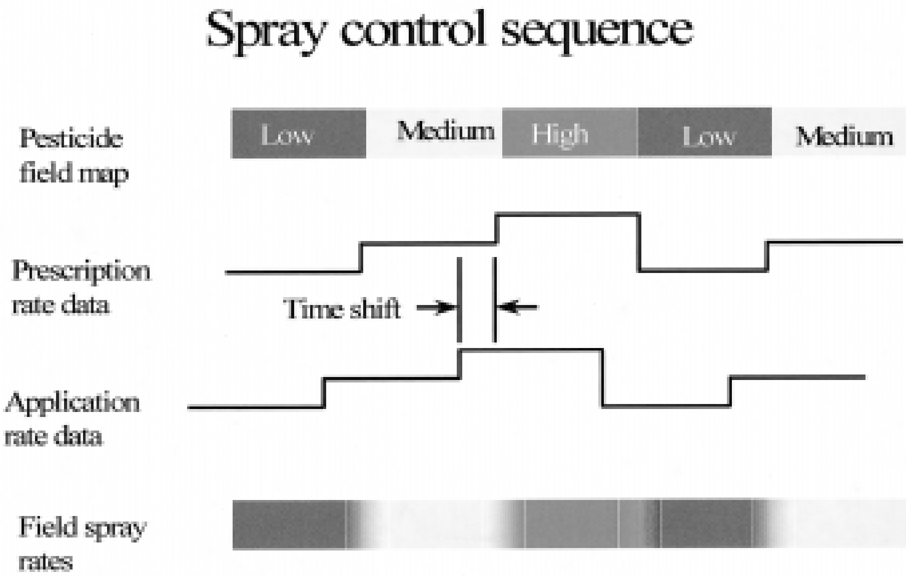

Fig. 1. Converting a spray map to field application.

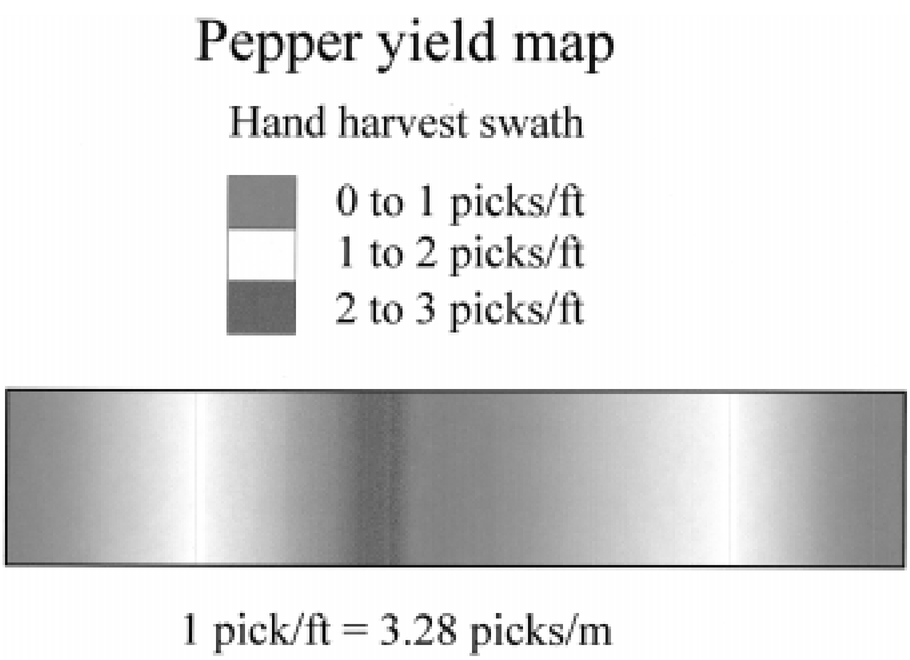

Fig. 2. Hand-harvested pepper yield map.

operator the ability to adjust seed population on the fly to match optimum field requirements.

Variable rate spreaders and sprayers are also key pieces of site-specific management technology. Variable rate applicators enable the grower to vary rates of inputs to match the specific requirements of management zones in the field. This is accomplished by using GPS to determine field position, and an onboard computer to read a prescription map or interpret data from sensors. The control system then adjusts the applicator settings to achieve the prescription rate. Variable rate application of lime, fertilizer, and pesticides are all technically feasible and have been demonstrated. Total usage of lime and fertilizer may not be reduced. However, it will be used more effectively in the field by matching application rates to specific site requirements. Pesticide application, using principles of integrated pest management (IPM), has the potential to reduce pesticide usage by 30% to 80% (Nuspl et al., 1996). As illustrated in Fig. 1, pest populations are mapped and prescriptions determined. Rate information is sent to the control system and the sprayer responds by changing application rates. Notice the rate change is a gradual one, thus the prescription cells should be sized to take advantage of the application equipment's characteristics.

Yield mapping is a vital part of the feedback loop in precision agriculture. A yield map may tell the grower what has happened in the field as a result of the management decisions made during the course of production. The grower can then use this information to fine tune the management practices for the following year (Morgan and Ess, 1997).

Yield monitors are available for some horticultural crops that are mechanically harvested. Present technology in yield monitoring horticultural crops fall into the mass flow or mass accumulation categories. Mass flow is used in machines where the crop harvested is conveyed on a belt or chain. Load sensors are placed on the idler wheels supporting the belt to record the weight of the material on the belt. The continuous weight sampling is combined with GPS data to create a georeferenced map of the harvest. (Harvestmaster, 1999). Mass accumulation yield monitoring uses load cells under a hopper or wagon to monitor the weight of the harvested crop as deposited in the hopper. By combining the weight change in the hopper per unit of time with GPS time and position data, a yield map is constructed.

The use of handheld GPS receivers and the Hand-Trak (Doane Agricultural Services, 1999) system to develop yield maps for hand harvested crops is under investigation in North Carolina. The Hand-Trak recorder is used in the field to count the number of picks each worker makes. A pick is a bucket of produce. Data are recorded by the Hand-Trak in the form of time, worker identification number, crop, and pick count. A pick is logged each time the worker dumps the bucket into the trailer. This data is used by the farmer to determine worker productivity and payroll processing. The GPS receivers record time and position. By merging these data files, a yield map of the hand harvested field is produced. Figure 2 is an illustration of a yield map for one 150-ft (45.7-m) swath through the field for a hand harvested crop. Maps produced by this method are not as precise as maps produced by yield monitors on mechanical harvesters, however the data do offer a means for the grower to determine variability in crop yield. Efforts to improve the quality of these maps are in progress.

Postharvest process management

Postharvest processing begins as soon as the crop is harvested. Improper handling of the crop during this period can be detrimental to quality. Precision agriculture applications of postharvest process management use sensors to monitor conditions in curing or storage to achieve the optimum parameters and preserve quality. Automatic controls are used to regulate temperature, humidity, and fresh air delivery. By continuously monitoring the curing or handling conditions, adjustments can be made that would not be possible in the conventional method of manual control. As in the other facets of precision agriculture, the feedback control loop is a critical element. By continuously monitoring the condition of the crop in storage or in curing, and analyzing the data in real time, adjustments can be made in storage or curing parameters to preserve or enhance quality.

Conclusion

Precision agriculture is a comprehensive system designed to optimize production. Using the key elements of information, technology, and management, precision agriculture can be used to increase production efficiency, improve product quality, improve the efficiency of crop chemical use, conserve energy, and protect the environment. Technology and management practices such as field scouting, field mapping, variable rate control, yield mapping, and postharvest processing can be readily adapted to horticultural crop production. Much of this technology is still in its infancy. More research will be necessary to allow the systems to reach maturity. While technically feasible, further research is also needed to clarify the economic and environmental benefits of many elements of precision agriculture.

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