Precision Agriculture in the Republic of Korea

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Figure 1. Paddy fields (top) and production machinery (bottom) suitable for the Korean rice production system (photos courtesy Sun-Ok Chung).

Precision agriculture is well established in North America, Europe, and Australia, where production fields are relatively large. Recently, precision agriculture has attracted interest and has seen limited adoption in Asian countries including Korea, where fields are 0.4 to 1.0 ha (1.0 to 2.5 acres) in size. Reasons for this interest include: (1) social concern regarding environmental problems such as ecosystem damage and ground water pollution from the heavy use of agricultural chemicals, seen as necessary to increase yields to feed rapid increasing populations on a limited amount of arable land, (2) global demands for environmentally safe agriculture, (3) pressure to strengthen the value of agricultural products to survive in competitive global markets, and (4) labor shortages due to an decreasing and aging rural population.

There had been some precision-related research and development under the concept of "Low Input Sustainable Agriculture" in Korea, but it was not until late '90s when the concept of precision agriculture was introduced to the public through international seminars and symposiums, and research projects were initiated by scientists in government agencies and universities. Activities have been mainly focused on rice production, since rice is a major crop to feed the population.

Site variables in interest are soil properties, crop growth status, and crop yield. Since rice paddy fields are flooded and flat, agricultural scientists had hypothesized that spatial variability in yields and soils might be negligible. However, significant levels of variability in rice yields and many soil nutrients, even in small Korean paddy fields, have been observed. Rice yield variations between high-yielding and low-yielding areas were about 30% even in small (i.e., 0.4 ha, or 1 acre) paddy fields. Spatial patterns of several soil properties (e.g., EC and P_2O_5) also showed within-field variability and were somewhat related to irrigation water flow.

Equipment such as electrical conductivity and yield monitoring sensors and software packages have been introduced from the U.S. and Canada, not only to learn about the technologies, but also to investigate the feasibility in unique Korean agricultural situations. Some of the introduced technology showed issues to be resolved to meet the Korean cropping systems. For example, grain flow sensors that were designed for wheat and corn production in large U.S. fields were unable to measure the small amount of flow in a Korean rice combine typically harvesting 4 to 6 rows. In addition to hardware issues, data filtering issues such as flow delay and inconsistent harvesting width are much more challenging. Crop growth sensors need to be calibrated for rice through intensive sampling and analysis, and variable rate nutrient application systems need to be reduced in size. Lessons from the experience are that site-specific variability exists among different countries and cropping systems, and that equipment and strategies should be developed and established to meet and manage the site-specific variability unique to Korea.

Korean-version equipment is under development as well as adoption of technologies from foreign countries. Some of them include field data collection platforms with the capability of logging GPS positional information along with sensor readings, soil sampling devices, sensors for soil properties such as organic matter content, soil strength, water content, and electrical conductivity, and sensors for crop growth monitoring such as plant height, leaf coverage, and chlorophyll content. Rice yield monitoring systems and variable rate controllers for liquid and granular agrochemicals have been also studied.

A Case Study of Farming Systems Research in Korea Rice Bowl Area

To obtain basic information for precision agriculture, the spatial variability of growth and yield for rice plants was investigated over a 0.4 ha (1 acre) paddy field in the Kimje plain area of Korea. The experimental field was divided into side-by-side control and variable rate treatment (VRT) areas, and soil samples, measured soil hardness, and ground conductivity by EM38 readings were taken yearly. Soil samples were analyzed for pH, EC, NH_4-N, NO_3-N, T-N, P_2O_5, K, SiO_2. Fertilizer recommendation maps were created based on results.

The pH and organic matter were at optimum levels for rice cultivation, and available phosphate was higher than optimum. EM38 measurements and soil EC were correlated, and the soil hardness was different before seeding vs. after harvest. Soil chemical properties showed a big variation within the field, as well as fertilizer recommendations. These results indicate that variable rate fertilization could offer a relative advantage in this field.

Grid sampling was conducted with each of the 4.3m x 10.2m (14ft x 33ft) plots in a 35m x 112m (115ft x 367ft) paddy field. Eighty-eight surface soil samples were collected before soil puddling to investigate the spatial variability of their chemical properties. The growth characteristics data were collected at heading stage from each plot and the grain yield was measured in each 8.6m x10.2m plot at harvest. Geostatistical analysis and mapping were performed by GS^+ Geostatistics software. The yield variations in the grid ranged from 7.5ton/ha to 10.2ton/ha (3.0 to 4.0 ton/A). The range of spatial dependence was about 40m (131ft) for grain yield. Yield maps correlated with growth maps, showing continuity in spatial variation. The spatial distribution of N recommendations for variable rate application showed similarity with the yield map in spatial variation.

Figure 2. Technologies are under development to meet Korean cropping systems. Some of them are a soil organic matter content sensor, a rice growth status sensor, a variable rate granular fertilizer controller, and a rice yield monitoring system (from top to bottom).

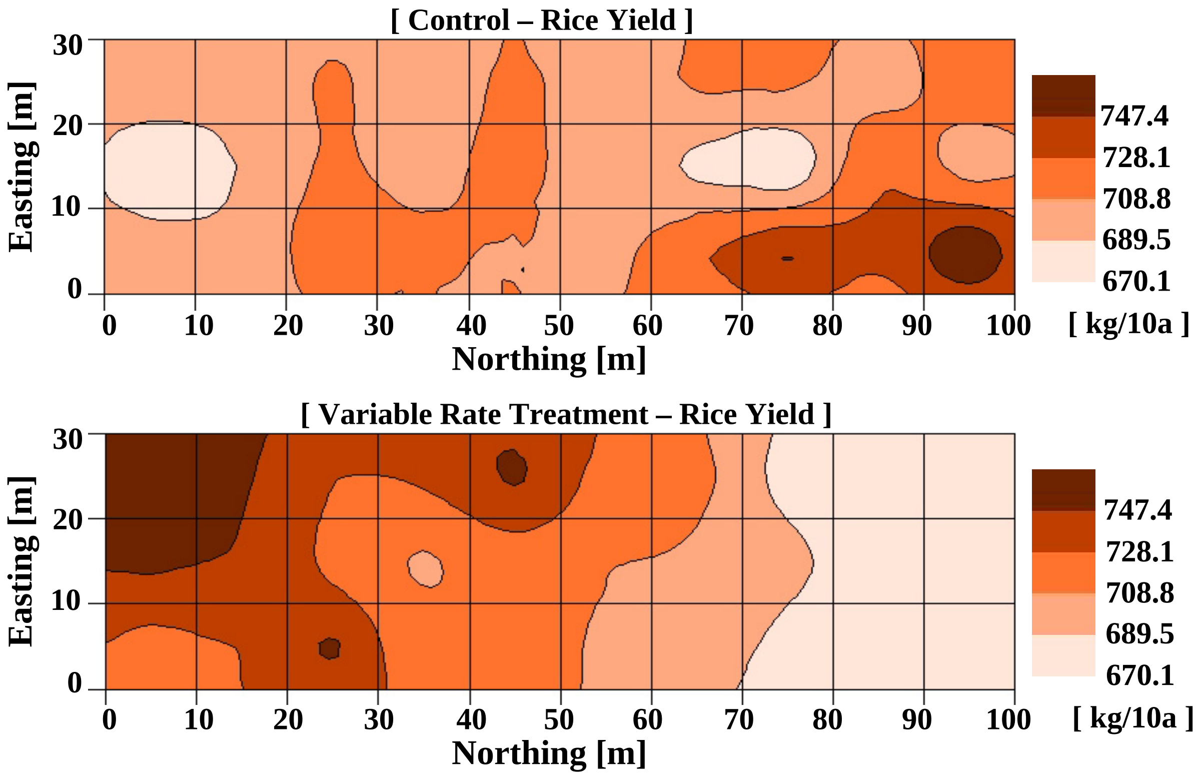

Figure 3. Rice yields in control (top) and variable rate nitrogen (bottom) experiments.

The experiment was conducted to verify the effect of variable rate nitrogen fertilization. A Micro-Track yield monitoring system was installed on Kukje 575-G combine. In outdoor calibration, the standard deviation of GPS was 1.2m (4 ft). The coefficient of variation of the tractor speed sensor 5% while that of flow sensor was 2%, but error was increased at cereal tank fills more than 3/4, or at starting harvest. Errors of acquired yield data were decreased by data cleaning and averaging by plot. Finally, the yield map could be drawn using cleaned and averaged data

The control plot was applied with a conventional rate of N fertilizer, while the VRT plot was applied with variable rate based on N fertilizer recommendation from soil analysis. The average amount of N fertilizer in the VRT plot was 18kg/ha (16lb/A) less than in the control. Most of growth values in the VRT plot were higher than in the control. Coefficients of variation in grain yield were 64.1% in the control plot, but 9.2% in the VRT plot, respectively. In the VRT plot, yield variation was minimized and average yield was 34% higher than the control. There was no difference on nitrate contents of infiltrated soil water in control and VRT plot, and quality of rice grain in the VRT plot was slightly better than the control. According to the results, variable rate fertilization of paddy rice was effective in reducing fertilizer without decreasing yields and variations in growth and yield.

Economic performance of precision agriculture was analyzed by the partial budget method based on production cost in the experimental farm households. According to the results of the economic analysis on the experimental plots and farm households, even though the fertilizer amount per unit area was more than fertilizer applied with the soil survey, if farmers bear the total expenses for precision agriculture, they were faced with a large deficit for their farm management. However, if government supports some part of cost for soil survey or GPS for precision agriculture, they showed the possibility for adopting techniques of precision agriculture. Precision agriculture results in reducing environmental pollution by using smaller amounts of chemical fertilizer and pesticides. It can justify government support for some part of its expenses.

Challenges and Opportunities of Precision Agriculture in Korea

When the Korean government pushed a production-oriented rice policy for food self-sufficiency in past years, rice farmers applied too much pesticide and chemical fertilizer for rice cultivation and resulted in serious pollution problems in rural areas. Recently, the international standard of organic farm products has been established and OECD is developing the index of agricultural environment. Therefore, the various regulations for agricultural environment should be strengthened in Korea. To meet such a changing situation Korean government established laws for encouraging environment-friendly farming, and carried out various plans to support them. However, the environment-friendly farming has its limitations in the purposes of both increasing productivity and expanding farm area.

Adopting precision agriculture is an alternative approach to overcome these limitations. Precision agriculture has the potentiality to achieve the reduced use of pesticide and fertilizer through variable rate fertilizer application, site-specific herbicide application, and field guidance systems while simultaneously increasing productivity through the large-scale farming. Therefore, precision agriculture is an intuitively appealing technology for large farmers and policy makers as a tool of responding in an environmentally sound fashion.

Measurement and management of the small-scale variability in Korean fields raises both challenges and opportunities for precision agriculture. Small-scale variability requires more careful consideration on determination of design parameters and data processing issues. Diverse strategies are under investigation, depending on controllability of the variability, type of operation, and economic feasibility: sensor-based vs. map-based practices and within-field vs. inter-field management. Experience and accomplishments in Korean precision agriculture might be also used for other Asian countries where agricultural environments and cropping systems are similar.

Korean precision agriculture seems to be entering a new phase. Although related technologies have been developing and economic benefits from site-specific field management have been reported, economic feasibility is still questionable. Establishment of pilot farms and long-term and inter-disciplinary investigation is critical. Rice production has been the main interest of past activities. There is a great potential to apply site-specific technologies and management strategies developed for rice production to other areas such as orchards and protected horticulture (e.g., flowers and ginseng) that would lead to good economic returns. Site-specific management presents opportunities to those who see things differently and try to manage them.

For More Information

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