Importance of New Technologies for Crop Farming

By Michael Boehlje and Michael Langemeier

Adoption of technology has been important to production agriculture for decades. Through the adoption of technology and improved managerial practices, aggregate agricultural U.S. farm output in the United States tripled from 1948 to 2017 with almost no corresponding increase in aggregate input (USDA-ERS, 2021). For reasons explained below, the adoption of technology in production agriculture is expected to accelerate in the next decade. This article discusses types of technology that are currently being adopted or that are likely to be adopted in the near future. Upcoming articles will discuss the critical role of information and precision agriculture technologies, possible payoffs of precision agriculture, automation and robotics, and gaps in skills pertaining to the adoption of new technologies.

CHANGES TO CROP AGRICULTURE

Crop farming around the world is undergoing a profound technological transition. The management of production is moving toward increased micro-management of production activities by individual field or location within a field driven by site-specific information about environmental, biological, and economic factors that affect physical output, profitability, and soil and water quality.

Increased use of monitoring technology will greatly expand the amount of information available regarding what affects plant growth and well-being. This will be made possible by innovations in sensors to use in monitoring and control systems, communication technologies, and data analytics. In addition, greater understanding of how various growth and environmental factors interact is forthcoming. This understanding will then be incorporated into management systems to determine optimum combinations of inputs at the field or within a field level. Precision farming in crop production includes the use of global positioning systems (GPS), yield monitors, and variable rate application technology to more precisely apply crop inputs to enhance growth, lower cost, and reduce environmental degradation.

Growing crops through precision production practices might be described as “biological manufacturing” which combines biotechnology and nutritional technology; monitoring, measuring, and information technology; and process control technology. The critical linchpin among these “technologies buckets” for successful execution is the data and information that can be continuously captured and utilized to manage the system and intervene in real time to control and enhance the plant growth process. The transition of production agriculture from an industry that grows crops to one that biologically manufactures raw materials with specific attributes and characteristics for food and industrial use products is well underway. The discussion below will focus on three types of technology: biotechnology and nutritional technology; monitoring, measuring, and information technology; and process control technology.

BIOTECHNOLOGY AND NUTRITIONAL TECHNOLOGY

The focus of biotechnology and nutritional technology is to manipulate the growth, attribute development, and deterioration process in plant production. An improved scientific base impacts not only plant growth but attribute development and is providing additional capacity to manipulate and control processes. Also, biotechnology is advancing our capacity to control and manipulate plant growth and development including attribute composition (for example, starch or amino acid composition) through genetic manipulation. By combining nutritional and biotechnology concepts with mechanical and other technologies to control or adjust the growth environment (temperature, humidity and moisture, pest and disease infestation, etc.), the process control approach and thinking that is part of the assembly line used in mechanical manufacturing becomes closer to reality in biological manufacturing.

MONITORING, MEASURING, AND INFORMATION TECHNOLOGY

The focus of this technology is to trace the development and/or deterioration of attributes in the plant growth process, and to measure the impact of controllable and uncontrollable variables that are impacting that growth process. In crop production, yield monitors, global positioning systems (GPS), global information systems (GIS), satellite or aerial photography and imagery, weather monitoring and measuring systems, and plant and soil sensing systems are part of this technology. In future years, inplant sensors to detect growth rates and disease characteristics may be available. These systems will be tied to growth models to detect ways to improve plant growth performance, as well as to financial and physical performance accounting systems to monitor overall performance. The computer technology to manipulate the massive amounts of information is readily available; new monitoring and measuring technology including near-infrared (NIR) and electromagnetic scanning is now being developed to measure a broad spectrum of characteristics of the plant growth process.

PROCESS CONTROL TECHNOLOGY

The concept of process control technology is to intervene with the proper adjustments or controls that will close the gap any time actual performance of a process deviates from potential performance. Greenhouse production increasingly utilizes such technology to manipulate sunlight, humidity, temperature, and other characteristics of the plant growth environment. Irrigation systems are an example of this technology in field crop production; modern irrigation systems tied to weather stations and plant and soil sensors automatically turn irrigation systems on and off to ensure that moisture levels are adequate for optimum growth. Variable rate application of fertilizer and chemicals and row shut-off technology are current examples of process control technology in rain-fed crop production. Modern precision planter technology that automatically adjusts seed placement, depth, and soil coverage based on soil sensors is another example.

Combining real time monitoring and measuring technology with anytime intervention process control technology has the potential to generate significant benefits. Any-time intervention technology allows one to detect a problem when it occurs and in real-time solve that problem rather than anticipate a possible problem and preemptively dispense control inputs that may be completely unnecessary (and thus costly) and possibly even harmful to the growth environment if that problem does not occur. For example, anytime intervention technology allows the detection of corn borers and the treatment of those borers once they meet an economic threshold, rather than spending funds and using materials in anticipation that a corn borer infestation might occur which are unneeded if the infestation does not reach an economic threshold during the growing season. A similar approach might be used to control weeds. Similar approaches to fertility management may facilitate lower levels of pre-season fertilizer applications by enabling additional applications during the growth season as real-time sensing technology and drop-down nozzle attachments for high clearance equipment enable split applications of fertilizer to be applied when needed. If such technology is developed, it may be less essential to use biotechnology to control certain insects or larger than necessary fertilizer applications to insure the optimum yield.

It would be unrealistic to expect these process control and sensing technologies and methods to be as successful as they have been in industrial manufacturing in reducing variability and systemizing the processes of producing manufactured goods such as automobiles, computers, or even chemical and industrial goods. However, it is also unrealistic to ignore the potential of these technologies in reducing variability and obtaining more control over biological growth processes so as to increase efficiency, reduce costs, improve quality, minimize environmental impacts and in general more systematically produce biological based attributes for food, feed, fuel, and fiber raw materials. In essence, this is what the concepts of biological manufacturing are all about, to use monitoring and measuring, biological and nutritional manipulation, and process control technologies to systematically manufacture food and industrial use products.

CONCLUDING COMMENTS

This article discusses types of technology that are currently being adopted or that are likely to be adopted in the near future. Specifically, technologies related to biotechnology and nutrition; technologies related to monitoring, measuring, and information; and technologies related to process control were briefly described. It is not an understatement to note that these technologies are going to result in profound changes to production agriculture operations. Upcoming articles will discuss the critical role of information technologies, possible payoffs of precision agriculture, automation and robotics, and gaps in skills pertaining to the adoption of new technologies in production agriculture.

REFERENCES

Erickson, B. and J. Lowenberg-DeBoer. “2020 Precision Agriculture Dealership Survey.” Departments of Agricultural Economics and Agronomy, Purdue University, August 2020.

Pope, M. and S. Sonka. "Evidence, Data and Farmer Decision Making." farmdoc daily (10):45, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, March 11, 2020.

Thompson, N.M., C. Bir, D.A. Widmar, and J.R. Mintert. “Farmer Perceptions of Precision Agriculture Technology Benefits.” Journal of Agricultural and Applied Economics. 51(Issue 1, 2019):142-163.

United States Department of Agriculture, Economic Research Service. Statistics Service. Agricultural
Productivity in the U.S., https://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us/,
accessed on February 26, 2021.

