Future of peanut pest management: A plant pathologist's perspective.

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ABSTRACT

Integrated pest management (IPM) is a broad-based approach for pest control that has been used since the 1950s. This approach uses a variety of management tactics to keep pest levels below an economic threshold level. However, choosing the appropriate tactics in a timely manner can be difficult in many agricultural production systems. Technology is continually revolutionizing agricultural decision making by transforming large quantities of data into useful and timely information. The focus of this article will be on what makes a successful IPM strategy, and how novel technologies can possibly be incorporated. Pests impacting peanut production are continually adapting and evolving, thus the tools used to manage them must also have this capability. The future of pest management lies with finding ways to incorporate novel information into established IPM programs and adapting them for future changes in pest populations.

Key Words: disease detection, IPM, scouting, machine learning

When thinking about pest management for the future, it is first important to think about the tools currently available to growers. Integrated pest/disease management (IPM or IDM) is the concept from which all pest and disease control strategies are based (Ehler, 2006). The four main IPM components are biological, cultural, mechanical/physical and chemical. Every pest or disease management strategy tries to combine these components to create a plan that is economically beneficial and sustainable. In peanut production, we already have an excellent example of an IPM program with Peanut Rx. Peanut Rx is unique in that it does not only focus on pests or disease, but rather the entire peanut cropping system. Peanut Rx is the standard program for comparing the effectiveness of new novel technology-based strategies and determining how best to properly incorporate these technology's into current IPM programs.

The core of every IPM program is proper pest or pathogen identification, allowing users to apply the correct management strategy for a given issue. A handheld tool that could identify a pest or pathogen in the field would be of benefit to growers and agricultural professionals. Unfortunately, the Star Trek "tricorder" has not yet been developed (Savolainen et al., 2005). However, there have been some advances made in the medical industry to develop such a tool, but it is limited to certain traits that do not benefit pest identification effecting plants. Developing and incorporating this type of tool would be beneficial to improving pest and disease management, but will require data collected from current management tools.

Current pest and disease identification tools combine traditional techniques with novel molecular and computer assisted diagnoses. A typical diagnostic lab already contains many components to take advantage of DNA, antibody and microscope-based identification techniques. The pest or pathogen type will determine which test to use for proper identification. For example, visual techniques (e.g. microscope or agar-plating) will be used with fungal and bacterial pathogens while submicroscopic organisms such as viruses and viroid's will require a DNA/RNA based technique. It is vital that we are able to distinguish biotic diseases from abiotic or stress related disorders (e.g. nutrient deficiencies). These diagnostic techniques allow us to accomplish accurate assessments. However, the tools used to identify pests or pathogens are not all in one contained unit, but research efforts to combine them are in progress. The goal is eventually to develop a diagnostic laboratory on chip (Lab on a Chip, Royal Society of Chemistry), but we still have many advances to make until this is a reality. However, tools like loop-mediated isothermal amplification (LAMP) and recombinase polymerase amplification (RPA) are creating handheld diagnostic platforms that can identify diseases and pests, and allow for multiplexing to look at more than one pathogen (Ereku, et al., 2018; Mayboroda, et al., 2018). These tools are a critical first step to determining optimum pest and disease management and could eventually aid in improving field diagnosis in the future.

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Scouting a production area is usually the first line of defense in any IPM program. Current scouting practices rely on a human to visit a field or location to assess the damage from a pest or pathogen. Conventional scouting techniques rely upon random point selection, site-specific sampling, or following a 'W' or 'M' sampling pattern across the area of interest. These measures are useful and often provide quality data about a pest or disease issue, but they are also infrequent and often not repeatable. Generally, the amount of information gathered from this practice is limited, and questions about the pest or disease's eventual spread and potential economic damage can go unanswered. Finding a way to bring all this information together while increasing the frequency of sampling will be critical to improving and sustaining IPM practices.

Using drones and high throughput imagining are two ways in which we can improve our scouting efforts. Drones can improve conventional scouting by taking the randomness related with this practice and focusing on areas of most concern (Kalischuk, et al. 2019). These technologies help identify the possible issues in a field so that a scout can investigate and establish the problem area. It also allows scouts to improve monitoring the spread and frequency of a field issue and management assessment decisions. While drones can improve scouting efficiency, they currently are not completely automated process. Intensive research is being conducted to develop optical and automated technologies that can detect and identify plant diseases and pest with high throughput imaging (Thomas et al., 2018). There have been many positive results from these studies, but limitations still exist and more data needs to be collected before these tools can become completely automated and operational.

Besides using imagery to help identify and monitor plant pests and disease, it is also important to know about the pathogen's population and its interactions with the environment. Recently, Xu (2016) proposed the use of a typing concept called "enviro-typing" used in complement with genotyping and phenotyping. The concept would include information about the crop, climate, soil, management practices and organisms of interest in identifying and managing a pest or pathogen problem. For example, in a peanut system, we would examine the impact of microclimate, soil types, fungicide program, and irrigation schedules on disease development. This information could improve the understanding of the variation associated with a management technique and target more effective strategies in areas where disease is likely to

occur, or be more severe. To do this and any of the other techniques discussed previously, more data needs to be collected and shared across the scientific community so accurate tools can be developed.

Gathering and sharing data (data management), is critical to developing sustainable tools. There is no one solution for data management, but a couple of ideas to pursue for pest management purposes are already available. In order to maintain the quality of data, a national pest observation repository has been developed (Anonymous A, 2019) for data aggregation and designed to maintain the quality and integrity of the data. Another option currently available is to look at the open science movement (Anonymous B, 2019) which has a goal to support the openness and reproducibility of scientific data and methods while creating a space for collaboration and dependable data repository. These are just two examples of data and methods management, but it will be important to monitor their usefulness in the years to come. It is critical for researchers to consider data storage and management when a project is complete. There is no one solution, but creating reproducible science is still very important as we work to develop and utilize new technologies.

Many novel management technologies have not been covered in this manuscript, but will be critical for peanut pest management. Some examples include peanut genome mapping (Dash, et al. 2016), pathogen population and genome analysis (Orner et al., 2015), climate and weather modeling (Olatinwo, et al., 2011; Velasquez et al., 2018), CRISPR/Cas9 (Das et al., 2019) and nanotechonolgy (Elmer and White, 2018). All of these tools will be invaluable in the fight against pest and pathogens in peanut production. Integrating these tools with the management techniques that came before will also be critical. It is important to remember the four components of IPM and that our goal is to integrate technology and not replace it.

As these tools continue to become available to producers around the world, it will be beneficial to assess the socioeconomic impacts they will have on various cultures (Garret et al., 2018). The adoption of any new technology requires an exchange of ideas and money. There should be assessment of impacts on rural communities to increase the successful integration of these new systems into production agriculture. This will be not be an easy task and will require pest management professionals to work with sociologists and economists to be sure these tools can be available to everyone.

This is not the first evaluation that the future of peanut disease management has been conducted. Sherwood *et al.* (1995) reviewed pest control advances for peanut. They identified that an understanding of interactions between pests and peanuts was needed, and that application of molecular biological techniques will be critical for pest management in this discussion. Those are still two important concepts for the future of pest management, and we should consider adding the incorporation of novel technologies for disease and pest identification, monitoring and management. Integration of these tools into current management strategies will be key to their success and sustainability.

The primary focus of this article was on pest management strategies for peanuts produced on Earth. However, NASA expects to have Earth independent Mars missions by 2030, which most likely means these missions will be looking for sustainable crop production methods in space. It is also likely that during these trips through our solar system that many of the rockets will be unmanned, meaning automated management of plants, pests and pathogens. The idea of having a device available will be critical to the success of these missions and having the proper IPM strategies in place for the automated systems will be vital to managing issues that arise far away from Earth. We have already identified opportunistic pathogens can make their way from earth to space (Schuerger et. al, 2017), so in the next 50 years we will need to think about managing pests in space. The tools we develop now and the data we collect will be critical to the success of our trips to Mars and beyond.

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