Yielding results

Dr Ronnie Heiniger describes some of the environmental challenges faced by corn farmers and the strategies that may help overcome them, detailing his research and the data collected to date.

What is the most important recent advancement to corn production, and why?

From my perspective, the most important recent advance in corn production is the development of drought tolerant hybrids. Whether developed through the use of genetic modification or through conventional breeding techniques, these new hybrids have expanded the opportunity to grow corn on marginal soils, improved the tolerance of corn hybrids to more intensive management and reduced the risk associated with adverse weather.

Is there an optimum soil moisture content? How can this be regulated?

Optimum soil moisture content for corn depends on the soil type. Some soils have the capability of holding more water and have higher optimum soil moisture content. From the standpoint of crop growth it is easier to consider soil water content as a percentage of the total soil volume. In this case, the optimum soil water content is 25 per cent of the soil volume. In an ideal soil this would provide water that is readily available to the plant while having enough air in the soil to ensure optimum uptake and nutrient availability. Drainage and irrigation are two methods of controlling or regulating soil water content. For corn, good drainage is the most critical of these. Too much water is often more detrimental than too little.

Why is growth and development so heavily influenced by temperature? Are there optimal growth conditions?

I like to think of temperature as the plant’s clock. Corn is a good example. In corn, growth and development will only occur when temperatures are optimal. The minimum temperature below which corn will not grow is 10 °C and the maximum is 30 °C. Based on these optimum temperatures we can calculate what is known as growing degree days. Growing degree days are defined as the average growth temperature for the calendar day less the minimum temperature (10 °C). These are the true clock for the plant. As they accumulate, the plant grows and develops. Once a certain number of growing degree days has passed the plant will flower, fill grain, reach maturity and eventually die. While the plant can survive temperatures above and below these optimums the plant will not grow or develop. In this project we examined the short-term impact of temperatures that were much above and below the optimum limits. Temperatures that are outside the optimum range can damage plant tissues, interfere with metabolic processes and cause the plant to change its morphology.

How does abnormal development impact quality, yield or nutritional content?

Abnormal development of corn’s reproductive tissues can have severe consequences for all three parameters. In terms of yield, abnormal ear development leads to reduced grain number and fewer kernels per plant. Abnormal development of the kernels can affect grain quality leading to a higher chance of fungal infections and mycotoxin production that can result in toxins in the grain. Finally, abnormal ear development often leads to kernels with less starch and energy compared to grain that has developed on a normal ear.

Could a move to temperature-controlled greenhouses help minimise losses? Why may this not always be appropriate?

Certainly, an environment where temperature could be controlled would be ideal. Unfortunately, given the tremendous amount of corn needed worldwide there would never be enough greenhouse space required. Therefore, the best approach is to understand the mechanisms by which adverse temperatures impact the plant and to devise genomic or management strategies that will allow the plant to cope with or avoid the problem. Our goal is to develop management strategies (planting dates, plant spacing, row orientation, etc.) that can be used to avoid temperature stress.

At what stage are you in your investigations? What results have you garnered so far?

We are in the early stages of our research. We have started by identifying the temperature extremes that cause the most damage to the plant and the growth period during which these temperature extremes have their greatest impact. To date, we have been able to isolate the critical temperatures, determine how long these must last to have an impact on the plant and decipher the growth stages during which these short-term temperature extremes have the biggest impact.
ENSURING A STABLE and sufficient global food supply is undoubtedly one of the most important challenges facing modern agriculture. Today, farming is often intensive and large-scale, so even small changes in environmental conditions can have impacts on year-on-year crop development and thus productivity. Perhaps the most important focus area in this context is the consequences of temperature fluctuations on crop health and yield. With global weather systems becoming less predictable and climate change taking effect, understanding the influence temperature has on crop yield is an essential piece of knowledge in the battle to ameliorate the severity of future changes. This need has not gone unnoticed, and one of the most rigorous and important research projects in this field is that led by Dr Ronnie Heiniger from North Carolina State University, whose work focuses on the role of competition and temperature on the development of corn.

Corn is a staple crop across much of the world and is popular commercially in the southeastern US. The development of corn is well understood and has been categorised into multiple stages depending on morphological features. The primary goal for Heiniger and his colleague’s is to therefore improve corn production by understanding the impacts of temperature and competition on these key stages of development, with a view to creating a framework for all cropping regimes.

DESIGNING A BETTER FUTURE FOR CORN YIELD

Teasing out the impacts of individual variables in real-world experimental set-ups is challenging and requires a detailed and highly focused methodology. Heiniger, with 19 years of research experience in agriculture, is well placed to deliver this required accuracy: “The keys to good research are careful collaborative development of proper protocols, attention to detail in establishing the experiment and recording information,” he highlights. These protocols are established in conjunction with all team members and are continually reinforced with regular protocol and methodology updates, ensuring accuracy from conception to completion.

The Carolina team has established two studies, each consisting of multiple smaller experiments. The first of these is designed to elucidate the impact of competition between plants for water and nutrients on canopy temperature – a key component of temperature stress in corn – as well as silk emergence (the functional stigmas of corn) and kernel set. This experiment is critical for establishing whether or not crop spacing should be adjusted for predicted temperatures or different hybrids. The second project is focusing on the specific challenge of temperature stress on key morphological characteristics, such as silk emergence, abnormal ear development and kernel set. Both studies are designed for a five-year period and compare open-field sites of various spacing patterns with greenhouse studies that utilise comparable spacing patterns. In combination, these studies will provide the team with the data necessary to better understand the responses of corn to short-term temperature stress and thus propose strategies for minimising this impact.

THE IMPORTANCE OF HYBRIDS

Annual fluctuations in corn yield are significant with measurements of yield per acre changing by as much as 30 per cent between years. Despite this unpredictability, average corn yield has been steadily increasing over the last 60 years with improvements in irrigation, soil quality, fertilisers and the arrival of tolerant hybrids. While major improvements in corn yield have been achieved with the arrival of drought tolerant plants, Heiniger feels that more can be done to breed better plants for the future: “It is the year-to-year variability in temperatures and weather that makes it difficult for breeders to use conventional breeding techniques of plant selection under pressure to safeguard the...
crop against temperature extremes”. Gaining an understanding of the metabolic and cellular processes that control the plants’ negative response to temperature extremes is crucial for designing hybrids that are better prepared to deal with these temperatures. Once these processes have been identified, work can begin to link them to their genetic determinants. “We can use that information to help breeders and genomics researchers find genes and plant traits that can be bred into corn to help the plant cope with temperature extremes,” explains Heiniger.

**FARMING OUT INFORMATION**

The data collected during the group’s work is valuable from both academic and commercial standpoints. As such, the researchers are keen to share their understanding with interested stakeholders, including plant breeders, agronomists, farmers and farming consultants. Training sessions have been held for extension agents and crop consultants. In total, the team has already provided training for over 250 relevant stakeholders on the effects of temperature, recognising temperature damage and management strategies for reducing temperature stress in this context. The group also provides seasonal advisory documents in response to periods of poor conditions that help farmers and consultants make decisions regarding replanting. These activities are an essential part of modern crop research and link efforts to outcomes, providing short-term benefits to society.

**PROOF OF PRINCIPLE**

The team’s work is still in its early stages and several years of data collection remain. Despite this, the group has already elucidated the upper and lower temperature boundaries at which impacts on plant development can be expected. They have stratified these impacts across different developmental stages to provide an understanding of how temperature influences growth throughout the entire lifecycle. Ultimately, this may pave the way for breeders to influence lifecycle timings to improve yield or help farmers to time crop seeding more effectively.

The work being conducted by the University of North Carolina researchers is undoubtedly important for corn breeders and agronomists but it may also be crucial for societies’ understanding of development in a wider range of crops: “The research will establish a template for similar efforts in modifying other crops to cope with temperature extremes,” highlights Heiniger.

The ultimate objective is to provide stakeholders with the relevant information necessary to create new corn hybrids and make evidence-based farming decisions that maximise yield. This has been a valid objective since the dawn of farming, but faced with the modern challenges of population growth, high-demand and unpredictable climate change, these aims have become increasingly salient and achieving them ever more important.

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**INTRODUCTION**

**THE INFLUENCE OF TEMPERATURE AND PLANT COMPETITION ON VARIABILITY IN GROWTH, SILK EMERGENCE AND ABNORMAL EAR AND KERNEL DEVELOPMENT IN CORN**

**OBJECTIVES**

- To identify environmental conditions, particularly temperature variables that lead to poor ear development and kernel set in corn
- To determine the impact of short-term periods of high temperatures at different growth stages on variability in silk emergence, ear size and kernel set
- To assess whether corn hybrids differ in their sensitivity to short-term temperature stress

**KEY COLLABORATORS**

North Carolina State University: Dr Jonathan R Schultheis, Professor of Vegetable Culture, Production and Physiology • Dr David Jordan, Professor of Weed Management • Mitchell Williams; Kyle Schmitt, Graduate Students

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**RONNIE HEINIGER** is Professor in the Crop Science Department at North Carolina State University. He received his PhD in Crop Ecology from Kansas State University in 1994. Heiniger has worked for the past 19 years as Research and Extension Specialist at the Vernon G James Research and Extension Center in Plymouth, North Carolina. His responsibilities include research into precision agriculture and corn-wheat-soybean cropping systems. Heiniger is known for his applied research using on-farm comparisons. He has published articles and presented papers covering his work in precision agriculture and the use of aerial photography to determine nitrogen requirements for corn and wheat. Recent research has focused on increasing light use in corn through the use of higher plant populations and fungicides and measuring root growth in response to pre-plant fertilisation.