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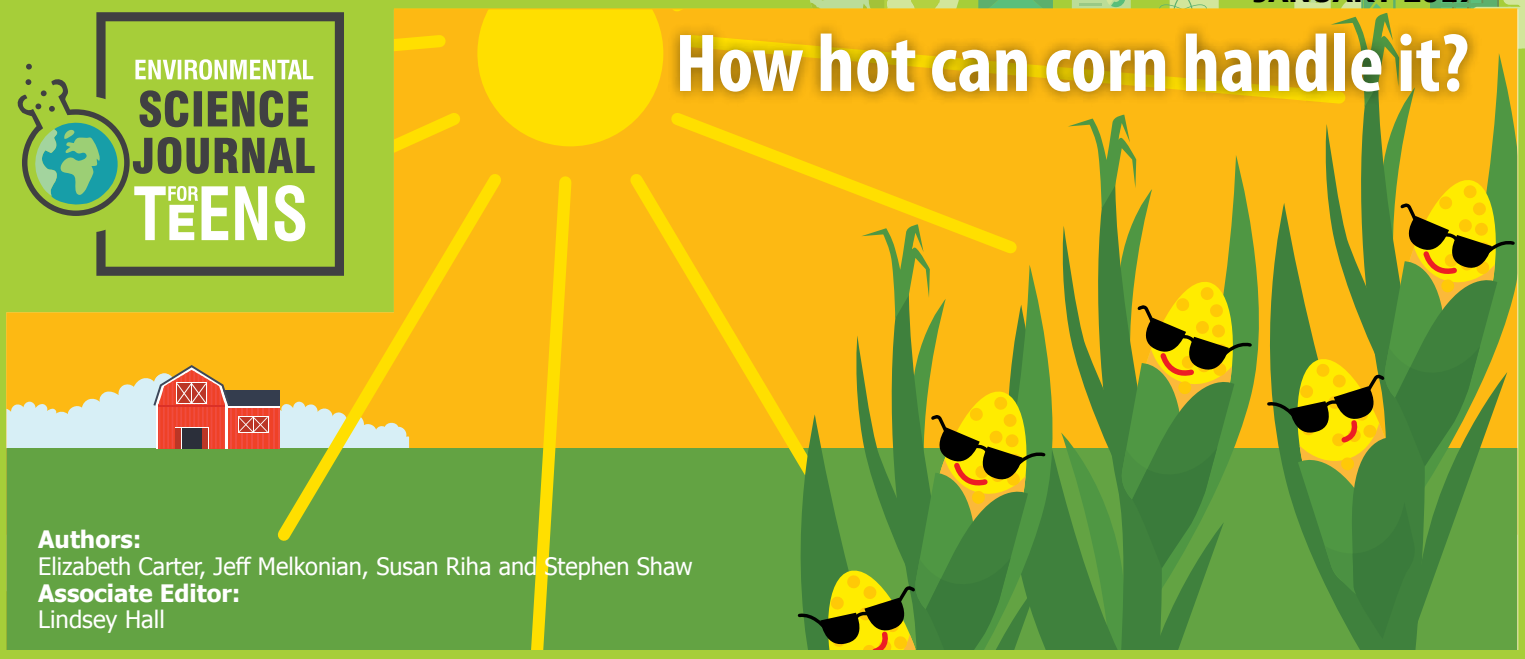
How hot can corn handle it?



Authors:
Elizabeth Carter, Jeff Melkonian, Susan Riha and Stephen Shaw
Associate Editor:
Lindsey Hall

Abstract

Can you remember ever feeling the sun blazing down on your head so fiercely it felt like you might melt? How do you think plants cope with this heat?

Scientists have previously thought that high air temperatures are limiting corn *yields* (see glossary). They predict that as temperatures rise, this will cause significant losses. But are they right? To answer this, we looked at irrigated corn yield data from three states in the western US Corn Belt. We found that the genetics of the crop and the crop management techniques explained differences in yield more than climate. These factors really changed the corn's response to the temperature.

Our findings can help farmers adapt to rising temperatures. Studies predict that by the year 2050, demand for corn will grow by 50% in the developing world and that the average global temperature will increase by roughly 2°C in this time.

Introduction

Most of the corn grown in the US is for animal feed, but in Sub-Saharan Africa and Latin America, it's a staple food for more than 1.2 billion people. A staple food is one that makes up a significant proportion of a person's diet, supplying most of their energy and nutrient needs (Fig. 1).

Previous scientific studies have suggested that daily maximum temperature higher than 30 °C limits corn *yields* (i.e. the amount of corn produced per area). This is a concern because studies show that the average global temperatures will increase in the next 30 years due to climate change. At the same time, the demand for corn is increasing in the developing world.

These prior studies looked only at rainfed corn (corn watered only by rainfall) or a mix of rainfed and irrigated corn. In a rainfed system, when temperatures are higher, the soil is normally drier. So this meant that scientists were looking at the combined effects of both temperature and soil moisture, not just temperature.

As there will not necessarily be a link between temperature and soil moisture due to climate change, we wanted to study the effect of temperature alone on crop yields.

To do this, we only looked at data from irrigated crops. These are crops that farmers water to keep the soil moisture content quite constant regardless of the air temperature.

The aims of our study were to:

1) Look at irrigated corn yield data for evidence of temperature-related yield *loss* at high temperatures

2) Test if *genetics* and *crop management* can help the corn to adapt to high temperatures

Figure 1:
Did you know that the number of rows on an ear of corn is always even? An average ear of corn has 800 kernels in 16 rows.

Methods

Every year, corn farmers submit information on their yields into the National Corn Growers Association's "National Corn Yield Contest". We took data between 2005 and 2012 for three states (Nebraska, Kansas and Missouri), which have some of the highest growing season temperatures in the Corn Belt (Fig. 2).

We analyzed data from almost 2000 farmers. This included information on grain yields, as well as important management data like planting date, planting rate, the previous crop they had grown on that soil, and *cultivar type* (the variety of corn).

We were also able to look at the specific growth stages of the corn to analyze the effect of high temperatures on each one. These stages were 'early growth', 'reproductive period' and 'grain-fill'. This meant that we could look at the effect of the climate variables over the whole growing season, but also by each growth stage.

We took temperature data from 66 weather stations and linked each farm's data to the nearest weather station. Where possible, the weather station was in the same county as the farm. If not, we used data from the weather station closest to that county.

We looked at seven different factors of temperature. These included the *total number of hours that the temperature went higher than 30 °C* (TT30) and *34 °C* (TT34), and the *average night temperature*. We also looked at the *cumulative incident solar radiation* (RAD – see glossary).

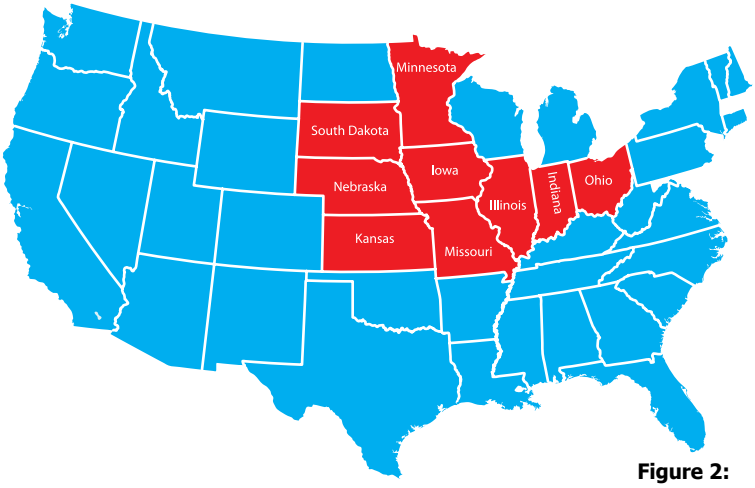


Figure 2:
In the US, most of our corn is grown in an area that we call the "Corn Belt". This is where the conditions are the best for growing corn.

Results

The factors of growing season daytime temperature that we studied were *not* significantly related to corn yields even in 2012 when there were record or near-record high growing season temperatures.

When we looked at the effect of temperature on the specific growth stages of the corn, we found that temperatures of 30 °C had no significant effect on any of the stages.

We found that temperatures over 34 °C did have a significant impact on yield, but the effect was quite complicated. High temperatures during the 'grain-fill' stage had a small, but significant negative impact on yield. But if the corn's early growth and grain-fill stages were both in high temperatures, then there were significant positive effects on yield. Overall, when we looked at the impact of high temperatures by corn growth stage, we found that high daytime temperatures had only a very small negative effect on yields.

We found that the amount of solar radiation during the growing season, and the average night temperatures were significantly related to yield. In fact, we found that cumulative incident solar radiation had the greatest positive impact on irrigated corn yields. We also found that higher average night temperatures had a negative impact on corn yield. However, this negative impact of higher night temperatures was because these temperatures were related to lower cumulative incident solar radiation, and it is the lower radiation that seemed to be responsible for the negative impact of high night temperature on corn yield.

We looked at the amount of *yield variance* (change in the yield) explained by climate and management (Fig 3). All the climatic factors only explained a small amount of the difference in yield. Instead, changes in crop management (like planting rate and date) and the genetics of the crop explained much more of the difference in yield.

Please see page 3, Figure 3

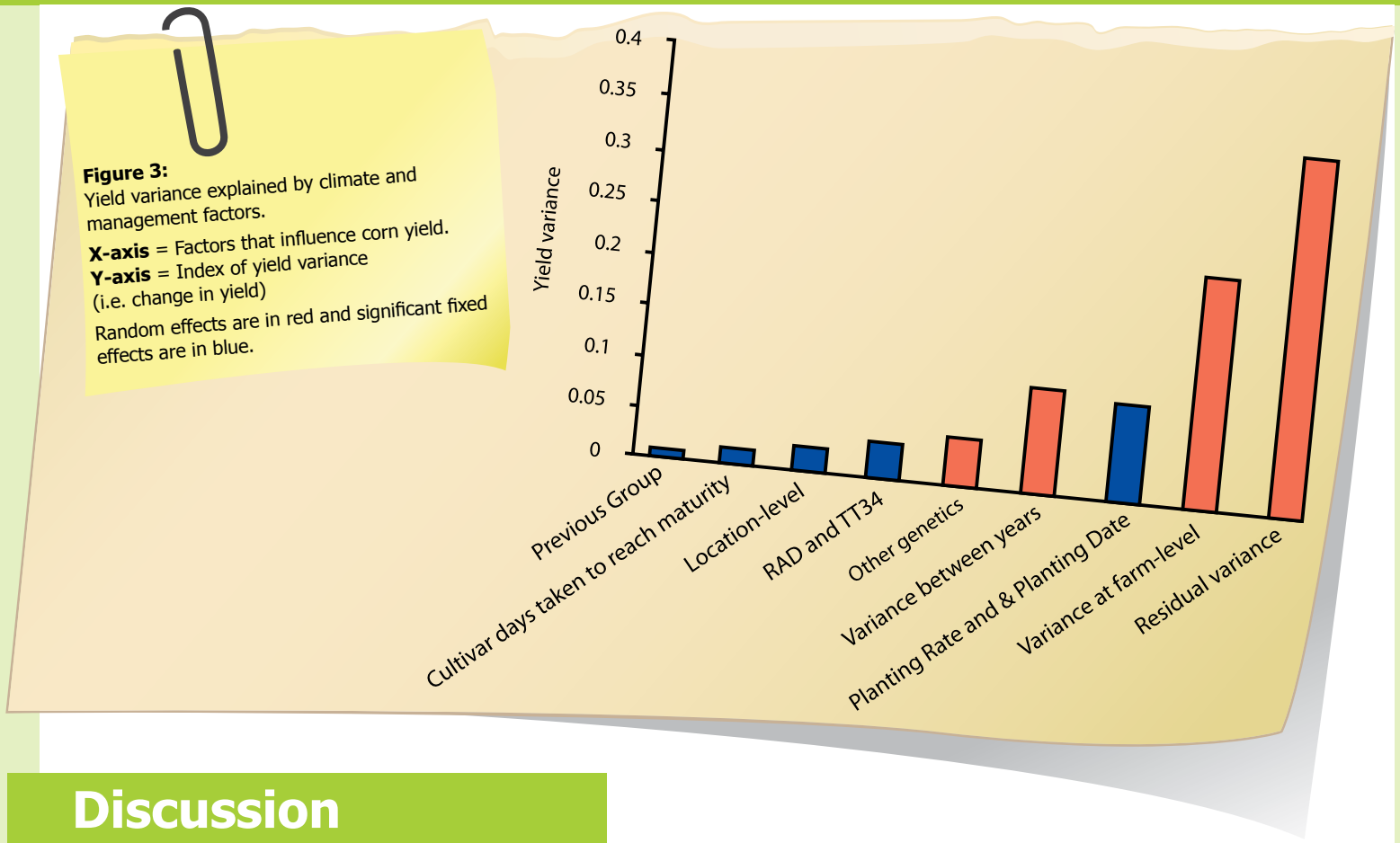


Figure 3:
Yield variance explained by climate and management factors.

X-axis = Factors that influence corn yield.
Y-axis = Index of yield variance (i.e. change in yield)

Random effects are in red and significant fixed effects are in blue.

Discussion

We found that when the plants experienced high daytime temperatures in early growth stages as well as in grain-fill, they actually had greater yields. We call this 'thermo-tolerance' and it could be very important when predicting irrigated corn yield responses to climate change.

We looked at several temperature factors that other scientists thought would negatively impact corn yields. We found that these were not linked to decreased yields in irrigated corn. This suggests that current thresholds for heat stress in corn may be too low.

The results of our study suggest that for irrigated corn, a combination of good crop management (e.g. planting rate and date) and corn genetics (e.g. selection of longer-season corn varieties) can make up for almost any losses in yield over a broad range of temperature, including some of the highest recorded temperatures in the US Corn Belt.

Keep in mind, though, that as temperatures increase with climate change, it is possible they will be significantly greater than those experienced in 2012. This means they may be high enough to reduce even irrigated maize yields. We'd need to do more research to figure out how high temperatures have to be for this to happen.

Conclusion

Studies like ours are very important to help us to understand the possible effects of climate change. They help us to see how we can improve our farming practices to prevent rising temperatures from having a negative effect on the amount of food that we produce.

As the world's population grows, we will need to grow more crops to provide for it. Learning how we can better manage our crops will help us to make sure that we can produce this extra quantity of food.

Glossary of Key Terms

Cultivar – a variety of plant created by plant breeders who combine different varieties together to develop a variety with the best features of each.

Cumulative incident solar radiation (RAD) – A measurement of the sun's energy on an area of land over a period of time. (Solar radiation isn't the same as nuclear radiation!). For this study it was the total over the growing season. It is measured in megajoules per square meter (MJ/m^2, or $MJ\ m^{-2}$)

Hectare – a unit of land area equal to a square of 100 meters x 100 meters.

Irrigated – when farmers use sprinklers or hosepipes and channels to supply water to crops. This gives the plants the water they need even when there hasn't been any rain

Maize – a scientific or technical name for corn. It comes from the Spanish word, "maíz"

Megajoule – a unit of energy. A million joules.

Metric ton – a unit of mass. One thousand kilograms..

Rainfed – when only the rain provides water for the crops

Significant – a result that is likely not due to chance, but rather due to a real process. Scientists define a result as "significant" if it would happen by chance less than 5% of the time (shown as $p < 0.05$). The more significant a result is, the lower its p value.

Yield – the amount of product (in this case, corn) produced. It is normally recorded in units of mass or volume, divided by a unit of land size. This allows us to compare the yield of different farms, regardless of their size. For our study we recorded yield as metric tons per hectare (MT/ha, or $MT\ ha^{-1}$).

Check your understanding

1. We used data from irrigated corn so that we could look at the effect of just temperature on yields. Why was it important for us to use irrigated corn rather than rainfed?
2. We measured cumulative incident solar radiation, or RAD, over the whole growing season. Why do you think that RAD had a positive effect on the yield of the corn?
3. In what ways do you think that planting date might affect the amount of yield?
4. Besides producing more crops, can you think of other ways in which we can make more food available to the world's population?

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