AGRICULTURE

Weather dilemma for African maize

The impact of climate change on food production remains uncertain, particularly in the tropics. Research that exploits the results of historical crop trials indicates that Africa's maize crop could be at risk of significant yield losses.

Maximilian Auffhammer

The growing global demand for calories — caused by an expanding population and a rise in average wealth — is one reason for the current peak in food prices. Coupled to this have been decreases in food supply caused by extreme weather events, such as last year's Russian heatwave. Regardless of where extreme weather occurs, the effects on food availability and price are disproportionately felt by the world's poor. Moreover, crop failures due to extreme weather not only affect those buying and selling in the global marketplace, but also have a direct impact on subsistence farmers. Understanding how such extreme weather events — which are predicted to become more frequent under climate change — affect both yields and total production of the world's staple food crops is thus an issue of both scientific and societal importance. Writing in *Nature Climate Change*, David Lobell and colleagues[1] present results that further our understanding of how maize yields — a crop on which millions depend for food and their livelihoods — respond to hotter days under both drought and non-drought conditions.


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Maize in a farmer's field in Kenya. Millions of people depend on maize for food and their livelihoods, so understanding the potential impacts of climate change on the crop is highly important. Using data from historical crop trials in Africa, Lobell and colleagues[1] show that yields of tropical maize are sensitive to exposure to very hot days and that drought stress significantly increases their sensitivity to warming — results that could help farmers adapt to climate change on the continent and elsewhere.

Global food markets have become increasingly volatile in recent years. Both supply and demand have contributed to this instability: rising incomes, growing populations and biofuel policies are upping the productivity required from a limited amount of agricultural land, and an almost incomprehensibly intricate set of agricultural support and trade policies within and across countries have historically made the economics of food supply extremely complicated.

Extreme weather events have also played a role. Wheat production in Russia decreased by almost a third last year[2], largely due to the summer heatwave, and the unusually high rainfall in Australia this past summer meant that a significant share of the nation's 2010–2011 wheat crop had to be downgraded to 'animal feed' quality. In the near term, the prospects for other major markets look equally pessimistic — the US Department of Agriculture and the United Nations Food and Agricultural Organization have both warned of a significant decrease in yields of Chinese winter wheat this year owing to drought[3,4]; a change that could result in the emerging superpower becoming a buyer of wheat on world markets.

Lobell and colleagues[1] exploit historical data from over 20,000 field trials of maize conducted in Africa over the past decade or so. The trials were originally conducted to test the resilience of the crop to different environmental conditions and involved varieties that are either currently in use or intended for planting by African farmers. Using daily weather records, the authors matched the yield results for each trial to the daily weather experienced by the plants while growing. They controlled for other factors that might affect the results at each site (such as soil quality) and during each season (such as changing global carbon dioxide concentrations) indirectly in a statistical model. This analysis allowed them to extract the effects of temperature and rainfall on yields.

The results show that each 'degree day' that the crop spends above 30 °C (a unit that reflects both the amount and duration of heat experienced by the plant) depresses yields by 1% if the plants are receiving sufficient water. This sensitivity is similar to that observed for temperate maize varieties in the United States[5]. However, Lobell and co-workers also show that water availability has an important effect on the sensitivity, with yields decreasing by 1.7% for each degree day spent over 30 °C under drought conditions.

To put these numbers in perspective, they indicate that under non-drought conditions 65% of the area in Africa that is under maize cultivation at present would experience yield losses from a uniform 1 °C warming. Under drought conditions, 100% of the present cultivated area would experience yield losses, with 75% of this area suffering yield losses of at least 20%.

What is most concerning about these results is the empirical confirmation that drought stress significantly amplifies the effects of heat stress. The authors are careful to caution that the field trials on which their results are based use fairly high levels of nitrogen fertilizers, which is not the case in many areas of Africa. Plants under nitrogen stress may react less strongly to temperature stress, suggesting that their results may be an upper bound for what one could expect in actual field settings. However, the close match with the field-based results for temperate maize in the United States[5] indicates that this effect is probably minor.

The study raises several issues related to how best to deal with the impacts of climate change on agriculture. It suggests that maize planted in a future Africa characterized by a drier and hotter climate will need to be able to withstand the joint stress imposed by heat and drought, which poses a challenge for the development of new varieties of the crop. But maize is not the only crop available to farmers, so they will most probably shift to growing other crops if maize yields are depressed to the extent that it is no longer profitable. Understanding the heat sensitivity of substitute crops is of prime importance for establishing the optimal sequence of crops that farmers could move to as temperatures rise.

One of the most important aspects of the work by Lobell and colleagues[1] is that it offers a new way of obtaining this information from a widely available source of data. Data repositories hold the results of field trials for a variety of crops and locations, and should be exploited in the same fashion to establish an 'atlas of climate sensitivities' for multiple crops in different regions. Finally, social scientists can help crop scientists understand how farmers' decisions may change with climate. Farmers mitigate the effect of a changing climate by adjusting the mix of crops they plant and inputs they use, but these factors are normally held fixed in experimental field trials and computer-based simulation models. Additional interdisciplinary research that takes the human response to changing weather patterns into account will be key to obtaining reliable impact estimates and therefore to designing optimal policy responses. ❒

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Published online: 13 March 2011

ECOLOGY

The secret of success

Flowering plants have expanded rapidly in Antarctica over the past 50 years. A study now reveals that an efficient way of acquiring nitrogen from protein-rich soils as they decompose has allowed these plants to take full advantage of a warming climate.

Nicoletta Cannone

Parts of Antarctica have experienced warming almost an order of magnitude greater than the global average over the past 50 years, with the Antarctic Peninsula ranking among the three fastest-warming regions on Earth[1,2]. Polar environments are particularly sensitive to changes in climate, so it is not surprising that Antarctic ecosystems have been affected by the warming that has taken place[2]. Perhaps the most notable impact has been a dramatic expansion of the two species of flowering plant that occur on the continent — Antarctic pearlwort and Antarctic hair grass (Fig. 1). Writing in *Nature Climate Change*, Paul Hill and colleagues[3] show that the proliferation of Antarctic hair grass may in part be explained by an ability to acquire nitrogen in the form of short-chain proteins, which gives it a competitive advantage over other plants as the climate warms.

Life is scarce on Antarctica. Two of the most important constraints on biological activity are low temperatures — which have a limiting effect on photosynthesis in this part of the world — and a lack of liquid water (which is trapped as snow and ice). Climate change is already lifting these constraints and thereby stimulating changes in the ecosystems that occupy the ice-free pockets of the continent. In particular, there has been a dramatic increase in the abundance and ranges of two species of flowering higher (or vascular) plants in coastal zones[4]. The expansion has been greatest for Antarctic hair grass: the size of most populations of this species has increased by about an order of magnitude since the middle of the twentieth century.

In field experiments in which soils were warmed artificially to explore the effects of climate change on Antarctic ecosystems, the above-ground biomass of both Antarctic pearlwort and Antarctic hair grass increased significantly[5], indicating that their expansion is at least partly due to increasing summer air temperatures. Warmer and/or longer growing seasons have probably also improved their reproductive success. The underlying mechanisms that have allowed the plants to expand remain uncertain, however, as do the consequences of their expansion for the algae, lichens and mosses that dominate the vegetation of the continent and compete with them for light and nutrients.

Nitrogen supply is often a limiting factor for plant growth, regulating primary productivity in many terrestrial ecosystems at high latitudes[6]. Most nitrogen enters soil in the form of proteins, which are then broken down — first into short chains of amino acids known as peptides, then into individual amino acids, and finally into inorganic forms (that is, nitrate or ammonium) — by microbes. Antarctic soils contain large stocks of nitrogen in the form of proteins, because low temperatures limit the rate of soil decomposition.

Until recently, it was thought that most flowering plants could only acquire nitrogen as nitrate or ammonium, and thus had to 'wait' for proteins to be broken down completely before they could exploit the nitrogen locked up in them. It is now known, however, that some Arctic plants can avoid this constraint by acquiring nitrogen in the form of amino acids[7]; and, taking things a step further, it was recently shown that some plants are able to acquire nitrogen in the form of short-chain peptides under laboratory conditions[8].

Hill and co-authors[3] proposed that an ability to acquire nitrogen in these complex