

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 States⁵ 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 colleagues¹ 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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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 place². 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 colleagues³ 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 zones⁴. 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 significantly⁵, 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 latitudes⁶. 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 acids⁷; 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 conditions⁸.

Hill and co-authors³ proposed that an ability to acquire nitrogen in these complex



Figure 1 | Monitoring the expansion of flowering plants in the maritime Antarctic. Antarctic hair grass — seen in the foreground of the image, which was taken at Anchorage Island, Marguerite Bay, close to Rothera research station in the Antarctic Peninsula — has expanded rapidly over the past 50 years in maritime Antarctica, out-competing the mosses and other lower plants that dominate the vegetation of these ice-free areas. Hill and co-workers³ show that the grass is able to take up nitrogen in the form of short-chain proteins, which are released during the early stages of decomposition of the protein-rich soils in Antarctica. They propose that this ability gives the species access to a store of nitrogen that is not available to mosses, allowing it to take full advantage of the favourable effect of rising temperatures on photosynthesis in the region.

forms might be the key to explaining the success of Antarctic vascular plants. Using a series of experiments in which they added inorganic forms of nitrogen, amino acids and peptides to soils and plants from Signy (an island off the coast of the Antarctic Peninsula), they explored how Antarctic hair grass acquires nitrogen in the field. Their results provide compelling evidence that the species is able to take up nitrogen as short peptides, and, moreover, that it is able to do so in the presence of microbes, which compete for nitrogen in this form. In fact, the plants acquired nitrogen in this

form more than three times faster than they acquired it as amino acid, nitrate or ammonium, and more than 160 times faster than the mosses with which it competes for soil nutrients, indicating that this process operates in the field as well as the laboratory.

Warming of cold Antarctic soils is likely to increase the rate at which the protein-rich organic matter within them decomposes, potentially providing a substantial new source of nitrogen. In this context, the ability of Antarctic hair grass to acquire nitrogen more efficiently than its competitors might provide an important advantage, allowing

the species to exploit the beneficial effects that warming has on photosynthetic activity in polar regions. Hill and colleagues propose that this advantage, together with the ability of higher plants to access a larger volume of soil than mosses and other so-called lower plants through their root system, is likely to explain the recent proliferation of Antarctic hair grass in maritime Antarctica.

Antarctic temperatures are still significantly below the 'photosynthetic optima' of both Antarctic hair grass and Antarctic pearlwort⁹. If the conclusions drawn by Hill and colleagues³ are correct, Antarctic flowering plants are likely to continue to benefit from warming as the supply of nitrogen from decomposition of soil organic matter continues to grow. Vegetation dynamics in the polar regions of both hemispheres should be monitored closely over the coming years to further test this important hypothesis, and to determine whether this pattern of change represents a more widely applicable model of the impacts of climate warming in polar regions. □

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ATMOSPHERIC SCIENCE

Tug of war on the jet stream

Recovery of the ozone hole and increasing greenhouse-gas concentrations have opposite effects on the jet stream. New model experiments indicate that they will cancel each other out over coming decades, leaving storm tracks at a stand still.

Judith Perlwitz

Over about the past 30 years, depletion of the ozone layer over Antarctica has had a greater effect on climate in the Southern Hemisphere than rising greenhouse-gas concentrations, causing a polewards shift of wind and

precipitation patterns. Since about 2000, the so-called ozone hole has stopped enlarging and it is expected to close completely sometime after the middle of the century, in response to a ban on the production and use of ozone-depleting

substances under the Montreal Protocol. This raises the question of whether wind and precipitation patterns will revert to their pre-ozone-hole conditions as the ozone layer recovers. Two new studies — one by Polvani and colleagues¹