Geophysical Union in Washington DC.

First, the 2016 geomagnetic pulse beneath South America came at the worst possible time, just after the 2015 update to the World Magnetic Model. This meant that the magnetic field had lurched just after the latest update, in ways that planners had not anticipated.

Second, the motion of the north magnetic pole made the problem worse. The pole wanders in unpredictable ways that have fascinated explorers and scientists since James Clark Ross first measured it in 1831 in the Canadian Arctic.

In the mid-1990s the pole picked up speed, from around 15 kilometres per year to around 55 kilometres per year. By 2001, it had entered the Arctic Ocean — where, in 2007, a team including Chulliat landed an aeroplane on the sea ice in an attempt to locate the pole.

In 2018, the pole crossed the International Date Line into the Eastern Hemisphere. It is currently making a beeline for Siberia (see 'Magnetic motion').

The geometry of Earth's magnetic field magnifies the model's errors in places where the field is changing quickly, such as the North Pole. "The fact that the pole is going fast makes this region more prone to large errors," says Chulliat.

To fix the World Magnetic Model, he and his colleagues fed it three years of recent data, which included the 2016 geomagnetic pulse. The new version should remain accurate, he says, until the next regularly scheduled update in 2020. (As *Nature* went to press, project leaders were trying to determine whether the model's release would be delayed by the ongoing US government shutdown, which includes NOAA.)

CORE QUESTIONS

In the meantime, scientists are working to understand why the magnetic field is changing so dramatically. Geomagnetic pulses, like the one that happened in 2016, might be traced back to 'hydromagnetic' waves arising from deep in the core (J. Aubert *Geophys. J. Int.* **214**, 531–547; 2018). And the fast motion of the north magnetic pole could be linked to a high-speed jet of liquid iron beneath Canada (P. W. Livermore *et al. Nature Geosci.* **10**, 62–68; 2017).

The jet seems to be smearing out and weakening the magnetic field beneath Canada, Phil Livermore, a geomagnetist at the University of Leeds, UK, said at the American Geophysical Union meeting. And that means that Canada is essentially losing a magnetic tug-of-war with Siberia.

"The location of the north magnetic pole appears to be governed by two large-scale patches of magnetic field, one beneath Canada and one beneath Siberia," Livermore says. "The Siberian patch is winning the competition."

Which means that the world's geomagnetists will have a lot to keep them busy for the foreseeable future. ■

AGRICULTURE

The quest to build a better cassava

Researchers in Nigeria are combining genomics and conventional breeding to improve the starchy staple crop.

BY AMY MAXMEN IN IKENNE, NIGERIA

"I like this one," says Ismail Rabbi, placing his palm on a cassava plant and smiling coyly, like a parent picking favourites. "It doesn't look impressive — it's not tall," he says, "but it beats all the obstacles we throw at it."

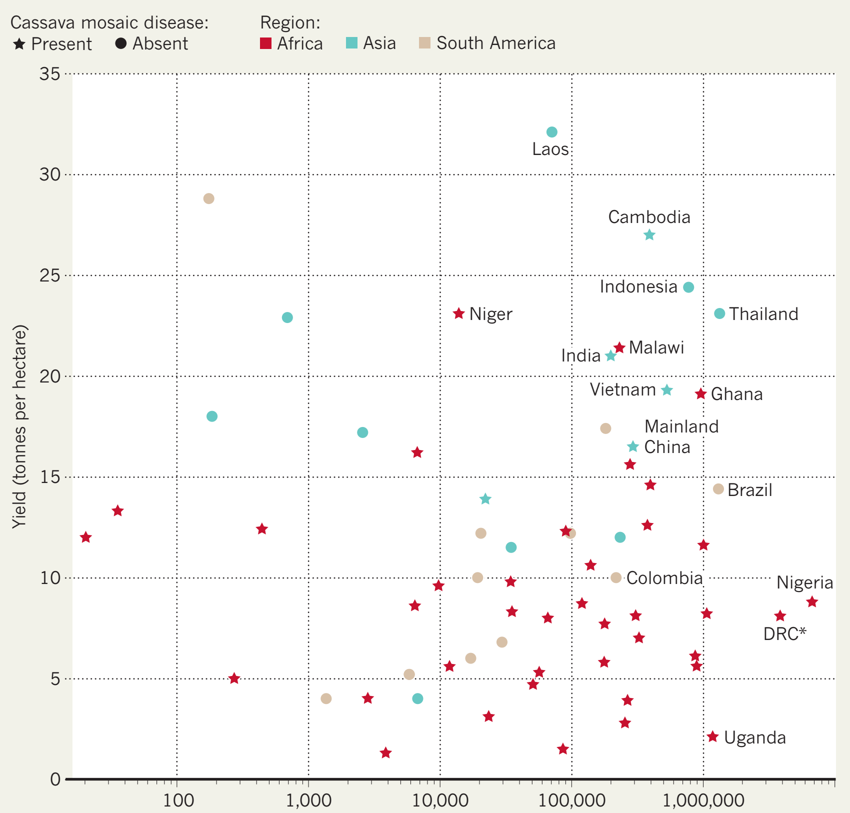
Rabbi, a geneticist at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, and his colleagues are on a mission to improve cassava (*Manihot esculenta*). Also known as yuca or manioc, its starchy roots provide food and income to more than 800 million people worldwide. In Africa, where consumption is highest, cassava plants bear smaller yields than their cousins in Asia and South America. But African varieties tend to be more tolerant of blights, such as the deadly cassava mosaic disease now spreading across Asia.

In November, Rabbi shipped five varieties of African cassava that resist the disease to Thailand, the world's largest cassava exporter. He and his colleagues created the plants under the auspices of the US$62-million Next Generation Cassava Breeding project, which the UK government and the Bill & Melinda Gates Foundation launched in 2011.

Project scientists are using genomic data to identify useful traits for breeding cassava varieties that will suit the world's needs

A STARCHY STAPLE

Cassava, also known as yuca or manioc, is crucial to food security in parts of Africa, Asia and South America. But the level of edible starch varies with geography and climate, as does the presence of a blight known as cassava mosaic disease.



* Democratic Republic of the Congo

SOURCE: UNITED NATIONS FOOD AND AGRICULTURE ORGANIZATION

AMY MAXMEN

Chiedozie Egesi, the director of the Next Generation Cassava Breeding project, surveys a field of plants in Nigeria.

— safeguarding against starvation as the climate warms, populations grow and viruses spread.

When the African plants reach Thailand, scientists there will cross them with cassava varieties adapted to Asia. They will screen the resulting offspring for genetic markers that Rabbi and his colleagues use to predict a plant's resistance to mosaic viruses and 12 other traits, such as the amount of edible starch in each root.

These genetic markers have helped the IITA scientists to breed eight types of cassava that are now growing at test plots across Nigeria. Scientists and farmers will compare them with the best cassava varieties in wide use.

On a blazing afternoon in November, Rabbi meanders through one such plot in Ikenne with Chiedozie Egesi, the leader of the Next Generation Cassava Breeding project and a geneticist at the IITA. Their conversations drift to agronomic and economic strategies that would help farmers to adopt the new cassava varieties, such as creating a market for the plants. "We aren't just sitting in a room and making sure a plant works perfectly," says Egesi. "We are bringing it to the places where problems arise, and always asking how we can make our science helpful."

Cassava is a mainstay for subsistence farmers on three continents because it survives in shoddy soil and weathers droughts, and its roots can be harvested at any time of the year. But there are wide geographical disparities in cassava yields. Varieties grown in Africa average 8.8 tonnes of usable root mass per hectare, compared with 13 tonnes per hectare in the Americas and 22 tonnes per hectare in Asia (see 'A starchy staple').

Researchers have long attempted to improve the situation for African farmers by importing Asian and South American varieties. But these foreign plants, which lack defences against African pathogens, have fared poorly. And breeding hardier hybrid varieties has proved challenging. It takes about five years of breeding to produce a worthy hybrid.

"It's fabulous that cassava is finally getting recognition."

After each cross, breeders must grow the offspring for about a year and then assess the quality of the roots — which requires them to harvest, soak, dice and dry the experimental plants before weighing the starch that remains. Even then, a high-yielding plant might founder when exposed to harsh environments.

This process wastes land, labour and money. And although cassava is one of the largest sources of carbohydrates for people in Africa, corn, wheat and rice vastly surpass it in terms of global sales and research grants. The Next Generation Cassava Breeding project aims to accelerate the creation of hardier cassava varieties, and improve yields, by using genetic sequencing to identify winning hybrids. Project researchers are also working to spur market investment, in part through discussions with entrepreneurs who want to buy and process cassava roots grown by small-scale farmers.

The effort is long overdue, says Ros Gleadow, a plant scientist at Monash University in Melbourne, Australia. "It's fabulous that cassava is finally getting recognition," she says. "It needs to be brought into the twentieth century."

The eight cassava varieties growing in test plots are products of the IITA team's first round of plant breeding. The researchers analysed DNA from around 2,500 seedlings that germinated in 2013, and identified promising varieties based on genetic sequences that they had associated with particular traits.

Data analysed in October 2018 show that seedlings bearing the genetic fingerprint associated with high concentrations of β-carotene — a precursor of vitamin A, which is sorely lacking in many Africans' diets — have an 83% chance of pumping out the nutrient at the predicted level, says Rabbi. And varieties with genetic markers for resistance to cassava mosaic disease turn out to be resistant around 60% of the time. "Genomic selection is not a panacea," Rabbi says. "But plot testing is so ▶

expensive that at least this helps you whittle it down."

Breeders around the world are already using the Nigerian team's data to check their plants for resistance to cassava mosaic disease. The viruses underlying the blight, which are spread by whiteflies, stop roots from growing. The viruses have already marched through Africa, causing famines in the 1920s and 1990s. In 2015, a severe strain appeared in Cambodia.

Farmers in Thailand, South America and the Pacific Islands — where cassava is highly susceptible to the viruses that cause mosaic disease — are hoping to mix resistant alleles from Africa into their crops through conventional breeding. One such cross between a Colombian plant and a Nigerian variety has been aided by the markers identified by the Next Generation Cassava Breeding project researchers, and is currently growing in test plots near the IITA.

SOWING SOLUTIONS

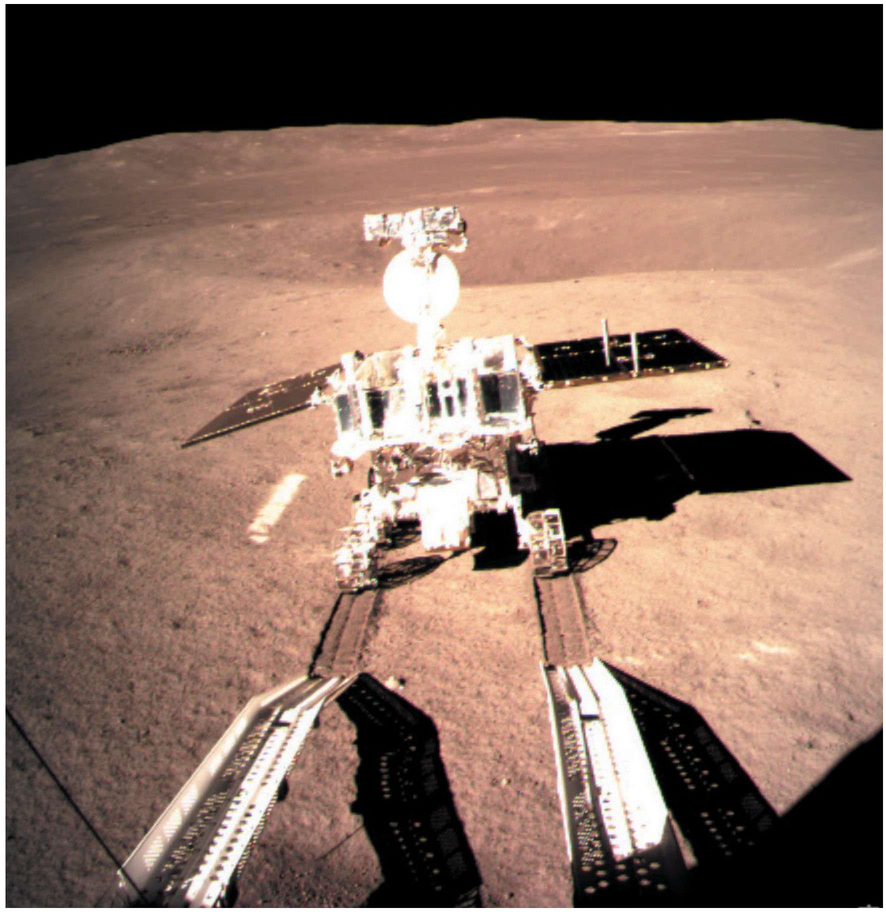
In 2020, the scientists will select varieties from their current top eight, and distribute them across Nigeria. They're also talking to colleagues in Thailand, Laos, Brazil, Uganda and Tanzania about shipping varieties there. And the team is trying to find ways to address issues that stop farmers from adopting new products.

When Nigerian farmers are asked why they don't grow more cassava varieties, they often reply that they don't have enough plants to do so. Cassava is propagated by sowing pieces of the stalk from a mature plant, rather than seeds. Each clipping sprouts a clone of its parent, and so years can pass before a field is filled with the same variety. And the genetic backbone of a variety degrades over time when cassava is cultivated this way, because clones acquire mutations; the latter can lead to 'mutational meltdown' (P. Ramu *et al. Nature Genet.* **49**, 959–963; 2017).

In 2016, IITA geneticist Elohor Mercy Diebiru-Ojo and her colleagues developed a work-around: the first semi-hydroponic system for growing cassava. In her lab, slim shoots of cassava grow under fluorescent lights in transparent plastic boxes filled with watery soil. Every two weeks, the team cuts the saplings at nodes where they branch, and repots the snippets. Within 2 months, they can produce 100 plants from a single parent.

Lifting a box of seedlings grown using the method, Diebiru-Ojo says some farmers she knows have told her they're willing to pay for such premium plants. She hopes that this will foster the growth of businesses that sell high-quality cassava shoots to farmers, so that the same plants are not cloned for too many generations. "When this project ends," she says, "I want the system to keep going."

If new varieties fail to take root, viruses will eventually have their way. Staring out at his field of cassava, Egesi says, "I'm really excited to see that none of these show any signs of disease." He adds, "the minute the government approves of them, we must get them out to people." ■



XINHUA/ZUMA WIREUNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE

The Yutu2 rover was deployed on the lunar surface on 3 January.

SPACE

China explores Moon's dark side

Chang'e-4 could send back clues about how parts of the Moon became pockmarked by asteroids.

BY DAVIDE CASTELVECCHI

A Chinese probe has become the first to touch down on the far side of the Moon, 60 years after an orbiter gave humans their first glimpse of the region.

Chang'e-4 landed inside the Von Kármán Crater at 10:26 China local time on 3 January, and sent back its first images. Twelve hours later, the mission's 140-kilogram Yutu2 rover drove down a ramp and onto the lunar terrain.

As the Moon's far side is permanently hidden from Earth, the news of Chang'e-4's successful landing was relayed by a spacecraft called Queqiao. It has been circling around a gravitationally stable point about 60,000 kilometres beyond the Moon since it launched in May.

The far-side landing location also meant that, during the final phases of the approach, Chang'e-4 was on its own, and could not be operated remotely. Starting from an altitude of 15 kilometres, the probe used a rocket booster to brake and briefly hover. Meanwhile, an on-board camera and a laser ranging system scanned the terrain to avoid boulders.

"The landing was a huge technical and scientific success," says Brad Tucker, an astrophysicist at the Australian National University in Canberra.

Chang'e-4 launched on 8 December, and entered a highly elongated lunar orbit