CLIMATE

The changing seasons of tea

When temperatures and rainfall patterns shift, tea plants undergo changes that affect growth, as well as the flavour and potential health benefits of the teas that they produce.

BY ANNA NOWOGRODZKI

When you take a sip of tea, you're drinking a beverage that is grounded in a particular time and place. In Yunnan province, southwestern China, which is the source of a highly prized tea known as pu-erh, summer brings monsoon rains, whereas spring is comparatively dry. Tea leaves that are harvested in spring therefore have different qualities to those collected in summer: each tea contains around 50 chemicals that are unique to its season of harvest, says Albert Robbat, a chemist at Tufts University in Medford, Massachusetts.

The sensitivity of tea plants to the environments in which they are grown is part of tea's appeal — connoisseurs can discern taste characteristics that can be attributed to growth conditions. But that also makes the crop vulnerable to the effects of climate change. Variations in temperature and precipitation are known to affect tea yield, as well as alter the complex balance of chemicals that gives tea its flavour and potential health benefits.

QUANTITY AND QUALITY

Changes in climate often affect the quantity of tea that farmers can grow. China and India produce the most tea worldwide, but both comprise regions with diverse climates. Although climate change affects each region differently, it influences tea yields across the board by altering precipitation levels, increasing temperatures, shifting the timing of seasons and encouraging insect pests.

About one-quarter of the world's tea is produced in India. More than half of that is grown in Assam, a state in the north-east of the country. In a 2018 survey of tea-farm workers in Assam, 88% of managers of plantations and 97% of smallholders said that adverse climate conditions were a definite threat to their tea-growing operations[1]. Climate change is pushing rainfall in Assam to the extremes, leading to an overall decrease in precipitation but with more instances of drought and heavy rain. The intense rains cause the erosion and waterlogging of soil, which damages root development and reduces the yield of the tea plants. A 2016 study in Assam found that drought did not affect yield[2], but other research suggests that drought increases the susceptibility of tea plants to insect pests[1].

When Selena Ahmed, an ethnobotanist at Montana State University in Bozeman, began her work on tea more than a decade ago, she travelled to Yunnan to study the farm-management practices of tea smallholders in the region. Pu-erh, the province's speciality tea, is fermented and then shaped into cakes and aged — sometimes for years. The farmers that Ahmed interviewed often mentioned effects wrought by climate change, and how those effects greatly influenced their decisions on tending to their small farms. In Yunnan, more rain during the monsoon season has been shown to decrease tea yield. Most of China's tea-producing regions are found in the south, where overall rainfall is increasing and instances of heavy rain that can damage tea crops are becoming more frequent.

In India and China, climate change seems to be shifting the timing of the seasons. In Yunnan, the onset of the monsoon season is falling earlier, which cuts short the drier spring. And the Intergovernmental Panel on Climate Change predicts that, in the next 50 years, the end of the East Asia monsoon season will be pushed back. Unfortunately, data gathered in China between 1980 and 2011 indicate that a later end to the monsoon season is a good predictor of a decrease in tea yield[3]. In Assam, plantation managers have noticed that a shift in the seasons can lead to a shorter growing season for tea, which especially lowers yields of the first flush and the second flush, the earliest and most valuable harvests.

Temperatures are climbing in both India and China. In Assam, plantation managers say that increasingly frequent hot spells are harming yield. Heatwaves are also dangerous for plantation workers. Exposure of tea plants to sunlight, which can damage crops, is increasing in both China and Assam.

Such changes in climate are also influencing the abundance of insect pests. Higher temperatures enable insects that attack tea plants to survive winter, giving them more time in which to reproduce. Plantation managers in Assam have noticed a greater number of insect pests on tea plants. "When temperatures start going up, the insects start coming out," says Colin Orians, an ecologist at Tufts.

The largest tea plantation in the province of Yunnan, China, is a source of prized pu-erh tea.

MICHAEL S. YAMASHITA/NATIONAL GEOGRAPHIC

THE NOSE MACHINE

Apart from whether farmers can grow enough tea in a changing climate, there's also the question of whether it will taste as good or retain its potential health benefits. Robbat, Orians and their colleagues at Tufts have been investigating how shifts in climate might affect the quality of tea.

About 20–30% of tea's mass is made up of chemicals known as antioxidants, says Robbat, which neutralize highly reactive molecules called free radicals in the body that can otherwise damage cells. These include a variety of phenolic compounds such as tannins and catechins, some of which have been linked to health benefits and give tea its bitter taste and astringent quality. Tea's antioxidant content is affected by temperature and rainfall. Robbat's team found that more rainfall increased the antioxidant level overall, even though levels of certain antioxidants decreased[4]. It also showed that tea grown at a higher elevation, where

Pu-erh tea is fermented, shaped into cakes and then left to mature.

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the temperature is lower, contains compounds potentially beneficial to health that are missing from tea grown at a lower elevation at the same location. This implies that tea would lose some of its purported health benefits should temperatures climb.

The most important chemicals in tea are the volatile compounds that affect how we perceive the flavour of its antioxidants. Such compounds pack an outsized punch, given that they are present in such small amounts — 0.1% by mass, according to Robbat. Tea contains hundreds of these flavour-giving chemicals, but most studies investigate fewer than 100 or so, says Robbat. "Nobody really knows what's in the tea." His team can measure tea's complexity more finely, thanks to a gas chromatography–mass spectrometry system at Tufts, which the team uses to identify chemicals in the beverage by mass. But Robbat's study has a further component: the human nose. A chemist sitting by the system is asked to describe each sample's smell — for example, strawberry, honey, flowers or rotten eggs — while the masses of its components are determined.

Using this approach, the team has found around 750 unique chemicals in tea. They have confirmed the identity of more than half by matching the compounds to commercially available reference chemicals. "The others you can't buy," Robbat says. Some have simply never been analysed before.

In Yunnan, farmers have told Ahmed that the quality of their tea is declining and customers won't pay as much for it as they once did. "The price of the tea dropped by about 50%," she says. "That really impacts the livelihoods of these farmers." Ahmed has linked the decrease in tea quality to the monsoon season's earlier start. The decline is partly attributable to a dilution of the chemicals that help to flavour tea — the leaves take in more water from the extra rainfall. But the effects on chemicals that have potential health benefits are more complex. When the monsoon season began earlier and temperatures were higher, Ahmed found that although the overall amount of phenolic compounds in tea increased, the levels of certain such chemicals decreased. She also showed that affected tea had less antioxidant activity — highlighting a possible negative effect of earlier rains on tea's potential health benefits.

TEA BUGS

Many tea farmers are already adapting their practices to the changing climate. One approach that Ahmed has found to be promising is agroforestry, in which tea is grown in a forest-like ecosystem with trees and shrubs instead of as a monoculture in a terraced garden. Agroforestry provides tea plants with more shade, which helps to protect them from the heat of the Sun, and also reduces the amount of moisture that tea plants lose by transpiration, protects them from frost, and helps to prevent soil erosion.

If legumes are incorporated into the forest, soil can be enriched through the actions of nitrogen-fixing microorganisms that live in the roots of such plants. Ahmed has shown that agroforestry seems to improve the quality of the resulting tea, by affecting the level of phenolic compounds it contains. "For tea agroforest, there's less of a drop in the level of epigallocatechin gallate and other catechins, compared to the terraced gardens," she says.

Farmers can also grow tea plants from seed, rather than cuttings. Such plants have a deeper, more resilient root system, which helps them to survive drought and prevent soil erosion.

Many tea farmers in Assam are taking steps to mitigate the effects of climate change[1]. Soil conservation is the most common practice, with 82–100% of plantations doing things such as: covering soil with mulch (to conserve moisture); contour farming (in which crops or drainage ditches are located along terraces that follow the slope of the land to help water better soak into the soil and prevent erosion); providing shade for tea plants; or filling in bare ground with vegetation. Some plantation managers also conserve water in ponds or behind dams for use in irrigation.

Assam's tea farmers also seem willing to listen to the findings of advisory groups and research associations: 95% of smallholders say that they would follow the recommendations of such organizations[1]. The Tea Research Association in Jorhat, Assam, suggests that there should be more region-wide efforts to mitigate the effects of climate change, including management of water resources across entire watersheds, which comprise areas of land drained by specific rivers. In particular, the association recommends that research should focus on the areas to which tea plantations are likely to move — generally, higher elevations and latitudes.

But the impact of climate change on tea farming is complex. Its effects on insects that live on tea plants are a case in point. Tea farmers seek to deter most insects that damage their crop, but the tea green leaf hopper (*Empoasca onukii*) actually makes tea more desirable and profitable. It feasts on young, growing tea plants by piercing leaves and stems to suck out juices. In response to this injury, tea plants produce compounds that form part of a defence mechanism, some of which are volatile chemicals with a pleasant taste. After tea bitten by tea green leaf hoppers was found to be especially flavourful, tea farmers began to cultivate it commercially in the 1930s. "It's a really good tea," says Orians. "It's got this sort of natural sweetness."

The premium that people will pay for this 'bug-bitten' tea is such that, even though plants affected by tea green leaf hoppers have yields that are 15–50% lower, according to Orians, farmers' profits can increase by up to 100%. The practice, which probably began in Taiwan, has spread to mainland China.

In a world affected by climate change, people are likely to be drinking tea that has had to adapt. Some tea might even be tastier and healthier than varieties available at present. It's also possible that there might not be enough tea to satisfy demand. People's actions in response to changes in climate will determine whether the beverage, as we know it, is here to stay. ■

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