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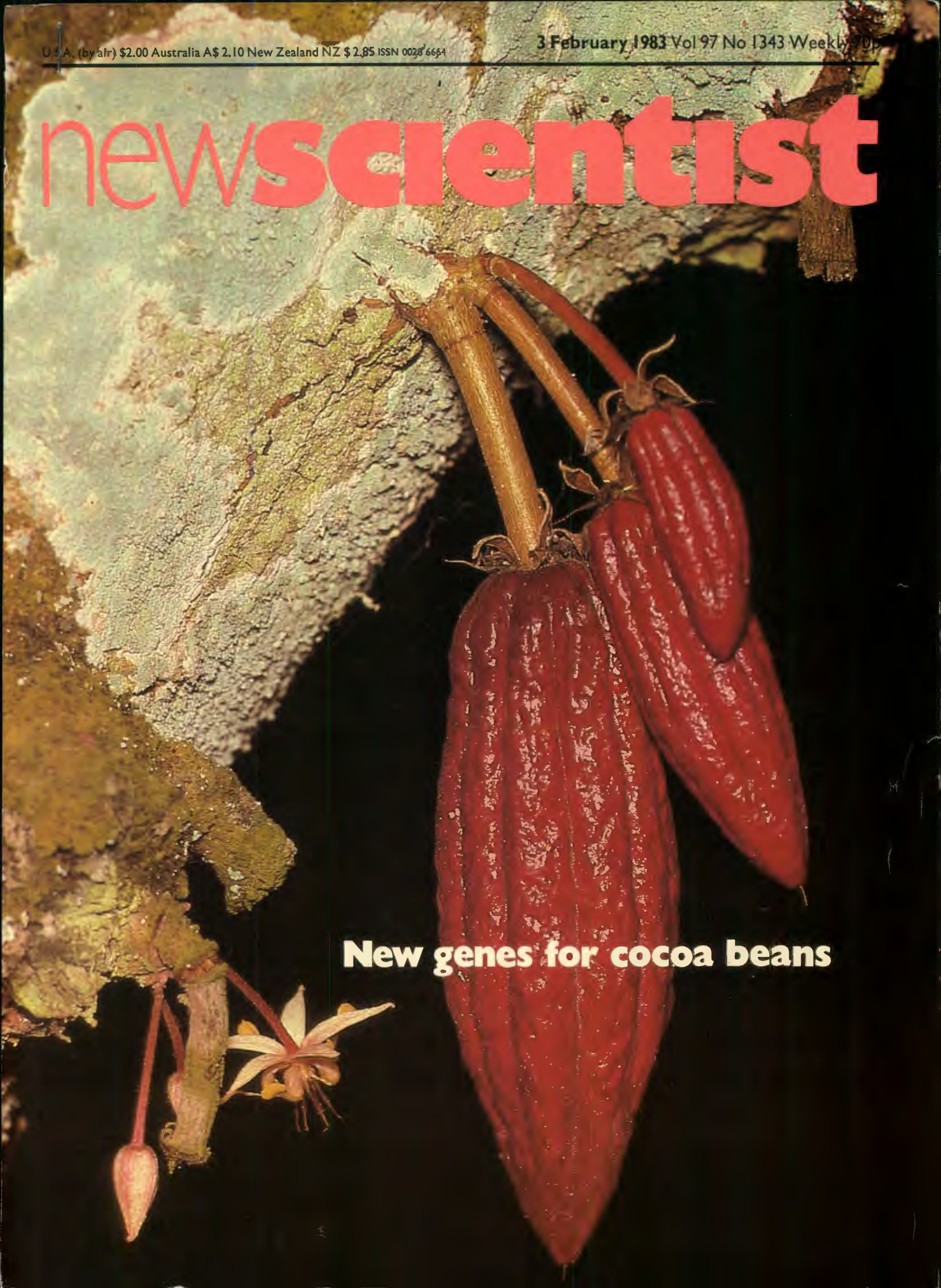


New genes for cocoa beans

Good cocoa country. Raul Salazar, of Ecuador's agricultural institute, scours the Rio Añangu for wild cocoa trees

In search of the perfect cocoa bean

The world's plantations of cocoa are short on genetic variability. Wild plants, in the Amazon, may contain the required genes. The first problem, is to find them

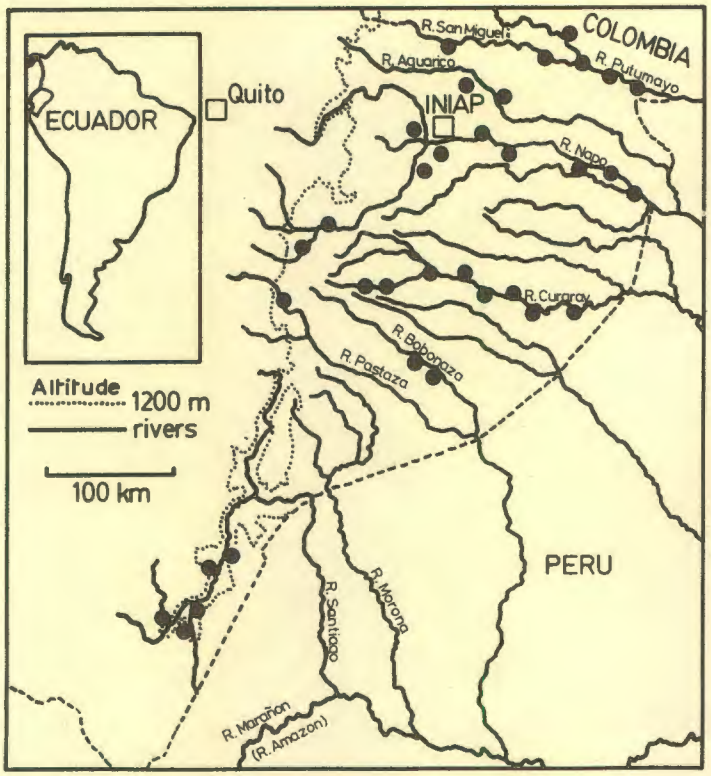
John Allen

IN *New Scientist* in October 1979 I saw a rather unusual job advertisement: "Plant collecting in the Amazon". It was not joking. Three months later I found myself settling down to life on a research station in the Amazon rainforest in eastern Ecuador. My job, financed by the London Cocoa Trade, was to collect wild cocoa.

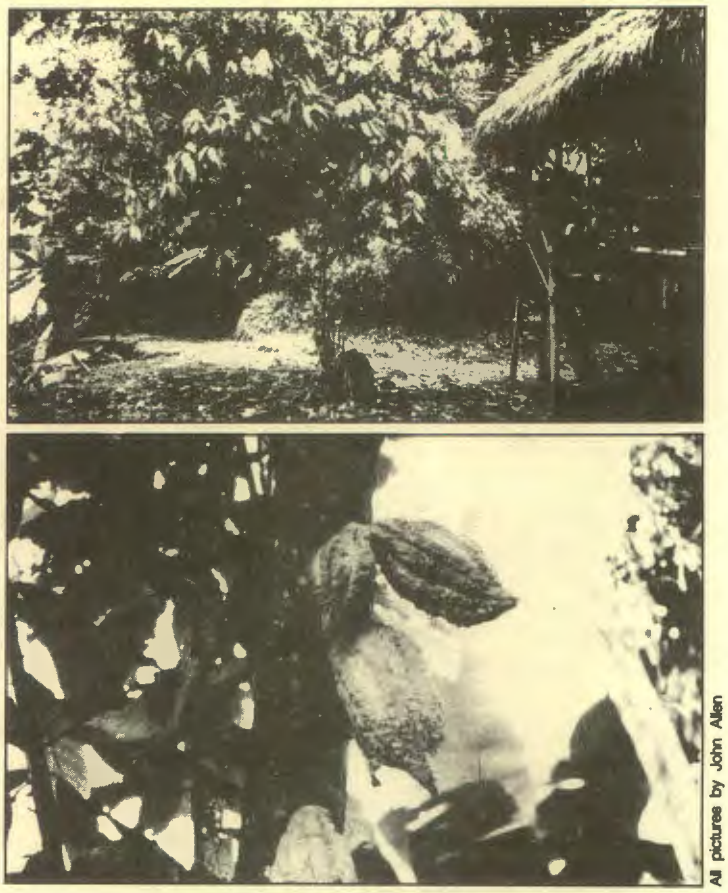
Cocoa cultivation spread so quickly around the world that all the crops derived from only a few wild ancestors, so that modern cultivated varieties suffer from a lack of genetic variation. This means that plant breeders who try to create higher-yielding or disease-resistant varieties by selection or hybridisation from existing varieties can make only limited progress; the genes they need are simply not found in the cultivated populations. But such genes may be found among wild cocoa trees; there were spectacular increases in yield and a partial increase in resistance to disease when the first collections of wild cocoa from the Upper Amazon, made by J. F. Pound in 1937-38, were supplied to breeders in the 1940s.

Forty years ago, the forests along the eastern fringe of the Andes were as inaccessible as anywhere in the world; but it is there that is found wild cocoa with the greatest genetic diversity. In the past 10 years, with the discovery and exploitation of important oilfields from Venezuela south to Bolivia, roads and airstrips have been built, colonists have poured in, towns have been founded and the rainforest is disappearing. It is now much easier to travel in these areas, but collecting wild cocoa and other species of the rainforest has suddenly become very urgent. The London Cocoa Trade Amazon Project, as my collecting programme had been christened, was to be the first stage in a rescue operation. With the support of the government agriculture research institute (INIAP) in Ecuador, I would have systematically to travel through the Amazon region of Ecuador, locating the wild cocoa and bringing back planting material to my base at the Napo Research Station.

The area around the Napo station is a microcosm of the region. Fifty kilometres to the north, the American oil company Texaco drilled its first productive well in 1967 in a clearing in the forest, bringing in its drilling rig by air as there were no roads. That well, still producing, is now almost surrounded by a town of 25 000 people, called Lago Agrio. From Lago Agrio a gravel road leads through the jungle and up into the Andes, reaching Quito, the capital of Ecuador, over a 4000 m pass. Another road runs south, through the oilfields, and is constantly being extended into virgin forest. Alongside these roads runs the 700 km trans-Andean pipeline, and there are side-roads and branch pipelines leading to about 200 individual oil wells. Ever since the roads were first planned, the colonists have been arriving, escaping from poor-quality land, drought, landowners and overpopulation in other parts of Ecuador. Now they are settled along the roads; each family is allowed to claim title to a 50 ha block of land, with 250 m of road frontage, and 2 km deep. Behind the first line of colonists is a second, and a third, and so on, some families being 10 km or more from the road along a muddy footpath. Throughout this settled area, the forest is being cut down. The farmers plant one or two crops of maize or manioc, and then use the land mainly as pasture for cattle or for small plantations of coffee. Around Napo, after 15 years of colonisation, there are still appreciable areas of untouched forest within 1-2 km of the road; elsewhere in Ecuador, after 30 or 40 years of colonisation, one can walk for a day away from a road without reaching the forest.



The Amazon region of Ecuador. INIAP is the experimental station and each large dot represents a collection of wild cocoa



All pictures by John Allen

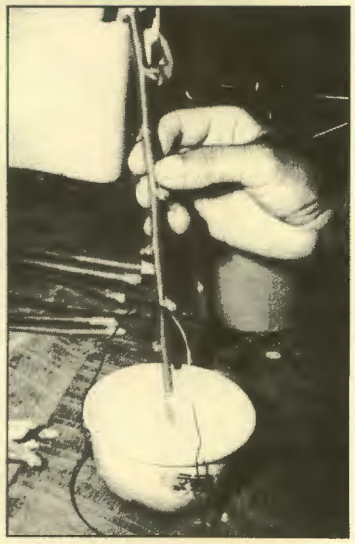
On the banks of the Rio Putumayo (top); cocoa is not generally cultivated but occasional trees grow by the native huts. Above, are fine wild pods

Arriving at Napo, I discussed plans for collecting with the INIAP technician, José Baquero, who was to be my assistant on the project. We supervised the clearing of land for a nursery and for the permanent planting of the wild cocoa after it had been collected. Some earlier teams collecting wild cocoa had lost 50 per cent or more of their material by attempting to send it directly to distant breeding centres; our intention was to bring the collections back to a local base for propagation and planting. The plants at Napo would then serve as a "gene bank" from which to send material to breeders anywhere in the world. The gene bank would also help Ecuador's own cocoa-breeding programme, run by INIAP in the traditional cocoa-growing area in the Pacific coast region.

By June 1980 we were ready for our first serious collecting trip. We chartered a STOL (short take-off and landing) aircraft from the Summer Institute of Linguistics, a missionary organisation, and flew to Loreto, which from the map appeared to be a promising area for collecting as it had no roads and therefore no colonists. I later discovered that the area was one of those settled by the original Spanish *conquistadores* in the 1560s; by 1980, Loreto itself, still largely cut off from the outside world, consisted only of a church, a school and five houses, although there were many more Indian families in houses scattered through the surrounding forest. Our plane landed and was immediately surrounded by children from the school, although the arrival of aircraft is no great novelty in the many villages in the region that have an airstrip but no access by road. We were made welcome by the teachers, provided with a floor to sleep on, and within an hour had set off into the forest to look for wild cocoa.

Here we were not disappointed. As it turned out, we only once failed to find wild cocoa in all the areas we visited throughout the region. At Loreto, we spent three days exploring the network of muddy paths through the forest around the village, crossing small streams on logs and one larger river on a suspension bridge which consisted of four rusting steel cables and a few loose planks. In the forest here, as elsewhere, the wild cocoa trees reach their full natural height of 20 m or so (under plantation conditions cocoa trees rarely exceed 10 m) and develop as clusters of a dozen or more leaning trunks. As the oldest trunks fall over, they are replaced by new shoots which appear continually around the base of the tree. The trunks that fall over sometimes take root several metres away from the base of the tree, at which point a new tree will grow up. This habit of growth means that a wild cocoa tree may be effectively immortal, which is just as well because, as we soon discovered, these trees produce very few pods.

Collecting wild cocoa is relatively easy if the trees have pods. One collects them by climbing the tree or by poking them with a long stick. In the wild, even ripe pods do not fall off the trees; they are opened *in situ* by squirrels or monkeys which suck the sweet pulp off the seeds. The seeds fall to the ground where they germinate immediately. Although most trees produce few seeds in any year, the energy stored in each seed is sufficient for a seedling to grow for several weeks with little or no photosynthesis. This is an important adaptive feature for a species that must reproduce under the dense canopy of primary forest. Long individual lifespan, a low rate of seed production and large seeds constitute, indeed, the classic "strategy" of tree species in stable forest environments. An unopened pod taken from the tree will keep for at least three weeks, and when opened back at the nursery it is usual to obtain 100 per cent germination of the seed. Even when pods have to be opened in the field, to save weight on the return journey, the seeds can be kept in good condition for two weeks by packing them in damp charcoal. Unfortunately, life is rarely so easy for the cocoa collector. Deep in the shade of the forest, few flowers are formed and pods are even rarer, for another peculiarity of cocoa is that only a tiny proportion of flowers—less than one per cent—are successfully pollinated. It is then necessary to collect budwood: short lengths of young branches with dormant growth buds. With the ends waxed to reduce water loss, and packed in damp newspaper, budwood can just about survive for 10 days, until back at the nursery the



Wild cocoa budwood is sealed with wax to stop it drying out on its way to the nursery (right). Dormant buds taken from a wild cocoa branch are grafted on to a seedling to preserve their genes (above). After six months in the nursery, wild cocoa seedlings are ready to be planted out in the "gene bank" (left)

buds are grafted ("budded") onto the stems of seedlings. Even with skill and experience, this operation can be exasperatingly unsuccessful.

We returned from Loreto with pods from two wild cocoa trees and budwood from another 15. Our collecting had begun successfully although I had failed to realise how cold it could be at night in the forest. We had forgotten to pack our blankets, and slept badly on the hard bamboo floor. By the end of 1980 we had made 160 collections and, despite problems with the budding technique, nearly 130 of these were safely growing in the nursery. We had also gained confidence in our collecting methods as we travelled more widely. Some interesting areas, particularly in the extreme south of the region, could be reached by road after four days' driving along the Andes.

Witches' broom disease, caused by a fungus, has wiped out 80 per cent of the cocoa trees in some South American plantations. Resistance is one quality still greatly desired

Here, in the valleys of the Rivers Zamora and Upano, several generations of colonists had cleared much of the forest, replacing it with pasture grazed by cattle. Fortunately for us, they had developed the custom of leaving a few of the wild cocoa trees when they felled the forest. These trees, in full sunlight, were growing more vigorously than the forest trees and produced enough pods to make our life easier. However, they were also more badly infected with witches' broom disease. This disease has devastated cocoa plantations in several countries; it is caused by a fungus which produces broom-like clusters of deformed shoots on the branches, and also infects the pods, making them worthless to the farmer. The hope of finding wild trees with natural resistance was a major reason for collecting wild cocoa in the Upper Amazon.

Previous expeditions had often collected from disease-free trees in the forest, but only a few of these trees had shown useful resistance in later trials. Now it seemed to us that freedom from disease was more likely related to the weak growth of the trees in the forest. This confirmed an earlier decision: as a general principle, we would not try to collect only those trees that seemed at first sight to be superior. After all, a plant that was doing badly in the Amazon may well do well elsewhere, or at least contain genes that would be useful in other environments. Our collections would be a random sample from the wild cocoa population, to be handed over to cocoa breeders who could screen them for genes that would be useful under their own conditions: a genotype that was susceptible to witches' broom disease might still be useful for other reasons to farmers in West Africa, where this disease does not occur.

We continued collecting through 1981, visiting ever more remote parts of the country, and using a variety of forms of transport. I learnt how to recognise a well-built, stable dugout canoe—it's no fun capsizing in a fast current with the river bank several hundred metres away. I also learnt the difference between a Helio Courier and a Pilatus Porter, two types of STOL aircraft often used in Ecuador; the former small and cheap to charter, the latter costing £150 an hour but able to carry a collecting team of three people, with our usual equipment and the 500 litres of petrol needed for a long river trip.

Away from the roads, most areas we visited were populated by Indians: Cofan, Secoya and Siona in the north, Quichua and Huaorani (Auca) in the central part of the region, and the Shuar in the south. The existence of large areas of apparently uninhabited forest, as seen from the air, is deceptive; the largest areas of fertile soils are found along the main rivers and these are quite densely populated, while the forest beyond serves as an indespensable hunting-ground for people whose diet is based on protein from the wild rather than domesticated animals. Wherever land has been colonised the Indians have lost much of their land. Only recently, Indian organisations such as the Shuar Federation have persuaded the government to grant legal titles to communal Indian land holdings, and in some cases this has been possible only after foreign volunteers have carried out the necessary land surveys.

Although both the Indians and colonists are involved in actual and potential conflicts, the people we met almost always helped in our work. Travelling along rivers, we were

offered shelter and space to sleep; houses in the jungle have large floors to accommodate frequent visitors. Discussions about wild cocoa would be accompanied by the drinking of bowls of *chicha,* the daily staple diet of the Indians, made by the women from manioc: ground, masticated, and fermented. After such discussion one of the men would usually offer to show us a wild cocoa tree in the forest beyond his planted clearings.

Only one river, the Curaray, proved uninhabited for a considerable distance. Here, after flying into one village, we travelled downstream slowly for four days, sleeping on sandbanks as the river was low. Every morning we woke to find ourselves surrounded by fresh tracks made by capybaras (the world's largest species of rodent, looking something like a giant guinea pig); on our last evening, the boatman killed an alligator as it crawled past our camp-fire to go hunting in the reeds beyond. Every few minutes down the river we would see a wild cocoa tree on the bank, and exploring in the forest behind we usually found many more trees. Only a few of these had pods, but here and elsewhere we found enough pods to make an important observation: all the wild cocoa throughout the Amazon region of Ecuador shares a common set of genetically determined characteristics including white seeds, very rough-surfaced yellow pods, and the absence of red pigmentation in the leaves. As these features are not found together in any group of cocoa varieties already in cultivation, this is definite evidence that we have added some new genes to the "gene pool" of cultivated cocoa.

Mary Evans

Mary Evans

Today's enormous chocolate industry has been founded on the remarkably few wild trees that first were distributed among the world's plantations

Back at Napo, the young cocoa trees in the nursery were growing well, and in February 1981 we planted out the first trees in our "gene bank". We planned to include 10 plants from each collection in the bank, enough to offset the risk of trees dying through disease or neglect, while keeping the overall area within manageable limits. We hoped that the gene bank might ultimately contain 500 collections, and we knew that maintenance would become a problem sooner or later. Evaluation of potential new varieties held in such gene banks is a long-term affair; for example, it may take 10 to 15 years to prove disease resistance. Agricultural research organisations in most countries are affected periodically by shortage of money or political instability, and it is difficult to assure the continuity for breeding tree crops such as cocoa.

By the end of 1981 we had 310 collections and reckoned to have covered about three-quarters of the region. It was time to turn our attention to another aspect of the project: sending our wild cocoa to quarantine, before sending it on to breeders in Brazil, West Africa, Malaysia or elsewhere. Quarantine is important, because each cocoa-growing area suffers from a different set of diseases. The most catastrophic disease, witches' broom, has never spread beyond South and Central America and the Caribbean; even in Brazil, it occurs only in the Amazon basin and not in the main cocoa-growing region of Bahia, 2000 km to the south-east. On the other hand, swollen-shoot disease, caused by a virus, is found only in West Africa.

Cocoa can be held in quarantine at the Royal Botanic Gardens, Kew, and at Miami. At Kew, a large greenhouse, with temperature and humidity controlled at tropical rainforest levels throughout the year, contains a collection of several hundred clones of cocoa (clones being groups of genetically identical individuals that have been derived from a single parent by asexual reproduction). Plant breeders anywhere in the world can write in to ask for budwood from these clones, some of which are wild in origin while others have been selected from plantations in various countries. Each clone must have been grown for at least 18 months at Kew before being distributed; during this period, the plants are regularly inspected for disease and insects. As far as is known, no disease ever has been transmitted with cocoa material distributed from Kew, but the danger is real, and without such quarantine facilities the spread of such diseases as witches' broom would be almost impossible to prevent. The special characteristics of most of the clones held at Kew are listed in documents such as the *International Cacao Cultivar Catalogue,* so that the breeder can request clones with features relevant to local needs, such as ease of propagation by cuttings, or ability to grow well without shade.

What of the future? We have nearly finished collecting in Ecuador. There remain some inaccessible areas close to the frontier with Peru; again, we are in luck, because the state oil company CEPE is drilling exploratory wells there, and has offered to fly us in by helicopter. At Napo, the "gene bank" is filling up, and the first trees, planted 20 months ago, are 2 or 3 metres high and growing fast. We have begun to measure these trees, noting characteristics that give us clues to their genetic relationships: these trees, growing under plantation conditions, will eventually tell us whether we really have collected new genes useful to farmers who grow cocoa.

However, we are not the only team collecting wild cocoa. The Brazilian cocoa research organisation, CEPLAC, has organised a series of expeditions in the Amazon region of Brazil, a vast area that will take many years to cover completely. Some collecting has been done in Colombia and Peru, but not enough; in Central America, some primitive cultivated varieties in danger of extinction are now preserved in the germplasm collection at Turrialba in Costa Rica, but there, as elsewhere, the present-day status of the wild cocoa populations remains mysterious. Only one thing is certain: the search will continue for many years to come. □

John Allen works for the London Cocoa Trade Amazon Project. He wishes to acknowledge the technical support of the London Cocoa Terminal Market Association and the Cocoa Association of London.