Pest control included

The reasons to prefer organic farming are accumulating, says **S Ananthanarayanan**

ORGANICALLY grown food, meaning that which is grown without the help of synthetic fertiliser or insecticides, is feted as tastier and more nutritious. The claim is doubtful as the flavour and composition of a plant depend on its genes and not particularly on the manner of cultivation. But whatever the truth, organic food is expensive because as "unaided" cultivation, for the benefit of the consumer, is said to need costlier tending and to have lower yield.

Recent work shows that this is not true. Organic farming is found to promote biodiversity that has, in turn, been found to lead to natural pest resistance. All pesticides have a major negative that they get less effective and need to be used in progressively larger quantities. They also poison both the soil and groundwater. To find that organic farming is economical would thus have commercial importance.

Allen Herre of STRI

David W Crowder—entomologist

Colorado beetle (feeding on potato plant, below).

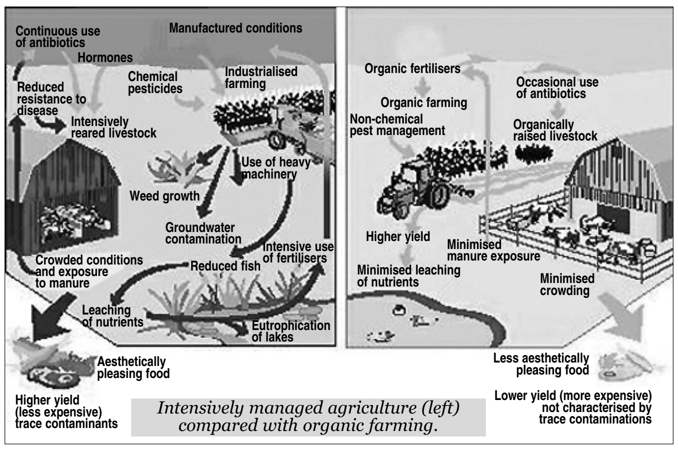
Biodiversity

Natural environments usually have many species living together. The relationship is symbiotic, with species mutually providing nutrition for or controlling predators of other species. The proliferation of one species at the cost of others then affects the growth of the proliferating species, which would reverse the trend. Over time, a balance of relative abundance is struck, including a balance in the rate of relative exploitation of soil resources, in keeping with the pace of their natural replenishment.

Agriculture, which is organised cultivation of a single plant variety, is a celebrated villain in disturbing the balance. With the loss of the safety net of balancing species, the cultivar needs special protection against pests — and hence the need for chemical pesticides. But along with the pests, conventional farming also destroys the natural enemies and predators of the pests themselves. The use of the pesticide then creates more work for itself, apart from the resistance that the pests develop against the pesticide.

This effect is avoided in organic farming. While it is accepted that such farming promotes biodiversity, with higher abundance and greater species richness, there has still not been clear evidence that this increased biodiversity translates into better pest control.

A study by entomologists (insect scientists) at Washington and Georgia, USA, notes that conventional farming methods degrade ecosystems in two ways — one, by reducing the number of species and, second, by disturbing their relative abundance. This idea of relative abundance is a statistical measure of the distribution of different populations in an aggregate and has been formally studied in the field of information theory. There is then a unit of the level of "evenness" of the populations, which helps measure the effectiveness of the different species acting together.



Intensively managed agriculture (left) compared with organic farming.

The study has looked into the effectiveness of "evenness" of the pest reducing populations and it finds that the balance of populations as found in a rain tropical forest or organic farming conditions dramatically increases the action of the natural pest control and also makes for more luxuriant growth of the subject vegetation!

Colorado beetle

The study, just described, in *Nature* was conducted in Washington, whose potato crop faces extensive damage by the infamous *yellow-striped Colorado beetle.* The attacks are so intense that crops need to be regularly rotated to avoid total destruction. The usual remedy is spraying with a mix of insecticides, but the beetle keeps getting resistant. The sprays then need to be intensified and the range of chemicals widened, which increases costs.

The good news is that there is a variety of bugs and beetles that attacks the Colorado beetle in the potato plant leaves and also worms and fungi that attack the beetle pupae below the ground. But conventional farming, in a bid to control the Colorado beetle, also puts paid to the beetles' natural enemies and, hence, the farmers' friends. But what is more significant is that apart from reducing the pest predator populations, these measures also affect their population distribution, which can make the surviving predators many times less effective.

The scientists divided the potato field into enclosures with equal infestation by the beetle pest, but with different combinations of different insects that prey on the beetle and pathogens that affect its breeding and growth. The effectiveness of the combinations was compared with the "evenness" of the distribution of pest control agents.

The potato crop scientists found that increased evenness of both predator and pathogen communities resulted in better pest control and, more importantly, larger potato plants. Higher evenness of these agents leads to more efficient attack, probably because they forage on different parts of the plant and, collectively, they complement each other for better results.

The study shows that even subtle damage to pests' natural enemy communities, like changes in *evenness*, can have large effects on crop performance. Reduced effectiveness of natural pest control leads to greater reliance on pesticides and further weakening of natural control. The study also shows the way to more effective biological pest control, by the release of several predatory species rather than the traditional mass release of a single species.

Predators promote diversity

Another study by the Smithsonian Tropical Research Institute in Panama, described in *Nature* a week earlier, finds that species specific enemy organisms which proliferate in the vicinity of an adult plant actually limit seedlings of the same plant and promote relative abundance of other species. This behaviour, known as negative feedback, has been documented in forest ecosystems but how this comes about has not been clear.

In the Stri study, seedlings of different species were grown in the presence of different enemy organisms, for example mammals, invertebrates and microbes, both in controlled greenhouse conditions and in the field. The results showed a clear negative feedback effect of soil-dwelling organism. Above ground enemies, like mammals, leaf-eaters or leaf pathogens seemed to have little effect.

The study has revealed the importance of soil biota in maintaining abundance of plant varieties. The role of soil biota has not received attention so far and it was believed that the self-limiting — negative feedback effect — was strongest in abundant species. But it is found that the opposite, in fact, is the case.

Studies that illuminate the mechanisms of diversity in ecosystems will enable sustainable farming as demands on agriculture and forestry swell with increasing centres of consumption.

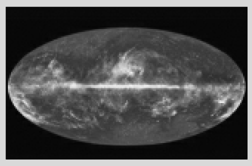
The writer can be contacted at simplescience@gmail.com

Captured: Big Bang's 'afterglow'

Scientists are now close to producing the best-ever image of this fossilised relic from the dawn of time, writes **Steve Connor**

IT'S sometimes known as the "afterglow of creation" because it was the first light to be produced when matter began to form following the Big Bang some 13.7 billion years ago. Now scientists are close to producing the best-ever image of this fossilised relic from the dawn of time.

On Monday, the European Space Agency released the first image of the entire sky taken by the Planck satellite which was launched last year with the aim of mapping the cosmic microwave background radiation – the afterglow of creation – in every part of the known universe. The image was produced following the satellite's first full-scan of the entire sky. It will be used to produce the most detailed and precise picture of the background radiation left behind by the fireball of the Big Bang.



The "ghost" of the Big Bang.

In this image, we are seeing the universe from the centre of the picture looking out. The microwave background radiation is in the further reaches of the universe in the upper and lower regions of the map. Radiation from our own galaxy, the Milky Way, shows up as the streak of white light running through the middle, while the swirls on either side represent the radiation given off by the dust and hot gas of interstellar space.

The thin disc of white light from the Milky Way separates the northern sky at the top of the image from the southern sky below. This extraneous radiation which conceals the microwave radiation closest to our own place in the universe will be digitally erased to produce the most detailed map of the microwave background radiation as seen with nine different bands or "colours" of the microwave light.

"Planck has 'painted' us its first spectacular picture of the universe," said David Parker, director of space science and exploration at the UK Space Agency, which supports British participants on the international research project. "This single image captures both our own cosmic backyard – the Milky Way galaxy that we live in – and the subtle imprint of the Big Bang from which the whole universe emerged," said Dr Parker.

Scientists first predicted the existence of the cosmic background radiation more than 60 years ago and it was first detected in the 1960s. Sixteen years ago, the Cobe satellite produced the first full-sky map of the radiation, showing that it must have derived from the Big Bang because it exists in every direction of the universe that is scanned.

"It has taken 16 years of hard work by many scientists in Europe, the USA and Canada to produce this new image of the early universe. Planck is working brilliantly and we expect to learn a lot about the Big Bang and the creation of our universe," said Professor George Efstathiou, the Planck survey scientist at Cambridge University.

The cosmic background radiation was released about 400,000 years after the Big Bang when the first atoms were beginning to form. Scientists believe that the "clumpiness" of the background radiation is actually the cosmic blueprint from which today's clusters of galaxies formed under the influence of gravity – a relic map of the universe from the beginning of time.

The Independent, London

The dark corners of evolution

Why sex and why Y is one problem biologists have never quite fathomed. Much more work is needed to delineate the workings of the varied elements that constitute the stuff of life, writes **Tapan Kumar Maitra**

EVOLUTIONARY biologists always ask, why does sex exist? A haploid, asexual way of life seems like a very efficient form of existence. The haploid fungi can produce thousands of haploid spores, each of which can grow into a new colony. What evolutionary benefit do organisms gain by developing diploid and sexual processes? Although this may not seem a serious question, evolutionary biologists have always looked for compelling answers.

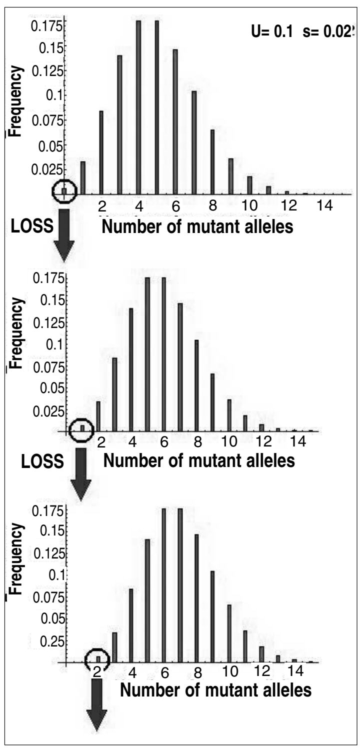
Biologists look for an adaptive advantage in most evolutionary outcomes. Thus they ask, what is better about the combining of gametes to produce a new generation of offspring? Why would a diploid organism take a random sample of its genome and combine it with a random sample of someone else's genome to produce offspring? Why not simply produce offspring by mitosis? If offspring are produced by mitosis, all of an individual's genes pass into the next generation with every offspring. Not only does just half the genome of an individual pass into the next generation with every offspring produced sexually, but half is a random fumble of what might be a very highly adapted genome. In addition, males are doubly expensive to produce because males themselves do not produce offspring: males fertilise females who produce offspring. Thus, on the surface, evolutionary biologists need to find very strong reasons for an organism to turn to sexual reproduction when an individual might be at an advantage, at least evolutionarily, to reproduce asexually.

There have been numerous suggestions as to the advantage of sex, nicely summarised in a 1994 article by James Crow of the University of Wisconsin in *Developmental Genetics*, and more recently in a special section of the 25 September 1998 issue of *Science* magazine. We aren't really sure what the true evolutionary reasons for sex are, but at least three explanations seem reasonable to evolutionary biologists:

Sexual reproduction allows for much more variation in organisms. A haploid asexual organism collects variation over time by mutation. A sexual organism, on the other hand, can achieve a tremendous amount of variation by recombination and fertilisation. Remember that a human being can produce potentially $2^{1000,000}$ different gametes. In a changing environment, a sexually reproduced organism is much more likely than an asexual organism to produce offspring that will be adapted to the changes.

A haploid, asexual organism accrues mutations as they happen over time in a given individual. A sexual organism can combine beneficial mutations each generation by recombination and fertilisation. Thus, sexually reproducing organisms can adapt at a much more rapid rate than asexual organisms.

Removing deleterious mutations is also one major reason. Mutation is more likely to produce deleterious changes than beneficial ones. An asexual organism gathers more and more deleterious mutations as time goes by — a process referred to as Muller's ratchet, in honour of Nobel Prize-winning geneticist HJ Muller and referring to a ratchet wheel that can only go forward. Sexually reproducing organisms can



A graphic representation of Muller's ratchet.

eliminate deleterious mutations each generation by forming recombined offspring that are relatively free of mutation.

Another subtle question about sexual reproduction that evolutionary biologists ask is, why is there a Y chromosome? In other words, why do we have, in some species (eg humans), a heteromorphic pair of chromosomes involved in sex determination, with one of the chromosomes having the gene for that sex and very few other loci? In humans, the Y chromosome is basically a degenerate chromosome with very few loci. This morphological difference between the members of the sex chromosome pair is puzzling. After all, chromosome pairs that do not carry sex-determining loci do not tend to be morphologically heterogeneous. Consider the following possible scenario that Virginia Morell presented in the 14 January 1994 issue of *Science*.

In a particular species a sex-determining gene arises on a particular chromosome. One allele at this locus confers maleness on its bearer. The absence of this allele causes the carrier to be female. At this point, millions of years ago, the sex chromosomes were not morphologically heterogeneous: the X and Y chromosomes were identical. In time, however, the Y chromosome came to carry a gene that was beneficial to the male but not the female. For example, there might be a gene with an allele for a colourful marking; this allele confers a reproductive advantage to the male but also a predatory risk on the bearer, whether male or female. Males have a reproductive advantage to outweigh the predation risk, whereas females don't. Thus, the allele is favoured in males and selected against in females.

An evolutionary solution to this situation is to isolate the gene for this marking on the Y chromosome and keep it off the X chromosome so that males have it but females don't. This can take place if the two chromosomes do not recombine over most of their lengths. Assume then, that some mechanism evolves to prevent recombination of the X and Y chromosomes. Thereafter, the Y chromosome degenerates, losing most of its genes but retaining the sex-determining locus and the loci conferring an advantage on males but a disadvantage on females.

What evidence do we have that any of these links in this complex line of logic are true? To begin with, when we look at evolutionary lineages we usually see a spectrum of species with sex chromosomes in all the stages of differentiation. Evolutionary biologists generally accept the notion that the similar sex chromosomes are the original condition and the morphologically heterogeneous chromosomes are the more evolved condition. In addition, as reported in the same issue of *Science*, William Rice of the University of California at Santa Cruz has shown experimentally with fruit flies that if recombination is prevented between sex chromosomes, the Y chromosome degenerates — it loses the function of many loci that are also found on the X chromosome. Rice showed this with an ingenious set of experiments that successfully prevented a nascent Y chromosome from recombining with the X. The results confirmed the prediction that the Y chromosome degenerated.

In an October 1999 article in *Science*, Bruce Lahn and David Page of the Massachusetts Institute of Technology, reported research findings indicating that degeneration of the human Y chromosome has taken place in four stages, starting as long as 320 million years ago in our mammalian ancestors. Using DNA sequence data and methods they showed that the 19 genes known from both the X and Y chromosomes were arranged as if the Y chromosome had undergone four rearrangements, each preventing further recombination of the X and Y. According to their calculation, this process began shortly after the mammals split from the birds, which themselves went on to evolve a ZW pair of sex chromosomes.

Clearly, much more work is needed to validate all the steps in this logical, evolutionary argument. However, at this point, enough empirical support exists to make the idea attractive to evolutionary biologists.

It is of course a good idea to keep an evolutionary perspective on processes and structures. Presumably, evolution has shaped us and the biological world in which we live. If that is so, we should be able to figure out how evolution works. That thinking should hold from the level of the molecule — enzymes and DNA — to that of the whole organism. Behind every process and structure should be a hint of the evolutionary pressures that cause that structure or process to evolve.

The writer is Associate Professor of Botany, Ananda Mohan College, Kolkata