Science Last Fortnight

Prehistoric Small Mammals

Fossils found in Siwalik

About 25 million years ago, when the Indian plate was pushing against the Eurasian plate, the fluvial sediment in the foreland of the rising Himalayas started folding up to evolve into what we now see as the Siwalik ranges. Stretching about 2000 kilometers, from north Pakistan to eastern parts of India, these hills must once have been much lower and would have provided an entirely different ecosystem for life to thrive.

Varun Parmar and team from the University of Jammu have been searching for fossils in the Lower Siwalik for some time now. 'The paucity of small mammals, such as rodents in the Lower Siwalik fossil assemblage of Ramnagar seems to be an artefact of sampling bias rather than due to preservational bias', says Varun.

With his colleague Guntupalli Prasad and collaborator Rigzin Norboo, he located an exposed area half a kilometer from Dehari village on the Ramnagar–Dhar road. Below the brown mudstone found at the top, there is a layer of gritty brownish-grey sandstone, where they found quite a few fossils of rodents that lived in the area some thirteen to fourteen million years ago.

'Ever since the bulk screen washing technique has been employed, the game has changed for the paleontologists, says Rigzin Norboo, University of Jammu.

The team took about 200 kilograms of rock samples from the site. After a series of washing, cleaning and sieving, they separated the fossils and started identifying them. Based on dentition, they identified four rodents: *Kanisamys indicus*, *Sayimys sivalensis*, *Myomimus* sp. and *Tamias urialis*.

The family Rhizomyine represented by *Kanisamys indicus* is an indicator of subtropical forests. The family Ctenodacylids, represented by *Sayimys sivalensis*, once diverse and widespread, now only exists in arid habitats in Africa. The Glirid family, represented by the *Myomimus* species, was scarce and known to prefer areas with vegetation cover. The small mammals of the Sciurid family, represented by *Tamias urials*, were terrestrial as well as arboreal and existed in low numbers in open dry habitats.

'On the basis of earlier studies on the Siwalik belt, we inferred that the age ranges of these small mammals were about 13.6–13.2 million years ago. The presence of these rodent remains suggests that the region was humid forested landscape between 14 to 13 million years ago', says Guntupalli Prasad, Delhi University.

J. Asian Earth Sci., **162**: 84–92

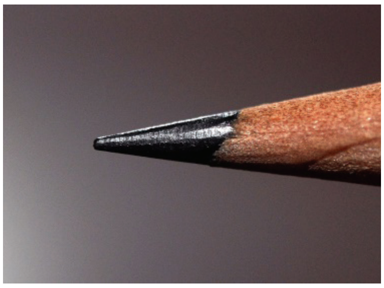
Detecting Arsenic Onsite

Electrochemical sensor

Arsenic is a heavy metal present in both soil and water due to anthropogenic as well as geologic sources. Elevated levels of arsenic in the body lead to arsenic poisoning – thickening and darkening of skin, abdominal pain, diarrhoea, heart disease, numbness and cancer. A common reason for long-term exposure is contaminated drinking water.

Existing methods to detect arsenic require high sample volume, need skilled personnel to operate and consume time, leading to high costs.

Recently, scientists from the Punjab University, the Guru Jambheshwar University, Haryana and the Hanyang University, South Korea developed a low-cost electrochemical sensor for arsenic ions using a simple graphite pencil electrode modified with tin oxide nano-needles.



Pencil graphite – Image: Juliancolton, from Wikimedia Commons

The team used a lead pencil, as working electrode, modifying it with tin oxide nano-needles. They coated the pencil with these nano-needles with the help of nafion – a binding agent.

Then, the researchers evaluated the pencil electrode's electrochemical performance towards arsenic ions. They developed a cyclic voltammetry based detection method and validated the results against arsenic, real as well as laboratory samples. The sensor was efficient and accurate for qualitatively and quantitatively determining arsenic ions in industrial waste. The sensor had a detection limit of 10 parts per billion!

'No pre-treatment is required for real sample analysis. We can directly use the sample from the site', says Sandeep Kumar, GJUST, Haryana.

'A lead pencil can be a very cheap source to develop an efficient working electrode in various electrochemical experiments', adds Neeraj Dilbaghi, GJUST.

App. Ener., **262**: 198–204

Arsenic Stress in Rice

Silicon alleviates

Crops, grown in arsenic contaminated soil or irrigated with contaminated water, become a sink for arsenic. This not only adversely affects health but diminishes crop yield as well.

Image: C. Frank Starmer, frank.itlab.us – Creative Commons License

Arsanilic acid, an organic form of arsenic, contaminates paddy fields in many parts of India. Rice grown in such regions becomes a major source of slow arsenic poisoning even in other regions.

In recent years, scientists have found that silicon salts can be used to reduce salinity and drought stresses in various plant species. However, their impact on the growth of rice in soils with arsanilic acid has not been investigated. Now, scientists find that adding silicon to soil contaminated by arsanilic acid alleviates oxidative stress and improves growth and yield in rice plants.

The research team selected three different rice cultivars – hybrid, indica and glutinous. They cultivated seedlings *in vitro* and designed three different treatments: arsanilic acid or sodium silicate or both arsanilic acid and sodium silicate.

After 20 days, the team collected the seedlings and analysed their various morphometric and antioxidant properties. Under combined treatment, all the cultivars, especially hybrids, showed healthier growth with increased shoot and root biomass than did cultivars treated with arsanilic acid alone. This shows that silicon plays a major role in the growth and development of rice seedlings under arsenic stress.

The scientists measured lipid peroxidation – destruction of cell membrane lipids by oxidative stress. And found it to be significantly less in seedlings treated with silicon and arsanilic acid than in those that were treated with arsanilic acid alone.

Among cultivars under combined treatment, the team also observed enhanced levels of enzyme antioxidants, such as superoxide dismutase, catalase and peroxidase, as well as non-enzymic antioxidants such as ascorbate and glutathione.

They also noticed a reduction in soluble protein content in arsanilic acid-treated plants whereas adding silicon improved the protein level. This could either be due to the reduction of free radicals in stressed plants or to the improvement of lipid stability, say the scientists.

Though the molecular mechanisms behind silicon enhanced rice growth and development under arsanilic acid stress are not completely understood, there is scope for field trials using silicon for rice seedlings growing under arsenic stress.

The research indicates the possibility of ameliorating the effects of other heavy metals on crops in general. Since silicon is an abundant element and a necessary mineral for plants, it is a natural fertiliser and protectant for plants.

Ecotoxicol. Environ. Saf., **30**: 266–273

Combo for Heavy Metal Pollution

The right plants and earthworms

Heavy metal toxicity is a serious environmental concern. Heavy metals are carcinogenic. Yet, contamination continues to increase due to industrial activities and intensive agriculture. There are several physico-chemical technologies to tackle the issue. Of these, phytoremediation, based on the natural potential of plants to take up metals from the soil and water, is a more sustainable solution. However, this only transfers the metal from the soil or water to the plant, to be released back into the environment if the plant is not properly treated.

Now, scientists from the IISER Kolkata and collaborators from the BHU and the University of Calcutta combined phytoremediation with vermiremediation to deal with the issue.

Sutapa Bose and team selected water hyacinth, *Eichhornia crassipes*, an efficient phytoremediator. They first tested the ability of hyacinth to take up heavy metals from water spiked with arsenic, lead and cadmium. The scientists found that it was an effective phytoaccumulator, as reported by earlier studies.

Eichhornia crassipes – Image: Wouter Hagens, Public Domain

Next, the scientists used the hyacinth as source of organic supplement for preparing vermicompost with the earthworm, *Eisenia fetida*. They found a complete reduction of arsenic and other toxic metals in the mature vermicompost. The earthworms synthesise phytochelatin, a glutathione-based peptide derivative. This binds arsenic, cadmium and other heavy metals and facilitates their transport to the vacuoles, resulting in a reduction of metal concentration in mature vermicompost. Thus, vermiremediating arsenic and other toxic elements restricts the bioavailability of soil pollutants.

The researchers tested the vermicompost as organic fertiliser for growing chickpea, coriander, tomato and chilli. They found that it enhanced growth and production. What is more, the amount of metal in the final agricultural produce was negligible.

Bio-converting water hyacinth into vermicompost provides a sustainable way to phytoremediate plants. Such vermicompost could be applied in agriculture to promote plant growth. As vermicompost is an organic manure, there is nutritional enhancement, as well.

Indian mustard, willow, poplar, Indian grass, and sunflower have phytoremediation potential. Researching a combination of such plants and earthworms will help sustainably manage heavy metal toxicity.

Environ. Manage., **220**: 118–125

Tweaking the Tomato Pest

Temperature alters fitness

Temperature affects all species. In plants, it alters the composition of secondary metabolites. Due to a cascading effect, such variations affect herbivore performance and population dynamics. The invasive tomato pest, *Tuta absoluta*, which plays havoc with the productivity of the crop, also responds to temperature changes.

Recently, researchers from the ICAR-Indian Institute of Horticultural Research, Bengaluru in collaboration with a researcher from Turkey looked into the impact of increased CO_2 and the subsequent increase in temperature on *Tuta absoluta*. Usually, a female based age-specific approach is used to construct life tables that describe the response of the insect population. These researchers, however, used both male and female as well as age.

Tuta absoluta by Patrick Clement – CC BY 2.0, via Wikimedia Commons

The researchers first collected *Tuta absoluta* larvae from an infested field and maintained them in a growth chamber. They also raised tomato seedlings in two open top chambers. The team supplied elevated carbon dioxide continuously to one chamber and, in the other, an ambient level of carbon dioxide was ensured.

To obtain eggs of uniform age, the team released twenty pairs of males and females into a rearing container with a small potted tomato plant. They collected the eggs daily, separated them using a fine brush and placed them on fresh tomato leaves obtained from the respective open top chambers. The leaves and eggs were then placed in petri dishes. For observations, the petri dishes were placed in bio-oxygen demand incubation chambers with four different constant temperatures and two different carbon dioxide levels.

'We monitored the eggs daily for hatching percentage, larval duration, larval mortality, pupal period and adult emergence under different temperatures and carbon dioxide levels' says Nitin, Indian Institute of Horticultural Research.

As soon as adults emerged, they were transferred to open top chambers where the tomato plants were maintained. Adults were allowed to mate in the chamber. The researchers recorded the number of eggs laid and adult survival and mortality rates. These data were subjected to an age-stage, two-sex life table software for analysis.

The scientists found that temperature decreased larval duration at all stages while elevated CO_2 increased it. The duration of the adult pre-oviposition period, the total pre-oviposition period, and the longevity of males and females shortened with increase in temperature in both elevated and ambient CO_2 conditions. The duration of the adult pre-oviposition period was longer in the ambient CO_2 condition. The total pre-oviposition period was longer under elevated CO_2 except at 32°C, where total pre-oviposition period values were similar.

'This age-stage, two-sex life table is more accurate than traditional female age-specific life tables. Unlike female based life tables, the two-sex life table describes stage differentiation, incorporating all individuals, including males and pre-adult mortality' says Onkara Naik, Indian Institute of Horticultural Research.

This life table study with respect to changing temperature and CO_2 levels helps researchers find the weakest link in the population. Using this, researchers can attack the weakest point to control the pest and bring its damage impact below economic threshold levels.

J. Econ. Entomol., **111**(4): 1614–1624

Reducing Drought Stress

Polymer supplement

Global water scarcity calls for technologies to efficiently manage water for agriculture. One approach is to develop drought tolerant crop varieties using genetic engineering and breeding techniques. Such approaches, though effective, are time consuming. What is needed is instant relief from water stress without toxic effects on plant, animal or environment.

Recently, Chinese scientists reported successfully protecting crops from drought stress using poly-γ-glutamic acid, a macromolecular superabsorbent polymer. Poly-γ-glutamic acid is highly water soluble and can retain water for a long time, making it perfect as fertiliser synergist. The polymer is a common bacterial fermentation product, long used in food and medicines. Many traditional fermented foods contain poly-γ-glutamic acid.

Fermented soybeans – Image: JD, via Flickr, CC BY 2.0

The team isolated two bacterial strains of *Bacillus subtilis*, from fermented soybeans, which produce poly-γ-glutamic acid in growth media. They directly mixed the fermented liquid in soil and planted maize seedlings. And simulated drought stress by reducing soil moisture. The scientists found that the fermentation liquid promoted growth in the seedlings, even after thirty days of stress.

They also noted that the broth did not change soil pH and conductivity significantly and that the water and nutrient content of the treated soil was higher than that of the control. The broth did not affect the microbial community predominant in the soil. However, it increased the diversity and biomass of the soil bacteria. Most of these bacteria are plant growth promoters and are known to inhibit plant pathogens.

Poly-γ-glutamic acid consists of hydrophilic carboxyl and peptide bonds that crosslink with water to form a hydrogel. This improves the water holding capacity of soil particles. Moreover, the bonds have chelating and adsorbing capabilities that attract nutrients and make them accessible to plants.

A soil mix containing poly-γ-glutamic acid could provide instant relief to farmers during sudden adverse conditions. The scientists believe that applying bacterial fermentation liquid as soil mix during crop cultivation can cost effectively manage water stress. The ability to increase nutrients is an additional benefit.

Appl. Soil Ecol., **129**: 128–135

Bacteria to the Rescue

Soil microbes as plant saviours

Toxic heavy metals pollute the biosphere. These metals affect soil microbes and alter soil properties, leading to loss of soil fertility. They cannot be degraded and, hence, persist in the environment. Further, their uptake by plants affects growth, and symbiosis. And, thus, reduces crop yield.

Scientists have been trying to identify microbes which can tolerate heavy metals and survive on contaminated soils – free living rhizosphere bacteria that colonise plant roots and promote plant growth even under stress conditions.

Recently, Asfa Rizvi and Saghir Khan from the Aligarh Muslim University reported an inexpensive microbial management strategy for metal contaminated soils. They isolated and identified the rhizobacterium, *Azotobacter chroococcum*, from metal contaminated agricultural fields.

The bacterium was then grown on media containing high concentrations of heavy metals. The strain could tolerate 1400 ppm copper and 2000 ppm of lead. The bacterium produced plant growth promoting substances even under metal stress. It also produced a compound, melanin, with metal chelating ability.

The scientists then tested the effects of *A. chroococcum* inoculation, on maize. The crop was grown in the presence of heavy metals under pot culture conditions. The metals caused distortions in root and leaf morphology. The roots of inoculated plants accumulated the highest amounts of metals. The heavy metals accumulated in the kernels also.

The team found reduced antioxidant responses in maize foliage and an improvement in the yield of maize kernels when the pots were inoculated with the bacterial culture. The concentrations in the kernels declined following *A. chroococcum* inoculation.

Azotobacter chroococcum, thus, plays a natural role in remediating heavy metal contaminated soils and protecting crops. This inexpensive technology can be a panacea for polluted soils.

Isolating such beneficial bacteria from contaminated areas in diverse agro-climatic conditions, culturing them and then introducing them into contaminated sites can help reduce heavy metal toxicity in agricultural produce. Understanding the mechanisms that the microbes use to remediate heavy metal pollution could help manipulate them for better performance.

Ecotoxicol. Environ. Saf., **157**: 9–20

Graphene Ribbons

Tilting the efficiency scales

Surpassing the Shockley–Queisser limit is a major drive for research on solar cells. This intrinsic barrier limits the efficiency of solar cells in converting sunlight to electricity. To overcome this challenge, scientists are combining nano-particles to absorb more photons. The problem now is to identify the materials that can work in tandem.

Kusuma and her group from the Jain University, Bengaluru explored the properties of graphene oxide for quantum dot cells. They wanted to utilise the light absorbing and charge carrier capacity, vital for successful recombination. These properties of graphene oxide pair nicely with titanium oxide, a popular metal oxide for solar cells. The team tweaked the arrangement of the oxides by rolling them into nano-ribbons.

'The size and number of layers modify the chemical and physical features of the nano-ribbons', says Geetha Balakrishna, Jain University. She adds that the synthesis process is also a variable to tune the properties of the graphene.

Her lab processed nano-ribbons by 'unzipping' the graphene sheets using controlled oxidation. This method allows precise alignment of the molecules with no voids in between.

One-dimensional strips of graphene oxide give a large surface area for titanium oxide nanoparticles to travel across the electrodes. Also, the geometric honeycomb architecture of graphene allows the molecules to sit tight next to each other. This facilitates faster electron transport from the conduction band of titanium oxide to graphene.

'Enhanced charge separation is crucial for reducing recombination', explains Geetha Balakrishna. This is the first reported hybridisation of graphene into quantum dot cells. Though the fusion of titanium oxide and graphene is the focus here, the group is positive that such combinations will help improve the efficiency of solar cells.

The research is funded by the Nano-mission project of the Department of Science and Technology for knowledge-based applications in various fields.

Sol. Energy Mater. Sol. Cells, **183**: 211–219

Seeking Feedback

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