Current Science Reports

Image: Sanjay Acharya via Wikimedia Commons

Experimenting with Evolution

Drosophila melanogaster, the dew loving black bellied fruit fly, is a model organism for those who wish to pry into the forces of evolution and ecology. The high rates of reproduction and low intergenerational durations of this common insect make it easy to understand the forces of evolution at work.

In this issue of the column, we report significant results from two leading labs in India that use the model organism to understand evolution.

Effective Lifespan in Fruit Flies

Impacting sexual selection, conflict

Natural selection and sexual selection are both important factors in evolution. Though these factors are often considered to be independent of each other, they may not be so, say researchers from JNCASR, Bengaluru.

About two decades ago, Amitabh Joshi's lab in JNCASR had selectively bred a set of fruit fly populations that emerged out of the pupa much earlier than their ancestors.

While the ancestral population had a 21-day generational cycle, these fruit flies had a 10-day cycle. This population had a reproductive phase of only three days, instead of eleven days as in the ancestral populations.

To understand the interdependence of life history and sexual selection, the lab now compared proxies of sexual selection in the populations that had a longer life cycle with those of the population whose lives played out faster.

Avani Mittal started recording the time for the females to mature, frequency of courtship by the males, duration of copulation and frequency of mating during a lifetime.

Though the females in the shorter life-cycle populations emerged earlier from the pupa, they took longer to become sexually mature and active.

'These flies are much smaller and the females have to acquire metabolic resources for reproduction. That may be the reason for the delay,' explains Avani.

Courtship among fruit flies with a longer life cycle was much longer. Courtship was negligible in the populations selected for a shorter life cycle. Most females in those populations were ready for copulation even without courtship, suggesting lower sexual selection.

'Our calculations show that while males in the long lived populations had an average of six matings, males in the fast forward populations had an average of one,' says Neha Pandey.

Duration of copulation was also shorter in the short-lived population. During copulation, after sperm transfer, fruit flies are known to transfer accessory gland proteins that modulate the receptivity of the females later.

'Lower courtship frequency and shorter copulation duration, indicate potentially reduced investment in pre- and post-copulatory male–male competition,' adds Manaswini Sarangi.

'Our study demonstrates the interconnectedness of life-history evolution, sexual selection, and sexual conflict,' says Amitabh Joshi.

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Desiccation Mediates Dispersal

Costs of survival and reproduction

Lack of resources is a major reason for the migration and dispersal of individuals. But dispersal itself consumes body resources and may lead to stress.

To understand the impact of desiccation stress on dispersal and associated costs, Sutirth Dey's lab in IISER Pune experimented on fruit flies. The researchers used an experimental set up, comprising a source container and destination container connected with a six-metre-long tube. To limit the return of the flies from the destination container to the source container, they made the path tube protrude into the destination container.

Male and female fruit flies were released into the source container. To induce desiccation stress, the team did not put any food in the source container and allowed the fruitflies to disperse for 5 hours via the connecting tube. The dispersed flies were collected from the destination container and non-dispersed flies were collected from the source container. Sample males and females from each group were kept separately in empty vials and monitored till they died of desiccation.

Fruit flies die of desiccation stress three to six times sooner than they die of starvation. In this case, non-dispersers had better desiccation resistance than dispersers. The males paid a higher cost for dispersal than females and died earlier.

Cost of dispersal showed up as reduced fecundity of the females, explain the researchers.

They then checked the duration of desiccation needed to initiate dispersal, starving the fruit flies for various durations before connecting a two-metre tube to the destination. Dispersal increased with the duration of desiccation stress.

Initially, males migrated more. But, after five hours, the sex difference was negligible.

The cuticle of females, but not of the males, starts hardening when exposed to desiccation. The initial difference between males and females could be due to that, explain the researchers.

The researchers had earlier selectively bred over generations for a propensity for migration. They checked the differences in desiccation resistance between this highly migrant variety and

that of the controls. The differences were not significant.

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Sepiolite for Ethylene Scavenging

Biofilms for fresh storage

Removing ethylene as it is liberated from fruits and vegetables can help maintain their freshness. However, most films made for the purpose contain potassium permanganate as an ethylene scavenger. Potassium permanganate is toxic.

Sepiolite clay, a natural fibrous clay, has good ethylene scavenging properties. Could we try preparing films with sepiolite?

Kirtiraj K. Gaikwad and a team from IIT Roorkee proceeded to investigate.

Corn starch, cheap and biodegradable, can be used for large-scale film development. So the researchers prepared a film based on corn starch and gum acacia with varying concentrations of glycerol as plasticiser. Adding gum acacia strengthens corn starch's film-forming nature.

The team added different ratios of sepiolite clay to make the ethylene scavenging films. As the amount of sepiolite clay increased, the film thickness also increased. This could be due to the overall increase in total solid content in the film. Scanning electron microscopy and X-ray diffraction analysis suggested an even distribution of sepiolite over the film.

The team evaluated the elasticity, tensile strength and thermal stability of the films. The films were durable and the durability increased when sepiolite clay was added.

To investigate the ethylene scavenging features, the researchers coated fresh broccoli florets with the film. And they monitored weight loss, colour change and other parameters after a six-day storage. Twenty per cent sepiolite clay in corn starch-gum acacia maintains freshness longer.

It may be a boon for farmers and traders of fresh fruits and vegetables if they could get such ethylene scavenging films, to reduce losses while transporting and storage.

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Apple Production Kinnaur

Soil nutrition distribution influences

In the Kinnaur cold desert regions, apples have a major role in the survival of people. So the total area under apple farming has increased from 35,076 to 99,564 hectares from 1975 to 2010. But productivity has declined at the same time.

Image: Nawabtanweer via Wikimedia Commons

Apple is a nutrient hungry horticultural crop. And we do not have adequate data on the soils in this highly undulating landscape to suggest fertilisation packages to apple farmers.

So Nagender Pal Butail and team from the Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishva-vidyalaya, Palampur and the ICAR-Indian Institute of Soil Science, Bhopal set out to explore soil nutrition distribution in Kinnaur district, Himachal Pradesh. The team analysed soil nutrients at 191 sites systematically sampled from existing orchards and potential areas for apple cultivation within an area measuring over 1300 square kilometres in the district.

They estimated soil nitrogen, phosphorus, potassium, and other properties and carried out various geostatistical analyses.

Among the major nutrients essential for apple production, the researchers found nitrogen to be low to medium with the lowest levels found in the northern and southern edges of the area. Phosphorus was low in the western part and medium in the rest, while potassium was high throughout.

'The knowledge of site-specific nutrient distribution will help local farmers and the horticulture department address precise requirements,' remarks Pardeep Kumar, CSKHPKV, Palampur.

Frequent soil tillage, erosion and continuous nutrient uptake by crops, deplete soils. Lack of natural replenishment, and erratic climate conditions add to the woes.

'There is a need for scientific intervention in the indigenous way of apple cultivation,' suggests Praveen Kumar, CSKHPKV, Palampur.

With the nutrition distribution data, the researchers used interpolation techniques to visualise the spatial distribution of the nutrients. Principal component analysis helped demarcate the management zones.

Based on soil properties and macronutrient concentrations, the team found a clear distinction in soil properties under the different management zones.

'This demonstrates the effect of management practices on soil nutrition distribution,' concludes Arvind Kumar Shukla, ICAR-Indian Institute of Soil Science, Bhopal.

Zone-specific nutrient management can help sustainable apple production and boost the local economy.

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Peptide Vaccines

Curbing future COVID-19 strains

SARS-CoV-2 has evolved into many distinct strains during the last two years. Some strains are more infective and some are more transmissible. This happens because of mutations in the spike protein which change its binding affinity with the human ACE-2 receptor, the site for viral entry into our cells.

For vaccine development, we need to target peptide regions with a low tendency for mutation. Such conserved peptide regions should also be accessible for recognition by the immune system.

Researchers from Jadavpur University and the Centre for Interdisciplinary Research and Education, Kolkata took spike protein sequences of the COVID-19 virus from the National Center for Biotechnology Information, a molecular database. Using a mathematical approach, they identified the regions of the spike protein with low probability of mutations.

To check for solvent accessibility values for each amino acid position of the spike protein sequence they used a moving average technique with a

window of 12. Thus they identified peptide segments that are 12 amino acids long which are conserved and accessible to solvents. There were 16 such zones in the spike protein.

The area that is exposed must be large enough to act as an immunological epitope. The researchers used the 2D polygon representation method to investigate the span of exposure. This helped eliminate a few epitope candidates.

The researchers then checked whether the remaining peptide regions can indeed act as T-cell epitopes by checking with the MHC-II binding predictions in the Immune Epitope Database Analysis Resource. Those peptide segments that can stimulate T-cells may also cause autoimmune responses. The researchers eliminated that possibility also using BLAST search against known auto-immunogenic peptide regions.

These steps reduced the number of potential epitopes to only four. The researchers examined these four regions using 3D simulation, created in PyMOL, a molecular visualisation system. One of the four peptide segments was partially occluded by other amino acids.

Would the three potential candidates work as epitopes for the B cells of the immune system? The researchers checked using the ABCpred server and found that all three served the purpose.

It is now left to the wet lab scientists to use these peptide stretches and combine them with suitable adjuvants to design effective peptide vaccine formulations, say the researchers.

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Biopolymer and Biodiesel

From microalgae

Microalgae are third-generation feedstock for biofuel production. The use of this source does not impact our food as in the case of first-generation feedstock, and does not have any lignin moieties that complicated the process in second-generation feedstock.

But it is still not economically attractive enough.

Researchers from Tamil Nadu recently collaborated with colleagues from Thailand, Taiwan, Viet Nam and Saudi Arabia to explore the potential of *Chlorella vulgaris*. Besides biofuel, the species is capable of producing poly(3-hydroxybutyrate), used in biomedical and tissue engineering. This biodegradable polyester-like polyglycolide is more recyclable and biocompatible than petroleum-based polymers.

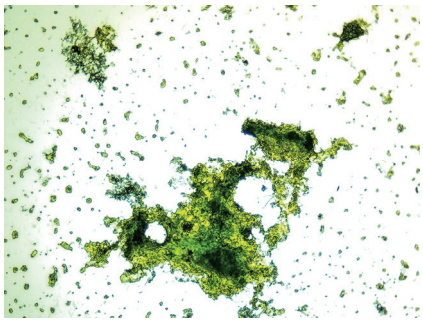

Image: Shipelin via Wikimedia Commons

The researchers cultivated *C. vulgaris* in municipal wastewater loaded with organic waste and harvested the biomass. They extracted the algal oil using a parabolic solar trough collector with calcium oxide as catalyst for maximum biodiesel production. The maximum lipid yield was more than a quarter of the biomass.

'After extracting the lipids from *Chlorella vulgaris*, we used the de-oiled cake to produce the biopolymer,' says Sivakumar Shri Vigneshwar, Sri Sivasubramaniya Nadar College of Engineering, Kalavakkam.

The team added the sugars from the de-oiled cake to a nutrient-rich culture medium. When the microorganisms had feasted enough, they restricted certain nutrients.

'The switch from feasting to fasting compels the organism to use the sugars from the deoiled cake to produce the polyhydroxybutyrate polymer,' says Authilingam Swetha, his colleague.

'This is an added incentive for bio-based algal refineries. A great way to use algal biomass sustainably,' adds Kannappan Panchamoorthy Gopinath, Sri Sivasubramaniya Nadar College of Engineering.

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Paraffin-blended Hybrid Fuels

Beeswax for rockets

Paraffin waxes have been used as solid fuel in hybrid propellants. Hybrid propellants have many advantages over solid and liquid propellants. They are low cost, easier to procure and process. They are stable under atmospheric conditions, making storage and transport less problematic. Low viscosity and surface tension make them viable alternatives to conventional rocket fuels.

But they have poor combustion and low volumetric efficiency.

Wax from beehives has better combustion characteristics than paraffin. Could beeswax partially replace paraffin, wondered a research team from NIT, Tiruchirappalli.

To check, they added some beeswax to paraffin. To improve the mechanical stability of the fuel blends, they used different additives: ferric oxide as catalyst, sulphur to enhance the performance of the wax-based fuel and charcoal to improve combustion efficiency and the rate of conversion of solid fuel to gas during combustion.

The team compared the morphological, thermal, and chemical properties of the paraffin and paraffin-based blends. Scanning electron microscope images showed that paraffin blended samples had better structural integrity and the additives improve the quality of the wax material. Differential scanning calorimetry indicated that heat loss in paraffin wax during volatilisation was reduced when blended with additives.

The heterogeneous fuel blend had improved thermal stability. It had better ignition temperature and burnout temperature. The additives accelerated the oxidation reaction and enhanced the heat of combustion.

The blended fuel has good mechanical and barrier qualities and can yield high-performance rocket fuels. But the performance and efficiency of these hybrid fuel combinations have yet to be tested in rocket engines.

Blending paraffin wax, beeswax, and other chemical additives is simple. And the blended fuel is easy to use and environmentally safer.

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Twitter-image Classification

To manage and mitigate disasters

On Twitter, people upload images during disasters. This input can be useful to manage and mitigate disasters. However, the large volume and variety of images make it impossible to analyse them and to take appropriate action.

Image: ChiefHira via Wikimedia Commons

Can an automatic filtering of relevant images tackle the issue?

To segregate images that are of significance, researchers from Jamia Millia Islamia, New Delhi used artificial intelligence techniques. They analysed seven disasters that happened around the world and developed models using three deep learning frameworks.

The first framework is based on transfer learning: a model trained for one task is used for solving other tasks similar in nature.

The researchers designed a second framework using labelled and unlabelled images of disaster to generate a model based on VGG19, a deep learning network. The framework used domain adaptation with supervised, labelled and unsupervised, unlabelled disaster images. In domain adaptation, knowledge gained from one disaster is applied to a new one.

The third framework was supervised learning. The model learns from labelled images of disaster to predict informative and non-informative images on Twitter.

The second framework was based on the third framework as it is the baseline for using labelled images of disaster.

'We propose the use of the second framework based on the maximum mean discrepancy metric. This gives an average accuracy of approximately 80% for all seven disasters,' says Anuradha Khattar, University of Delhi.

'Unsupervised domain adaptation is an excellent choice as it reduces the discrepancy and learns dominant invariant features,' explains S. M. K. Quadri, Jamia Millia Islamia, New Delhi.

This framework based on deep learning can be applied to any new or ongoing disaster. As the time for response is reduced significantly, authorities could apply it to manage and mitigate disasters.

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Reports by: **Ravindra Jadav, G. Sharath Chandra, Sileesh Mullasseri, K. V. Aneesh Kumar, K. M. Meera, Ankita Saha, Shwetakshi Mishra** and **J. Nalini**

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scienceandmediaworkshops@gmail.com