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Environmental Biology at a Critical Juncture in Human History

The *Journal of Environmental Biology* is an international research journal publishing peer-reviewed studies in environmental sciences and toxicology focusing on issues pertinent to India and other regions of the world. Now in its 40th year, the editorial board seeks to raise its international profile and its contribution to achieve environmental sustainability. Within this context, issues of the journal will now contain an editorial placing the contributions of respective papers into their broader scientific and societal contexts. I am pleased to contribute such editorial. Rapidly rising population and material aspiration pose major issues to the sustainability of critical ecological services. The articles in this issue of the *Journal of Environmental Biology* represent contributions to understand critical scientific issues, developing requisite technologies, and realizing the transition to sustainable agriculture, industrial production, and environmental management.

The articles in this issue of the journal assess possible solutions to several critical issues facing sustainable crop production. Development of drought-resistant crops is an important component of a holistic strategy of adaptation to a changing climate. Kaur *et al*. examined variance of seven root architecture traits among 200 diverse lines of barley subjected to simulated drought stress. They identified seven accessions and wild barley as potential genetic resources for breeding of drought tolerance for use in rain-fed production systems. The authors recommend that results be validated under field conditions and that a candidate-gene association study seek genomic regions associated with drought tolerance. It is difficult to meet consumer demand for warm-season crops year-round. The difficulty of producing cold-sensitive crops such as cucumber in unheated greenhouses was approached by Kumar et al., who grafted cucumber plants onto cold-tolerant rootstock of five different species. Because of its vigorous roots even at temperatures suboptimal for cucumber, the highest yield was obtained in grafts to figleaf gourd, showing the effectiveness of grafting for maintaining cucumber production under cold conditions. Physical degradation of soil due to waterlogging affects 10-30% of sugarcane production area, reducing productivity. Planting ten sugarcane varieties under waterlogged and control conditions, Singh *et al*. show that stalk growth rate, chlorophyll stability, and leaf potassium concentration are useful traits for screening varieties for waterlogging tolerance. At a practical level, reduction of losses effectively increases yield. Post-harvest deterioration of sugarcane due to invasion of soil bacterium *Leuconostoc* leads to decreased sucrose yield and sour smell. Misra *et al*. assess the importance of cracks in standing sugarcane to invasion of this bacterium. Canes possessing cracks showed higher invasion by *Leoconostoc* and higher content of reducing sugars and dextran, suggesting the need to control this bacterium even in standing cane. Deterioration of ozone layer is leading to increased UV light exposure on the earth's surface. Kumar and Bhardwaj investigated the effects of different exposures to UV-B radiation on germinated roots of cumin, an important spice crop. Increasing exposure to UV-B radiation increased the frequency of chromosomal abnormalities; decreased chlorophyll *a* and *b* and carotenoid content, survival, and plant height; and increased the content of proline, a stress marker. The authors suggest that mutation breeding might lead to desirable yield traits in cumin. Jute is an important crop, producing versatile, environmentally friendly fiber and edible leaves. Salt stress limits jute production, especially as coastal cropland becomes more salinated. Naik *et al*. assessed the performance of five jute cultivars at salinities ranging from 0 - 250 mM NaCl. While all morphological traits, including height and leaf area, were negatively affected by salinity, two cultivars were relatively tolerant, and may prove useful in future breeding programs. Environmentally friendly, effective fungicides have been extracted from plants for use in agriculture. Lam-Gutierrez *et al.* screened chemicals extracted from chilca roots for activity against *Aspergillus ochraceus* and *Fusarium moniliforme*, two fungi affecting crop plants. A crude extract showed antifungal activity, and the authors suggest use of these compounds for biological control of pathogenic fungi in maize and coffee crops.

Fisheries production provides much of the animal protein consumed globally, especially in poorer regions. In the face of flat or declining yield from wild fisheries, increasing demand for fisheries products will have to be met by increased aquaculture production. Aquaculture in the Indian subcontinent is dominated by production of the Indian major carps, including catla. Induced breeding of catla would be a boon for regional aquaculture operations. Ghosh *et al*. assessed various hormone-induced breeding treatments upon catla brood stock held at relatively low temperature in hatchery tanks. The authors report successful induction of spawning at temperatures of 18.6-24.7°C, opening the possibility of hatchery-based seedstock production in cool, hilly regions of the subcontinent. Scientifically informed management will be needed to conserve the unique ichthyofauna of the region. Farooq *et al*. examine sexual and gametic maturation in snow trout, a species native to the Himalayan region, in Kashmir. The results revealed that the fish matures at age two, with gametic maturation in April and spawning in May, knowledge that will inform seed production and fishery conservation strategies.

To realize global sustainability, industrial products and processes will have to be considered not only regarding profitability, but also regarding environmental impacts. Activated carbon, a versatile product used in many industrial processes, can be produced from a variety of stating materials, often agricultural wastes. Kumar *et al*. evaluated various processes for production of activated carbon from mango seed coat, an under-utilized byproduct of mango processing. Activated carbon produced using H_3PO_4 treatment showed clear, open pore structure and larger pore size than commercially available activated carbon, presenting economic and environmental benefits. Rose Bengal, a dye widely used in the textile, paper, cosmetics and printing industries, is harmful to eyes, skin, and the environment. Current coagulation and adsorption treatment processes are expensive and present drawbacks, so Mabel *et al.* assessed the utility of adsorbent beads made from Indian shoot powder, chitin (a shrimp-waste byproduct), and sodium alginate under various conditions. With an optimized ratio of bead components, maximum adsorption of 97.8% was achieved at pH 6 with 80 minutes of contact. This treatment process is cost-efficient and ecologically friendly. There is a considerable potential for using crop plants not only for food, but also for sustainable bioenergy production. To produce biofuels, pretreatment of input biomass is needed to allow catalytic enzymes access to cellulose for hydrolysis. Using banana pseudostem as a starting stock, Sivanarutselvi *et al.* show 92% delignification after a pretreatment of soaking in 1.5% alkali at 30°C, which yielded maximum sugar and butanol production. Hence, banana pseudostem can be a useful feedstock for biobutanol production. Biofuel production potential must be assessed in the context of a warming climate with increasing impact of drought. Ogbaga *et al*. assessed the possibility of using drought-tolerant sorghum and drought-sensitive maize for biomass production. Their review provides insight into known and novel mechanisms promoting drought tolerance and biomass accumulation in sorghum, suggesting the possibility of genetic manipulation and gene transfer into maize. They suggest field testing, metabolic pathways studies, and breeding directed at advancing biofuel production in crops.

The contribution of environmental biology to sustainability will include development and application of methods for addressing past industrial and agricultural impacts on the environment. Widely used especially in the plastics industry, phthalate esters are not degraded effectively by natural processes such as hydrolization and photodecomposition. Cevik *et al.* conducted diethyl phthalate (DEP) degradation experiments with bacteria isolated from oil-contaminated soil, and reported that Pseudomonas putida reduced DEP concentration by 85.5% through 5 days of incubation at pH 7 at 30°C and that ability to degrade DEP was plasmid-mediated. CMIT, a broad-spectrum biocide used in personal care and other products, has been shown to cause peripheral airway dysfunction in humans. Noting that certain phytochemicals may reduce CMIT toxicity, Jeong and Lee investigated DNA and cell damage in rat lymphocytes and human lung cancer cells. The results showed that the phytochemicals vitamin C, berberine, curcumin, and resveratrol might be used in preventative or therapeutic anti-CMIT agents. 4-nitrophenol (4NP) – which is used to produce pesticides, dyes, petrochemicals, and pharmaceuticals – often pollute soils, and knowledge of pathways for microbial degradation would be of interest for advancing bioremediation strategies. Sengupta *et al*. examineed biodegradation pathways for 4NP in soil bacterium *Rhodococcus* sp. strain BUPNP1 isolated from a landfill. The results of a novel bioinformatics analysis showed the involvement of monooxygenase enzymes and heretofore unknown hypothetical proteins, suggesting a path for developing more effective bioremediation strategies. While River Sutlej, a tributary of the Indus in western India, has supported locally important capture fisheries, it has become subject to dumping of untreated sewage and industrial wastes. Measuring lead, copper, chromium and zinc concentrations in water, sediment, and fish tissues, Kaur *et al*. found higher concentrations below than above the confluence with the polluted Buddah Nallah Stream near Ludhiana City. All metal concentrations were within the limits recommended by FAO/WHO, except for lead in the catfish *Wallago attu*, which pose a threat to human consumers. Intensification of aquaculture production leads to anaerobic decomposition of wastes in the pond sediment, in turn leading to production of hydrogen sulfide that is toxic to fish and invertebrates. Nadella *et al*. isolated sulfur-oxidizing bacteria from shrimp-pond sediment and show that maximum sulfate ion production and sulfur oxidase activity were exhibited by an isolate identified as *Halothiobacillus* sp. strain rk3. This bacterium may prove useful as a bioinnoculant to enhance sulfur oxidation in pond sediments.

A prospective view

The papers appearing in this issue of the *Journal of Environmental Biology* represent an impressive body of contributions towards achieving sustainable agriculture and industry. What other advances do we need to achieve sustainable societies? While I aim to be general in my viewpoint, the actions that I suggest below will to some degree reflect my role as a geneticist working in the fisheries and aquaculture sector.

Research on the agrotechnical aspects of food production (e.g., Lam-Gutierrez *et al.*, this volume) will remain important, especially as climate change goes forward. Improvement of technology (e.g., Kumar *et al.* this volume) and enhanced application achieved through improved extension of research results to farmers, will increase agricultural production and rural income, hopefully with declining environmental impacts. Agrotechnical advances will be particularly important in the aquaculture sector, where domestication of key species – such as catla (Ghosh *et al.*, this volume)– is still ongoing and production methods are still being developed for many species. Not all crop and animal lines in agricultural production are genetically improved, especially in the aquaculture sector. Hence, achieving sustainable intensification of agriculture must include genetic improvement of crop and animal lines. Genetic improvement through classical selective breeding (e.g., Kaur *et al.*, Naik *et al.* and *Singh et al.* this volume) will remain relevant for traits including increased growth rate, stress tolerance and disease resistance, especially as production intensifies. While some species are amenable to enterprise-level selective breeding (e.g., tilapia – Hallerman, 2000), other breeding efforts require larger-scale programs (e.g., that of the International Livestock Research Institute, https://www.ilri.org/livegene). While classical phenotype-based breeding will remain important, I anticipate increasing application of molecular-based breeding technologies. Such approaches will include application of enhanced knowledge of linkages between molecular genetic markers and quantitative trait loci through marker-assisted selection, or MAS, leading to increased rates of genetic progress. This approach has been applied widely to crop plants (Singh and Singh 2015), and is increasingly being applied in animal systems (e.g., dairy cattle – Hayes *et al.*, 2009, Atlantic salmon – Moen *et al.,* 2015). While adoption rates have varied widely among countries, I expect that agricultural biotechnology will be applied more widely because of the benefits that it uniquely offers. As noted by Ogbaga *et al.* in this issue, gene transfer might be applied to improve drought tolerance in maize; the approach also might address such traits as increased micronutrient content or resistance to insects, nematodes, diseases, or wilt (Hallerman and Grabau, 2016). Adoption of genetically modified (GM) crops (ISAAA 2019), while rapid in some countries (e.g., United States – 203 lines in 21 crops), has been slow in others (India – 11 cotton and soybean lines, Pakistan – six cotton and maize lines, Bangladesh – *Bt* brinjal). Meanwhile, golden rice, which offers a heightened level of provitamin A to consumers (http://www.goldenrice.org/), remains unapproved. Acceptance of GM lines will require changes in public perception in the respective countries (Li *et al.*, 2015, 2016). Regional development of such lines (e.g., *Bt* brinjal in India) may address any fear of western corporate dominance. Clearly, public engagement on a range of issues is needed, as well as enabling public policies (Tizard *et al.* 2016; Li *et al*. 2014, 2016a, 2016b, 2018). I predict that readers will accept agricultural biotechnology if they perceive benefit, as for *Bt* brinjal in Bangladesh. The potential of animal biotechnology remains little realized – limited to small-scale production of growth hormone-transgenic Atlantic salmon (Stotish, 2018) and field deployment of reproductively confined mosquito (Capuro, 2014). Other genetically engineered animal lines pose benefits accruing from growth promotion, disease resistance, reproductive confinement, nutritional enhancement or hornlessness (Hallerman, 2019).

Realization of ecological sustainability will depend upon programmatic application of environmental monitoring, continued development of environmental science, and adoption and implementation of well-considered environmental policy. Kaur *et al.* (this volume) address environmental toxicology. As the field develops, we find that exposure to toxic compounds has not only lethal, but also important sublethal effects upon individuals and populations. Identification of molecular pathways underlying response to toxic compounds depends upon development of suitable assays. One particularly interesting approach is toxicogenomics, in which next-generation DNA sequencing is used to screen expression of all genes transcribed in a tissue of interest. This approach, termed RNAseq, makes possible quantitative comparison of gene expression in selected tissues among toxin-challenged and control individuals. The approach identifies genes of interest not only in known, but also in unknown biochemical pathways. For example, Michalak *et al.* (2016) show changes in gene expression in the freshwater mussel pheasant shell following exposure to sulfate and arsenate, pollutants resulting from coal mining and combustion. Clearly, advancement of science (Sengupta *et al.* this volume) and technology (Civik *et al.*, Jeong and Lee, Kumar *et al.*, Mabel *et al.,* Nadella *et al.*, Ogbaga *et al.,* Sivanarutselvi *et al.*, this volume) is not the only issue; advances in ecological sustainability will depend critically upon development and enforcement of well-designed environmental policy and a large investment in water treatment and other infrastructure.

In conclusion, at this critical moment of human history, our contribution as environmental biologists is crucial; we must contribute the finest, best-directed science that we can muster, and we must engage effectively with society and decision-makers to advance towards sustainability.

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