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FORUM

Ajay Kumar Parida (1963–2022), an eminent plant biotechnologist with a passion for mangrove biology

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Abstract

We remember Dr Ajay Parida, a leading plant biotechnologist, whose premature passing has deprived the Indian plant science community of a committed scientist and an able administrator. Born on 12 December 1963 in Bhagabanpur, Cuttack District (now Jajpur district), Odisha, he passed away in Guwahati on 19 July 2022. A collegial scientist, his down-to-earth and approachable nature, as well as his resourcefulness were instrumental in advancing the cause of Indian science and harnessing frontier biotechnological tools as vehicles of social consciousness. His expertise in quantitative DNA variation and molecular marker analysis, paved the way for subsequent research on mangrove molecular diversity at the M. S. Swaminathan Research Foundation (MSSRF), Chennai. His contributions to mangrove biology, genetics and genomics as well as extremophile plant species in the Indian context over two decades are a benchmark in his field. He also provided commendable leadership in his capacity as Director, Institute of Life Sciences (ILS), Bhubaneshwar during the COVID-19 pandemic.

Keywords Mangroves · Abiotic stress tolerance · Plant molecular biology · Genomics · Department of biotechnology (DBT)

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Introduction

Dr Ajay Parida (hereafter AP) made significant research contributions in the fields of DNA-based fingerprinting, plant molecular biology, and biotechnology. He was a committed scientist and able administrator who applied himself tirelessly to the cause of Indian science. Among his many remarkable achievements, AP's pioneering work in the domain of mangrove molecular markers and molecular biology is a trailblazing milestone, elevating research on species biology of this diverse and unique plant group to national and international prominence. In the following sections, we present an illustrative account of his contributions to Indian plant science, especially extremophile biology, his institution-building and administrative capabilities that were put to good use for national causes and his contributions to marshaling resources for the COVID-19 response in the state of Odisha.

Scientific contributions

Mangrove molecular diversity

After completing a doctoral degree under the supervision of Professor Soom Nath Raina (Laboratory of Cellular and Molecular Cytogenetics, Botany Department, Delhi University; Fig. 1A), AP briefly worked as a Research Associate at Delhi University. His selection for the position of a scientist at the M. S. Swaminathan Research Foundation (MSSRF), Chennai was a turning point in his career. AP was shortlisted from a large number of applicants after a rigorous selection process. His academic credentials, vast knowledge of molecular markers, and broad area of research expertise were keenly noted by Professor M. S. Swaminathan and were in line with the research mandate of MSSRF. AP started research at MSSRF in 1993, first as a Principal Scientist and then subsequently in other capacities such as Director (Biotechnology) in 2000 and Executive Director (MSSRF) in 2009 (Fig. 1B). This marked the beginning of his remarkable journey in the field of mangrove research and the pursuit of innovative solutions for salinity tolerance in plants. He led a laboratory that did pioneering work on molecular mapping and genetic enhancement of coastal agrobiodiversity for more than two decades. In 1988, Professor Swaminathan had recommended that anticipatory research on existing genetic resources of Indian mangroves, conservation, management, sustainable utilization would be a key adaptation/mitigation strategy to coastal erosion and sea level rise (Selvam and Thamizoli 2022). Until then, mangroves in India had been largely understudied, resulting in significant gaps in information on species identity and richness, inter-relationships and evolution. Available reports were fragmentary, making it difficult to differentiate between environmental and heritable factors contributing to observed variations. The dynamic coastal environment of mangroves strongly influences phenotypic variation, confounding species identification and taxonomy based on quantitative characters and phenotypic markers (Parida et al. 1998). Therefore, molecular marker-based analyses of genetic material and gene products were essential to address these challenges and examine species identification, diversity, relationships, and phylogenetic trends among Indian mangroves. AP's expertise in quantitative DNA variation and molecular marker analysis, gained during his doctoral tenure, laid the foundation for his subsequent work on mangrove molecular diversity at MSSRF. A series of nine articles titled 'Molecular Phylogeny of Mangroves' through molecular markers, examined population and phylogenetic relationships in mangroves (cited in Schwarzbach and Ricklefs 2001). Previous studies using protein markers had examined only two mangrove species in detail. AP's group examined many more mangrove species in India using molecular markers. Natural hybridization in mangrove species has been reported using morphological data (reviewed in Ragavan et al. 2017). However, using Restriction Fragment Length Polymorphism (RFLP) markers of genomic and mitochondrial origin, the parentage of a *Rhizophora* hybrid was established for the first time in a mangrove species (Parani et al. 1997). Further, molecular data supporting the placement of *Avicennia* species in a separate monotypic family (Avicenniaceae) (and away from their initial placement in Verbenaceae) was generated using Random Amplified Polymorphic DNA (RAPD) and RFLP methods (Parani et al. 1998). The experience gained from molecular marker studies in mangroves was extended to genetic indexing of crop wild relatives, landraces of cultivated legumes, millet species, and rice.

Abiotic stress tolerance in extremophiles and transgenic approaches

AP had a keen and instinctive grasp of the utility of new biotechnological tools in answering key research questions. This is evident in the adoption of Expressed Sequence Tags (EST) or subsequent Next Generation Sequencing (NGS) methodologies to isolate genes (cDNA expression libraries) from mangrove and associate species (*Avicennia marina*, *Porteresia coarctata*; reviewed in Rajalakshmi and Parida 2012), drought tolerant species, *Prosopis juliflora* (George et al. 2007), and other abiotic stress tolerant species such as *Chrysopogon*, *Macrotyloma* at MSSRF and subsequently at the Institute of Life Sciences (ILS), Bhubaneshwar.

Fig. 1 **A** AP (on the right) with his doctoral supervisor, Prof. SN Raina at the XVI International Congress of Genetics (Toronto, Canada,1988). **B** AP with MSSRF senior staff and research scholars he mentored on Annual Day [(MSSRF], 2019). **C** AP with research scholars and staff at ILS. **D** AP (inset arrow, seated in the audience with senior MSSRF staff) at an organized to mark activities carried out for rehabilitation after the tsunami at Sadras, Kalpakkam (2005) supported by both DAE and DBT, Government of India. Professor M. S. Swaminthan was present along with DAE and DBT officials. **E** AP (extreme right, arrow) present at inauguration of the Biju Patnaik Tribal Agrobiodiversity Centre (MSSRF), Jeypore (2004). Also in the picture, the Chief Minister of Odisha, Mr Naveen Patnaik (centre, white kurta) and Prof. M. S. Swaminathan (to the left of the Chief Minister). **F** AP (online; television screen) on the 32nd Foundation Day at ILS (2021), presenting a report to DBT, GoI senior staff (picture source: https://twitter.com/drharshvardhan/status/1362378884004474887). **G** AP receiving the prestigious Padma Shri from President, Shri Pranab Mukherjee (2014). **H** AP with extended family members at his village (2007): Left to right: Father (Mr Dibakar Parida), paternal uncle and aunt (Mr. Karunakar Parida and Mrs. Panchali Kumari Rout), Dr Rashmi Mohapatra (spouse of AP), AP, AP's brother (behind), mother (Saralata; front of AP), paternal uncle and aunt (elder). **I** AP (sitting, right) during a doctoral training stint in the laboratory of Dr. RKJ Narayan (sitting, left) at Aberystwyth, Wales (1990)

A significant achievement in AP's research career was the successful development of salt-tolerant transgenic rice lines incorporating stress-responsive genes isolated from the mangrove species, *A. marina*. The transgenic introduction of a 'mangrove' anti-oxidant gene (Cu/Zn Superoxide Dismutase) to enhance oxidative, salinity, and drought stress tolerance was demonstrated to be highly effective in greenhouse conditions (reviewed in Rajalakshmi and Parida 2012). With a focus on the biofortification of rice, overexpression of soybean ferritin cDNA (using an endosperm-specific promoter) conferred enhanced iron accumulation in the rice endosperm (Sivaprakash et al. 2006). Transgenic SOD and ferritin (L12 and Fer respectively) lines, were comprehensively characterized by molecular analysis (Sadhasivam 2011). Transgene mapping revealed *AmSOD1* integration in a 10.8 Mb region of chromosome 2 and soybean *Ferritin1*

within 14.1 Mb to 15.7 Mb regions of chromosome 9 of rice. Selected transgenic events were introgressed into local rice varieties by extensive backcross breeding, with gene-assisted foreground selection till the BC_5F_1 generation. The BC_5F_3 generation was then genotypically characterized to obtain pure transgenic lines. In addition, research by his group at MSSRF on structural [NHX, HKT, redox enzymes, dehydrin, metallothionein] and regulatory (*AmMYB1*) ortholog genes from mangrove species and associates offer insights with respect to abiotic stress tolerance and occupy a unique niche in Indian plant science (reviewed in Rajalakshmi and Parida 2012; Kizhakkedath et al. 2015; Chidambaram et al. 2015). His passion for mangroves was also evident even during his tenure at ILS, Bhubaneshwar where he took over as Director in 2017. In a collaborative endeavor involving ILS and the SRM-DBT Partnership Platform for Advanced Life Sciences Technologies, a reference-grade whole genome sequence for a mangrove species, *Avicennia marina*, was reported for the first time from India (Natarajan et al. 2021).

Generating genomic resources for under-utilized plants with agricultural or medicinal potential

At ILS, Bhubaneshwar, AP's group was part of many national network projects that focused on generating genomic resources for many under-utilized plants with significant agricultural and/or medicinal value. NGS resources at ILS were employed for RNA-Seq (gene expression profiling) as well as genome re-sequencing for the identification of variants with the potential to be developed into molecular markers for plant breeding. In *Panicum sumatrense* (little millet), leaf and tissue RNA-seq profiles under drought and salinity stress were generated (Das et al. 2020) and data was mined to select a zinc finger containing transcription factor for functional characterization. A similar study was also conducted on *Phragmites karka*, an invasive halophyte that grows in diverse regions of the world, to identify a serine/threonine protein kinase that could enhance salinity stress tolerance in plants (Nayak et al. 2020). A comprehensive gene expression atlas for various tissues of moth bean (*Vigna aconitifolia*) was developed (Suranjika et al. 2022) and was also generated for mung bean. Whole genome sequencing of a drought-tolerant variety (Bhagya) of *Moringa oleifera* identified Heat Shock transcription Factors (HSFs) that were under purifying selection with a probable role in drought tolerance (Shyamli et al. 2021). AP's laboratory also identified members of the R2R3-MYB gene family in *Avicennia marina* (Pradhan et al 2021). Molecular marker information for cucurbit species is limited and information on genes regulating fruit size and development is also scarce. His laboratory at ILS was also engaged in generating genomic resources for cucurbits of economic relevance to India such as ivy gourd, pointed gourd, and *Momordica* species at the time of his premature passing (Fig. 1C: with scholars and staff at ILS). He was also involved in a network project on Himalayan bioresources to generate genomic information for important medicinal plants in India.

Administrative competence

Bioresource conservation, biotechnology policy dialogues, and social consciousness

AP had an easy-going, down-to-earth and approachable nature. He also had the gift of getting the best out of co-workers with divergent personality traits. This, coupled with a 'can-do' spirit, the ability to build a good working team and excellent networking skills were put to institution building both at MSSRF and ILS. In keeping with the spirit of Prof Swaminathan's message on sustaining coastal ecosystems, AP had been involved with both on-field and laboratory-based programs to conserve and sustainably use coastal bioresources and in doing so, ensuring livelihood security of small and marginal farmers and fisher families. These programs received widespread appreciation from stakeholders and were supported by government agencies including the DBT and the Department of Atomic Energy (DAE), Government of India (Fig. 1D). As an example, the tsunami in South Asia (26th December 2004) led to widespread death and destruction. Mangrove saplings produced by women Self Help Groups (SHGs) were promoted as a livelihood microenterprise and supplied to the Puducherry Forest Department. About 12 hectares of intertidal area in Sea Gull, Karaikal were afforested with mangroves. Two hectares of non-mangrove bioshield in coastal sand dunes in Puthukuppam village near Poompuhar were established. Four Village Knowledge Centres were established in marine fishing villages of Nagapattinam district, the worst tsunami hit district in Tamil Nadu. Thus, AP contributed not only to basic research on mangroves but also to mangrove conservation in coastal regions of southern India. Appropriate models for sustainable development in coastal regions were developed to strengthen the livelihood security of the local communities in the Kalpakkam and Kudankulam regions in Tamil Nadu. As Coordinator of a DBT -supported project, an in-depth status report on bioresources in seven selected sites along both the east and west coasts of India was prepared (http://59.160.153.188/library/sites/default/files/Bio%20Resources%20Status.pdf).

Under the guidance of Professor M. S. Swaminathan at MSSRF, AP contributed significantly to organizing many international dialogues related to policy issues in agriculture and regulatory processes for the approval and commercialization of genetically modified crops (Swaminathan and Parida 2014). He also contributed substantially to establishing the 'Biju

Patnaik Medicinal Plant Garden and Research Center' (currently renamed as Biju Patnaik Tribal Agrobiodiversity Center; BPTAbC) at MSSRF, Jeypore, Odisha in 2007 (Fig. 1E).

Inspired by Prof. Swaminathan's words that 'children need to develop a scientific outlook' and with support from the DBT, Government of India, AP played an active role in organizing 'Nature Resource Awareness Clubs' to create consciousness on relevant issues in biology, biodiversity conservation, biotechnology at the middle and high school levels in 2008. His calm outlook was invaluable in navigating deadlines and tight situations. His outward cheerfulness never flagged under any crisis and he had the ability to focus on the immediate task at hand, to deliver, often under immense pressure.

The state of Odisha has a significant tribal population and marginalization of tribal communities and poverty have had significant effects on their health Therefore, under the leadership of AP, ILS launched a flagship program focusing on understanding genomic diversity, the effect of diet on immunity, prevalent diseases, and the role of the gut microbiome in ethnically distinct, well-differentiated and geographically distributed tribal communities (a total of 22 communities reported in the ongoing study) in the state of Odisha. Under this program, exhaustive clinical profiling has been carried out, the prevalence of infectious diseases, disease hotspots mapped and their influence on the immune profile and health examined. Exome and whole genome sequencing, immunophenotyping, and microbiome diversity analysis have also been generated. AP was an integral part of all phases of this ongoing, from its initiation to execution.

The COVID-19 pandemic: contribution to national response

The years 2021–22 were a defining period in the lives of people all over the world with many fatalities accompanying the COVID-19 pandemic. The state of Odisha was no exception. Under AP's astute leadership at ILS, research took a frontline role in both the detection of SARS-CoV-2 viral loads in infected individuals and also in documenting viral genetic variation. Under his inspiring leadership, a team of scientists and scholars at ILS came together to attain new milestones in COVID-19 testing (over 3.0 lakh samples (as on 12 November 2021; https://pib.gov.in/PressReleasePage.aspx?PRID=1771252). ILS also set up a bio-repository to document and sequence emerging SARS-CoV-2 strains, in an effort to understand the molecular structure of the virus and mutations (Fig. 1F). He co-led the efforts by the Indian Government to understand SARS-CoV-2 genome evolution in the national context via the participation of ILS in the Indian SARS-CoV2 Genomics Consortium (INSACOG) (Sen et al. 2021 and Ghosh et al. 2022). AP was a constant presence at ILS, overseeing and coordinating with various establishments that were a part of the INSACOG coalition.

He also supported research efforts at ILS which led to a better understanding of the immune responses of individuals with underlying comorbidity to SARS-CoV2 infection (Sengupta et al. 2022). Effects of SARS-CoV2 on microbiome diversity were also examined under his leadership. Abundance of *Mycobacteria* and Mycoplasma opportunistic pathogens in COVID-19 patients was observed and their relationship correlated with symptoms, indicating the possibility of co-infections (Prasad et al. 2022). Thus, AP contributed significantly during a national crisis, leading exemplary work even outside his main domain of expertise.

AP's contribution to combating misinformation and providing scientifically precise information about the pandemic via local and vernacular media in Odisha are well documented. His calm and measured responses during the pandemic, succinct addresses in local news channels provided information on safety guidelines, and encouraged people in the state of Odisha to get vaccinated against SARS-CoV2, when they became available. His dedication to the national task at hand entrusted to ILS always took priority and his approachable personality made him a household name in Odisha. The respect he earned for his scientific contributions was evident when ordinary citizens of the state of Odisha turned out to honor his memory in large numbers when his mortal remains were consigned to flames with full state honors.

Awards and recognition

AP's pioneering work in mangroves received national recognition in the form of many awards (National Biosciences Award for Career Development 2006; Prof. Umakanta Sinha Memorial Award, 2009; NASI-Reliance Award 2009; Tata Innovation Fellowship 2011; Padma Shri 2014; Fig. 1G). He was an elected Fellow of the National Academy of Sciences, Allahabad (2006) and National Academy of Agricultural Sciences, New Delhi (2007). He also received recognition in the form of many other awards [Award for Crop Improvement (National Academy of Agriculture Sciences; 2014); the Prof. T. S. Sadasivam Memorial Award, Madras Science Foundation, Chennai; and National Biosciences Award for Career Development, (Department of Biotechnology, GoI, 2006)], for his many research achievements.

Early life and education

AP's father, Mr. Dibakar Parida, was a primary school teacher at a school in village Arabal (Jajpur district) and his mother, Saralata, was a homemaker. Seeing his curiosity and a keen interest in learning, he was sent to study at

the age of five at Narla Primary School in Kalahandi District, Odisha under the supervision of his paternal uncle and aunt, Mr. Karunakar Parida and Mrs. Panchali Kumar Rout (Fig. 1H shows AP with his family). At the primary level, he excelled in academics, receiving several awards and actively participated in locally organized lectures and science fairs. His academic excellence was recognized by the Kalahandi District Education Department and he received a scholarship in the fifth grade. Realizing his potential, his father enrolled him in Jagulai High School, Cuttack district where he completed his schooling with distinction. He graduated with Honours in Botany from Utkal University (Narasingh Choudhury College, Jajpur, Odisha) in 1982 and received a government scholarship to complete his post-graduation in Botany from Ravenshaw College[1] in 1984. He qualified the CSIR-UGC examination and received a fellowship to pursue doctoral studies under the supervision of Professor Soom Nath Raina (Laboratory of Cellular and Molecular Cytogenetics, Botany Department, Delhi University). His thesis titled 'Quantitative DNA variation between and within chromosome complements of *Vicia* species and genome analysis in *Vicia faba* and its wild relatives' explored the cytogenetic, DNA composition and genome size basis for phylogeny in *Vicia* for which he was awarded a Ph.D. degree in 1992 (Parida and Raina 1988). In addition, AP was actively involved in research investigations on genetic analysis in micro-propagated plants (first few reports of detection of subtle somaclonal variation among micro-propagated plants using DNA markers; Rani et al. 1995), nature of chromosomal and genome size variation in callus cultures of diploid vis-a-vis synthetic auto-tetraploids (Raja et. al., 1992), the relationship between nucleotypic changes and success of neo-polyploids and sex differences in meiosis. During his Ph.D. tenure, he was a visiting fellow at the University College of Wales, Aberystwyth (1988) where he determined quantitative DNA variation between and within chromosome complements in *Vigna* species (Parida et al. 1990; Fig. 1I: AP with colleagues at Wales). His fellow researchers would often say "Any scientific conversation with him would mostly turn into an erudite discussion" (SN Raina, personal communication). AP took this spirit of inquiry and excellence further in his professional life.

AP's commitment to the tasks on hand was resolute. He was incredibly proud of the institutions he was associated with and placed great trust in his co-workers. An avid researcher to the end, he envisioned ILS as a center for excellence that would be known for its cutting-edge science as well as for contributions that could benefit society directly. He was instrumental in upgrading infrastructural facilities and inducting new staff at ILS, Bhubaneswar. He inspired researchers to collaborate on interdisciplinary areas of research, encouraging them to work cohesively for tribal health and societal good. The onus now falls on the scientific community at ILS to carry this legacy forward. AP was a warm, empathetic human being. His sense of humor and infectious laughter were well-known to close friends and colleagues at MSSRF and ILS and will be missed greatly. We remember him with great affection and warmth.

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Declarations

Competing interests All authors have read and approved the manuscript. All authors declare there are no professional or personal conflicts of interest.

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