Jatropha, Challenges for a New Energy Crop

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Editors

Jatropha, Challenges for a New Energy Crop

Volume 3: A Sustainable Multipurpose Crop

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Foreword – I

Despite its proven potential as a cost-efficient bioenergy feedstock, *Jatropha curcas* L. (Jatropha) remains to be a domesticated plant in terms of various traits. These include processes such as its reproductive biology, which is critical in gaining an insight into breeding for synchronous flowering. That insight would accrue through a molecular understanding of the process, for which genomic information on the plant is required.

Nearly more than a decade and a half of systematic, international, collaborative studies has been conducted on understanding the morphological and genetic diversity of Jatropha in order to guide parent selection for cross-pollination. Numerous genetic markers have been developed for the purposes of uncovering genetic diversity to assist in the breeding efforts. Hence, the first wave of Jatropha improvement is coming from traditional breeding approaches that utilize natural variations within *J. curcas* and in other genetically compatible species. There have also been efforts to introduce more variation through mutagenesis. Commercially relevant traits of shorter stature, higher number of female flowers, better self-branching, increased seed oil content, and decreased input requirements are being targeted. While efforts through traditional breeding are beginning to show initial successes in these target traits, there are many problem areas where traditional breeding-based solutions have limitations. These include Jatropha plant diseases, oilseed toxicity, and its less than ideal fatty acid profile.

Modern plant science-based approaches provide a valuable avenue in further improvement of Jatropha, similar to crops such as cotton, canola, soybean, and maize. Such approaches include the biotechnology-mediated possibility of introducing some well-characterized genes from other organisms to test for effects in Jatropha. Fine-tuning the seed's fatty acid profile and its biosynthesis and that of other metabolites such as the seed oil toxins is a primary target. A precondition to Jatropha biotechnology is the availability of efficient and robust regeneration systems and transformation systems, preferably through *Agrobacterium*. There have been several reports on regeneration and genetic transformation of Jatropha, and it remains to be tested if there is an efficient and robust protocol across laboratories.

With good transformation system, it is also important to have promoters that can drive spatiotemporal-specific gene expression to suit various objectives. The primary source of such promoters would be known from promoters of other plants, but a systematic understanding based identification of endogenous promoters is also required. Similarly, a good structural, functional, and comparative understanding of the Jatropha genes, genomes, and genotypes will help in achieving the goal of manipulating its secondary metabolism. A recent report of seed-specific enhancement of oleic acid in Jatropha illustrates the beginning of utilizing biotechnology in Jatropha improvement. Also noteworthy are the use of one endogenous promoter and the deletion of antibiotic selection marker gene in the final transgenic Jatropha. The use of CRISPR technologies, absence of foreign genes, and the fact that humans will not be directly exposed to the transgenic Jatropha products will all help in regulatory approvals for commercialization. With such possibilities in understanding and manipulating the most desirable traits of better biotic and abiotic stress tolerance, and quality and quantity improvement in seed oil, the doors will open to addressing traits that impact a whole range of products, including oils and bio-plastics, along value addition, in establishing Jatropha plant as a natural bioreactor. Thus the "explosion" of scientific activity on Jatropha since 2008 leading to the availability of a genome sequence and a lot of upstream research within 4 years since, coming up to successes with regeneration and transformation, is already establishing Jatropha as a model non-edible oilseed crop, including as a first crop to be purposely domesticated in modern times. Availability of records on such a process would be very useful in comparative evolution.

Publication of this book intends to produce a synthesis of what has been achieved and to help scientists move forward in understanding and utilizing Jatropha. It serves as a milestone but also showcases how quickly we can achieve a critical understanding on a novel bioenergy plant with the help of accumulated knowledge on model food crops and with the advanced scientific and research tools and technologies. The editors of the book, Drs. Mulpuri, Carels, and Bahadur, are the doyens in Jatropha research and development and have made significant contributions in our understanding of the potential and uses of this plant. It is most appreciated that they work closely and tirelessly to bring together information to update and guide the Jatropha research into the future through the present volume on *Jatropha, Challenges for a New Energy Crop*: *Volume 3 – A Sustainable Multipurpose Crop*. Their efforts and results, and those of all the scientists, presented in this volume and as a body of research outputs, will hopefully contribute to an increased funding from public and private sector to further support Jatropha research and development, which will further expedite the process of developing Jatropha as a new energy crop.

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Foreword – II

During his tenure as Director General, Indian Council of Agricultural Research, Dr. R.S. Paroda made several efforts to significantly boost oil seed productivity in the country.

I am indeed happy that the learned Editors have decided to bring out the present volume on *Jatropha curcas*, considered as a potential bioenergy feedstock plant. This is the third volume which speaks of their dedication, diligence, and sheer determination to popularize this oil seed plant.

The present volume covers several areas like *physiology and plant production, selective breeding and genetic diversity, feeding use, coproducts, processing, and socioeconomic sustainability*.

Undeniably, the plant has been around for the past several decades, though it is only recently that attempts are being made to understand its reproductive features and genome information. Initially, improvement was based on traditional breeding that utilizes natural variants existing within *J. curcas* and in other genetically compatible species. With a view to raising desired hybrids, suitable parents with desired traits, based on morphological and genetic diversity, need to be identified for crossing. Consequently several genetic markers have been developed with a view to unravel the genetic diversity. With a focus on several desirable traits, e.g., increasing oil productivity and decreasing input, better self-branching, shorter stature, higher number of female flowers, and higher oil content are being developed, and time-tested techniques like mutagenesis and transgenesis have been exploited.

Unarguably, traditional breeding poses several “roadblocks,” for instance, *Jatropha* pathogens, toxicity of oil seeds, and its less than ideal desired fatty acid profile. In this context, biotechnological techniques provide valuable alternative to traditional methods as demonstrated in several cash crops including oilseeds. I am happy to state that the umpteen impressive publications on Jatropha of the editors of the present volume, in high-impact journals, need special mention.

In my view, the present volume provides a deep glimpse of our revered experts in their respective fields of specialization and explores all conceivable horizons in the field.

I am of the considered opinion that it offers a broad perspective on the current status on the economic and sustainable aspects of this important bioenergy plant.

I congratulate the eminent editors for timely bringing out this publication which will enthuse the growers to domesticate this important oilseed species.

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C. P. Malik

Preface

We initiated the Jatropha books project about 9 years back, and the first volume, entitled *Jatropha, Challenges for a New Energy Crop: Farming, Economics and Biofuel* (30 chapters), was published in 2012 followed by the second volume *Genetic Improvement and Biotechnology* (31 chapters) in 2013 both published by Springer New York. At that time, physic nut (*Jatropha curcas* L.) was emerging as an oilseed option to expand biodiesel production especially in marginal land poorly suitable for the cultivation of crops producing edible oil. These books gave a comprehensive account of the research going on internationally with the purpose of stimulating future development in this area. Five years went by since the publication of the first two volumes, and an update is now proposed with a third volume. Considering its potential as an alternative to fossil fuel, there have been considerable works on various technological aspects of physic nut, but it must still be considered as a semi-wild species. Further efforts considering selective breeding are necessary to increase yield and improve agricultural features to bring physic nut to the status of an industrial crop, which is needed for a commodity such as oil for biodiesel, given that selling prices can only be low. Volume 3 (25 chapters) intends to give a positive global picture on physic nut, a crop that has suffered from the fact that it is not yet fully domesticated despite its promising agronomical and economical features. Physic nut has the benefit of a high potential productivity larger than 7 tons of seeds per hectare (but actually commonly less than 2 tons per hectare) associated to proper oil composition for biodiesel conversion. In addition, physic nut is easy to subculture in vitro and to manipulate in laboratory as well as to transform in vitro genetically. Furthermore, it has a significant genetic diversity in its center of origin (Central America) and is relatively easy to cross-hybridize within the various species of the genus. Because of these promising features, physic nut is definitively on the rise as a crop, and some companies have already successfully understood how to handle it up. Thus, it is our concerted duty to sustain the efforts at domestication of this crop in order to provide additional solutions to the still too few industrial oilseed crops available for biofuel production.

The Editors have the expertise in agronomy, botany, selective breeding, biotechnology, molecular biology, genomics, and bioinformatics, which enabled them to gather worthy and sounding contributions. Actually, at this stage of physic nut journey as an industrial crop, the understanding of its physiology and its selective breeding remain the main bottlenecks to improve its economic status. In addition, we dedicated some chapters to the discussion on (i) how its return can be improved by the exploration of by-products such as animal feed, biomass, and chemicals for health and medicinal aspects, (ii) how its oil can be better processed into biofuel, and (iii) what are the objectives to be reached to warrant its sustainability in the future. Thus, Volume 3 should interest biologists, biotechnologists, agronomists, breeders, decision-makers, and investors of the biodiesel chain.

By publishing this book, we aimed at supporting the people in developing a crop that should help populations from marginal areas to gain access to a biofuel that may boost their economy. In that respect, we believe that the book will be seen as helpful by the interested communities as has already been proven by the success of the two previous volumes.

We wish to express our gratitude to all the contributing authors from all over the world for readily accepting our invitation not only for sharing their knowledge but also for admirably integrating their expertise to the vast information from diverse sources and enduring editorial suggestions to finally produce this venture. We also acknowledge the huge support received from many colleagues in the preparation of the manuscripts as well as to our family members and relatives for bearing with our commitment to the book. We wish to express our appreciation for the help given by Dr. Mamta Kapila (Senior Editor, Springer Nature India, New Delhi), Mr. Daniel Ignatius Jagadisan, Project Coordinator (Books) for Springer Nature, and their team for the excellent cooperation being extended and many valuable suggestions. We wish to thank Dr. Kenneth Teng from Springer New York, USA, where the book proposal for Volume 3 was submitted and approved prior to be subsequently transferred to Springer India.

We wish a pleasant reading of Volume 3 to scientists and students around the world who are interested in the subject of physic nut as a multipurpose crop.

Finally, we would like to apologize for any omissions or mistakes, or failures that may subsist in the book.

Hyderabad, India — Sujatha Mulpuri
Rio de Janeiro, Brazil — Nicolas Carels
Warangal, India — Bir Bahadur

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About the Editors

Sujatha Mulpuri graduated in Plant Sciences from the University of Hyderabad (UoH), India. She has a Ph.D. in Genetics from Osmania University (OU), Hyderabad, and has worked on intergeneric and interspecific affinities between Ricinus and Jatropha. Dr. Sujatha is a versatile researcher, adopting conventional and modern tools for the improvement of oilseed crops encompassing the areas of genetics, tissue culture, and biotechnology. Her achievements include the development of stable male sterile lines in safflower, sunflower, and niger, optimization of tissue culture and genetic transformation protocols, development of transgenic events in castor for foliage feeders and sunflower for resistance to necrosis disease, and use of molecular markers in diversity analysis and tagging of desirable traits in sunflower (downy mildew, fertility restoration) and Jatropha (non-toxicity). Dr. Sujatha has also carried out pioneering work on Jatropha with regard to tissue culture, genetic diversity analysis of native and world collections, and interspecific hybridization, which have provided valuable leads for genetic enhancement of *J. curcas*.

Nicolas Carels graduated in Agronomy in Belgium and completed a Ph.D. in Plant Pathology (FUSAGx, Gembloux) prior to working as a scientist on the elaboration of the first genetic map of sugar beet at the end of the 1980s (ICIseed-SES, Belgium). He then moved to Paris (IJM, CNRS, France) where he completed a second Ph.D. on the genome organization in plants. He continued his work on genomics in Italy (SZN, Naples) and Spain (INTA-CAB, Madrid, Torrejon de Ardoz) before moving to Brazil (Bahia, Ilhéus, UESC), where he contributed to the application of bioinformatics and genomics to the improvement of cocoa and rubber tree for resistance to fungal diseases. His initial investigations on Jatropha covered the measurement of the genome size by flow cytometry and the application of reverse genetics to detect QTLs for oil production with the purpose of breeding Jatropha for this trait. He is now a Federal Officer of Fiocruz (Rio de Janeiro, Brazil) and is interested in the exploration of genomics, system modeling, bioinformatics, computational biology, and natural products for the benefit of human health, with a particular focus on therapeutics for cancer.

Bir Bahadur former Professor, Chairman and Head of the Department, and Dean of the Faculty of Science at Kakatiya University, Warangal, India, has also taught at Osmania University, Hyderabad, India. He obtained his Ph.D. in Plant Genetics from Osmania University and was closely associated with Prof. J.B.S. Haldane, F.R.S, a renowned British geneticist. He made significant contributions in several areas of plant biology, especially heteromorphic incompatibility, genetics, mutagenesis, plant tissue culture morphogenesis, biotechnology, plant asymmetry and handedness, ethnobotany, application of SEM pollen and seeds in relation to systematics, medicinal plants, and Jatropha and Castor. He has mentored thousands of graduates and postgraduate students and taught genetics, biotechnology, plant molecular biology, plant reproduction, and related subjects for over 45 years and has accumulated 50 years of research experience in these areas. He has been the recipient of numerous awards, fellowships, and honors, including the Prof. Vishwambhar Puri Gold Medal, Bharath Jyoti Award, and Royal Society Bursary & Honorary Fellow of Birmingham University (UK).

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