change the projected GHG production figures of India and may have serious implications in the coming days for Indian agriculture and its participation in global climate change programmes. There is a possibility that India might be forced to expand its cultivable area or convert rainfed areas in the form of wet agricultural lands through construction of dams and/or interlinking of rivers, etc.

In this context, discussing the above based on the following questions will allow us to draw a clear mandate for future climate change, rice promotion, GHG mitigation and India's participation in climate change programmes. (a) Is the availability of organic carbon content in soils the only reason for enhanced methane production? If so, what is the water to organic matter ratio required for the hyper production of methane or to keep the production at optimum levels? In such cases, is it possible for us to create such conditions in natural environment? (b) Do we have technologies to mitigate/quench methane production or capture in rice fields/wetlands through some other means? (c) What role does the soil carbon play in an agricultural system apart from plant promotion and acting as a substrate for methanogens to produce methane? (d) If the paddy fields are culprits, what will be the case of shallow/stagnated water bodies and those with higher organic carbon content? (e) Of late, there is greater momentum of organic cultivation of foodgrains. They seem to fetch good profit for farmers even in wetland areas. Will methane mitigation have any implication on organic cultivation? (f) It has been reported[5] that fertilizer application may lead to a reduction of methane emission from wetland rice fields to the tune of 57%. This is new and supplements the earlier impression that considerable methane produced by methanogens in rice paddies is consumed by methane-oxidizing bacteria associated with the roots of rice[6]. Will this have any impact on the global organic agricultural movement or do we need to stay with chemical fertilizer application in the agricultural fields? (g) In such cases, is it necessary to have a relook at soil pollution and the subsequent water pollution due to fertilizer application and soil quality management related to GHGs? (h) Considering the vulnerability, is it good to encourage organic cultivation of rice in lowland areas? (i) Will there be a moratorium on cultivation of rice also, if our GHG emission crosses the limit through these so-called water bodies and rice fields? (j) Will India be forced to pay for the GHG credit for pollution in the international market? In such a situation, would our farming community be forced to shoulder the burden?

Considering all the above, it is time for us to start discussions in this direction at the policy level to protect rice farming, farmers and sustained food security in India. As rice is the staple food for people living in Asia, especially in India, this needs urgent attention to solve a crisis that may arise in future as a result of the GHG mitigation measures of IPCC. I believe a strong follow-up action at policy, scientific and implementation levels after a series of debates on the above would help devise best remedial measures and possible alternatives to have a foolproof food security programme in India and Asia to feed the population without much difficulty.

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Biotechnological intervention in jatropha for biodiesel production

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Energy demand in India is increasing at the rate of 6% annually compared to 2% for many other countries. Currently, imported petroleum crude supplies about 70% of the energy requirement. Vegetable oils, fats and their derivatives have been proposed as an alternate renewable and eco-friendly energy source. As India imports more than 40% of its edible oil requirement, it has to depend on non-edible oils for biodiesel. Various non-edible tree-borne oils such as neem, mahua, jatropha and pongamia, are available in the country. However, oil yields are insufficient to meet the demand.

Biotechnology could contribute to yield improvement strategies in the following ways:

1. Improving seed yield

Mapping genes and breeding: Genetic analysis in species with a view to identify quantitative trait loci (QTLs) for useful characters inherited in a multigenic fashion is now possible even without prior information of allelic differences because of the development of molecular techniques such as RAPD and AFLP, which directly detect variation at the DNA level rather than at the phenotypic level. To begin with, an elite mapping population with the desirable characteristics that breeds true would have to be established in jatropha. Information from the elite mapping population data could then be used to rapidly screen germplasm of jatropha to identify DNA markers or major QTLs associated with high yield and the same could be used in marker assisted selection (MAS) breeding strategies to jumpstart genetic improvement of jatropha for yield characteristics.

Interspecific and intergeneric crosses: It is possible that variation within a species may not exist for economically important characters. In such cases breeding strategies may involve introgression of genes from other species of the genera or related genera. Techniques in tissue culture such as *in vitro* fertilization, somatic hybridization and gene transfer technologies can be employed to overcome any existing barriers in making such crosses.

Generation of variability: Improvements in crops such as jatropha and karanja are being studied using mutation breeding at the Bhabha Atomic Research Centre (BARC), Mumbai. As jatropha is a tree species and a longer duration crop, three types of mutants are being sought: (i) morphological mutants, (ii) physiological mutants and (iii) biochemical mutants. Exposure to gamma radiation is known to produce mutants in all three categories. Tissue culture of plants is known to induce variability (somaclonal variation). Although culturing techniques have been standardized in several laboratries, somaclonal variants for yield have not been reported in jatropha or karanja.

Clonal propagation: Asexual propagation has several advantages over sexual methods; hence planting through cuttings is generally advocated, but non-availability of sufficient cuttings is a major impediment in promoting clonal planting on a commercial scale. Non-availability of superior clones/varieties, shortage of cuttings, low clonal multiplication rate, gaps in knowledge of clonal technology, inadequate evidence about success of clonal plantations, higher cost of clonal plantation, etc. are the major factors that limit large-scale application of clonal technology in India. Micropropagation and other tissue-culture techniques could be usefully employed for the multiplication and distribution of suitable planting material.

2. Improving oil content in seed

A jatropha seed contains 31–37% extractable oil. A better understanding of the molecular biology of seed-oil accumulation is emerging from studies in other oil-seed crops, particularly members of the genus *Brassica* and its wild relative *Arabidopsis*. For instance, in *Arabidopsis*, disruption in the homeobox protein encoding gene *GLABRA2* reportedly resulted in a mutant accumulating 8% more seed oil than the wild type. A reference dataset on fatty acid composition and distribution of mass and oil between tissues of *Arabidopsis* has been established and is expected to help in prediction of the applicability of results obtained with *Arabidopsis* to other oilseeds. Given that most metabolic pathways, including that for oil accumulation in seeds are conserved across plant species, information gleaned from model systems may be applied for improvement of oil content in tree species.

3. Improving oil quality and esterification properties

The physico-chemical properties of jatropha and pongamia oils are different. It appears that pongamia oil has higher quantities of unsaponifiables than jatropha oil, while the acid value variation is similar for both. Presence of high unsaponifiable matter content in pongamia hinders its processing for biodiesel production. Studies are being made on tree improvement to increase the energy rating of *Jatropha curcas* that is comparatively low (40 MJ/kg) compared to other species, e.g. *Jatropha glandulifera* (57.1 MJ/kg). Oil yields, however, are much higher in *J. curcas*. Thus crossing these two species may result in plants with higher oil and energy content.

Currently, only 10% of the vegetable oils produced are used in nonfood applications such as lubricants, hydraulic oil, bio-fuel, or oleochemicals for coatings, plasticizers, soaps and detergents. The economic requirements for industrial raw materials are quite different from those for nutritional oils. Genetic engineering of new storage oils and fats has produced oil crop plants with fatty acid compositions unattainable by plant breeding alone. The combination of classical breeding methods with molecular techniques provides new ways for designing oils for food and nonfood uses. Alterations in the position and number of double bonds, variation in fatty acid chain length, and the introduction of desired functional groups have already been achieved in model systems. It is possible that the same may be applied to jatropha and pongamia to improve their physico-chemical properties and to make them more suitable for biodiesel production.

In India, work on biodiesel from plantation to seed crushing to biodiesel production is being actively pursued by both government and private organizations. A major bottleneck in the widespread adoption of the technology however is the non-availability of jatropha or pongamia oils in larger quantities. This note is an attempt to define the scope of employing biotechnological tools for improving the productivity of biofuel oilseed crops and production of biodiesel.

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