the quality of today's genetic information. Therefore, it is relevant to analyse the phenotype with greater precision.

The automated phenotyping which involves various non-invasive techniques is not only precise but also efficient in terms of rate of phenotyping. Large number of plants can be screened at early and later stages to obtain maximum information of a particular trait and also measure different traits at a time. Plant organs such as roots are difficult to characterize, but are essential to understand the nutrient uptake phenomenon and other mechanisms of growth and development. Root structure can be characterized precisely using three-dimensional image analysis along with appropriate softwares[2]. Techniques such as X-ray, CT Scan[3,4], MRI along with positron emission tomography[5], which are being used in medicine and other fields are now available to study soil structural heterogeneity and also nutrient uptake phenomenon of roots. Thermal images obtained using infrared cameras provide useful information on drought, heat and salt stress. Hundreds of genotypes can be screened for stress tolerance using these thermal images at a single point of time[6,7]. The parameter Fv/Fm measured using chlorophyll fluorescence meter depicts the quantum efficiency of photosystem-II[8]. Chlorophyll fluorescence images are useful in analysing plants for biotic stress in very early stages of infection[9]. By measuring spectral reflectance at canopy level in the field, one can obtain enormous information of various traits such as photosynthetic rate, nitrogen uptake, biomass, pigment content and water content[10]. Mounting spectrometer on tractor or harvester increases the efficiency of measurement in field. Phenotyping facilities are created in the field by installing sensors, cameras, spectrometers to study the growth and development of plants and also their responses to various biotic and abiotic stresses. These instruments should be mounted using appropriate vehicles or towers with uninterrupted power supply and protected from adverse environmental effects. One such facility is being created at Canberra, Australia. The Australian plant phenomic facility is available for global research on high resolution and high throughput plant phenotyping[11]. In India, efforts are underway to develop high throughput phenotyping facility at the Indian Agriculture Research Institute, New Delhi. In this facility, pots with plants are labelled using barcodes; these pots are made to run along a conveyer belt into a chamber containing cameras, sensors and other equipments which capture the images and quantify the traits. The data of individual plant will be recorded in a computer system. Using this information, desirable plants are selected among the population for future crop improvement. Screening a large set of germplasm at early stages of growth will reduce the load of field evaluation for plant genetic resource managers and also for breeders. Precise phenotypic characterization of germplasm will enable breeders to use these readily in their breeding activity. In the present erratic climatic conditions, it is necessary for the breeders to be equipped with new technology and new sources of variation to generate crop varieties to suit changing climate and cropping patterns.

New technologies are emerging in every field and these new technologies have no boundaries and can be used in every sector. Agriculture is not spared from using new development in mathematics, physics, chemistry, computer science, space science and others for developing high throughput plant phenotyping technology. This inter-disciplinary approach promises significant new breakthroughs in plant science. Precise information on high throughput phenotyping technology complements the high quality genetic information available today from sophisticated sequencing technologies. Linking genomic information with the phenotype, aids in improvement of crop species for higher yield and sustainability to meet the global demand for food, fodder and fuel.

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Kerosene revisited – excellent fuel for rural households

All his life Mahatma Gandhi studied and wrote under the light of kerosene hurricane lanterns. These lanterns were always kept close to him since their light is feeble. How much kerosene-laden vapour he inhaled in his lifetime is anybody's guess. Yet he never suffered from any asthma attacks nor showed any other symptoms of respiratory disease. In fact, he also used to apply kerosene to his body as a mosquito repellent!

Yet there is a tremendous tirade by the Western countries against the use of kerosene as a household fuel and especially kerosene lanterns. As a result, the Indian Government has also decided to phase out kerosene, thereby depriving the poor people of a convenient household fuel.

It is the way in which a fuel is burnt that makes it clean or dirty. Thus liquid

petroleum gas (LPG), compressed natural gas or ethanol become clean fuels only because of excellent combustion technologies available. Unfortunately, during Gandhiji's times and even today the hurricane lantern is an inefficient and unclean combustion device. However, if an excellent kerosene-based lighting device is developed then it can be a boon to the rural poor.

The Nimbkar Agricultural Research Institute, Phaltan has recently developed an extremely efficient and clean-combustion kerosene lanstove (combined lantern and cooking stove) for rural households[1]. It simultaneously provides excellent light (equivalent to that from a 200 to 300 W electric bulb) and cooks a complete meal (including bread like chapattis and bhakaris) for a family of five. Besides, it produces 10 litre of clean drinking water. Thus, one device provides excellent light, clean cooking energy and clean drinking water.

Lanstove has been tested for the last eight months in 25 rural huts in western Maharashtra which do not have electricity[1,2]. It has shown excellent results with users commenting that it does not produce smoke like the existing biomass-powered chulha and gives excellent light compared to the presently used hurricane lanterns and tin wick lamps. The carbon monoxide levels (measure of how good the combustion is) from these lanstoves are less than 3 parts per million (ppm), whereas those from regular chulhas are between 250 and 400 ppm or 80 to 130 times more than from the lanstove. Thus the lanstove is an extremely clean device and equivalent to the LPG stove[1].

Yet the lanstove cannot be spread on a large scale in rural areas because of unavailability of kerosene. Today below poverty line (BPL) families get only 5 litre of kerosene per household every month. Most of the times even this meagre amount is not available since kerosene is diverted for adulterating diesel. Nevertheless, 5 litre/month is wholly inadequate since this much kerosene can only be sufficient for inefficient hurricane lanterns. Lanstove users need at least 15–20 litre of kerosene/month.

What is therefore needed is an enlightened Government of India (GoI) policy which removes the subsidy on kerosene and allows it to be sold in open market freely. For the BPL families the subsidized kerosene should be made available through the UID card. Once kerosene is sold freely in the open market, it is hoped that it will not be diverted for diesel or any other fuel adulteration.

The lanstove has been designed so that kerosene is pressurized and stored in a small separate cylinder from where it flows into the combustor and burns cleanly just like in the LPG cookstove[1]. This detachable cylinder can be filled up in the kerosene dispensing shops, which will be like mini petrol pumps. This filling of kerosene in a cylinder will be similar to getting an LPG cylinder charged. Regular users of kerosene will have to pay the open sale price, whereas the BPL families can pay a subsidized price through the UID card. This availability of subsidized kerosene through the UID card will be a boon to the rural poor and will allow them to improve their quality of life through availability of excellent light and clean cooking fuel.

Electricity-based lighting is most efficient, but it is difficult to see how in near future electricity can be made available in rural India. According to the latest GoI census, around 300 million people are without electricity even after 65 years of independence[3]. Various NGOs, foreign agencies and even GoI departments are therefore promoting solar-powered light emitting diode (LED) lanterns. These lanterns are costly, difficult to maintain because the lead acid battery in them fails easily and are energy guzzlers during their production (solar cells consume more energy in their manufacture than they will ever produce in their lifetime). Besides, solar lanterns cannot cook!

Recently, it has also been shown that LED light is harmful to the eyes and produces irreparable damage to the retina[4]. On the other hand, light from the lanstove has a continuous visible spectrum and is like daylight and hence easy on the eyes.

The critics of kerosene lanterns contend that as kerosene is a fossil fuel, its burning contributes to harmful Earth-warming greenhouse gases. However, the fact remains that in the last 15 years, the average air temperature of the Earth has remained constant[5]. Further, a recent study suggests that Earth warming is caused mostly by chlorofluorocarbon emissions rather than those of carbon dioxide[6]. Thus, there is a need for the rich nations to put their house in order.

The poor cannot wait indefinitely for the Western countries to develop cheap renewable energy technologies and give it to them. They need devices now to improve their quality of life and I feel excellent kerosene combustion devices like the lanstove will go a long way in doing so. The best strategy, therefore, is to develop rapidly technologies which make the existing fuels burn efficiently and in an environmentally safe manner.

Besides, there are extensive efforts world over to produce kerosene-like fuel from agricultural residues so as to make it renewable. I hope these efforts are also undertaken in India which has huge amount of agricultural residues and huge demand for kerosene as a household fuel.

I am also sure that Mahatma Gandhi, if he were alive today, would have wholeheartedly promoted the use of lanstove among the rural poor.

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