Energy Cane : An Option for Sustainable Development of Sugar Industry

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Introduction

A sustainable energy future depends on an increased share of renewable energy, especially in developing countries like India. In the case of energy, exhaustible fossil fuels represent ~80% of the total world energy supply. At constant production and consumption, the presently known reserves of oil will last around 35 years, natural gas 60 years, and coal 150 years. Besides the issue of depletion, fossil fuel use presents serious environmental problems, particularly global warming.

The growing interest in bioenergy in recent decades pushed scientists to better understand the physiological source-to-sink process as an obvious basic step to get efficiency either in the process of capture of Sun's energy by the plant or its subsequent accumulation of sugar and ultimately the use of the resultant total plant by mankind. Nowadays, with the growing need for alternative sources of energy other than the currently predominant fossil fuels, there has been resurgence in interest in biomass as a renewable energy source Sugarcane stands as one of the most dependable biomass crop due to its high productivity. However, the positive and significant contribution of sugarcane to the energy matrix can be further augmented with "energy cane," a distinct form of that plant selected for total biomass production rather than for sucrose and some surplus fibre.

Concept of Energy Cane

In India, sugarcane breeding was started more than hundred years ago in the early part of the twentieth century. Then, the objectives were to improve the sugar content and stress tolerance in the North Indian canes. Out of this breeding prgramme, number of sugarcane varieties were evolved that sustained the sugar industry for long period. Till date, in most of the sugarcane breeding programmes, the major emphasis is being given on improvement of the sugar content. Dry matter of *Saccharum* spp. is composed of sugars, mostly sucrose, and fiber, cellulose, hemicelluloses, and lignin. The species *Saccharum officinarum* is noted for its capacity to divert an exceptionally high proportion of photo-assimilates to sucrose and store it in the culms. However, a favourable partition between sugar and fibre for facilitating mill extraction is high sucrose and low fibre. It has been one of the significant constraints in the sugarcane breeding. Backcrossing to *S. officinarum*, the high sugar and low fibre ancestral species, reduces overall vigour and so, the varieties are more susceptible to stresses and, consequently, the productivity is restricted. The potential field productivity of sugarcane is known to be nearly 400 tons of fresh biomass per hectare per year in optimum conditions, but the world commercial sugarcane average productivity is less than 100 tons per hectare. The main products of sugarcane processing are raw sugar, molasses and bagasse (fibre). Ethanol is also obtained, either as a primary or secondary by-product. Sugarcane varieties typically have 13-15% sucrose, 15% or less fibre, and about 70% water. Bagasse dry matter is having about 48% cellulose which can be hydrolyzed to produce ethanol. Alexander argues that sucrose recovery per hectare could be greater with 'Energy Canes' than with conventional cultivars, even though energy canes produce low quality juice. This is because yield of energy canes far surpasses that of conventional sugarcane varieties.

Present day varieties are selected for sugar content and having relatively high sucrose content and poor in fibre. These features facilitate to sugar mill in easy processing and resulting good recovery. Sucrose and fibre ratio in cane breeding programme for biomass production is important. As the negative correlation between sucrose and fibre is exist, there are four different types of cane varieties that could be clearly defined by integrating cane quality and cane biomass character.

Fig: Types of cane for sugar and energy production

Cane type	Sucrose content	Fibre content	Yield
Type-1 (Commercial varieties)	13%	12%	High sugar yield
Type-2 (Enhanced fibre)	13%	>14%	High sugar yield
Type-3 (Multi-purpose cane)	<12%	>22%	High biomass yield
Type-4 (Cogeneration)	<5%	>22%	High biomass yield

Traditional commercial varieties have been assigned as Type 1 cane. Type 2 cane, termed as enhanced fibre type, is essentially one with sucrose concentration and sugar yield comparable with the commercial varieties but with higher fibre content. With Type 1 and Type 2 canes, sucrose content and sugar yield are above average. Type 3 and Type 4 canes represent situations where concessions are made for sucrose content to the advantage of fibre content. With Type 3 canes, the compromise is moderate, while with Type 4 canes, the concession is severe.

The future viability of sugar industry in India has been questioned in view of present status of the same. It is generally agreed that the industry will have to undergo some changes for its sustenance. Falling price of sugar in the international market is the main reason of current crisis in the industry. Cane dues of more than 20,000 crore rupees are pending with sugar mills. Sugar mills are not in position to pay cane dues to the distress sugarcane farmers.

Sugarcane Biomass for Energy Production

The stalks represent 80% to 85% of the total sugarcane biomass, and the untapped remainder is constituted of leaves and immature top. In the industry, after extraction of the juice, the remaining residue is named bagasse that, in the past, was used to be an undesirable residue. However, with the growing scarcity of wood, bagasse has become an important substitute for the production of sugar in the mill itself. Subsequently, the residue has also been used to generate the electricity necessary in the process and, following through the evolution, it started to be used to produce surplus electricity to be added in the public grid (cogeneration).

The sugarcane industry has been exploited for thousands of years to produce sugar. In 1975, Brazil led the way for its new use, the production of ethanol fuel on a large scale in its PROALCOOL program. However, in addition to ethanol, thermal, and electrical energy which are also obtained from sugarcane. More recently, the production of other biofuels as well as valuable co-products is becoming very promising, from direct fermentation of the juice or after digestion of the fibre. Commonly called as trash, leaves and top represent about 15% weight of the stalks of adult sugarcane at harvest, or 12% when dry. On purely energetic subject, this 'trash' is almost 40% of non-utilized energy. Even if the trash is not harvested together with the stalks, it can be collected after drying in the field and be utilized for both direct combustion and conversion, as cogeneration of energy into heat or electricity, or conversion into liquid fuel, through the technology of cellulose digestion. This last alternative of the production of cellulosic ethanol or other biofuels is requires subs-tantial technological investment in developing countries such as India, since its efficiency will be even greater when compared with the current technology of sucrose transformation.

Saccharum Complex Germplasm and Energy Cane

The five species of *Saccharum* and the related genera comprising of *Erianthus*, *Miscanthus, Narenga* and *Sclerostachya* form the basic genetic resources of sugarcane. They form a closely related interbreeding group involved in the evolution of the cultivated sugarcane referred to as *Saccharum complex*. *S. officinarum, S. barberi*, and *S. sinense* are the cultivated species while *S. robustum* and *S. spontaneum* represent wild species. the Indonesia-New Guinea area is the major centre of diversity for *S. officinarum* and *S. robustam* while diversity for *S. spontaeum*, *Erianthus, Narenga* and *Sclerostachya* is abundant in the north eastern state of India. *S.barberi* and *S. sinense* have been totally replaced from cultivation, following the introduction of the new hybrid varieties and can be found only in the field gene banks.

In sugarcane breeding programme very limited genetic resources have been utilized that resulted sugarcane varieties having very narrow genetic base. Breeding programme for energy cane can be initiated with the objective of genetic base broadening by utilization of basic accessions of S. *spontaneum* and related genera *Erianthus, Miscanthus, Narenga* and *Sclerostachya*. The traits essential for energy cane such as high biomass, high fibre, better growth in marginal land, ratoonability etc are found in greater intensity in these basic germ plasm. Therefore, in initial breeding programme for energy cane, these basic germplasm can be effectively utilised.

Breeding for energy cane

The visionary scientists crossed succulent plants with fibrous plants to take advantage of the rusticity genes in the fibrous plants and subsequently, all sugarcane breeding programs in the world held divergent selection for sucrose content. Now, those fibrous plants should be used in a new process of diverting introgression, this time, directing the selection for hardy plants, less juicy or even no juice at all but with high productivity of fibre instead. To accomplish that, nature will bring back its essential contribution, the ancestral species and genera that in millions of years led to the development of forms exploited by man should constitute the basis for the divergent selection of the new type of cane, the energetic plant. The potential existing in the *Saccharum* complex for this new divergent selection can be realized.

The raw material that enabled man to discover the possibility of the production of sugar was a plant containing sweet juice found in the humid regions of New Guinea which was later called as 'sugarcane', the botanically classified species of Saccharum officinarum. The species *S. officinarum* is a juicy sugary form not known in the wild state, and later utilized by the sugar industry as commercial forms, whereas *S. spontaneum* is a grassy wild species encountered growing naturally in diverse environments. Its evolution in such contrasting environments has generated a widely diverse gene pool adapted to a vast range of environments, including resistance to many diseases that attack sugarcane. These characteristics were incorporated by introgression into the *S. officinarum* genome in the pioneering breeding in Java in the late 19th century and later followed by the Indians and other breeding centers. Concerning energy cane, if one looks for higher biomass production a penalty must be paid in terms of sugar content, at least if considering the traditional sugarcane ideotype. The interest is productivity of total biomass, ultimately fibre. Although there are studies sustaining a negative relationship between sugar content and fibre content. High fibre is an important component of energy cane.

Hybrids produced by crossing the wild species *S. spontaneum* with either *S. officinarum* or existing commercial varieties or near-commercial clones lead to a very wide segregation of characteristics in the F1 population and many transgressive forms showing that high heterosis may be identified. Depending on particular commercial interest, distinct individuals could be selected from these populations that tended towards the traditional sugarcanes or to the ideotype of the energy canes as defined here. Genetically, the distinct outcome of selection is probably a direct reflection of the ratio between the *S. officinarum* and the *S. spontaneum* chromosomes: the more the contribution of this second species, the more the shifting for fibre and simultaneously for hardiness and all complementary characteristics. If energy cane is the goal, the selection pressure is for final biomass productivity and several studies have shown the potential to significantly increase it selecting clones directly from F1 population.

Traits like high biomass, fibre content etc can be introgressed into the commercial hybrids of sugarcane from the wild species of *Saccharum* and related genera. The selection for the traits in question is to be carried out in the F1 generation itself to exploit the maximum hybrid vigour. In addition to this, an intra-specific improvement programme for the energy cane development may also be fruitful in *S. spontaneum* and *Erianthus* species.

Future Prospects

- Because of the high biomass productivity, the energy cane has the potential to produce much more non-cellulosic sugars per hectare than the conventional sugarcane varieties. If so, we speculated that energy cane can replace, in the near future, a significant share of the current sugarcane areas, even those aimed to the first-generation industry with the purpose to produce ethanol for fuel. Again, this will only be possible by overcoming the challenges in processing of energy cane and the delivery of an assortment of varieties designed specifically by different purposes, *i.e.*, 1G or 2G ethanol, electricity, and/or cellulosic sugars for biochemical production.
- The energy cane can be planted in marginal lands or areas of soil and climate worse than those reserved for the production of food or even conventional sugarcane and also will be more environmental-friendly as it requires less use of fertilizers, herbicides, and pesticides, products that are among the biggest offenders of the environment and human health.
- Energy cane produce more stalks and allows a higher multiplication ratio (1:30 or more, against the 1:10 common rate of sugarcane), which turns out to be another great economic advantage.
- The crop of energy cane will be important for the containment of soil erosion and to assist in rescuing those degraded, given the known ability of grass to do that, because of its strong and abundant fasciculate roots.
- Additionally, due to the stronger ratooning ability, energy cane will allow higher number of ratoon harvests. Thanks to the vigorous rhizome of *S. spontaneum*, precisely the characteristic that the pioneer breeders of sugarcane sought in this species as a complement to the vulnerability of the species *S. officinarum* for this feature, it can be predicted 10 to 12 ratoons or even more.