ICAR

IISR-Industry Interface on Research and Development Initiatives for Sugarbeet in India

28 & 29th May, 2013

Sugarbeet Breeding Outpost of IISR
IVRI Campus, Mukteswar-263138, Nainital

Souvenir

Organized by

Indian Institute of Sugarcane Research (ICAR)

Association of Sugarcane Technologists of India
Lucknow-226002

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MESSAGE

Sugarbeet has an important position in the global economic scenario as an alternate source of white sugar, contributing to approximately one fourth of the world sugar production. This temperate crop has the genetic versatility to adapt to sub-tropical climates and even to the tropical growing conditions. The emerging bio-fuel scenario also has brought out the potential this crop has in our country. With its in-built tolerance to saline and alkaline conditions, sugarbeet can also serve to satisfy the demands of feed and fodder. This has much scope as an intercrop with sugarcane, in increasing sugar productivity per unit time and area.

At this juncture, it gives me immense pleasure to know that Indian Institute of Sugarcane Research, Lucknow along with Association of Sugar Technologists of India, is organizing IISR-Industry Interface on Research and Development Initiatives for Sugarbeet in India at its Sugarbeet Breeding Outpost, IVRI Campus, Mukteswar, Nainital on 28-29 May, 2013.

I hope that this Interface will provide a unique opportunity to the various stakeholders to discuss the constraints and emerging challenges in integrating sugarbeet into the existing cropping system and to develop strategies to overcome these challenges.

I congratulate the organizers and wish the Interface a grand success.

(S. Ayyappan)

Dated the 23rd May, 2013
New Delhi

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सत्यमेव जयते

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(कृषि एवं सहकारिता विभाग)
कृषि भवन, नई दिल्ली - ११०००१

Agriculture Commissioner
Government of India
Ministry of Agriculture
(Department of Agriculture & Cooperation)
Krishi Bhawan, New Delhi-110 001

Message

I am delighted to know that there is a renewed interest in sugarbeet owing to pressure on Indian agriculture to produce more from less land and depleting natural resources. Sugarbeet is a versatile crop and can occupy agricultural niches not amenable to sugarcane such as vast tracts of salt affected soils. In areas with shortage of water, sugarbeet has the potential to yield reasonably well with much less irrigation required than sugarcane. Its compatibility as an intercrop with autumn sugarcane can be an added attraction in increasing sugar/biomass productivity per unit area and time. I thank Indian Institute of Sugarcane Research, Lucknow and the Association of Sugarcane Technologists of India, Lucknow, who are shouldering the responsibility of organizing IISR-industry Interface on Research and Development Initiatives for Sugarbeet in India at Sugarbeet Breeding Outpost of IISR, IVRI Campus, Mukteshwar, Nainital on 28-29 May, 2013.

I hope that the Interface will provide an unique opportunity to the stakeholders to interact with each other on one platform. I am sure that the deliberations during the interface will be fruitful in developing research and development strategies to make sugarbeet cultivation more productive, profitable and sustainable.

I complement the organizers for organizing such an event and wish a grand success.

(J.S. Sandhu)

डा० एस० सोलोमन
निदेशक
Dr. S. Solomon
Director

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Message

Sugarbeet is the second important sugar crop after sugarcane and accounts for approximately one-fifth of the world sugar production. India is blessed with a wide agro-climatic diversity suitable for both these major sugar crops. Systematic research on sugarbeet has established that the crop can be grown successfully in India as a winter crop. The emerging biofuel scenario has also opened up opportunities for its alternate uses, other than the traditional sugar manufacturing. It can also serve to satisfy the feed and fodder demands.

In India where sugarcane production sees an almost regular "boom and bust cycle", sugarbeet can be a feasible option to supplement the future sugar demand along with sugarcane. Pressure on sugarcane for ethanol and limited water availability may act as limiting factors in enhancing sugar production solely from sugarcane. The built-in tolerance of sugarbeet to saline and alkaline conditions, its shorter duration and its feasibility as an intercrop in autumn planted sugarcane crop are other attractions for Indian farmers to grow this crop. Even though the feasibility of growing sugarbeet in India has been established through extensive research, sufficient impetus to grow it at a commercial level is still lacking.

The IISR- Industry Interface aims to examine in detail, the constraints and challenges in integrating sugarbeet into the existing cropping system and to suggest strategies to enhance its economic and industrial feasibility, so that the crop is able to get a much-awaited and well deserved commercial breakthrough in India. This souvenir is a modest attempt to trace out the path traversed till now in this regard and to chalk out the future strategies.

I am sure that this two-day Interface will provide an excellent platform for effective dialogue among the various stakeholders to deliberate on various issues related to sugarbeet cultivation, for its successful integration into the Indian sugar and ethanol scenario.

(S. Solomon)

Dated : 20 May, 2013

Lucknow

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Sugarbeet as an energy crop

S. Solomon

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Sugarbeet (*Beta vulgaris*) is a temperate crop and is mainly cultivated in the temperate countries where sugarcane cultivation is not feasible. Out of the total sugar production in the world, 22% sugar is produced from sugarbeet and remaining comes from sugarcane. Some countries in tropics as well as sub-tropics have taken up sugarbeet cultivation under the banner of TSB. Sugarbeet root contains 15-20 % sucrose and in the process of sugar extraction, 12-14% recovery is possible. The crop remains in the field for 5 to 6 months. Sugarbeet being a salt tolerant crop, can also be grown in saline soils where other crops fail to grow. Sugarbeet is not only the source of sugar, but also provides several by-products like ethanol, cattle feed & betaine. Like sugarcane molasses, beet molasses can also be used in ethanol production as well as in the pharmaceutical industry for vitamin B_{12} production. In spite of above advantages, the sugarbeet cultivation has been declining in Europe. The annual world production of sucrose is around 168 MT, it is produced mainly for utilization in food, and nearly 45% is traded in the world market. Unlike sugarcane where sugar extraction is done through milling, the sugar from the beet, is extracted by diffusion process. The beet roots are washed and cut into thin slices (cossetts). These slices are put in hot water which soaks the sugar out and forms syrup. The syrup is then purified, filtered and boiled again. Finally it is dried to sugar, which is packaged and marketed. Once the juice has been extracted, pressed or dehydrated beet pulp provides an ideal foodstuff for cattle. Pulp can also be used to produce industrial pectin or dietary fibre contained in foods that have been "enriched with fibre".Under normal conditions processing of 100 kg fresh sugarbeet can give 12 – 15 kg sucrose, 3.5 kg molasses, 4.5 kg dried pulp and varying amounts of filter cake and these products are utilized for various purposes including energy generation. Beet pulp is utilized for ruminant nutrition. Filter cake is used as fertilizer. Molasses are combined with beet pulp to provide animal feed, or used as feedstock in the chemical and pharmaceutical industries for fermented products such as citric acid and its esters. Sugarbeet molasses are of limited value for large scale ethanol fermentation. In Europe the sugar industry has been enabled to provide sucrose for chemical and biotechnological industries at prices similar to those of the world market. Sugarbeet is an excellent source of energy for human being and animals and renewable energy source for a wide range of transportation vehicles (FFV).

The regulatory reforms to remove trade tariffs in Europe and the need for renewable sources of fuel have driven the search for more valuable by-products and the use of sugarbeet as a feedstock for ethanol production. Sugarbeet pulp also contains valuable polysaccharides such as a low molecular weight, arabinan or arabinogalactan-branched pectin and parenchyma cellulose that have excellent properties as emulsifiers. Additionally, a sugarbeet pulp/polylactic acid (PLA) composite thermoplastic was developed with mechanical properties with less density and lower cost. A pectin-reduced sugarbeet pulp was used for fermentation by *Escherichia coli* to produce ethanol following pectinase treatment. Ethanol yields were equivalent to that produced from pure cellulose even though the sugarbeet pulp feedstock contained low levels of glucose and contained arabinose-rich pectin. Processing sucrose from sugarbeet produces betaine as a by-product. Betaine is used in applications as diverse as sports nutrition, stabilisers and emulsifiers for food production, cosmetics and de-icers for airport runways. It also has many pharmaceutical uses, including the treatment of stomach problems and heart and liver disease. More outrageous" products are being developed using beet, such as the production of polyester granules, polyhydroxyalkanoates (PHA). PHAs are biodegradable plastics that can offer controlled degradation rates, so there is considerable interest in their use in medical applications such as tissue engineering, drug delivery, stent manufacturing, surgical sutures, wound dressing and endodontic material.

A. High energy food and food additives

Sugarbeet is the principal sugar crop in many countries viz., USA, France, Germany, Denmark, Canada, Netherland etc. Sugarbeet contains 15 to 20% sucrose which is used widely as a pure high energy food or food additive. High fiber dietary food additives are manufactured from sugarbeet pulp and major food processors in the United States have used these dietary supplements in recently introduced new products including breakfast cereals.

Unrefined sugary syrup is produced directly from sugarbeet. This thick, dark syrup is produced by cooking shredded sugarbeet for several hours, then pressing the resulting sugarbeet mash and concentrating the juice produced until it has the consistency similar to that of honey. No other ingredients are used. In Germany, particularly the Rhineland area, this sugarbeet syrup (called *Zuckerrüben-Sirup* in German) is used as a spread for sandwiches, as well as for sweetening sauces, cakes and desserts.

B. Livestock feed

Sugarbeet pulp and molasses are processing by-products widely used as feed supplements for livestock. These products provide required fiber and energy in rations and increase the palatability of feeds. Sugarbeet tops also can be used for livestock feed. Sheep and cattle ranchers allow grazing of beet fields in the fall to utilize tops. Cattle and sheep also will eat small beets left in the field after harvest. Beet tops (leaves and petioles) also can be used as silage. Sugarbeets that produce 20 tonnes/acre of roots also produce a total of about 5 tonnes/acre of TDN per acre in the tops. Tops are an excellent source of protein, vitamin A, and carbohydrates but are slightly inferior to alfalfa or corn silage for beef cattle. Tops are equal to alfalfa or corn silage for sheep. Beet top silage is best fed in combination with other feeds. Tops should be windrowed in the field and allowed to wilt to 60-65% moisture before ensiling.

C. Industrial Uses

Methane production

Sugar production from sugarbeet generates a co-product stream called raffinate, desugarized molasses or concentrated separated by-product (CSB). About 0.25 tonnes of raffinate is generated for every tonnes of sugar produced. Bio-gasification of raffinate at 55^{o}C produced methane gas. Every metric tonnes of raffinate can generate 4300 MJ of thermal energy from combustion of methane or about 300 KWH of electricity. Anaerobic digestion method for whole beet /ensilaged beet to produce bio-methane is also an important and viable technology.

Bio-fuels from sugar crops

Present situation and global players

Ethanol (C_2H_5OH) is the most used liquid bio-fuel, currently accounting for 86% of total liquid bio-fuel production. Of all ethanol produced, about 25% of global ethanol production is used for alcoholic beverages or for industrial purposes. The other 75% is fuel for transportation (World Watch Institue, 2007). Most ethanol (95%) is produced by fermentation of carbohydrates derived from agricultural crops, the remainder is synthetic ethanol. Both products are chemically identical. Another difference in ethanol that can be made is its purity. Anhydrous ethanol is at least 99% pure while hydrous ethanol contains some water and has a purity of 96%. Since gasoline and water do not mix, only anhydrous ethanol is suitable for blending. Hydrous ethanol is used as 100% gasoline substitute for cars with adapted engines. The United States is still the world leader in ethanol manufacturing with more than 45 billion litres of ethanol production in 2010. At the other end of the spectrum, many developing countries including Nigeria and Malawi are turning to ethanol to boost their economies and secure their future energy needs. The Global Renewable Fuels Alliance (GRFA) in its 2010 production forecast for ethanol and the future continues to look positive for growth in the industry. Total ethanol production for 2009 was 73.9 billion litres according to data assembled by F.O. Licht. According to GRFA global production of ethanol in 2010 has reached 85.9 billion which will displace the need for 370 million equivalent barrels of oil globally.

The current volatility in the oil market and finite oil resources and the effect on global climate change from the addition of CO_2 to the atmosphere as a result of burning fossil fuels has increased the interest in sustainable energy generation from renewable biofuels. At present, approximately 10% of the primary global energy demand is met using biomass (Antoni *et al.* 2007). Some of this is from primary biofuels (i.e., unprocessed biomass) but increasingly secondary (processed biomass) biofuels are being used (FAO, 2008). Secondary biofuels often are divided into 1st generation (with a feedstock of seeds, grains, or sugars), 2nd generation (from lignocellulosic biomass) and sometimes 3rd generation (from algae and seaweed) (Nigam and Singh 2010). Currently, only 1st generation biofuels are widely produced, with the wide adoption of 2nd generation biofuels requiring 5 to 10 years before the technology is available to economically produce them commercially. Because one of the main purposes of developing biofuels is the reduction of greenhouse gases (GHG), some sort of tools or sustainability metrics need to be used to compare biofuels' ability to reduce GHG. Once such metric is life cycle analysis (LCA), which is an attempt to measure the total GHG effects generated from the production of a product (biofuel) including the entire process from extraction of the raw materials to the end of their use. There is a strong need to use metrics that are based on international standards, do not put developing nations at a disadvantage and focus on the global good (FAO 2008). The conversion of sucrose to ethanol is a simple process requiring only yeast fermentation, whereas producing ethanol from maize, wheat or other cereal grains e.g., requires enzymes to convert starch to sugars .

However harvested sugarbeet root is more difficult to store than a cereal grain. Cereal grains (primarily wheat) were feedstock to more than 50% of the 3.7 billion liters of EU ethanol produced. Sugarbeet was the next most common feedstock. Although ethanol production in Europe is growing, Brazil and the United States are by far the largest producers of ethanol. The U.S.A., Brazil and the European Union produced over 81% of the global ethanol production (F.O.Licht's 2010).

On a per hectare basis, sugarbeet is one of the most efficient sources of ethanol. It has been calculated that sugarbeet produces between 100 and 120 l/t (fw) of ethanol through the fermentation process (110 l/t (FAO 2008). The dry weight equivalent of one tonne of sugarbeet (fw) has been calculated to contain about 3.89 GJ of energy . Ethanol has an energy content of 21.2 MJ/liter which would give an energy value of 2.44 GJ/t sugarbeet (fw), assuming production of 115 l/t when converted to ethanol. FAO (FAO 2008) calculates 5,060 litre/ha yield for sugarbeet compared with a 1,960 l/ha yield for maize or 952 l/ha for wheat, using a global estimate of average yield (46 t/ha for beet, 4.9 t/ha for maize, 2.8 t/ha for wheat). It has estimated that anaerobic digestion methods for whole beets to produce bio-methane would produce 137% more energy than would fermentation of sugarbeet to ethanol.

Bio-ethanol : Solutions for a low-carbon economy

Life Cycle Analysis (LCA) is one of the methods used to determine GHG effects generated from substitution of bio-fuels for fossil fuels. LCAs follow international standards that provide the framework for conducting these studies which are increasingly important because they are used by governmental agencies to design laws promoting or mandating the use of bio-fuels (US EPA 2010). Most LCA studies have indicated that 1st generation biofuels (bio-ethanol or biodiesel) have reduced GHG when compared to petroleum based fuels (Table 1) and sugarcane to ethanol route showed lowest carbon emission. Most sugarbeet LCA studies have focused on conditions present in central European, where most commercial bio-ethanol production from sugarbeet occurs (Hoffman, 2008). Bio-ethanol from sugarbeet reduces GHG comparably to maize or sugarcane. Small amounts of nitrous oxide (N_2O), a more potent GHG than CO_2, are released from soils by agriculture. The amount released is dependent on cropping practices associated with fertilization, use of manure, or cover cropping however, it is a 300 times more potent GHG than CO_2, and, therefore monitoring its release in the atmosphere is important. Studies have concluded that sugarbeet and sugarcane were effective in reducing N_2O emissions compared with maize; however, the authors stressed that management of crop nutrition, especially optimization of nitrogen fertilization was crucial in reducing N_2O emissions from the soil. Increasing resource use efficiency, where it occurs, will be critical in reducing GHG through the use of sugarbeet and sugarbeet co-products for bio-fuels in the future (Panella, 2010).

Table 1. Carbon emission in ethanol production from different crops

Crop	Carbon emission (t carbon/ha)
Sweet sorghum	1.1024
Corn	134.18
Sugarbeet	1.335
Sugarcane	0.422

The energy derived from sugarcane is the best clean source and has irrefutable environmental advantage through its good energy balance. Sugarcane and sugarbeet are small carbon emitters compared to corn, a crop which is largely used in U.S. for ethanol production (Table 1).

Bio-fuel business- Future needs and developments

As we move into the 21st century and move away from non-sustainable fossil fuels to more sustainable biofuels, 1st generation liquid biofuels will continue to play an important part in converting away from an oil-based transport system. It is believed that sugarbeet will play an important role as a feed-stock in the production of bio-ethanol. Most of the European bio-ethanol production is in France, followed by Germany and Spain. However, there is interest in exploring or expanding the use of sugarbeet as a bio-ethanol feedstock in a number of European countries, such as Ireland but especially in Eastern European nations including Slovenia and Serbia. In the Americas, Brazil (from sugarcane) and the U.S. (from maize) are the major ethanol producers and users. Globally, there is a strong interest in Asia in the use of sugarbeet as one of a number of potential bio-ethanol feed-stocks. Because storing the harvested roots is a large impediment to using sugarbeet as a bio-ethanol feed-stock, climates where sugarbeet can be cultivated both as spring or fall sown crops, will be the most attractive areas for bio-fuel production because the crop can be harvested daily most of the year. Bio-fuel production is possible where via anaerobic digestion, sugarbeet could be ensiled to extend the processing will be a useful technology . Nonetheless, in the long run, even the most optimistic scenarios do not see bio-ethanol (especially from 1st generation feed-stocks) replacing the fossil fuel now used in the transport sector (FAO 2008). If it was possible to convert the entire U.S. grain yields to bioethanol that would fill only 18% of the demand for automotive fuel in the U.S. With rapidly expanding fleets of personal vehicles in India and China, it is imperative for the transport sector transitioning from fossil fuel to liquid biofuels and hybrid technology and then to an increasingly electric based system. In Europe a Swedish heavy truck and bus manufacturer Scania has developed and manufactures ethanol-powered trucks and buses for urban use since the late 1980s. Currently, more than 800 Scania ethanol-powered buses are in service in various European cities, especially in the Swedish capital, Stockholm. The city is committed to replacing half its public transport fleet with vehicles powered by renewable energies by 2012.

Ethanol Summit 2011

Ethanol Summit 2011 held at Sao Paulo, Brazil (June 6 -7, 2011) also stressed on a variety of new trends and uses emerging around the world, for ethanol and sugar crops . From the growing use of bioelectricity generated from burning sugarcane bagasse in high efficiency boilers, to the increased use of ethanol in the production of bioplastics and progress in the development of so-called second generation ethanol, advances in flex-fuel technology for motor vehicles and in biotechnology, leading to the production of bio-hydrocarbon from sugarcane, including diesel, gasoline, jet fuel and fine chemicals.

Sustainable energy technologies: Important influences in the 21st century

The Socio-economic, political and environmental considerations will be the dominant factors in deciding the adoption of sustainable energy technologies in 21st century. A key factor affecting the use of sugarbeet (and many other crops) is the development rate of advanced technologies (2nd generation lignocellulosic feed stocks), which is hard to predict but offers very sustainable alternatives to some of the food crops now being used as feed stocks. Another resource requirement, which is receiving increased scrutiny is the water needed (or water footprint) for bioenergy crop production. Gerbens-Leenes et al. (2009) found sugarbeet, and potato, are more efficient than maize and sorghum as sources for biofuels in most regions of the world. However, once sugarbeet is irrigated, as it is in most areas where winter beet is grown its water footprint also grows (Gerbens-Leenes *et al.* 2009) and may impact regions with fast growing populations dependent on irrigated food production.

As the global population moves toward the projected 8 to 10 billion people in 2050 the discussion of whether to grow potential food crops for biofuels will intensify. There is serious concern that the use of crop land will both cause the grassland and forest to be brought into cropping and, thereby, both threaten food security and cause environmental damage (FAO 2008). Although there is still uncertainty about the impacts of using abandoned agricultural land, or different cropping systems, this is a continuing dialog and a balance must be found .This is not just a challenge for biofuels; if we are to feed a growing global population and maintain biodiversity in a sustainable manner, agricultural research must be focused on increasing global food production per hectare while reducing inputs– a formidable challenge!

Sugarbeet and bio-fuels scenario

Current technology is looking at ethanol as the primary fermentation product of sugarbeet. There are, however, other choices for an end bio-fuel, including biomethanol, biobutanol ETBE, bio-methane, and bio-hydrogen, many of which are more energy dense than ethanol. Storage of sugarbeet is a problem that could be solved by ensilage and anaerobic digestion producing a biogas, yielding more energy per hectare than bioethanol .Once 2nd generation liquid bio-fuels come online, there will still be niche markets for specialty fuels form locally grown crops with high conversion efficiency; sugarbeet might be an excellent feedstock to produce products such as jet fuel (Kozak and Laufer 2009). The introduction of a $30/t carbon tax, in the United State has been predicted to reduce the beet sugar production by 87% because of the extensive use of coal to power processing factories. One solution to this cost would be using the sugar co-products – pulp and molasses (Kozak and Laufer 2009) – to generate bio-methane to provide the energy to process the sugar. There may be a trend in beet sugar processing to make the processing energy neutral – much as we see in sugarcane processing today. We may see adoption of small factory based on site energy production from renewable bio-fuels. In most sugarbeet producing countries, in next few years economic conditions will demand a "dual purpose" sugarbeet – one that may be grown as a sugar crop as well as an energy crop. However, in those areas where sugarbeet is used only as bio-fuel feedstock, different criteria will become important. Sugarbeet breeding companies have already begun or are discussing in house breeding programs for energy beets.

Around 2% of the globally produced sucrose is currently used as a source for value-added feedstock chemicals (Eggleston 2008). Sugarbeet pulp contains very little lignin, consisting of approximately equal amounts of hemicellulose and pectin. Sucrose and all of these compounds can be used as feed-stocks for several important industrial chemicals; and there is tremendous potential to expand this market . As the global economy moves away from fossil fuels, sugar crops especially sugarbeet will play an important role in the adoption of more sustainable energy generation; large-scale replacement of fossil fuels with renewable option is a reality in 21st century.

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Current status of sugarbeet research in India

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Sugarbeet (*Beta vulgaris L.*) is one of the three crops (sunflower and soybean being the other two) which were introduced in India around the same time. While the last two have now established themselves commercially in India, sugarbeet is still awaiting to contribute significantly to the Indian agricultural scenario. None of these crops have been lacking in potential but till government push and industrial support became a reality, even sunflower and soybean were struggling to find their economic niche. Sugarbeet is the last of the trio whose potential still remains untapped. It would be worthwhile to discuss the strengths of the crop and the constraints that have weighed against its acceptance till now. Sugarbeet is a temperate crop, botanically known as *Beta vulgaris* L. It is a man-made crop and is the product of human selection from fodder beet for higher sugar content. The impetus for the development of sugarbeet in Europe came when there was an embargo on the import of sugarcane sugar during the world war.

Sugarbeet is a very efficient converter of solar energy to a form that can be utilized by men and animals. Most plants consume sugar for their own use but a few store it in the plant parts, which act as warehouse. Sugarcane and sugarbeet are such plants. Sugarbeet is a crop of the temperate region but its cultivation is now expanding from subtropical tracts to tropical world. Besides its conventional home in the temperate zone, it is now being successfully grown in Iran, Iraq, Algeria, Egypt, Afghanistan and Pakistan. Today, more than 25% of the world sugar requirement is met from sugarbeet and beet sugar industry is well established in 45 countries spread over four continents of the world. The studies carried out in our country have established the agricultural feasibility and economic viability of sugarbeet in subtropical to tropical parts of the country. The success of commercial cultivation and processing of sugarbeet in Sriganganagar has further reinforced the above findings. For India, sugarbeet can be an important sugar crop by supplementing sugarcane. This is mainly because of its short-duration (6-7 months as compared to 10-12 months of sugarcane), high sugar content (15-17%), high sugar recovery (12-14%) and high purity (85-90%). As such, it has good prospects for bridging the gap between present sugar production and anticipated national sugar requirement. In addition to sugar, sugarbeet provides valuable by products like green beet tops and beet molasses which are of value as cattle feed and in fermentation industry. Because of its high chemical quality, beet molasses is a priced item with potentialities for export. Hence, sugarbeet is capable of occupying an important place in the sugar economy of the country.

Sugarbeet is a versatile crop as it can withstand various climatic and soil conditions. Being tolerant to salinity and frost, it can help to bring several hundred hectares of uncultivable land under cultivation. The crop also can help to extend the factory season and consequently promote employment. Available in the beginning of April, sugarbeet enables the factory to process both the raw materials-sugarcane and sugarbeet during their high efficiency periods. It provides the added advantage of a combined agricultural and manufacturing economy.

For farmers, sugarbeet is important for three main reasons. First, it is a dependable cash crop; second, it ameliorates salt affected soils with promoting soil fertility through sound farming practices and third, the by-products provide nutritious cattle feed during the hot months of the year when green fodder is not readily available.

The national scene with respect to demand for sweetener

According to the Vision document for 2025 of Indian Institute of Sugarcane Research and Sugarcane Breeding Institute, there is a scope for almost doubling the productivity levels due to the gap between the achievable and achieved. According to the estimates of National Commission on Agriculture (1976), the population of India may rise to 1.4 billion by 2025 AD. The country will require nearly 49 million tonnes of sweeteners by 2025 AD. With decreasing trends in jaggery and *khandsari* production, the country has to produce about 30 million tonnes of sugar. With an average sugar recovery of 10.75 per cent, about 495 million tonnes of sugarcane will be required by 2025 AD (60 per cent cane will be utilized for white sugar manufacture and 10 per cent will go for ethanol production). The productivity requirement will have to be 100 t/ha, as sugarcane area may stabilize between 4.5 and 4.75 million hectares by 2025 AD.

It becomes a matter of concern when we see that the best we have achieved is about 350 million tonnes of sugarcane. There are increasing demographic pressures on agricultural land resulting in shrinkage of cultivable area. Therefore, unless there is a commensurate vertical increase in productivity per unit area and time, it would be difficult to meet the rising demand. This can come from better implementation of sugarcane production technology and considering options such as sugarbeet and sweet sorghum to supplement sugar/ ethanol production.

Sugar Scenario and Sugarbeet role

Riddled by the cycles of boom and bust in sugarcane production in India, the sugarbeet crop was introduced with the object of augmenting sugar production. In 1960s, extensive exploratory trials were conducted all over the country to find out suitable areas of root and seed production. Based on the preliminary results, it was felt that sugarbeet could be grown during winter in north India, while Kashmir valley and hills such as Darjeeling and Shimla were found suitable for seed production. In 1971, an All India Coordinated Research Project on Sugarbeet was launched by the Indian Council of Agricultural Research with centres at Lucknow, Pantnagar, Sriganganagar, Phaltan, Jalandhar and Kanpur. Later on, Kalyani in West Bengal, Solan in Himachal Pradesh and Mukteswar in Kumaon hills were added. At the same time, a sugarcane-cum-sugarbeet sugar factory was established at Sriganganagar in Rajasthan.

The 1970's and 1980's was a period of intense research activity on sugarbeet. Work was carried out in germplasm evaluation, varietal development, and agronomical, pathological, entomological and agricultural engineering aspects. Sriganganagar provided the testing ground of the production technology. India opted for self reliance for sugarbeet seed and an open-pollinated, diploid Russian variety namely, Ramonskaya-06 (R-06) was found suitable for Indian conditions along with some other anisoploid varieties from Europe. The seed production of R-06 was successfully undertaken by the National Seeds Corporation in Sringagar and later on in Himachal Pradesh. The crop was a success with the farmers and the factory. It had a commercial run of over thirty years when the factory was closed due to reasons not exclusive to sugarbeet. One of these however, was the trade liberalization which closed the remunerative disposal of sugarbeet molasses to a Mumbai-based pharmaceutical company. The best average root yield obtained was 39 t/ha and a sugar recovery of 11.32 %. It may be borne in mind that this was made possible without the best available varieties. The sugarbeet crop was found to be the most remunerative rabi crop as compared with wheat and mustard.

Sugarcane production in the country has seen many ups and downs, sometimes brought about by failure of rains. In early 2000s, many southern states were reeling under consecutive droughts leading to insufficient cane supplies to the factories. At this juncture, some multinational sugarbeet seed companies came out with tropicalized sugarbeet varieties and a need was felt to conduct feasibility trials. The ICAR responded with an AP Cess Network project in 2004. The work done at the five centres with two of these in Maharashtra showed that sugarbeet could be grown successfully from October-November to April-May. The package of practices along with the suitable varieties was developed. The potential for root yield was observed to be 60-80 t/ha with a sugar content in the roots of 13-15%. The following table gives the performance of sugarbeet varieties from diverse seed sources (IISR, Syngenta, SES Vanderhave, Iran and KWS):

Performance of sugarbeet varieties averaged over locations (2007-08)

S.N.	Varieties	Sucrose content (%)		Root yield (t/ha)		Gross sugar at 180 DAS (t/ha)
		150 DAS*	180 DAS	150 DAS	180 DAS	
1	**LK-27**	13.05	14.93	78.22	67.92	10.868
2	**LKC-95**	12.71	14.98	76.00	65.05	**11.058**
3	**SYT-06-07**	**14.26**	16.40	**84.79**	70.99	10.807
4	**SYT-06-13**	**14.50**	**16.67**	75.37	69.24	10.890
5	**IN-06**	14.13	16.06	**90.77**	69.33	9.566
6	**IN-07**	**14.28**	15.76	65.27	61.32	10.248
7	**PAC-60002**	14.88	**17.14**	**81.49**	70.62	**11.444**
8	**PAC-60006**	13.56	16.18	72.20	66.97	11.097
9	**FELICITA**	13.07	15.19	**84.63**	**80.82**	**11.728**
10	**RASOUL**	13.38	14.88	64.86	55.56	9.044
11	**LS-6**	13.14	16.22	**82.77**	70.42	**11.484**
12	**SHUBHRA**	**13.78**	**17.67**	**93.59**	**77.77**	**13.253**
Mean		**13.73**	**16.01**	**79.16**	**68.83**	**10.957**

DAS: Days after sowing

Mean of four locations: Lucknow, Pune, Digraj (Sangli, Maharashtra) and Sriganganagar

Those underlined are the best performers for that trait

Similar to any other crop, the availability of genetically superior varieties adapted to local agro-climatic conditions is a pre-requisite for its lasting success. This explains the need for intensive efforts to breeding indigenous varieties/hybrids of sugarbeet in India. In this direction 350 germplasm /varieties were evaluated for adaptation to Indian conditions. Lines with high root yield, top yield, sucrose content, and resistance to root rot, tolerance to high temperature, Bihar hairy caterpillar and salinity were identified and subsequently utilized in genetic enhancement of sugarbeet under Indian agro climatic conditions. The germplasm with male sterility and compatible restorers and maintainers are requirement for exploitation of heterosis. The sources for male sterility are being studied in available germplasm. Sugarbeet is a highly cross-pollinated crop and the improved hybrids varieties have been primarily evolved by private companies abroad. For efficient domestic breeding, capable of yielding quick results, advantage of the vast experience in improvement technology and breeding advance abroad need to be taken through appropriate international cooperation. This will enable not only the availability of established in bred lines but also the germplasm, which is essential pre-requisite for plant improvement. Although, the breeding efforts made at Pantnagar and Lucknow are encouraging, appropriate strengthening of the programme by way of facilities, expertise and genetic material is urgently needed.

Complete package of practices, including plant protection measures has been developed. Sugarbeet cultivation research under saline soil conditions of Sunder Ban (WB) started and extended to other salt – affected soils of subtropical India Pant S-1, Pant S-10, IISR Comp-1, IISR-2 and Mezzanpoly identified as sugarbeet varieties suitable for saline & alkaline soil conditions. Work on utilization of sugarbeet for alcohol production initiated in Sunderban (WB).

Standardization of sugarbeet seed production was done under Indian conditions at altitudes above 5000′, such as Mukteswar & Ranichauri (Kumaon Hills), Auli (Garhwal Hills), Shimla & Kalpa (Himachal Pradesh), Darjeeling (West Bengal) and Kashmir by the Lucknow (IISR Comp-1 and LS-6) and Pantnagar (Pant S-10) centers. Indigenous diploid varieties developed and recommended for general cultivation. In India, high temperature (40-45^{0}) tolerant varieties have been identified.

Foundation seed production standardized and routinely carried out by the Kalpa center. Machines for seed polishing, core sampling for sugar determinations root digging and seed drill (Hand & Bullock – Drawn) were developed.

The present scenario

The changing bio-fuel scenario in the country has started looking at sugarbeet with ethanol as the end product. Several sugar factories in Andhra Pradesh, Maharashtra, Karnataka and Punjab have been keen to give sugarbeet a fair trial, after having been convinced of its agronomic feasibility through in-house crop experimentation. In this, a key role has been that of the multinational sugarbeet seed companies, such as Syngenta, SES Vanderhave and KWS through their Indian operations. These companies are still active in providing the know-how, seed and guidance in growing and handling of sugarbeet. IISR and VSI are playing a crucial role. The SDF has financed the fabrication and setting up of a pilot plant for sugarbeet processing at Samarth SSK Ltd. in Maharashtra. Besides, a sugarbeet-based ethanol production unit has been set up at Harneshwar (Maharashtra). While we await a feed-back on these ventures, many more of such initiatives by private entrepreneurs are needed for demonstrating the economic viability of sugarbeet and provide a model for others to learn from their experience.

The need for a stimulus

The history of sugarbeet development in Europe and the USA, and also at Sriganganagar (Rajasthan) in India shows that unless there were incentives given by the government, sugarbeet could not be a success. In Sriganganagar, it was the extra canal water for every acre of sugarbeet that was a big attraction, and the assured purchase of sugarbeet by the sugar factory. Similarly, farmers need to be attracted to the crop through such incentives. Being an industrial crop, a contract for the timely purchase of the entire produce has to be in place. Further, support for availability of seed, fertilizers and pesticides along with technical guidance in raising the crop has to be provided. The central and state agricultural extension and development machinery has to make an all out effort to be equal partners with the farmers and the factory to lend the necessary support with their active presence and post-harvest management of the produce.

The positives and pitfalls

Sugarbeet has been shown to be agriculturally feasible under Indian conditions. It has the potential to yield comparable to sugarcane in half the time with water saving of 30-40%. The suitable varieties have been identified and the production technology has been developed. The mechanization of sowing operation has been done. The ecological niches for the successful cultivation of the crop have been identified. As we go along and gain experience of growing it in specific locations, innovative refinements in crop and produce management shall be introduced by the farmers and factory personnel themselves. In fact, working models are provided by the successful cultivation of sugarbeet in countries like Egypt, Morocco, Iran, Pakistan, EU and North America, which have a wide range of agro-climatic conditions and from largely manual to totally mechanized precision farming.

India is blessed with a wide range of climatic conditions which allow us to be self-reliant in sugarbeet seed production. Depending on the demand, some multinationals may shift their seed production to India to reduce the seed costs. So the availability of seed of the desired varieties has to be assured. A business model has to be developed in the form of *contract farming* where various stakeholders commit themselves to their specific role in the entire venture. This was being done at Sriganganagar among farmers, factory and seed companies. The state government has to play the role of a facilitator and observer for fair play by various stakeholders.

Thus sugarbeet can become an agricultural reality. Most of the components are already worked out and can be integrated in a mission mode with the appropriate government policy, industrial entrepreneurship and a committed agricultural department. It may also be mentioned that sugarbeet has an in-built tolerance to saline and alkaline soil conditions. It has therefore the potential to bring under plough and reclaim vast tracts of salt-affected soils in the country, estimated to be around 6.7 million hectares. For integrating sugarbeet with the existing cropping pattern, a lot of work has been done but still some more research may be required for the new locales. It can easily be grown as an intercrop with sugarcane to increase sugar productivity per unit time and area. The issues of the need of extraneous fuel and additional processing machinery are not insurmountable.

Processing of sugarbeet for sugar manufacture

Sugarbeet, unlike sugarcane, cannot be processed for gur or khandsari, and can only be used for vacuum-pan sugar production. Hence its commercial cultivation is possible only around the processing units. Sugarbeet roots deteriorate fast after harvesting and have to be supplied to sugar-mill within 48 hr of harvesting. Stock-piling is not possible even for a few hours and hence a well co-ordinated plan of harvesting and supplying of roots is of utmost importance.

Sugar from sugarbeet roots is extracted by adopting diffusion process in special diffusers based on the counter-current washing technique. It is not possible to extract juice from sugarbeet roots with roller mills. The juice characteristics of sugarbeet also necessitate adoption of carbonation process only for clarification, and hence carbonation with diffusers and related accessories is essential to process sugarbeet in traditional sugarcane-based sugar-mills in the country. Unlike sugarcane, extraneous fuel is also required for processing of sugarbeet, as it does not provide bagasse for use as fuel. However, the beet-pulp and molasses produced as by-products from manufacturing of beet-sugar have a good market and should be expected to more than offset extra cost on fuel in beet-processing. The establishment of a profitable outlet for the by-products is, therefore, an economic necessity with this crop.

By-products of sugarbeet and their utilization

Beet-pulp, a residue obtained after extraction of sugar, is a highly valuable cattle-feed that can largely replace barley-grains in feed concentrates. Beet-pulp can be fed to cattle as fresh or in dried form. The mixing of molasses with pulp improves its palatability.

The beet molasses are used as raw material for several special fermentations and also form a rich source of lactic acid, vitamin B and other pharmaceutical preparations.

Beet-tops are a highly nutritious cattle-feed and are known to improve milk yield of cows. They, however, contain oxalic acid, and hence fresh-tops must not be fed to cattle. Sun-dried tops 100 kg + 60 g finely ground lime is a good cattle-feed.

The important findings of the sugarbeet research in India led the anxiety of beet workers for practical utilization of their efforts. The thing which now needs critical examination is whether technology of sugarbeet production is an economical proposition for sugar production in comparison to sugarcane, which is the traditional sugar crop. Sugarbeet is par excellence in many aspects. The questions must now be posed to the sugar technologists, to the sugar industrialists and economists in the country. We have reached a stage on the agricultural technology where we say, here are the roots, we can produce them now, can you process them economically and compete with cane? Although when we conceived of the sugarbeet crop, the idea was not that it would compete with sugarcane crop but that at the far end of the cane season (April onwards) when sugarcane crop is difficult to harvest, and starts deteriorating; sugarbeet may be processed in the same sugar factory with some modifications in the plant.

There are three major requisites for the efficient commercial exploitation of sugarbeet:

- Sufficient availability of high quality seed material with the desired genetic potentiality;
- Availability of modern beet sugar manufacturing facilities;
- Appropriate public policies

Future Needs

Efforts should be made to evolve a production technology for high yield of quality beet. As sugarbeet is important for its chemical characteristics, care should be taken that sugar-producing ability of the roots is not affected by cultural practices. Being a new crop in our country, it calls for foresight while planning studies leading to plant protection measures. This is important as new disease and pest problems are likely to occur with the spread of beet cultivation in the country.

The availability of efficient sugar processing technology particularly suited to our indigenous factories is essential for the successful commercial exploitation of sugarbeet. Efforts are called for systematic studies resulting in definite information enabling selection of the most ideal diffusers, production of beet molasses of high chemical quality and efficient utilization of the by-products.

Critical studies on the economic aspects, needed to further confirm and preliminary findings regarding the economic viability of the crop in the country and profit ability to farm and industry, would be of great value for beet development in the country.

Future R and D could focus on the following areas:

1. Adapting sugarbeet to saline-alkaline soil conditions.
2. Finding alternative uses of sugarbeet such as jaggery, jam, etc.
3. Promoting sugarbeet for cattle feed.
4. Technology and economics of sugarbeet for ethanol production.
5. Mechanization of sugarbeet cultivation, particularly harvesting.
6. Integrating sugarbeet cultivation in the present cropping systems.
7. Government policies and incentives for sugarbeet Industry.

Production economics of tropicalized sugarbeet

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The three thousand years' monopoly of sugarcane on the provision of sweetness was broken by arrival of its rival in the nineteenth century the 'Sugarbeet'. By 1880, sugarbeet had replaced sugarcane as the main source of sugar in continental Europe. In the 16th century, Olivier de Serres discovered the value of sugarbeets for preparing sugar syrup. In his notes, he wrote: "The beet-root, when being boiled, yields a juice similar to syrup of sugar. Although the Indians devised the first techniques for extracting sugar from cane and called it "sarkara", a Sanskrit term from which the words for sugar in many European languages originate (sucre, zucker, zucchetto, azúcar, etc.).

The methodical use of sugarbeets for the extraction of sugar dates to 1747, when Andreas Sigismund Marggraf, professor of physics in the Academy of Science of Berlin, discovered the existence of a sugar in beets similar in its properties to that obtained from sugarcane. The discovery was little used at first, however, and the manufacture of sugar from beets did not attain commercial importance for over half a century. Marggraf's student and successor Franz Karl Achard began selectively breeding sugarbeet from the 'White Silesian' fodder beet in 1784. By the beginning of the 19th century, his beet was approximately 5–6% sucrose by (dry) weight, compared to around 20% in modern varieties. Under the patronage of Frederick William III of Prussia, he opened the world's first beet sugar factory in 1801, at Cunern in Silesia.

The work of Achard soon attracted the attention of Napoleon Bonaparte, who appointed a commission of scientists to go to Silesia to investigate Achard's factory. Upon their return, two small factories were constructed near Paris. Although these factories were not altogether a success, the results attained greatly interested Napoleon, and in 1811, he issued a decree appropriating one million francs for the establishment of sugar schools, and compelling the farmers to plant a large acreage to sugarbeets the following year. He also prohibited the further importation of sugar from the Caribbean effective in 1813.

The beet sugar industry in Europe rapidly developed after the Napoleonic Wars. By 1812, Frenchman Jean-Baptiste Quéruel, working for the industrialist Benjamin Delessert, devised a process of sugar extraction suitable for industrial application. By 1837, France was the largest sugarbeet producer in the world, a position it continued to hold in the world in 2010. By 1837, there were 542 factories in France, producing 35,000 tonnes of sugar. By 1880, Germany became the largest sugarbeet to sugar producer in the world.

Successful sugarbeet and associated sugar production started in the United States in about 1890. The states of California and Nebraska were early pioneers of sugarbeet industry.

Sugarbeets were not grown on a large scale in the United Kingdom until the mid-1920s, when 17 processing factories were built, following war-time shortages of imported cane sugar. One factory had, however, been built by the Dutch at Cantley in Norfolk in 1912.

Sugarbeet seed from France was listed in the annual catalogues of Gartons Agricultural Plant Breeders from that firm's inception in 1898 until the first of their own varieties was introduced in 1909. The worldwide distribution of sugarbeet is presented in table 1.

Table 1. Top ten sugar beet producers in the world (2011)

	(million tons)
Russia	47.6
France	37.2
United States	26.2
Germany	25.0
Ukraine	18.7
Turkey	16.1
Poland	11.6
China	10.7
United Kingdom	8.5
Egypt	7.4
World Total	**271.6**

Source: UN Food & Agriculture Organisation (FAO)

Sugarbeet (*Beta vulgaris* L., Family Chenopodiaceous the spinach family) is an native of the temperate climate but its cultivation has extended to subtropical countries and is being successfully grown in Iran, Iraq, Algeria, Egypt, Afghanistan and Pakistan. Today, more than 20% of the world sugar production is attributable to sugarbeet and beet sugar industry is well established in 45 countries spread over four continents of the world.

Sugarbeet is essentially a crop of temperate region and initially it is being cultivated in cold countries where sugarcane cultivation is not feasible. Lately, a few countries in sub-tropics and tropics have taken up its cultivation. In India, growing of sugarbeet was tried at the farm of Indian Institute of Sugarcane Research, Lucknow during 1959 – 60. In 1960s, the crop was also tried at Padegaon (Maharashtra State). Now with the availability of tropicalized sugarbeet varieties, a hope has been generated to use sugarbeet as a supplementary crop to sugarcane.

Sugarbeet is grown for its root which contains exorable sugar. It is biennial crop, where in root growth take place in the first growing season, followed by flowering and seed production in the next. Suagr beet was introduced in India in 1950s with the aim to supplement sugar production. Exploratory experiment were conducted all the country in 1960s in which the Indian Institute of Sugar Research has played a pioneering role. Based on the encouraging result, an All India Coordinate Research Project on Sugarbeet was launched in 1971 with centers spread all over the country and the Project Coordinator based at

GBPUA&T, Pantnagar. It was operative for nearly three decades, resulting in the standardization of the cultivation practices for sugabeet as a *rabi* crop for subtropical India.

On the basis of the agronomic trials conducted at various locations in India, it was established that sugarbeet can successfully be cultivated as a winter crop in the irrigated plains of Punjab, Haryana, Uttar Pradesh and Rajasthan. Similarly tropicalized varieties can be grown in the tropical region of the country. Sugarbeet roots contain 15-16 per cent sucrose and in the process of sugar extraction 10-12 per cent recovery is obtained. The crop remains in the field only for six months. All the points mentioned above go in favour of sugarbeet cultivation. Sugarbeet, being a salt tolerant crop, can also be grown in saline soils where other crops fail to grow. Sugarbeet is not only the source of sugar but also provides several useful by-products. One hectare of sugarbeet crop yields 20-22 tonnes of beet tops which can be fed to the cattle by mixing it with other feeds. Sugarbeet pulp, a factory product, is also used as a cattle feed and molasses is used by pharmaceutical industry for producing vitamin B_{12}. Thus sugarbeet can be grown successfully as a supplementary crop to augment sugar and alcohol production.

The initial efforts also led to the establishment of a dual purpose cane-cum-beet sugar factory at Sriganganagar (Rajasthan) in 1970, with a capacity to process 600 tons of beet per day. Sugarbeet was found to be a most remunerative crop in Sriganganagar as compared to wheat and mustard. The Ganganagar Sugar Mills achieved a maximum average root yield of 39 t/ha and 11.32% sugar recovery. Yet, the unavailability of quality seed and lack of modernization of the factory led to waning of interest in sugarbeet resulting in the closure of the sugar mill in 1998. Coupled with the fact that no new factory was coming up, research on sugarbeet was tapered off only IISR continued with the crop by maintaining suagrbeet germplasm and indigenous varieties with limited seed production at its breeding outpost at Mukteswar in Kumaon hills.

In the early years of 2000s, there was drastic reduction in sugarcane production on account of successive droughts in Maharashtra, Andhra Pradesh and Karnataka which prompted a revival of interest in sugarbeet for its potential to provide a buffer. Concurrent with this was emergence of topical sugarbeet as a result of efforts of the multi-national sugarbeet seed companies, mainly Syngenta. A Network Project on Sugarbeet was approved by the ICAR from 2004-08 to study the feasibility of sugarbeet under tropical growing conditions of the country. It resulted in the development of agro techniques for the successful cultivation of sugarbeet for tropical India. This national efforts was carried out under the leadership of IISR Lucknow.

Sugarbeet can be introduced in the Indian agricultural scenario as the future demand for sugar may not be easy to meet from sugarcane alone due to limitation of area and productivity. Pressures on sugarcane for ethanol land reduced water availability are going to be major limiting factors in enhancing sugar production. Large areas, such as salt-affected soils not suited for sugarcane cultivation may be brought under sugarbeet. Farmers with small holding may prefer sugarbeet in there cropping system due to its short duration. It can be successfully grown as an intercropping in autumn sugarcane.

Cost concepts and items of cost

Cost is the value of the factors of production used in producing and distributing goods and services. The cost of a factor unit equals the maximum amount which the factor could earn in alternative employment. Concept means idea underlying or general motion.

The cost of production of a crop is considered at three different levels viz. Cost A, Cost B and Cost C. The concept of three costs such as Cost A, Cost B and Cost-C is followed by the Directorate of Economics and Statistics, Government of India in their cost studies. These cost concepts are generally followed in the studies of cost of production of crops.

The input items included under each category of cost are given below.

Cost A: Actual paid-out costs for owner cultivator, inclusive of both cash and kind expenditure which include following cost items,

1. Hired human labour
2. Total bullock labour (Owned / Hired)/ tractor/ machines
3. Seeds
4. Manures
5. Fertilizers
6. Insecticides and pesticides
7. Irrigation charges
8. Land revenue, cusses and other taxes
9. Depreciation or capital assets
10. Transport and Marketing
11. Interest on working capita1

Cost B: If the amount invested in purchase of land would have been put in some other long term enterprise or in a bank, it would have yielded some returns or interest. But due to the investment of the amount in purchase of land, the farmer has to scarify returns or interest that he would have otherwise gained. And as such this loss is considered as cost, it is called rental value of land. Similarly, the hypothetical interest that the capital invested in farm business would have earned, if invested alternatively is also considered as cost. Rental value of land and interest on fixed capital represent imputed costs which are added to Cost A to give Cost B.

Cost B = Cast A + Imputed rental value of owned land + Imputed interest on owned fixed capital.

Cost C: It is the total cost of production which includes all cost items, actual as well as imputed. The value of holding's own labour is to be imputed and added to cost B to workout Cost C.

Cost C = Cost B + Imputed value of family human labour.

Cost of cultivation and cost of production

The term "Cost of Cultivation" and "Cost of Production" is used as synonyms for the purpose of cost study. However, nice distinction can be made between the two, the cost of cultivation includes factor costs up to the stage of gathering the harvest and that cost of production to include factor costs up to the stage of marketing the produce.

Per unit Cost of Production: Cost of production is to be worked out as cost per unit or area and production i.e. per hectare and per quintal/tonnes.

A) Per hectare cost of production: Total cost / Area under crop (ha)

B) Per quintal/tonne cost of production: Total cost – Value of by product/ Qty of main produce in quintals/tonnes.

Measures of Farm Income: The profits at different cost levels provide different measure of returns to the cultivator. These are discussed below:

1) Profit at Cost A: It is also known as farm business income. It provides an estimate of returns to the farmer for his investment and profit.

Farm Business Income = Gross Returns – Cost A

2) Profit at Cost B: It is also termed as family labour income. It provides an estimate of returns to the farmer for his labour and profit.

Family labour Income= Gross returns - Cost B

3) Profit as Cost C: It is also known as net income. It provides an estimate of returns to the farmer purely of profit.

Net Income = Gross returns - Cost C.

Gross returns or gross income is the total of the values of both the main and byproducts. Farm business income, family labour income, and net income are the measures of farm income.

4) Cost benefit Ratio = Gross income / Cost C

5) Cropping Intensity (%) = Gross Cropped area/Net Area x 100

Cost of production of Sugarcane and Sugarbeet

The cost of production of sugarcane and sugarbeet are presented in tables 1 and 2 respectively. Cost of production of sugarcane + sugarbeet intercropping aims for higher profitability and extended crushing season also presented in Table 3.

Table 2. Cost of production of sugarcane 20012-13

Items of ependiture (input)	**Operation**	Required	Rate Rs/ Unit	Total
1.Seed bed preparation	Deep ploughing one 4hrs/ploughing	4	300	1200
	Cultivator-2 , 2 hrs/cult. So, 4hrs	4	300	1200
	Harrowing -2 ,2hrs/harrow So 4hrs	4	300	1200
2.Manure and fertilizer	FYM/ PMC @10t/ha wet	10	100	1000
Ferilizer 150:60:60 (NPK)	Urea- 300 kg/ha with DAP(Cost Rs 6/kg)	300	6	1800
	DAP- 130kg/ha (Cost Rs 14.7/kg)	130	14.7	1911
	MOP-100kg/ha (Cost Rs 4.9/kg)	100	4.9	490
	Cost of application- 6 man days	6	200	1200
3. Seed and planting	Cost of Seed 60q/ha	60	314	18840
	Fungicide for seed treatment	250 g	1000	250
Cost of planting	Furrow opening- normal at 60cm, 4hrs	4	200	800
	Labour -35 mandays	35	200	7000
4.Irrigation	8(including pre planting)-12hrs @100/hr	8	1200	9600
	Labour -1mandays per irrigation	8	200	1600
	Canal dues and other charges	12	50	600
5. Interculture	By Tractor 2hrs/ha @300/hrs, 3 hoeing	3	600	1800
	Manual Hoeing 3 with 10 labour each	30	200	6000
	Earthing up by tractor 2hrs/ha	2	300	600
	Tying 6 mandays/ha	6	200	1200
6. Plant protection	Chlorpyriphos @ 5 lit/ha cost Rs180/lit	5	180	900
	Furadan @33kg/ha cost Rs 70/kg	33	70	2310
	Application cost 6 man days @ Rs 80/m	6	200	1200
7. Harvesting & cleaning	60 mandays/ha excluding top 30mandays	30	200	6000
8. Transportation	Rs 120/t for 70 t crop it is Rs.8400	120	70	8400
9. Repair & depreciation	of other than hired equipments like kudal	10	100	1000
10.Int. on working capital	10% on above expenditure	78101	0.1	7810
11. Rental value of land	Rs 480/ha	40	12	480
12.Supervision and management	Rs 500/month/ha	500	12	6000
	Total			**92391**
Gross Income	Yield: 70 t/ha @Rs 2800/t	70	2800	196000
Net Income	NI = GI-CP			**103609**

Table 2. Cost of Production of Sugarbeet (Ridge-Furrow) 20012-13

	Cost of Production of Sugarbeet (Ridge-Furrow) 20012-13			
Items of ependiture (Input)	**Operation**	Required	Rate Rs/ Unit	Total
1.Seed bed preparation	Deep ploughing one 4hrs/ploughing	4	300	1200
	Cultivator-2 , 2 hrs/cult. So, 4hrs	4	300	1200
	Harrowing -2 ,2hrs/harrow So 4hrs	4	300	1200
2.Manure and fertilizer	FYM/ PMC @10t/ha wet	10	100	1000
Ferilizer 120:60:60 (NPK)	Urea- 210 kg/ha with DAP(Cost Rs 6.0/kg)	210	6.0	1260
	DAP- 130kg/ha (Cost Rs 14.7/kg)	130	14.7	1911
	MOP-100kg/ha (Cost Rs 4.9/kg)	100	4.9	490
	Cost of application- 6 man days	6	200	1200
3. Seed and planting	Cost of Seed 200/kg @12kg/ha	12	200	2400
	Fungicide for seed treatment	250 g	1000	250
Cost of planting	Ridge-Furrow making (50x20) 4hrs	4	300	1200
	Labour -20 mandays for seeding	20	200	4000
4.Irrigation	8(including pre planting)-12hrs @100/hr	8	1200	9600
	Labour -1mandays per irrigation	8	200	1600
	Canal dues and other charges	12	50	600
5. Weeding/thinning/ singling	Cost of Weedicide & spray	10	200	2000
	Thinning 10 mandays	10	200	2000
	Singling 10 mandays	10	200	2000
	Weeding 3 times 30 mandays	30	200	6000
6. Plant protection	Cost of chemical (Insecticide Rs1000)	2	500	1000
	Cost of Chemical (Fungicide 100)	2	500	1000
	Application cost 6 man days @ Rs 200/m	6	200	1200
7. Harvesting & cleaning	60 mandays/ha	60	200	12000
8. Transportation	Rs 120/t for 60 t crop it is Rs.7200	60	120	7200
9. Repair & depreciation	of other than hired equipments like *kudali*	10	100	1000
10.Int. on working capital	10% on above expenditure and half	64511	0.05	3226
11. Rental value of land	Rs 480/ha	40	12	480
12.Supervision and management	Rs 500/month/ha	500	12	6000
	Toal			**74217**
Gross income	Yield: 60 t/ha @Rs 2500/t	60	2500	150000
Net income	NI = GI-CP			**75783**

Table 3. Cost of production of sugarcane + Sugarbeet 2012-13

Items of ependiture (Input)	Operation	Required	Rate Rs/Unit	Total
1.Seed bed preparation	Deep ploughing one 4hrs/ploughing	4	300	1200
	Cultivator-2 , 2 hrs/cult. So, 4hrs	4	300	1200
	Harrowing -2 ,2hrs/harrow So 4hrs	4	300	1200
2.Manure and Fertilizer	FYM/ PMC @10t/ha wet	10	100	1000
Sugarcane-ferilizer 150:60:60 (NPK)	Urea- 300 kg/ha with DAP(Cost Rs 6/kg)	300	6	1800
Sugarbeet	DAP- 130kg/ha (Cost Rs 14.7/kg)	130	14.7	1911
	MOP-100kg/ha (Cost Rs 4.9/kg)	100	4.9	490
	Cost of application- 6 man days	6	200	1200
3. Seed and planting	Cost of Seed 60q/ha	60	314	18840
	Fungicide for seed treatment	250 g	1000	250
Cost of planting	Furrow opening- normal at 60cm, 4hrs	4	200	800
	Labour -35 mandays	35	200	7000
4.Irrigation	8(including pre planting)-12hrs @100/hr	8	1200	9600
	Labour -1mandays per irrigation	8	200	1600
	Canal dues and other charges	12	50	600
5. Interculture	By Tractor 2hrs/ha @300/hrs, 3 hoeing	3	600	1800
	Manual Hoeing 3 with 10 labour each	30	200	6000
	Earthing up by tractor 2hrs/ha	2	300	600
	Tying 6 mandays/ha	6	200	1200
6. Plant protection	Chlorpyriphos @ 5 lit/ha cost Rs180/lit	5	180	900
	Furadan @33kg/ha cost Rs 70/kg	33	70	2310
	Application cost 6 man days @ Rs 80/m	6	200	1200
7. Harvesting & cleaning	60 mandays/ha excluding top 30mandays	30	200	6000
8. Transportation	Rs 120/t for 70 t crop it is Rs.8400	120	70	8400
9.Additional inputs for Sugarbeet	FYM/ PMC @10t/ha wet			0
(i).Fertilizer(Half of the sole), No manure	Urea- 210 kg/ha with DAP(Cost Rs 6.0/kg)	105	6.0	630

Ferilizer 120:60:60 (NPK)	DAP- 130kg/ha (Cost Rs 14.7/kg)	65	14.7	956
	MOP-100kg/ha (Cost Rs 4.9/kg)	50	4.9	245
	Cost of application- 6 man days	6	200	1200
(ii) Seed and planting	Cost of Seed 200/kg @6kg/ha (Half of sole)	6	200	1200
	Fungicide for seed treatment	250 g	1000	250
Cost of planting	Ridge-Furrow making (50x20) 3 hrs	3	300	900
	Labour -20 mandays for seeding	20	200	4000
(iii). Weeding/thinning/ singling	Cost of Weedicide & spray	10	200	2000
	Thinning 10 mandays	10	200	2000
	Singling 10 mandays	10	200	2000
	Weeding 3 times 30 mandays	30	200	6000
(iv) Plant protection	Cost of chemical (Insecticide Rs1000)	2	500	1000
	Cost of Chemical (Fungicide 100)	2	500	1000
	Application cost 6 man days @ Rs 200/m	6	200	1200
(v) Harvesting & cleaning	40 mandays/ha	60	200	12000
(vi) Transportation	Rs 120/t for 40 t crop it is Rs.4800	40	120	4800
10. Repair & depreciation	of other than hired equipments like kudal	10	100	1000
11.Int. on working capital	10% on above expenditure	119482	0.1	11948
12. Rental value of land	Rs 480/ha	40	12	480
13.Supervision and management	Rs 500/month/ha	500	12	6000
	Total			**137910**
14.Gross income (Rs/ha)	Sugarcane Yield: 70 t/ha @Rs 2800/t	70	2800	196000
	Sugarbeet Yield: 40t/ha @Rs 2500/t	40	2500	100000
	Total			296000
15.Net income(Rs/ha)	NI = GI-CP			**158090**

Integrated msanagement of *Spodoptera litura* in sugarbeet

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In tropical countries the sugarbeet crop can offers a valuable alternative or supplementary to sugarcane. About 72% sugar is produced from sugarcane and 28% from sugarbeet in the world (Patil and Patil, 2010). Beet crop is one of the preferred host of many devastating pests, during its growth. Among the leaf and crown feeders, sugarbeet crown borer (*Hulstia undulatella* Clemens), Web worm (*Spoladea recurvalis* Fab.), Cut worm viz. Black cut worm (*Agrotis ipsilon* Hufnagel), Cut worm (*Euxoa auxiliaries* Grote), Army worms (*Spodoptera litura, Spodoptera exigua* Hub.) and Grass hoppers (*Melonoplus differentialis* Thomos) are important to infests the sugarbeet. (Whitney and Duffus, 1993) In India, defoliating insects *viz. S. litura* , *Diacrisia obliqua* Walker, *Plusia orichalcea* Fabricius, *Agrotis ypsilon* Rott. have cause the appreciable damage to the crop at different growth stages in India (Khan and Sharma, 1971; Avasthy and Shrivastava, 1972; Singh *et al*., 1980; Tewari *et al*., 1986; Patil *et al*., 2007). Defoliating pests of sugarbeet caused appreciable damage at different growth stages (Avasthy and Shrivastava, 1972; Khan and Sharma, 1971). *S. litura* is the most destructive pest in sub-tropical and tropical agriculture and has a potential to be a serious pest of crops in Asia (Nathan and Kalaivani, 2005).

Beet armyworm, *S. litura* (Lepidoptera: Noctuidae) is the most important pest that causing severe damage to the beet crop in India and occurs in epidemic form in many states during winter and summer season. Young larvae of *Spodoptera* spp. skeletonised the leaves however, the older ones eat the entire lamina and able to defoliate the crop completely in a very short period (Cooke, 1993 and Patil *et al*., 2007).

Considering the environmental hazards of chemical insecticides and their resistance in the pests, it is a high time to search for effective and cheaper integrated pest management strategies for *S. litura* in sugarbeet. Therefore, considering the scope to increase area under sugarbeet and its excellent potential in India, it is necessary to combat *S. litura,* as it is one of the most important and major barrier in commercial cultivation of sugarbeet.

Material and Methods

Research trials of IPM were conducted in two winter seasons at VSI Research Farm and the experimental plots were laid out as per Randomized Block Design (RBD) with five replications. In all the experiments, Posada variety was used for sowing with a distance of 50 x 20 cm except the varietal screening trials. Sowing was done on 30.11.2005, 07.12.2006 and harvested after six months of crop age i.e. on 30.05.2006, 26.05.2007 during first and second year respectively. Fertilizers were applied @ 120:60:60 Kg NPK/ha. Various control measures against *S. litura* were tested with the different concentrations in sugarbeet for evaluating the effective treatments.

Five sugarbeet varieties *viz*. Posada (Indus), Dorotea (Cauvery),

HI-0064 (Shubhra), IISR Comp-1 and LS-6 were used for screening. Sowing was done by dibbling the seeds on 14.12.2004, 28.11.2005 and 06.12.2006 for winter crop.

Experiment Details

Expt. 1 –Seasonal incidence of *S. litura.*

Expt. 2- Hand collection and destruction of pest stages.

Expt.3- Placement of heaps of grasses and destruction pest stages.

Expt. 4 - Placement of bird perches.

Expt. 5- Placement of pheromone traps.

Expt.6- Release of *T. chilonis, an egg* parasitoid.

Expt. 7- Spraying of *Sl* NPV.

Expt. 8 -Lannate 40 SP baiting.

Treatments of above experiments were compared with untreated control plot separately except varietals screening. Observations on *S. litura* infesting sugarbeet (leaves and roots) were recorded at fortnightly interval till harvest of the crop in each experiment. Five plants from each of 20 m^2 plot were selected at randomly for recording the larval population of *S. litura* and observations were taken on aerial parts of the plant. Plant population was recorded before harvesting. At harvest, randomly five beet roots per plot were harvested for juice analysis. Weight of beet roots/plot was taken Quality attributes *viz.* Brix (%), purity (%) and pol (%) of juice of five beet roots /plot were recorded. Juice analysis was done by Cold Extraction method.

RESULTS

Expt.1-Seasonal incidence of *S. litura* on five sugarbeet varieties.

Incidence of *S. litura* was observed firstly at 120 and 95 days after sowing during first and second year, respectively and it was remained up to harvest. After complete defoliation, larvae also feed on exposed beet roots by making the holes. Three winter seasons data (Table 1) revealed that the minimum (2.68/plant) *Spodoptera* larval infestation was noticed in HI 0064 followed by IISR Comp-1(4.28) while it was maximum (7.74) in Dorotea.

Expt. 2- Hand collection and destruction pest stages

All the treatments (Table 2) noticed significantly effective in reducing the *S. litura* larval population except collection of pest stages at six days interval. Minimum population of 1.8 larvae per plant was noticed in collection of pest stages at two days interval. Collection of pest stages at two days and three days interval observed equally effective in reducing the *S. litura* larval population and recorded the minimum population, 0.5 larva per plant. Considering the minimum population (0.4 larva/plant) at 21 DAT (Days after treatment) with a maximum beet root yield, (73.79 t/ha), the collection and destruction of pest stages at four days interval proved beneficial in reducing the *S. litura* incidence. Hand picking and destruction of egg masses and early instar of larvae of tobacco caterpillar (*S. litura*) plays an important role in IPM package as suggested by Mandal *et al.* (2006), Singh *et al.* (2006) and Choudhary *et al*. (2007) in cormel, pigeon pea and soybean crop, respectively.

Expt. 3 -Placement of heaps of grasses and destruction of pest stages

Minimum population of larvae (0.9 larva/plant) was noticed in the placement of heaps of grasses at three days interval, while it was maximum (7.6 larvae/plant) in control (Table 3) at 7 DAT. Placement of heaps of grasses at two and three days interval found equally effective (0.3 larva/plant) in reducing *S. litura* population followed by placement of heaps of grasses at four days interval and observed 0.5 larva/plant. Considering over the seasons data and severe infestation of pest, cost of labours, yield obtained etc, the placement of heaps of grasses and destruction of larvae beneath it at four days interval noticed useful and cheaper.

Expt. 4 -Placement of bird perches

Significant larval population reduction noticed (Table 4 and 5) in placement of bird perches @ 25/ha and recorded minimum (0.9 larva/plant) *S. litura* larva followed by placement of bird perches @ 20/ha (3.1 larvae/plant) at 15 DAT. Considering the 1.20 larvae/plant in a season and 66.96 t/ha beet yield, placement of bird perches @ 25/ha noticed effective. Total 832 birds recorded to rest in the field during morning and evening hours in 15 days observational period. Singh *et al*. (2006) suggested installation of 25 T-shaped wooden bird perches/ha in a pigeon pea, while it was reported to 60 numbers in ground nut crop by Singh *et al*. (2005). Similar recommendations were also suggested by Choudhary *et al*. (2007) in IPM module, Common Indian Myna and House sparrow were visited maximum times in the sugarbeet field.

Expt. 5 - Installation of pheromone trap

Spodoptera incidence was started at 120 DAS (Days after sowing) and minimum of 2.20 larvae/plant were observed in the treatment of pheromone traps installed @ 25/ha and it was maximum (10.70 larvae/plant) in control (Table 6). Significantly minimum population (0.1 larva/plant) was observed in pheromone traps used @ 25/ha at 150 DAS, while it was maximum (3.2 larvae/plant) in control. Considering the minimum incidence (0.97 larva/plant) of *Spodoptera* in the treatment of placement pheromone traps @ 25/ha in the season with a maximum (76.33 t/ha) beet yield and mean trapping of 19.49 male adults of *S. litura*/day /trap, the placement of pheromone traps @ 25/ha noticed suitable and effective (Table 7). IPM module in groundnut + sunflower (5:1) production system and pigeon pea, 10 Pheromone trap/ha are recommended by Singh *et al*. (2005) and Singh *et al*. (2006).Placement of one pheromone trap/ ha for monitoring and 10 pheromone traps/ha for mass trapping of *S. litura* was suggested by Anonymous (2001). Due to trapping of male adults and their destruction, the mating chances with female adults seem to be reduced and this may be the reason for less incidence of *Spodoptera* in sugarbeet.

Expt. 6- Release of an egg parasitoid, *T. chilonis*

Significant reduction of *Spodoptera* larval population was recorded (Table 8) in release of *T. chilonis* parasitoids @ 100000/ha and *Spodoptera* incidence was (2.1 larvae/plant) at 7 DAT. All the treatments noticed significantly effective at 21 DAT in reducing the *Spodoptera* incidence with minimum 0.2 larva/plant in *T. chilonis* release @ 75000 parasitoids/ha. Less than one larva per plant was noticed in remaining treatments except untreated. Considering the minimum larval population of 1.37 larvae/plant in a season with a maximum beet root yields of 73.66 t/ha, the release of *T. chilonis* parasitoids @ 100000/ha in two installments noticed effective. In untreated, the incidence of *Spodoptera* was 3.93 larvae/plant and beet root yield was 54.39 t/ha. Anonymous (2001) also reported the releases of *T. chilonis* @ 50000/ha, twice (7-10 days interval) against defoliators, while Singh *et al*. (2006) recommended release of *T. chilonis* @ 125 000/ha against *S. litura* in pigeon pea. Considering the usefulness of *Trichogramma* parasitoids in destroying the pest in a egg stage before larva could cause damage, good searching ability of parasitoids female to host egg stage, ease method of release of parasitoids at farmers level, low cost of treatment, during the severe infestation of *Spodoptera* and at initiation of pest incidence, the release of *T. chilonis* Ishii parasitoids @ one lakh parasitoids per ha in two installments definitely found effective.

Expt. 7 -Spraying of SLNPV

All the treatments observed statistically significant (Table 9) over control in regard to reduction of *S. litura* larval population after 7 DAT and spraying of *Sl* NPV, 700 ml/ha has recorded the minimum incidence (1.9 larvae/plant) of *Spodoptera*. In the spraying of *Sl* NPV, 600 ml/ha, the minimum incidence (1.5 larvae/plant) was observed followed by spraying of *Sl* NPV 500 ml/ha and *Spodoptera* population was 2.9 larvae/plant at 15 DAT. Minimum population of *Spodoptera* (0.2 larva/plant) was recorded in 600 ml/ha spraying of SLNPV, while it was maximum (1.4 larvae/plant) in control at 21 DAT. Use of *Sl* NPV @ 250 LE (6 x 10^9/LE)/ha found effective by Anonymous (2001), when there is a large number of egg masses and early instar larvae noticed. Considering the *Spodoptera* incidence (1.53 larvae/plant) over the season and maximum beet root yield (73.21 t/ha), spraying of *Sl* NPV, 600 ml/ha seems to be the most effective amongst the other treatments, whereas, in untreated the larval population in a season and beet root yield was 5.53 larvae/plant and 51.59 t/ha.

Expt. 8 -Lannate baiting

Minimum larval population(1.20 larvae/plant) was observed in a baiting of Lannate 40 SP @ 30 gm/ha, while it was maximum (6.40 larvae/plant) at 7 DAT. Lannate 40 SP @ 30 gm/ha, found effective at 15 DAT and recorded the minimum incidence (0.3 larva/plant) followed by Lannate 40 SP @ 25 gm/ha (0.6 larva/plant). No incidence of *Spodoptera* on sugarbeet at 21 DAT was recorded and considering 0.67 larva/plant in a season with maximum beet root yield of (62.88 t/ha), the application of lannate 40 SP @ 25 gm/ha found effective in a winter season (Table 10). In untreated, where no lannate baiting was done, the larval population over the season and beet root yield was 3.97 larvae/plant and 52.52 t/ha.

Conclusion

On the basis of the results obtained during 2004-05 to 2007-08, the IPM Module is prepared for the effective control of *Spodoptera litura* in Tropical sugarbeet in India.

INTEGRATED PEST MANAGEMENT (IPM) PACKAGE

- ✓ Considering the low incidence of *Spodoptera,* farmers should prefer the sugarbeet variety HI 0064 (Shubhra).
- ✓ Placement of bird perches @ 25/ha, one month after sowing.
- ✓ Hand collection and destruction of *Spodoptera* stages at four days interval and this operation needs to be done minimum four times during the severe incidence of the pest.
- ✓ Placement of heaps of grasses at 4 – 5 days interval and destruction of larval stages.
- ✓ Placement of pheromone traps @ 25/ha at four months after sowing (or second fortnight of February) in a winter season and at one month after sowing during summer season. Lures can changed every 15 days interval to attract the male adults of *Spodoptera.* One or two pheromones traps can be placed from germination till fifth month of crop age for monitoring of the *Spodoptera* population.
- ✓ On the basis of collection of *Spodoptera* adult moths in the pheromone traps, the releases of *Trichogramma chilonis,* an egg parasitoid, @ 100000/ha in two installments (50000 parasitoids/installments).
- ✓ Two spraying of *Sl* NPV @ 600ml/ha at 15 days interval in winter season and 500 ml/ha in the summer season, when *Spodoptera* population is at initial stage.
- ✓ Application of Lannate 40 SP @ 25 gm/ha baiting (975 gm wheat husk + 25 gm methomyl (Lannate) + 100 gm jaggary in 1 lit. water) during the severe incidence of *Spodoptera.*
- ✓ Need base and single spraying of quinalphos 25 EC @ 0.05% (or 2 ml/lit. of water) during the severe incidence.

Cost of Integrated Pest Management Module

The cost of IPM module as per the control measures practices is given to combat the *Spodoptera* damage in sugarbeet. Per hectare cost of *Spodoptera* management as per the present investigation is Rs. 3965/ha and considering the severe damage by *Spodoptera*, this cost seems to be minimum.

Cost of IPM module in sugarbeet

Control measure	**Market cost (Rs.)**	**Material required/ ha**	**Material cost / ha (Rs.)**	**Labour cost (Rs.)**	**Sub total (Rs.)**	**Time of application**	**Total cost (Rs.)**
Release of *T. chilonis parasitoids* (one lakh/ha)	40/card	5 cards	200/-	-	200/-	Two installments at anterval of 15 days	200/-
Placement of wooden bird perches	10/piece	25	250/-	75/-	325/-	One time	325/-
Making of heaps of grasses and destruction of larvae	-	-	-	50/- each time	150/-	Three times at 4 days interval	150/-
Sparying of *Sl* NPV (500ml/ha)	700/litre	500ml	350/-	250/-	600/-	Two times at 15 days interval	1200/-
Placement of pheromone traps @ 25/ha	17.34/unit	25	435/-	38/-	473/-	One time	473/-
Pheromone lure	15.11/lure	25	378/-	-	378/-	Two lures/trap at 15 days interval	756/-
Methomyl 40SP @ 25gm/ha	1106/kg	100 gm	111+135 other material	38/-	284/-	One time	284/-
Quinalphos 25 EC	326.92/lit	1 lit /ha	327/-	250/-	577/-	One time	577/-
Total cost (Rs. /ha)							**3965/-**

Table 1. Incidence of *S. litura* on sugarbeet crop during winter season.

Variety	**Over the season mean larval population / plant**			
	2004-05	**2005-06**	**2006-07**	**Average**
Posada (Indus)	4.90	7.40	**7.95**	6.75
Dorotea (Cauvery)	**2.08**	13.23	7.90	7.74
HI 0064 (Shubhra)	3.53	**2.33**	**2.18**	**2.68**
IISR Comp-1	2.22	8.20	2.43	4.28
LS-6	2.58	8.47	3.83	4.96

Table 2. Hand collection and destruction of stages of *Spodoptera*

(Pooled mean of winter season, 2005-06 and 2006-07)

Treatment		**Mean larval population of *S. litura*/plant**					**Average yield (t/ha)**	**Pol (%)**
Collection of pest stages at an interval of days		**Pre count**	**Days after treatment**			**Over the season**		
			7	**15**	**21**			
T1	2	7.4	**1.8**	0.9	0.2	0.97	71.83	14.20
T2	3	4.9	2.7	0.5	0.1	1.10	59.43	13.63
T3	4	8.4	2.7	**0.5**	**0.4**	**1.20**	**73.79**	13.61
T4	5	18.6	3.1	1.4	0.7	1.73	69.84	11.99
T5	6	18.0	11.0	1.7	0.4	4.37	73.27	14.00
T6	Control	15.7	10.3	4.0	1.0	5.10	52.89	11.99
S.E. ±			0.97	0.39	0.15	-	-	-
C.D. at 5%			2.87	1.14	0.45	-	NS	-

Table 3. Placement of heaps of grasses and *Spodoptera* population

(Pooled mean of winter season, 2005-06 and 2006-07)

Treatment		**Mean larval population of *S. litura*/plant.**					**Average yield (t/ha)**	**Pol (%)**
Placement of heaps at an interval of days		**Pre count**	**Days after treatment**			**Over the season**		
			7	**15**	**21**			
T1	2	8.5	2.1	0.3	0.79	1.06	60.17	14.37
T2	3	10.4	**0.9**	0.3	0.82	0.67	62.48	15.73
T3	4	12.9	1.9	0.5	0.88	**1.09**	**70.86**	13.10
T4	5	16.5	1.9	0.5	0.85	1.08	67.80	13.92
T5	6	8.1	2.0	0.9	0.85	1.25	66.62	14.37
T6	Control	16.5	7.6	1.5	0.76	3.29	55.82	12.67
S.E. ±			-	-	0.25	-	-	-
C.D. at 5%			NS	NS	0.73	-	NS	-

(Pooled mean of winter season, 2005-06 and 2006-07)

Treatment		Mean larval population of *S. litura*/plant.					Average yield (t/ha)	Pol (%)
Number of bird perches/ha		Pre count	Days after treatment			Over the season		
			7	15	21			
T1	5	7	6.9	5.6	1.5	4.67	58.70	13.66
T2	10	5.3	4.8	3.9	1.9	3.53	65.30	14.44
T3	15	7.9	4.2	4.7	2.7	3.87	68.51	14.32
T4	20	6.7	5.2	3.1	1.5	3.27	69.08	13.42
T5	25	8.1	2.4	0.9	0.3	1.20	66.96	13.80
T6	Control	9.5	10.3	11	4.7	8.67	54.99	13.79
S.E. ±		-	1.20	0.74	0.40		-	
C.D. at 5%		-	3.54	2.18	1.18		-	

Table 5. Number of birds recorded within 15 days at morning and evening hours

Sr. No	Name of bird		Number of birds recorded on bird perches within 15 days				
	Common name	**Scientific name**	**@ 5/ha**	**@ 10/ha**	**@ 15/ha**	**@ 20/ha**	**@ 25/ha**
1.	House sparrow	*Passer domesticus* L.	60.50	101.50	112.00	133.50	165.50
2.	Crow	*Corvas splendens* L.	34.50	39.00	43.00	55.00	77.00
3.	Kokila	*Eudynamys scolopacea* L.	9.50	18.00	29.50	23.50	13.50
4.	Common Indian Myna	*Acridotheres tristis* L.	91.50	109.00	119.00	164.50	174.00
5.	Bharadwaj	*Centropus sinensis* Stephens	6.50	16.50	31.50	32.00	48.50
6.	Bulbul	*Pycnonotus cafer* L.	13.50	20.00	24.00	29.00	37.00
7.	Titwi	*Vanellus indicus* Boddaert	83.50	75.50	93.00	122.50	110.00
8.	Unknown	-	105.00	137.00	140.50	177.00	206.50
Total			404.50	516.50	592.50	737.00	832.00

Table 6. Use of pheromone traps in control of *Spodoptera*

(Pooled mean of winter season, 2005-06 and 2006-07)

Treatment		Mean larval population of *S. litura*/plant.				Average yield (t/ha)	Pol (%)
Number of traps/ha		Days after sowing			Over the season		
		120	135	150			
T1	5	6.60	3.2	0.7	3.50	65.42	13.07
T2	10	5.00	3.3	0.8	3.03	65.17	14.29
T3	15	5.80	3.6	0.7	3.37	58.51	14.97
T4	20	4.10	1.9	0.4	2.13	76.09	13.87
T5	25	**2.20**	**0.6**	**0.1**	**0.97**	**76.33**	14.06
T6	Control	10.70	9.1	3.2	7.67	55.13	13.93
S.E. ±		1.01	0.90	0.33	-	-	-
C.D. at 5%		2.97	2.65	0.96	-	NS	-

Table 7. Mean of *S. litura* male adults trapped/Trap during the peak infestation (Pooled mean winter season, 2005-06 and 2006-07).

Day	Mean of *S. litura* male adults collection/Trap				
	@ 5 traps /ha	@ 10 traps/ha	@ 15 traps/ha	@ 20 traps/ha	@ 25 traps/ha
1	22.00	39.00	49.80	55.15	61.30
2	5.30	16.75	26.40	34.60	102.50
3	4.00	15.40	32.20	36.30	18.10
4	4.00	4.10	10.35	17.95	16.30
5	5.30	13.63	44.65	20.90	25.00
6	3.00	14.63	19.10	26.55	15.70
7	4.00	24.80	25.80	11.13	12.40
8	5.10	11.60	24.00	3.43	14.00
9	24.50	13.75	23.67	7.83	15.60
10	11.10	13.45	19.93	12.10	12.20
11	16.50	17.60	22.83	14.43	13.90
12	7.50	13.10	27.23	12.23	7.60
13	11.00	10.10	15.90	14.68	10.40
14	16.60	13.20	3.00	16.50	4.60
15	8.20	16.75	12.40	9.63	8.80
16	6.00	13.45	14.97	6.00	9.90
17	11.50	9.45	7.67	6.45	5.20
18	17.50	13.50	7.70	11.75	5.40
19	11.20	4.10	3.73	7.20	11.40
Mean	**10.23**	**14.65**	**20.60**	**17.09**	**19.49**

Table 8. Role of *T. chilonis* in reducing population of *Spodoptera*

(Pooled mean of winter season, 2005-06 and 2006-07)

Treatment		Mean larval population of *S. litura*/plant.					Average yield (t/ha)	PoI (%)
Release No. of *T. chilonis* egg		Pre count	Days after treatment			Over the season		
			7	15	21			
T1	25,000	7.6	3.1	2.9	0.4	2.13	59.79	13.55
T2	50,000	7.7	4.2	3.8	0.4	2.80	64.06	13.60
T3	75,000	4.6	3.3	2.9	**0.2**	2.13	55.61	13.15
T4	1,00,000	4.2	**2.1**	**1.5**	0.5	**1.37**	**73.66**	12.35
T5	1,25,000	2.9	7.4	6.7	0.8	4.97	72.14	12.43
T6	Control	8.8	5.3	5.2	1.3	3.93	54.39	12.20
S.E. ±			0.68	0.70	-	-	-	-
C.D. at 5 %			2.02	2.07	NS	-	NS	-

Table 9. Effiect of spraying of *SL*NPV on *Spodoptera* population

(Pooled mean of winter season, 2005-06 and 2006-07)

Treatment		Mean larval population of *S. litura*/plant.					Average yield (t/ha)	PoI (%)
Spraying of *Sl* NPV (ml/ha)		Pre count	Days after spraying			Over the season		
			7	15	21			
T1	300	15.8	2.4	2.9	0.3	1.87	59.33	14.59
T2	400	17.7	2.1	3.8	0.2	2.03	69.44	12.01
T3	500	18.6	2.0	2.9	0.1	1.67	66.73	11.83
T4	600	16.1	2.9	**1.5**	**0.2**	**1.53**	**73.21**	13.85
T5	700	8.8	**1.9**	6.7	0.2	2.93	73.04	11.77
T6	Control	8.5	10.0	5.2	1.4	5.53	51.59	10.77
S.E. ±			1.06	0.35	-	-	-	-
C.D. at 5%			3.11	1.04	NS	-	NS	-

Table 10. Use of Lannate (Baiting) in reducing *Spodoptera* population

(Mean of winter crop, 2005-06 and 2006-07)

Treatment		Mean larval population of *S. litura*/plant.					Average yield (t/ha)	Pol (%)
Baiting of Lannate (gm/ha)		**Pre count**	**Days after application**			**Over the season**		
			7	**15**	**21**			
T1	15	12.1	3.30	1	0.1	1.63	50.76	12.77
T2	20	5.5	3.30	1.2	0.1	1.43	56.55	11.42
T3	25	5.2	1.90	0.6	**0.0**	**0.67**	**62.88**	12.77
T4	30	8.8	**1.20**	**0.3**	0.0	0.57	60.89	13.49
T5	35	6.8	1.70	1.1	0.1	0.93	59.30	13.39
T6	Control	10.1	6.40	3.8	1.1	3.97	52.52	11.37
S.E. ±			0.51	0.23	0.13	-	-	-
C.D. at 5 %			1.52	0.68	0.39	-	NS	-

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Unique features of sugarbeet and its comparison with sugarcane

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Sucrose ($C_{12}H_{22}O_{11}$, Molecular weight 342.3) is β-D-fructofuranosyl α-D-glucopyranose, a most ubiquitous and abundantly occurring disaccharide. For sugar, its sweetness was primary but its nutritive value (calorific and others) was a secondary realization. Important sugar crops include, sugarcane, sugarbeet, sugar maple, various types of palms and sweet sorghum. Sugarbeet (*Beta vulgaris*), a plant belonging to the family Chenopodiaceae, is the second most important source of sugar (21.5 % of the world sugar) after sugarcane which is grown in 57 countries. It is a biennial halophytic (as well as Na- salts scavenger) C_3 plant containing up to 20 % sugar on fresh weight basis; and for its flowering (for seed production), it requires vernalization. In this plant sugar is stored in root. The latter is composed of 90% root derived part and the remaining 10% (the crown) is derived from the hypocotyl.

Uniqueness of this sugar yielding plant are:

- It is a halophyte (can tolerate a salinity level of 9.5 m mhos/cm) as well as scavenger of sodium salts. Thus it may be a most suitable crop to cultivate several thousands hectares of uncultivable *usar* lands.
- It is a C_3 plant
- Selective breeding and improved agricultural practices have improved sugar concentration in its roots from 4% to 18% on fresh weight basis and around 75% on dry weight basis, in a relatively shorter period of time.
- It is a temperate biennial plant (for a seed crop) but for the root crop it is cultivated as an annual crop.
- For flowering, vernalization is obligatory.

Leaves of sugarbeet exhibit rates of photosynthesis in the range of 38-52 μmol/m^{-2}/second, chlorophyll contents 1.20-1.75 mg/g and carotenoid contents 3.6 to 7.76 mg/g fresh weight of the leaf. Biochemically, sugarbeet is a C_3 plant with RuBP Carboxylase as carboxylating enzyme with phosphoglyceraldehyde (PGAl)/dihydroxyacetone phosphate (DHAP) as primary carboxylation products. The enzyme, Ribulose 5-Phosphate Kinase primarily regulates rates of photosynthesis. Sucrose synthesis in the leaves is primarily achieved by the activity of transglucosylases namely Sucrose phosphate synthetase, SPS and Sucrose synthetase, SS. Sucrose translocates in the leaves through a *symplastic pathway,* however, in young and mature storage roots, it is by the *apoplastic pathway*. Sucrose is stored in vacuoles by an active uptake process and follows an ion co-transport mechanism.

With respect to its life cycle, sugarbeet is a biennial plant; comprising a period of vegetative growth, cold-induced vernalization, production of upright extended flowering stem and seed production. After vernalization, bolting occurs where the stem elongates in to a tall shoot like structure. Axillary buds in the axil of the leaves on the shoots quickly develop into inflorescence (an indeterminate raceme) on which sessile flowers are borne. It is cross pollinated crop and a humidity of 75% is important for it. Warm and dry period after the pollination (during the seed development and ripening) leads to good seed setting and production of good quality seed.

Composition wise, a freshly harvested sugarbeet root contains 75-76% water, 15-20 % sugars, 2.6% non-sugars and 4-6 % the pulp. Processing one ton of fresh sugarbeet roots yields 121 kg sugar, 38 kg molasses (containing 18.2 kg sugar, 12.1 kg impurities and 7.8 kg water) and 50 kg of pulp.

Some of the physiological criteria used in selection of sugarbeet are: High pulp content for high sugar, maintenance of green foliage cover during drought for drought tolerance, restricted chloride accumulation in shoots for salt tolerance, carbon isotope discrimination for improved water use efficiency, etc. Tropicalised sugarbeet hybrids have been selected for heat tolerance and disease (especially the ones prevalent in tropical regions) resistance from the sugarbeets growing in extreme American and European locations. These may be utilized as a valuable complimentary crop with sugarcane in tropical areas of the world.

There are differences in sugar and sugar-products derived from sugarbeet and sugarcane. Sugarbeet sugar/ sugar products are characterized by more negative values of $^{13}C/^{12}C$ ratio and absence of theanderose.

Sugarcane and sugarbeet compared

A comparison of sugarcane and sugarbeet is given in Table-1

Table-1: Comparison of sugarcane and sugarbeet

S. No.	Characteristic	Sugarcane	Sugarbeet
1.	Contribution to world sugar production	78.5%	21.5%
2.	Cotyledonous nature of the plant	A monocotyledonous	A dicotyledonous plant
3.	Crop duration	10- 24 months	6 months
4.	Photosynthetic characteristics	A C_4 photosynthesizing plant	A C_3 photosynthesizing plant
5.	Response to salinity	Can grow only on partially reclaimed soil	Grows well/in adapted to saline soils
6.	Organ and tissues storing sugar	Parenchymatous cells in the stalk (in the vacuoles and cytoplasm)	Parenchymatous cells in the concentric rings in the roots

7.	Sucrose content in juice	15-20%	15-20%
8.	Process for extraction of sugar (in juice)	Shredding and application of pressure	Slicing and diffusion
9.	Method of propagation	Vegetative, by planting, cuttings with 1,2 or 3 buds or even the whole cane	By true seed
10.	Uniqueness of sugar and sugar products:		
	(a) Ratio of $^{13}C/^{12}C$(in sucrose)	Less negative values (-14 o/oo)	More negative values (-29o/oo)
	(b) Theanderose (in sugar and sugar products)	Present (passes through crystallization process)	Absent
11.	Source of energy for processing (for sugar)	Bagasse, a by-product of milling sugarcane is used as fuel	Has to be provided exogenously (as coal or electricity)
12.	Molasses characteristics		
	Carbohydrates	Contains relatively less of sucrose (32%), more of reducing sugars (12-30%) and **no raffinose**.	Contains relatively more of sucrose (63%), less of reducing sugars (1%) and also 1% raffinose.
	Minerals (ash)	Relatively lesser (8.0%)	Relatively higher (11.5%, with 6% K)
	Non sugars (including nitrogenous materials)	10.0%; betaine isd absent	19.0%; contains betaine- an osmoregulant
	Vitamins	Biotin is present	Lacks biotin (vitamin H or B_7)

(Source: Shrivastava, 2006)

Thus sugarcane and sugarbeet, the two important sugar producing plants differ in their position in plant kingdom, process of photosynthesis, response to salinity, tissues storing sugar, process utilized for extraction of sugar, utilization of energy for their processing for sugar, mode of propagation, etc. Although they have nearly same level of sugar, sugar and sugar products from these as well as composition of their molasses in terms of carbohydrates, minerals, non sugars and presence of vitamins.

Suggested further reading

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Nitrogen management in autumn sugarcane + sugarbeet intercropping system under Indian subtropics

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Sugarbeet cultivation is becoming important in some areas of subtropical India because of its capacity to provide both cash from the harvested root and livestock feed in the form of above ground biomass (top) and root processing byproducts such as pulp and molasses. This dual benefit is suiting very well in present integrated crop livestock production system. Sugarbeet is basically a temperate crop and is mainly cultivated in cold countries where sugarcane cultivation is not feasible. The advent of tropicalized sugarbeet genotypes from Indian Institute of Sugarcane Research and its coordinating centres revolutionized its cultivation in subtropical India (IISR, 2008). Out of total sugar produced in the world, 20% sugar share comes from sugarbeet ranking the crop at second position in global sweetener requirements.

Sugarcane as a principal source of sugar has been rated as one of the most efficient converters of solar energy to its consumable form. Further, sugarcane as a raw material accounts for 80 per cent of sugar production to sugar industry in **'Produce to Product'** chain. Globally, sugarcane is grown in diversified cropping systems under varying edaphic and climatic conditions. As a result, not only sugarcane production fluctuates over the years but also the cost per tonne of cane produced varies considerably. Plateauing yield level, declining factor productivity and increasing production cost in recent years coupled with high water requirement posed serious concern before policy makers, cane growers and mill owners. In view of dwindling land and water resources, changing market scenario, consumers' preferences and global competitions, new input efficient, mid- term income generating opportunities need to be created through intercropping in sugarcane.

The sugarcane crops characteristically widely spaced initially slow growing, long duration and one time income generating crop, lends ample scope for intercropping with short duration, high value and mid-season income generating crops for household nutrition and economic security. To harvest more sugar per unit area and time, intercropping of sugarbeet with sugarcane (cane + beet) can be done for achieving higher profit, increase in vertical land productivity and to supply of raw material to sugar industry for extended crushing season. It is doable only by bow of tropical sugarbeet, because the time of sowing coincides with planting time of autumn sugarcane.

Nitrogen management affects the root and top biomass production of sugarbeet (*Beta vugaris* L.). Primitive studies on nitrogen management in sugarbeet with respect to time, dose and methods of application under subtropical Indian conditions were carried out and recommendations renowned (Chauhan, 1991). However work on nitrogen management in sugarcane + sugarbeet intercropping systems is meagre. In view of above an experiment was conducted with the objectives to find out optimum dose of nitrogen for sugarcane + sugarbeet intercropping system.

Materials and Methods

Field experiment was conducted during 2012-13 at the Research Farm of Indian Institute of Sugarcane Research, Lucknow (26^0 56′ N, 80^0 62′ E and 111 m above sea level), Uttar Pradesh, India falling in subtropical belt of sugarcane cultivation. The soil of the experimental field was sandy loam (*Inceptisol*), neutral in reaction (pH 7.6), low in organic carbon (0.32%) and available N (177.5 kg/ha), medium in available P (16.7 kg/ha) and K (235.4 kg/ha). The treatment consisted of five doses of nitrogen *viz*. 0 (control), 30, 60, 90, and 120 kg N /ha. The experiment was laid out in randomized block design with four replications. CoLk 94184 variety of sugarcane and LS-6 of sugarbeet was taken in the experiment. Sugarcane crop received uniform doses of N (150kg/ha), P (60kg/ha) and K(60kg/ha). The recommended doses of P and K were given at the time of planting/ sowing and N was applied as per the treatment. Splitting of nitrogen was done as per recommendation. Total nine irrigations were given to both the crops. Sugarcane and sugarbeet was harvested in the month of February and May respectively. Observations on both the crops were recorded during growth and at harvest. Sugarcane juice and beet roots were analysed for sucrose content.

Results

The data on number of millable canes and cane yield clearly indicate that the significantly highest number of millable canes (134.5 thousand/ha) and cane yield (79.5t/ha) was recorded at highest dose of nitrogen(120kg N/ha) to sugarbeet (Table 1). The sucrose content in terms of pol% juice was significantly reduced at higher dose of nitrogen(120kg N/ha), however, rest of the doses were found at par. The significantly highest beet root yield (53.6 t/ha) was obtained by application of 120 kg N /ha, however this was recorded at par with 60 and 90 kg N/ha dose. Statistically similar top yield was also harvested at 60, 90 and 120 kg N/ha application. Sucrose content in sugarbeet was generally analysed very low and not significantly affected by different treatments.

Conclusion

Intercropping of sugarbeet can be done in autumn planted sugarcane with the application of 60 kg N/ha in addition to nitrogen applied in cane. The phosphorus and potassium doses should be applied separately to both the crops to obtain higher beet root and cane yield aims to increase in vertical land productivity, system profitability and availability of raw material for extended crushing season.

Table 1: Effect of nitrogen levels on yield and sucrose content in sugarcane and sugarbeet grown in association

Treatment *N levels (kg/ha)	**NMC (000/ha)	Cane Y t/ha	Pol %	Beet root yield t/ha	Beet top yield (t/ha)	Sucrose %
0	120.3	72.51	16.45	36.84	6.67	12.21
30	122.4	72.34	16.34	40.25	8.25	12.34
60	123.6	75.26	16.24	45.24	10.24	11.35
90	122.5	76.21	16.42	48.97	11.21	11.64
120	134.5	79.51	14.40	53.64	12.34	11.24
CD (P= 0.05)	6.82	4.70	0.51	11.27	6.27	NS

*Treatmental N was applied only in sugarbeet in addition to doses of sugarcane

**Number of Millable canes

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Useful products from sugarbeet

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Sugarbeet (*Beta vulgaris*), belonging to the family Chenopodiaceae, is the second most important source of sugar (21.5 % of the world sugar) which is grown in 57 countries. It is a biennial halophytic (as well as Na- salts scavenger) C_3 plant containing up to 20 % sugar on fresh weight basis; and for its flowering (for seed production), it requires vernalization. The storage organ of this plant is usually called the root; of which 90% is actually *root derived* and the remaining 10% (the crown) is derived from the hypocotyl.

A freshly harvested root of sugarbeet contains 75-76% water, 15-20 % sugars, 2.6% non-sugars and 4-6 % the pulp. Processing one ton of fresh sugarbeet roots yields 121 kg sugar, 38 kg molasses (containing 18.2 kg sugar, 12.1 kg impurities and 7.8 kg water) and 50 kg of pulp. Out of sugar present in fresh sugarbeet roots, nearly 83% is recovered as white sugar, 12.5% is lost in molasses and 4.4 % is lost in some other ways. Beet roots also contain 0.3% betaine, an important osmoregulant. Molasses obtained after processing sugarbeets (as % of dry weight) contains 66.5% sugars (sucrose 63.5, raffinose 1.5 and other sugars 1.5%), 23 % other organic compounds (Glutamic acid + Pyrrolidine carboxylic acid 4.0%, other amino acids 3.0%, Betaine 5.5 %, Pectins 5.0%) and 10.5% inorganic compounds with 6% K_2O. Beet pulp consists of water insoluble fibrous materials which are: pectins (2.4%), cellulose (1.2%), hemicellulose (1.1%), proteins (0.1%), saponin (0.1%) and minerals (0.1%). It has been observed that high- sugarbeet roots have relatively higher amount of pulp.

After processing for sugar, sugarbeet molasses, on dry weight basis, contains about 50% sugar. The latter contains predominantly sucrose, and also glucose and fructose. Its non-sugar components are salts like oxalate and chloride of calcium and potassium. Molasses also contains betaine and a tri-saccharide, raffinose. These make beet molasses unpalatable for human beings. But its is mainly used as an additive to animal feed and also as a feedstock for fermentation. In comparison to sugarcane molasses, the beet molasses lacks biotin (vitamin H or B_7).

Besides extraction of sugar, sugarbeet as well as pulp and molasses obtained from its processing have been utilized for preparing some of the useful products for the benefit of mankind. Some of these are given below:

Human food

Sucrose from sugarbeets is the principal use for sugarbeets in the United States. Sugarbeets contain from 13 to 22% sucrose. Sucrose obtained from processing sugarbeets, is widely used as a high energy food as also a palatable food additive. High fiber dietary food additives have been manufactured from sugarbeet pulp. In the United States these dietary supplements have been recently introduced in breakfast items (Web siste-2).

A sugary syrup is also produced by cooking shredded sugarbeet for several hours. After pressing and filtering, a honey like dark syrup is obtained. In some parts of Germany, this syrup (called *Zuckerrüben-Sirup* or *Zapp*) is used as a spread for sandwiches, to sweeten sauces, cakes and desserts. This syrup is also hydrolyzed to a product akin to high fructose corn syrup.

Health benefits

Red beets have been alouded for their health benefits. Beets are enriched with nutrients like Mg, P, Na, K and Ca. It also contains ample of Se, Zn and Mn. The flavanoids and carotenoids present in it prevent damage to the cells. The red pigment of beets, betacyanin is effective in prevention of colon cancer. Intake of red beets also reduces high blood pressure. It helps in production of RBC in the blood and removes harmful and toxic substances accumulated in the liver. Leaves of sugarbeet are known to counter bad breath. In Roman times, Hippocrates advocated use of beet leaves for healing of wounds. Sugarbeets have been used to get rid of tumors and to help people with blood diseases and leukemia. It has also been used to treat and cure boils, abscesses and even acne so much so that these have earned the status of "*Beet Therapy*".

Beverages

In many countries molasses from sugarbeet is used to make a rum-flavored hard liquor like *Tuzemák* in Czech Republic and Slovakia, *Kobba Libre* in the Åland Islands and rectified spirit and *vodka* in the Czech Republic and Germany.

Feed for livestock

Being a good source of carbohydrates, protein, fibre and minerals, sugarbeet tops are used as animal feed, either as fresh or even in ensilaged form. Some of the sugarbeet varieties are grown as fodder beets. Once the juice has been extracted, pressed or dehydrated beet pulp provides an ideal foodstuff for cattle**.** Pulp can also be used to produce industrial pectin or dietary fibre for use with foods enriched with fibre. Processing by-products of sugarbeet, the beet pulp and molasses are also widely used as feed supplements for livestock. It contributes to fibre in the feed and adds to its palatability. In France, sugarbeet molasses is used as cattle fodder supplement.

Pharmaceuticals

Molasses, a by-products from sugarbeet processing, is widely used in the producing alcohols (ethanol and butanol), other pharmaceuticals and producing bakers yeast. A tonne of molasses yields approximately 300 litres of alcohol. Alcohol derived from sugarbeet is suitable for human consumption (in spirits, perfume, vinegar, pharmaceutical products, *etc.*) and ideal for use in household products (cleaning fluids, methylated spirits, *etc.*) and some other useful chemicals (solvents, *etc.*). For ethanol fermentation from sugarbeet molasses a new alginate–maize stem tissue matrix has been developed as a carrier for the yeast, *Saccharomyces cerevisiae*. The latter led to an ethanol production of 2.51 g/l/h. Fermenting beet molasses with potassium ferro- or ferricyanide with *Aspergillus niger* produced citric acid (approximately 50% of the available sugar as sucrose). *Betaine* can be isolated from molasses, a byproduct of sugarbeet processing using a chromatograohic technique called "simulated moving bed". This chemical is used as osmo-protectant for commercial crops under drought conditions. *Uridine* is also isolated from sugarbeet molasses. In combination with omega-3 fatty acids, use of this compound overcomes depression in rats.

Use in agriculture

Sugarbeet cultivation removes nearly 500 kg of sodium salts per ha. Thus its cultivation may reclaim sodic soils. Sugarbeet processing generates waste lime which, if amended in the acid soils, increases soil pH. Waste lime is also a good source of nutrients like P and K. Effluent of sugarbeet processing, after treatment, may also be used for irrigation.

Bio fuel/ fuel additives

Alcohol produced from sugarbeet molasses is also used as fuels (or mixed with petrol and diesel) for automobiles in many countries. Therefore, it takes 6.22 kg of sugarbeet to produce 1 kg of ethanol (approximately 1.27 l).

De-icing roads

Heavy snow fall makes the road transport very difficult. Salt is used for de-icing roads during heavy snow fall. Desugared sugarbeet molasses is mixed with salts in equal parts for de-icing or anti-icing products in winter control operations; and it has reduced the amount of salt on the roads as much as 30%. Sugarbeet molasses, in combination with salts, is rather more effective than the road salt used alone as it reduces corrosion to some extent and also lowers the freezing point of the de-icing mixture remains and it remains more effective under such conditions. Additionally, use of this mixture, reduces the bounce and scatter of the rock salt used and decreases the time for the snow to melt.

Recent trend of sugarbeet in world

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Sugarbeet (*Beta vulgaris* L.) has its origin in early nineteenth century from feral and fodder beets (Achard, 1979; Marggraf, 1979). Sugarbeet has been specially selected and bred for sucrose production over the past two centuries (Winner 1993). Nearly sixty countries are cultivating sugarbeet in world (2011). Top fifteen sugarbeet producing countries are Russian Federation, Ukraine, United States of America, Germany, France, Turkey, China, Poland, Egypt, United Kingdom, Iran (Islamic Republic of), Belarus, Netherlands, Italy and Belgium. Sugarbeet is mainly produced in Europe and, to a lesser extent, in Asia and North America. During last ten years (2000-2009), the area under sugarbeet was decreasing at the rate of 0.2 million hectare per year in world consequently its production was also decreasing 1.61 million tonnes per year in the world. World sugar production by sugarbeet has shown declining trend of 0.24 million tonnes per year. Roughly twenty per cent of world sugar produced comes from sugarbeet only. But the sugarbeet yield had positive linear growth with increase of 1.46 t/ha per year. Production does not exactly follow the same pattern as the drop in sugarbeet area has been mitigated by a significant increase in yields. In recent years, world sugarbeet harvested area has shown increasing trend. Among sugarbeet and sugarcane, sugarbeet accounts for only 16 to 20 % area of the world where as production accounts for only 11 to 13 % of the world. During 2011, sugarbeet had 5.06 million hectare area, 272 million tonnes of production with yield of 53.66 in world. The sugar reforms of the European Union Common Market Organization were adopted in 2006. The reforms cover a transitional period from 2006-07 to 2009-10 after that the impact has shown the results. The sugarbeet area in European Union countries (EU) has increased from 1546 thousand hectare to 1602 thousand hectare in recent years, during 2009-10 to 2011-12. One of the main goals of the reforms is to reduce sugar quota production by 6 million tons, white value, through voluntary quota reductions and through lower intervention prices. So far, in-quota sugar production has decreased by 5.8 million tons. Although duty-free access to EU markets by least developed countries began in October 2009 under Everything-but-Arms, non-preferential countries continue to face prohibitive import duties on sugar. Common Agricultural Policy of European Union (CAP) reforms continue in the EU. The sugar reforms of the EU Common Market Organization, which were adopted in 2006, were successful in reducing sugar quota production through voluntary quota reductions and lower intervention prices. To date, in-quota sugar production has decreased by 5.8 million tonnes (white value), just under the 6 million tonnes target. The EU's Renewable Energy Directive has a goal of 20 percent share for renewable energy in total energy consumption. In Russia (highest sugarbeet producing country) also, area under sugarbeet increased from 900 thousand hectares in 2009-10 to 1190 thousand hectares in 2011-12. In EU, Sugarbeet is financially more attractive than COP crops (Cereal, Oilseed and Protein crops) both in terms of gross margin as well as margin over total input per ha (before and after subsidies). In contrast with COP production, where the positive margins depend on the presence of subsidies, the greatest profitability of sugarbeet depends on a system of relatively high prices (Annon., 2003).

From Agricultural Outlook 2009-2018 (Annon., 2009), the EU could emerge as the leading global sugar importer, on account of sectoral reform that has led to a huge structural contraction in sugar production and sugarbeet cultivation. The majority of sugar inflows to the EU will be sourced under preferential import arrangements with the African, Caribbean and Pacific (ACP) countries in the context of new Economic Partnership Agreements (EPAs) and with Least Developed Countries (LDCs) under the Everything-But-Arms initiative, but uncertainty prevails regarding export capacity and incentives in many of these countries

Genetic diversity of sugarbeet evaluated by microsatellites DNA markers

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Sugarbeet (*Beta vulgaris* L.) a member of the family Chenopodiaceae is an important crop for sucrose production in the temperate climate zone. At present, hybrid varieties account for most of the sugarbeet production around the world. Although, hybridization with wild types has occurred, the genetic base of sugarbeet is assumed to be quite narrow. Molecular markers reflect the actual level of genetic variation existing among genotypes at the DNA level and therefore have been widely applied in population genetics research. To gain information on genetic variation and diversity within the sugarbeet breeding material, a set of breeding lines developed in India as well as from the germplasm collection at IISR, Lucknow have been analysed using fourteen SSR primer pairs comprising of dinucleotide and trinucleotide SSR motifs. Two hundred and forty three amplicons were obtained which were grouped into alleles of distinct molecular weight having sufficient polymorphism. Thus, a total of 88 alleles were scored across 13 varieties with molecular weight ranging from 124 to 1222 bp. Each SSR locus produced from four to 10 alleles and most of these alleles showed clear separation. All the primers showed complete parsimony and were very useful for diversity purpose. Each of the fourteen SSR loci displayed high levels of heterozygosity and moderate to high PIC values ranging from 0.625 – 0.851. The Dice similarity coefficients for SSR markers ranged from 0.01 to 0.73 with a mean similarity coefficient of 0.28 suggesting that these sugarbeet genotypes were quite diverse. Molecular diversity in these sugarbeet genotypes became apparently clearer through the dendrogram generated by UPGMA based cluster analysis. Two taxonomical groups were clearly resolved. The first taxonomical group consisted of eight varieties and the other taxonomical group clubbed the rest five varieties. Although this study describes only fourteen SSR loci, the amount of information is quite high and the study shows that microsatellite markers can be used as a potential cost effective method for molecular diversity analysis of sugarbeet in order to select the best parents and to obtain new genetic combinations.

Fermentation of sugarbeet pulp to cellulase and its partial characterization

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Sugarbeet pulp, the residue of sugarbeet processing, is low in sugar but high in fiber content. It contains 10 percent protein, 0.8 percent calcium and 0.5 percent phosphorus. In this study, the pulp was used for cellulase production using *Trichoderma sp*. Medium containing 5% (w/v) sugarbeet pulp at pH 5.5 exhibited maximum CMCase (0. 687 ug/ml/min), Cellulobiase (3.549 ug/ml/min) and FPase (0.152 ug/ml/min) production. It was observed that alkaline pretreatment suits FPase production. On 5^{th} day of incubation at 40^{0}C the CMCase (0.734 ug/ml/min) production was found maximum and cellulobiase production was higher (3.998 ug/ml/min) on 5^{th} day of incubation at 30^{0}C while FPase production was maximum (0.157 ug/ml/min) on 2^{nd} day of incubation at 30^{0}C incubation temperature. The protein concentration was found maximum on 2^{nd} day of inoculation (5.326 mg/ml). Purification to an extent of 20.86 fold was achieved by affinity column chromatography. Bands corresponding to 28.0 and 36.0 kDa molecular sizes were observed on 12% denaturing Sodium dodecyl sulphate-polyacrylamide gel electrophoresis (SDS-PAGE) while of 78.0 kDa on 10% non- denaturing Native-PAGE, proving its heteromeric multi-enzyme nature. The enzyme was stable over a range of 20-60^{o}C and pH of 3.5 -7.5.

Current status of sugarbeet production in India: Problems and future scenario

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Sugarbeet is an important root crop primarily cultivated in temperate countries. It became a key source of sugar in the 19th century when methods of sugar extraction from sugarbeet were invented and became popular. The sugarbeet roots contents 16-21 % sucrose vary depending on the cultivar and climatic conditions. The sugar recovery from sugarbeet used to be 3-4 % higher as compare to sugarcane. The world's sugarbeet production during 2011 was nearly 272 million tons with average productivity of 58.2 tons/ha. The Russia was the largest producer of sugarbeet with the annual production of 47.6 million tons followed by France, USA, Germany and Turkey in 2011-12.The global sugar production was 174 million tons and sugarbeet contributes nearly 20 percent of total sugar production and 10 percent bio-fuel in the form of ethanol production. Keeping in views, the economic importance of sugarbeet in sugar and ethanol production, some sub-tropical countries such as India initiated sugarbeet cultivation in some states under All India Coordinated Research Project (AICRP) on sugarbeet during1960's. The multinational company Syngenta India Ltd. had developed thermo insensitive varieties such as HI0064, Dorotea and Posada and were grown on experimental basis in 38 sugar factories in Maharashtra. Based on experimental trials conducted at various locations, sugarbeet cultivation was started in Sri-Ganganagar, Rajasthan for sugar production and in Sundarban, West Bengal for alcohol/ ethanol production. The sugarbeet is the short duration and salt tolerant crop compared to sugarcane. It matures in 5-6 month and grow successfully on saline soils where other crops fails. A Network Project to develop agronomical techniques for cultivation of sugarbeet in India was initiated by ICAR during 2004-07, with centers at VSI, Pune, RRS, Sangli, IISR, Lucknow and Sriganganagar. The experimental findings revealed that the productivity of sugarbeet grown in winter season was 60 -75 t/ha. However, the sugarbeet productivity was on 30-35t/ha at farmers field. Amongst the variety, HI0064 was the best followed by the IISR, Lucknow varieties i.e. LS-6 and IISR Comp-1. However, it is necessary to test these genotypes of sugarbeet for their performance related to quality parameters, and incidence of pests and diseases under Indian conditions. Sugarbeet is not only the good source of sugar, but also provides many by-products such as ethanol, cattle feed etc. The molasses of sugarbeet may be used in pharmaceutical industry for production of vitamin B_{10} and B_{12}. The pharmaceutical companies enthusiastic to buy sugar molasses extracted from sugarbeet due to better quality compared to molasses produced from sugarcane. There is need to develop sugarbeet processing industry so that the farmer's should reap the better economic returns. Sugarbeet may be explored as an alternative crop for sugar and ethanol production, keeping in view the trends of depleting natural resources for sugarcane production in future.

Optimizing irrigation water and land need for sugar production through intercropping sugarbeet in autumn planted sugarcane

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Sugarcane and sugarbeet are the major raw material for production of white sugar. Cultivation of sugarcane is highly water intensive but plays a vital role in economic development of farmers. The small growers having limited resources are not in a position to afford such a long duration sugarcane crop with heavy initial investment and water requirement. So, there should be a source of interim income compensating the initial investment with ultimate improved benefit to the farmers. Sugar production cost is also required to be lowered either by improving sugar recovery of cane or by utilizing land and water resources efficiently through intercropping. Autumn planted sugarcane and sugarbeet can be grown side by side. Sugarbeet is known for its high tolerance to saline and alkaline conditions and irrigation requirement is fairly low, not more than 4 to 5 irrigations amounting to 37.5 – 60 cm would be required for the purpose. Winter sugarbeet is a 6-7 months crop, sown in October and harvested in April and May. Sugarbeet is favoured by a long and moderately cool growing season, warm days and fairly cool night, favour rapid growth. These facts reveal that sugarbeet is not only the supplement crop of sugarcane but also can be grown with sugarcane. Sugarcane and sugarbeet inter cropping system may expand the crushing season of sugar industry up to 40-45 days and may also improve the overall sugar recovery per unit time per unit water and per unit area with ultimate reduced cost of sugar production. Intercropping of sugarbeet with sugarcane improves the profitability to a farmer by 50-55 per cent over growing sugarcane as mono-crop. Results of experiments conducted in Pakistan revealed that maximum cane yield of intercropped sugarcane (101.50 t/ha) with sugarbeet yield of 59.74 t/ha was obtained when sugarcane was planted at 120 cm apart in trenches with one row of sugar-beet in between. Maximum income was also recorded in the same treatment (1,61,245 Rupees per ha) as against alone sugarcane 1,04,588 Rupees per ha and alone sugarbeet 99,141 Rupees per ha. In yet another experiment, the highest significant average root yield of 102.48 t/ha and cane yield of 104.0 t/ha with higher average sugar recovery of 15.85 and 8.33% were found each for sugar-beet and sugarcane in treatments where single row of sugar-beet was sown in between 90 cm spaced sugarcane rows. The same treatments also showed the maximum average sugar yield of 16.28 and 8.87 t/ha each for sugarbeet and sugarcane. Sole crop of sugarcane exhibited the highest significant average cane yield i.e. 107.38 t/ha with sugar yield as 10.11 t/ha and sugar recovery of 9.36% in treatment with rows 90 cm apart. The efficiency of water use in sugarbeet was 3.7 t sugar/ha-Ml which exceeds the efficiency for sugarcane which is around 1.7 t sugar/ha-Ml. Efficiency of water use for sugarbeet is higher than for sugarcane as sugarbeet is grown in the winter period when irrigation losses to surface evaporation and transpiration are a lot less. It can thus be concluded that intercropping of sugarbeet in sugarcane enhances profitability by utilizing land and water resources more effectively.

Problems and prospects of sugarbeet cultivation as fodder crop in subtropical India

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Sugarbeet (*Beta vulgaris*) is generally considered a crop of temperate region. However, its cultivation is spreading to subtropical countries where it can be grown successfully during winter season. Most of the sugarbeet is grown for commercial sugar production, though it is sometimes fed to animals including ruminants as well as pigs. Sugarbeet by-products like sugarbeet pulp and molasses are also fed to animals. Various studies conducted abroad on sugarbeet, sugarbeet pulp and molasses feeding in dairy animals have indicated that feeding of whole sugarbeet or its by-products offers a great potential to be used as livestock feed in developing countries including India. Sugarbeet cultivation in India is being emphasized to impart stability to Indian sugar production as well as to gain from situations of high world sugar prices. Sugarbeet as fodder crop is also viewed as a precursor to main sugar crop so its establishment as fodder crop is also considered important.

The role of extension agencies like KVKs in introducing a new crop like sugarbeet to the farmers thus becomes of paramount importance. Sugarbeet was introduced to Lucknow dairy farmers of selected villages as a fodder crop for the first time in the year 2006-07 by Krishi Vigyan Kendra, IISR, Lucknow. About 250 gms of seed was distributed under Front Line Demonstration programme to 10 milk producers in 2006-07 for growing sugarbeet crop and using its roots and other plants part as fodder for animals. On an average 240 gm seed of sugarbeet was distributed every year to on an average 12 farmers regularly for 5 years. On an average, one farmer cultivated sugarbeet crop in 0.025 ha area which produced 1.6 tons of sugarbeet biomass (roots & leaves in the ratio of 4:1) which was able to meet the green fodder requirement of an average milk producing farm consisting of four lactating animals (50% buffaloes + 50% cows) fed at the rate of five kg/day/buffalo and four kg/day/cow for 90 days from April to June during lean period in summer. Crop planted in the 3rd week of October becomes ready for animal feeding by the 1st week of April.

The KVK intervention of the introduction of sugarbeet fodder crop was found satisfactory amongst selected dairy owners. Observations revealed that 'pregnant but lactating animals' maintained the milk yield level during summer months and did not experience any reduction in the milk yield. 'Animals in first lactation' also observed the same trend. Animal in second and third lactation were reported to produce on an average 0.8 kgs (range 0.5-1.2 kgs) and 1.30 kg (range 0.9-1.5kg) extra milk per day, respectively during the sugarbeet fodder supply period. An average dairy farm produced about 180 kgs to 450 kgs extra milk during lean period when no other fodder crop (even berseem crop) was available in hot summer months. The crop was found to be a boon for enhancing milk productivity of integrated crop and animal husbandry smallholder farms. The sugarbeet has great potential to be used as livestock fodder in our country. The whole sugarbeet as such is very good energy rich feed for livestock. As the cultivation of sugarbeet is becoming popular in the country which might stimulate establishment of sugar factories processing sugarbeet as substrate. As a result, production as well as availability of sugarbeet by-products like sugarbeet pulp and molasses will increase and will also be available as a feed for livestock. However, there are some constraints which need to be rectified soon. The crop needs adequate research and development backstopping for dissemination on a large scale in the district/zone/state. The input supply system pertaining to seed supply of the crop is also not developed and needs to be taken up on priority basis.

Sugarbeet: A supplement to sugarcane in non-traditional areas to meet future sugar demand

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In India, sugarcane is main crop grown for processing of sugar. However, an alternative crop of sugarbeet has an important role in decreasing the production cost, reducing crop period and arresting decline in factor productivity as well as sustaining crop productivity at higher level under abiotic stresses viz., water and salt stresses. In India, approx. 7 milion ha area is under saline and alkali range. Productivity in these soils are very low as compared to normal soils. Sugarbeet has better alternative to bring prosperity in for these areas.

Climatic endowments, soil and water resources are the key factors for high productivity in indo-gangetic plain region. Intensified agriculture coupled with indiscriminate use of irrigation water and heavy application of fertilizers and/ or plant protection chemicals to achieve maximum in production in irrigated areas has, however, led to various kinds of physical and chemical degradation of the soil. Besides, emergence of multi-nutrient deficiencies, the problems of soil salinity, alkalinity and waterlogging also got accentuated. These are termed as second generation problems or ill-effects of green revolution. To sustain continuity of green revolution, one has to tackle these second generation problems amicably. This calls for integration of technologies for conservation and management of resources *vis-a-vis* input use efficiencies while safeguarding the soil health and sustaining the productivity.

At the current level of cultivated area under sugarcane i.e., at about 5 million ha, to meet the sugar demand of country by 2030 which is estimated at about 44.1 m tonnes (@ 30 kg/capita /yr and estimated population 1470 million- Table 1), India would require to produce about 683.72 million tones of cane considering 10.75% sugar recovery and 60% cane drawl for crushing in 488 Sugar Mills. This quantity of sugarcane in future could be made available by increasing the sugarcane productivity from 62 t/ha to 136.7 t/ha (Table 2). Thus our first objective should be to increase crop and land productivity particularly in subtropical region.

Table 1 Growing population and estimated sugar consumption in India

Year	Population in millions	Sugar consumption (m tonnes)		
		@ 20 kg per capita	@ 30 kg per capita	@ 40 kg per capita
2010	1180	23.6	35.4	47.2
2030	**1470**	**29.4**	**44.10**	58.82
2050	1757	35.14	52.71	70.28

Table 2: Estimated growing demand of sugarcane and sugar in India by 2030*

S. No.	Item	Sugar consumption levels (in kg per capita per year)		
		20	30	40
1	Estimated population (millions)	1470	1470	1470
2	Total sugar demand (m tonnes)	29.4	44.1	58.8
3	Sugar recovery (%)	10.75	10.75	10.75
4	Drawl of cane in Sugar Mill (%)	60	60	60
5	Sugarcane required for crushing (m tonnes)	273.48	410.23	546.96
6	Total sugarcane production required (m tonnes)	455.8	683.72	911.6
7	Sugarcane productivity for self sufficiency (tonnes/ha)	**91.16**	**136.7**	**182.3**

Sugarbeet performs well in clayey loam, loam or sandy-loam soils displaying neutral to slightly alkaline reaction with regard to growth and high sugar accumulation. Soils having pH 7.0-8.5 are most favourable for sugarbeet crop. However, it can be grown on salt affected soils having pH range (8.0-9.6). In the Deccan tracts of Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu sugarbeet can be grown on black cotton soils. Sugarbeet requires fairly cool climate, good rainfall or irrigation and bright sunshine during its growth period. Under temperate and sub-tropical climatic conditions the optimum temperature for seed germination is 15-20^{0}C and for growth and sugar accumulation 20-25^{0}C. The optimum temperature for germination of tropical sugarbeet is 25^{0}C and for growth and sugar accumulation 25^{0}C – 35^{0}C.

Genotypes of sugarbeet are being tested for their adaptability under different agro-climatic locations. Some of the following important genotypes have been tested and grown successfully in tropical and sub-tropical agro-climatic regions of the country. These are HI006, Dorotea (Cauvery), Posada (Indus), IISR Comp-1 (Shubra), LS-6, R-06 etc. To obtain optimum plant population of 100000/ha, multigerm seed is required @ 10.0 kg/ha whereas, monogerm 120000 seeds are required for sowing in one hectare area. Field trials have indicated that a row spacing of 50 cm and intra row spacing of 20 cm gave the highest root yield of sugarbeet. This spacing provided about 1,00,000 plants or roots/ha. Therefore, 50 cm x 20 cm spacing has been found to be the best throughout India. Autumn sowing (October) was the best for obtaining higher root yield. Trials conducted to evaluate proper sowing season for sugarbeet in Maharashtra have revealed that winter season (October-November) crop yielded higher than summer (January-February) and rainy season (June - July). Delay in sowing beyond October usually reduces root yields. This indicated that October month proved to be the most suitable for sowing of sugarbeet.

Sugarbeet responds well to fertilizers (NPK) and manures. Soils deficient in potash and boron also respond positively to these nutrients. Sugarbeet requires about 100-120 kg N/ha and 60 kg P_2O_5/ha. Organic manures do have their favourable effect on sugarbeet growth. Thus, it is desirable to apply 10-15 tonnes FYM/ha before sowing, Green manuring in lieu of

FYM can be taken. Nitrogen should be applied @ 120 kg/ha. In loam and clayey loam soils, 40 kg N should be applied at the time of sowing as a basal dose, 40 kg N after one month of sowing and the remaining 40 kg N after two months of sowing. Late application of nitrogen delays crop maturity. Experiments on nitrogen doses have indicated that sugarbeet responds up to 240 kg N/hectare but sucrose content in roots decreases. This suggests that application of 120 kg N/ha is the optimum dose to harvest higher root and sugar yield. Under integrated nutrient management practice, recommended doses of NPK (120:60:60 kg/ha) along with F.Y.M. @ 10.0 t/ha produced the highest root yields at various centres in India. For crop establishment, first irrigation is crucial because of sensitivity of seed to water. Therefore, first irrigation should be given in such a way that water should not flow over the ridges. Depending on the soil type and rainfall, irrigation scheduling is required. For convenient scheduling of irrigation to the crop, cumulative Pan Evaporation (CPE) method has been employed on research farms. Irrigation scheduled at 75 and 50 mm evaporation produced the highest yield of sugarbeet. Under this scheduling, 10-12 irrigations are required to grow a luxuriant crop of sugarbeet.

October sown crop of sugarbeet starts showing signs of maturity by mid-April. Two conspicuous changes occur in the crop: (i) drying of lower leaves and (ii) sugar accumulation (15-16%) in roots and this continues till the end of May. But, by the first week of June, deterioration in juice quality starts. Irrigation should be stopped at least 3-4 weeks before the day of harvesting / lifting. However, if the soil gets too dry and hard for the harvest operation, it is, however necessary to arrange small flush irrigation for softening the soil to facilitate lifting of roots. Running of a country plough close to the rows helps in lifting roots because of loosening of soil. The roots should be detopped just below the crown portion because in this portion, sucrose content is almost negligible. If this portion is not cut, the chances of increasing impurities increase. After the harvest, unwashed roots should be transported immediately to the factory for processing. Delay at the harvest site favours microbial decomposition of roots.

Thus, if sugarbeet crop is promoted by policy makers, industrialist and farmers, it has wide scope in shaping rural economy in India.

Sugar beet a potential new crop for sugar and ethanol production in India

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Tropical sugar beet is yet to be produced in commercial scale in India and it is still considered to be toddling baby in the ethanol industry. Although, few industries are claiming to be using sugar beet as feed stock for ethanol production, its growth has not reached the level expected. JK Agri-Genetics Ltd., leading seed-company of India and KWS, Germany, world leader in sugar beet breeding joined hands (JK-KWS) to introduce real tropical sugar beet hybrids to India. Nation-wide trials from 16 locations, since three years across India (Table 1 and 2 give important locations list), has given some interesting insights in the sugar beet production and processing. The sugar beet growing was found to be profitable compared to the existing cropping systems in the post rainy season in Rajasthan, Punjab, Haryana, Maharashtra and North Karnataka. Farmers are willing to experiment new crop options looking to the profitability of the crop especially in sugar cane growing areas and saline affected areas of south Maharashtra. Sugar beet can be profitably produced in highly saline conditions or saline water irrigations as found from the experiments in Katchh area of Gujarat and Kolhapur area of Maharashtra. Growing salinity in the sugar cane areas warrants use of sugar beet as alternate crop for ethanol or sugar production. Widened cultivation window, storage experiments (indicated possibility of storing beet for three months) and storage possibilities of thick juice provide good scope for the enhancement of factory running period up to 10 months. JK-KWS is introducing new hybrids for India that too for wide range of sowing dates including that of August and December/ January as sowings in September – November has been found to be high yielding.

Trials were aimed in identifying high yielding hybrids in different agro climatic zones, including tolerance to sclerotium, rhizoctonia, spodoptera and nematodes. The salient observations and hybrids identified for different biotic stress has been briefed below

Sclerotium: Hybrids namely 4AEO754, 7KO1, Calixta and Mangnolia showed tolerance to Sclerotium in different trials in India. In commercial farmer fields at Maharashtra and Karnataka states of India, Calixta and Mangnolia also showed tolerance to Sclerotium.

Root knot nematodes: At Pune location, 7 hybrids (Sandrina, Calixta, Mangnolia, 7KO1, 4AEO754, 8K09, 8R81) were tested for root knot nematode screening in Sick plot (400 sq m area) during August 2009. In this field, previous crop was taken Tomato to create a sick plot.

In sick plot trial, very high infection of root knot was found in all the hybrids except 7KO1 and 4AEO754. Among all the hybrids, only 7KO1 and 4AEO754 hybrids survived in this trial.

At Jaipur location, screening was done in natural condition with 12 hybrids namely 4AE0754, 6GS1086, 6K73, 7K01, 8K09, 8R81, Arriba, Calixta, Capitana, Esperanza, Mangolia, and Sandrina. In natural conditions, 4AEO754, 7KO1, 8R81& Calixta hybrids, also showed tolerance to root knot nematodes at Jaipur, Rajasthan location. Based on the two locations data, 7KO1 and 4AEO754 are found to be highly tolerant and 8R81 and Calixta to be evaluated for one more year.

Powdery mildew: Sandrina, Esperanza, Calixta showed tolerance to Powdery mildew in different trials conducted in India.

Cercospora: Hybrids namely, 4AEO754, 7KO1 and 6K73 Showed tolerance to *Cercospora* infection in different trials.

Spodoptera: Among all the hybrids Clixta, Magnolia and Sandrina exhibited tolerance to leaf eating caterpillar.

High yielding hybrids with multiple tolerance level to different diseases have been identified for commercial cultivations. All the hybrids identified their important characters have been listed at the end of this article.

Srignaganagar in North and Jalgaon, Pune /Dharwad in South and West India have been identified for production of good quality beets with 90 – 100 t/ha yield and 16-24 % of Brix reading (Fig 1). These locations attract immediate possibilities for investments for economical ethanol and sugar production. Economics worked out with Rs 2000 (USD 40/ ton) per ton of sugar beet has been considered to be profitable to the farmers. Irrigation requirements ranged from 5-8 based on the soil conditions for the crop of 150 days. Higher yields in sugar beet depend on the plant population, which should be ideally 100,000 / ha and this can be achieved by very good land preparation at the planting time. Beet size of 1.0 –2.0 kgs have been found to have good sugar content and with increased size the sugar content tends to lower down.

Sugar beets are also highly suited for saline conditions; they produce highest usable biomass than any other crop in medium to highly saline conditions. Both Magnolia and Calixta were found to be highly adapted to the saline conditions (Table 3). Initial indications are that cultivation of Sugar beet in the long run in saline condition might help in significantly improves the soil health in saline conditions.

JK Agri Genetics and KWS are working together with Sri Renuka Sugars in Karnataka and Maharashtra for commercial cultivation of the Sugar beet. Magnolia and Calixta have been introduced in the target area successfully. Crop care extension has been found to be very essential factor in improving the crop yield. Yield ranging from 16 to 28 tons per acre were observed in the project area. Farmers have been very happy and likely to increase the area for Sugarbeet cultivation in Karnataka and Maharashtra.

Large scale demonstrations were made with Somaya Sugars in Smeerwadi Karnataka, which were also found to be highly profitable. Commercialization possibility in these areas is high. We envisage very good growth will come from this area in another two to three years. Technology for mechanical harvesting will substantially improve the prospects of this crop in India.

The support form the Government for the speedy introduction of sugar beet is essential as there is requirement of huge investment on machinery for processing, which can be exempted from the taxes and can be partly subsidized with low interest loans. There is huge scarcity of manpower for the technology transfer of the sugar beet cultivation in India, which might require the participation of seed companies, industries and government development departments. As an incentive to promote the new crop introduction in India, an initial subsidy in crop production will help to speed up the crop introduction. This subsidy will help farmers to take initial risk of opting to grow the crop. Sugar beet hybrids seed production technology is yet be seen India, currently we are producing seed in Europe and bringing in India, this attracts more than 18% custom duty, which should be exempted to speed up the process of introduction. More machines of diverse nature to be introduced to ease harvesting process, and such machines import should also be facilitated with least customs duty. Considering fluctuation of sugarcane production and international molasses prices and sugar beet can be a profitable alternative crop for the ethanol industry. Sugar beet produces more quantity of ethanol/sugar with half time land required, half the number of irrigations, lesser nitrogen compared to sugar cane indicating the crop contributes food/water/fertiliser security of the country.

Table 1: List of different industrial collaborators for sugar beet crop development in India from 2009 onward.

S. No.	Organization	Location	State
1	Crystal Energy and Foods Ltd.	Kalanur	Punjab
2	Mohan Meakings and Breweries	Abohar	Punjab
4	Excel Crop Care Ltd.	Bhuj	Gujarat
5	Tata Chemicals Ltd.	Aurangabad	Maharashtra
6	Ugar Sugars Ltd.	Ugar	Karnataka
7	Somaiya Organics Pvt. Ltd.	Sakarwadi	Maharashtra
8	Crest Biotech Pvt. Ltd.	New Delhi	New Delhi
9	Purti Sugars Ltd.	Nagpur	Maharashtra
10	Shree Renuka Sugars Ltd.	Athani, Belgaon	Karnataka
11	Somaiya Sugars Ltd.	Sameerwadi	Karnataka

Table 2: List of different adaptive trials locations for sugar beet crop development in India from 2009 onward.

S. No.	Organization	Location	State
1	Vasantdada Sugar Institute	Manjari	Maharashtra
2	Indian Institute of Sugarcane Research	Lucknow	Uttar Pradesh
3	Rajasthan Agriculture University	Sri Gagnganagar	Rajasthan
4	ARS, MPKV Maharasthra	Kasbe Digras	Maharashtra
5	Pune R&D Centre (JKAL)	Vadagaon	Maharashtra
6	Sriganganagar R&D Centre	Sadhuwali	Rajasthan
7	JK Sugars	Bareilly	Uttar Pradesh
8	JK Laxmi Cement	Sirohi	Rajasthan
9	MPUAT	Udaipur	Rajasthan
10	Chemtrol Engineering Ltd.	Belgaum	Karnataka

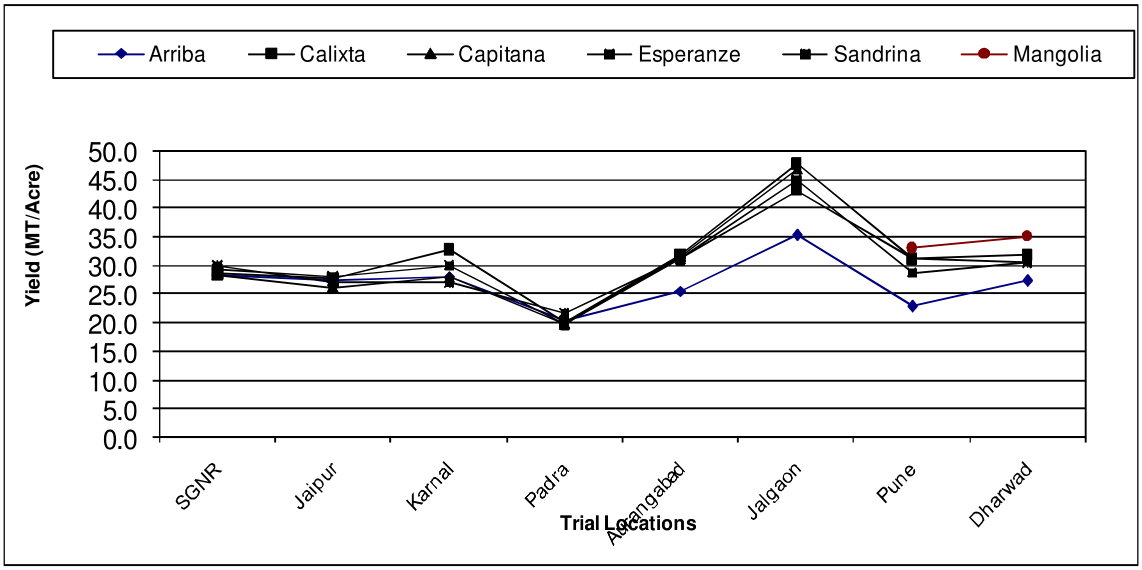

Fig 1: Average yield of sugar beet JK KWS hybrids at different locations of India 2007-11

Table 3: Soil improvement data after sugar beet growing farmers of Maharashtra and Karnataka state season 2011-12

Beet Grower Name	Village	District	Variety Grown	Soil testing Before Sowing		Soil testing after Sugar beet Harvest		Change in pH and EC (m mol/l) after beet crop grown		Beet root yield
			JK Seeds	pH	EC	pH	EC	pH	EC	MT/Ac
Aryant Birnale	Mouje Digraj	Sangali	Magnolia	8.6	5.2	8.5	3.8	0.1	1.4	19.5
Murgapp Budani	Sankaretti	Belgaum	Magnolia	7.9	2.7	7.9	2.2	0	0.5	19.1
Bramhkumar Madhabavi	Darur	Belgaum	Magnolia	8.5	3.8	8.4	1.2	0.1	2.6	13.0
Kalappa Yeladgi	Shegunsi	Belgaum	Magnolia	8.5	2.7	8.5	1.2	0	1.5	13.4
Narsappa Terdal	Hulugbal	Belgaum	Calixta	8.4	4.8	8.2	4.5	0.2	0.3	10.7
Raju Terdal	Hulugbal	Belgaum	Calixta	8.5	3.7	8.4	3.3	0.1	0.4	11.2
Seetal Math	Terdal	Bagalkot	Magnolia	8.4	5.6	8.4	4.5	0	1.1	19.1
Basavprabhu Telginmani	Terdal	Bagalkot	Magnolia	8.6	3.7	8.6	2	0	1.7	18.0
Hanmanth Imanavar	Ingalgi	Bagalkot	Calixta	8.6	1.3	8.6	1.2	0	0.1	14.9

JK Agri-Genetics Ltd, Hyderabad and KWS Germany introduces following hybrids for cultivation in different agro-climatic zones of India.

Arriba

- Very high levels tolerance to *Rhizoctonia*
- Tolerance to foliage feeders due to thick lamina
- Adaptability : North India

Calixta

- Very high levels tolerance to *Rhizoctonia*
- Medium to high level of tolerance to Powdery mildew
- Tolerance to foliage feeders
- Excellent variety for saline soil cultivation
- Adaptability : North India, South and South West India
- High yielding

Magnolia

- Very high levels tolerance to *Rhizoctonia*
- High level of tolerance to Powdery mildew
- Tolerance to foliage feeders
- Tolerance to Sclerotium root rot and Cercospora leaf spot
- Comparatively requires less irrigation or sustains water stress, harvest friendly
- Adaptability : North , South and South West India

Sandrina

- Very high levels tolerance to *Rhizoctonia*
- Tolerance to Powdery mildew
- Tolerance to foliage feeders
- Tolerance to Sclerotium root rot and Cercospora leaf spot
- Adaptability : North India

Esperanza

- Very high levels tolerance to *Rhizoctonia*
- Tolerance to Powdery mildew
- Adaptability : North India

7KO1

- Very high levels tolerance to *Rhizoctonia*
- High level of tolerance to Powdery mildew
- Tolerance to foliage feeders
- Tolerance to Sclerotium root rot and Cercospora leaf spot
- Adaptability : North , South and South West India
- Very high yielding

Registration of sugarbeet varieties in India: a pressing need for future

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Since its introduction to India in 1950's, to date, when efforts are on to popularize tropicalized sugarbeet, the role of imported varieties has been in the fore front for making the sugarbeet cultivation possible. The efforts made by the research institutions of India in maintenance, evaluation and documentation of sugarbeet germplasm as well as finalization of agronomical practices for its successful cultivation in different agro-climatic conditions, deserves due credit. Now, with Protection of Plant Varieties & Farmers' Rights Act, 2001 already enacted, the future of varietal development programmes, either based on introduction of varieties or breeding varieties in India, will definitely be governed by this law. Thus, it is now high time to initiate the development of DUS Testing guidelines for sugarbeet, both fodder and sugar production types. A perusal of the available guidelines under UPOV system indicates that a lot of progress has already been made for the morphological characterization of sugarbeet varieties. The characters in the UPOV guidelines need verification under Indian conditions and their applicability for Indian germplasm can be studied in a short period.

As per the UPOV guidelines, there are two separate set of characteristics available for DUS Testing of fodder beet and beet root. Under fodder beet (*Beta vulgaris* L.) two characters are considered for grouping of varieties viz. Germity and Ploidy. There are 20 characters in the table of characteristics for fodder beet including those related to germity (1), ploidy (1), hypocotyl (1), leaf (7), petiole (2) and root (8). For beet root, there are 05 grouping characters viz. Germity, Leaf blade: color, Root: shape in longitudinal section, Root: external color and Bolting tendency (from an early sowing). The table of characteristics include 27characters including those related to germity (1), seedling (1), leaf (3), leaf blade (8), petiole (2), root (11) and bolting (1).

Thus, it can be inferred that the necessity of registration of sugarbeet varieties for IPRs under PPV&FR Act, 2001 is the need of the hour and it can be taken-up by adopting available UPOV guidelines after verification in Indian conditions and over available germplasm.

Sugarbeet diseases and their management

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Sugar is mainly obtained from two crops i.e. sugarcane and sugar beet. Sugar beet (*Beta vulgaris* L.) is the second most major source of sugar in the world and contributes about 20-25% of the world sugar production. Sugarbeet, is a temperate region crop but can also be grown in sub-tropical areas, like India, Bangladesh, Pakistan, etc. In India, it is successfully grown in Uttar Pradesh, Uttarakhand, Maharashtra, Punjab, Rajasthan, Karnataka and Andhra Pradesh.

Several factors are responsible for its low yield and poor sugar content of which the diseases caused by plant pathogens are of major concern. Several etiological agents such as fungi, bacteria, viruses and nematodes can cause various diseases to this crop but seedling, root rot and foliage disease are of major importance. In India, the seedling diseases are mainly caused by *Pyhtium aphanidermatum*, *P. ultimum*, *P. debaryanum, Rhizoctonia solani, Sclerotium rolfsii, Phoma betae* etc. Among the foliar diseases, leaf spot caused by *Cercospora beticola* is one of the most widespread and destructive of both root and seed crop. In seed crop, it adversely affects the size and quality of the seeds. In addition leaf spot caused by *Alternaria alternata* and *A. brassicae*, bacterial leaf spot caused by *Pseudomonas aptata* and powdery mildew caused by *Erysiphae betae* are also common in some areas. Being a root crop, root diseases are of utmost importance as it directly affects the yield and quality. Among the root diseases, root rot caused by *Sclerotium rolfisii*, charcoal rot caused by *Rhizoctonia bataticola*, *Rhizopus*rot and *Fusarium* root rot caused by *Fusarium* sp. rot are most destructive and also considered important in certain areas.

Besides, nematode diseases caused by *Meloidogyne javanica* and *M. incognita* and nematode fungus complex (*Melodogyne* spp. + *Pythium* or *Rhizoctonia* spp.) are also considered as a big challenge for sugar beet production. Non-parasitic diseases, like heart rot (Boron deficiency), tip burn (Calcium deficiency) etc has been also reported with considerable economic importance.

Disease management:

- Cultural practices like, early sowing of crop, burning of infected crop debris, crop rotation with suitable non-host crops, soil amendment with groundnut, mustard or neem cakes, proper drainage and judicious irrigation (less than 8-10) and fertilizer application (NPK) are effective to minimize the incidence of various diseases.
- Seed treatment with Thiram @2g/kg or Bavistin @1.0 g/kg using bentonite clay as base material and methyl cellulose as sticker have been found effective in containing seed borne and seedling diseases.
- Seedling and root rot disease can be contained through the application of bio-agents (*Trichoderma viride* or *T. harzianum*) @ 20 kg/ha at the time of planting followed by seed pellating with bio-agents or drenching with Bavistin @ 0.5% or Thiram @ 1.0%@ at 45 days after sowing.
- Grow tropicalized varieties *viz.*, LS-6, IISR- Comp 1 and Ramonskaya 06.