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REVIEW ARTICLE

Sugarcane and Sugar Industry in Bangladesh: An Overview

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Abstract The current production of sugar in Bangladesh is only about 5% of total demand. About 20% demand is fulfilled by jaggery production mainly from sugarcane and remaining 75% of total requirement is fulfilled by importation. The main causes of lower sugar production of the industry include less supply of sugarcane in the factories and very poor sugar recovery. The area under cane cultivation is drastically reduced due to pressure of cereals and other short-duration crops which cause lower amount of sugarcane production. The yield of cane per unit area is lower than the other sugar producing countries. The government of Bangladesh is emphasizing the attainment of self-sufficiency in sugar and jaggery production by boosting up the sugarcane production in the country. Moreover, the government has taken some steps to introduce tropical sugar beet for sugar production. Considering this aspect, Bangladesh Sugarcrop Research Institute (BSRI) has developed and recommended a good numbers of sugarcane production technologies from planting to harvesting. The technologies include releasing of a large number of high yielding, high sugar content, diseases and pest resistant sugarcane varieties, intercropping with sugarcane, spaced transplanting technology, ratoon management technology, diseases and pest management technology, updating the fertilizer dose for 12 agro-ecological zones and development of some important implements for sugarcane cultivation. BSRI released some varieties which are suitable for jaggery production and some are abiotic stress (drought, water-logging, saline and flood) tolerant. Moreover, BSRI has been doing research on tropical sugar beet to introduce its cultivation in the country. Introduction of sugarcane in the river basins, plain land of hilly areas and the saline areas can considerably increase the sugarcane production. Furthermore, if the BSRI-recommended technologies are followed properly, the sugarcane production and thereby sugar and jaggery production will be certainly increased.

Keywords Bangladesh · Sugarcane · Sugar industry · Jaggery · Sugar beet · Saline area

Introduction

Sugarcane is the important cash-cum industrial crop and only the source of white sugar in Bangladesh. It occupies about 1.52% of the country's total cultivable land in every year (Anonymous 2016a, b). Among the cash crops, sugarcane ranks second, and among major field crops, it ranks third in the country. Its cultivation is concentrated mainly in the low-rainfall belts of the northwestern parts of Bangladesh. Less productive river basins (*Char* lands) and plain lands of hilly areas are also being increasingly brought under sugarcane cultivation. It is also traditionally grown in the high lands of the central parts of Bangladesh. The sugar industry of Bangladesh consists of 15 sugar mills under Bangladesh Sugar and Food Industries Corporation (BSFIC). Most of the sugar mills are located in the northwestern zones of the country where concentration of growing sugarcane is high. Currently, on an average, sugarcane is grown in 0.13 million ha of land of which about 50% is located in the sugar mills zones, where sugarcane is mostly used for sugar production and remaining 50% is situated in the non-mill zone, where sugarcane is mostly used for jaggery production and chewing purposes.

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Fig. 1 A sugar mill located at Thakurgaon, Bangladesh

Presently, on an average 5.79 million metric tons (MMT) of sugarcane is being produced in Bangladesh. Out of them, 1.56 MMT are used by sugar mills to produce 0.10 MMT of sugar and 3.50 MMT are used to produce 0.35 MMT of jaggery and remaining 0.87 MMT are used for seed and chewing purposes (Anonymous 2015b). The increasing demand of sugar is caused by increasing of population. A large amount of sugar is being imported every year to meet up the rising demand. However, government of Bangladesh is taking various initiatives to produce more sugar and jaggery in the country. Moreover, government wants to introduce sugar beet instead of sugarcane cultivation where the growers are diverting to other short-duration crop. The present scenario of sugar, sugarcane and jaggery production including the progress of sugarcane research in Bangladesh is briefly discussed in this paper (Fig. 1).

Current Status of Sugarcane, Sugar and Jaggery Production in Bangladesh

Bangladesh sugar industry in mill zone at a glance (2014–2015). *Source*: BSFIC (2015b)

Area	0.06 (Million ha)
Sugarcane production	2.65 (MMT)[a]
Yield	42.31 (tha^{-1})
Number of factories in operation	15
Average milling duration	120 (days)
Average capacity	1200 ($ton\ day^{-1}$)
Total cane crushed	1.22 (MMT)[a]
Total sugar produced	0.07 (MMT)[a]
Average sugar recovery	6.36%
Molasses produced	0.05 (MMT)[a]

[a] *MMT* Million metric tons

Sugarcane Production

Over the years, the total area under sugarcane, sugar and jaggery production in Bangladesh is fluctuating. Several factors are responsible for these fluctuations. The reduction in area is occurring due to increasing of cultivation of cereal and other vegetable crops and lower price of cane compared to other competing crops. As a crop, sugarcane is suffering from threatening of cereal food and other short-duration crops. As a result, sugarcane cultivation has been pushed to marginal less fertile land where other crops are not grown well. Average sugarcane area, percent sugarcane used for the production of sugar, jaggery, seed and chewing during 1992–2002 and 2005–2006 to 2014–2015 are presented in Table 1. The table shows, during 1992–2002, the total area under sugarcane cultivation was 0.17 million ha, but the area of sugarcane during 2005–2006 to 2014–2015 has reduced to 0.13 million ha. Simultaneously, the sugar production and sugar recovery were decreased from 2.28 to 1.56 MMT and from 7.68 to 6.85%, respectively. From Table 2, it is revealed that the average yield of cane in the mill zone and non-mill zone is 45.81 and 41.02 tha^{-1}, respectively. The causes of lower yield in the non-mill zone compared to mill zone includes lack of recommended high yielding sugarcane varieties, absence of disease-free clean seeds program and finally not following modern cultivation technologies. Department of Agricultural Extension (DAE) is responsible for sugarcane technology transfer in non-mill zone. In fact, the extension workers of DAE become always busy with cereal and other short-duration crops except sugarcane (Fig. 2).

Sugar and Jaggery Production

The production capacity, actual production and capacity utilization of 15 sugar mills during 2005–2006 to 2014–2015 production years are presented in Table 3. The present average annual sugar production capacity of 15 sugar mills is 0.21 MMT. With the present production capacity, the country produces an average 0.10 MMT of sugar annually. Average capacity utilization is almost 50.00% of all sugar mills. There are many ups and downs of the sugar industries in the country. The main factor for attributing the production variation is availability of sugarcane to the sugar mills. Sugarcane availability to the sugar mills is subjected to depend on (1) overall production of sugarcane in the country and (2) diversion of sugarcane to jaggery making. The sugarcane production of mill zone was 3.23 MMT, but the sugarcane used for sugar production was only 1.56 MMT. That large amount of sugarcane was diverted into jaggery production (Tables 1, 2). The diversion of sugarcane to the jaggery

Table 1 Area (under mill and non-mill zones) and production of sugarcane, and the recovery of sugar and jaggery in Bangladesh. *Source*: Anonymous (2015a)

Year	Area under mill and non-mill zone (Million ha)	Sugarcane produced (MMT)	Sugarcane used for production (MMT)			Production (MMT)		Recovery (%)	
			Sugar	Jaggery	Seed and chewing	Sugar	Jaggery	Sugar	Jaggery
1992–2002	0.17	7.17	2.28	3.81	1.07	0.17	0.38	7.68	10.00
2005–2006	0.14	5.51	1.85	2.89	0.77	0.13	0.30	7.14	10.00
2006–2007	0.15	8.23	2.33	2.63	0.80	0.16	0.27	7.07	10.00
2007–2008	0.15	4.09	2.29	4.03	1.05	0.16	0.30	7.16	10.00
2008–2009	0.14	5.85	1.12	4.88	1.02	0.08	0.46	6.75	10.00
2009–2010	0.10	5.67	0.87	3.90	0.91	0.06	0.37	7.17	10.00
2010–2011	0.12	6.64	1.58	4.05	1.01	0.10	0.38	6.38	10.00
2011–2012	0.13	6.29	1.04	3.97	1.08	0.07	0.37	6.61	10.00
2012–2013	0.10	5.24	1.56	2.86	0.51	0.10	0.35	6.86	10.00
2013–2014	0.12	5.51	1.82	2.92	0.77	0.12	0.28	7.06	10.00
2014–2015	0.11	4.96	1.21	2.95	0.79	0.07	0.30	6.37	10.00
Mean (2005–06 to 2014–15)	0.13	5.79	1.56	3.50	0.87	0.10	0.35	6.85	10.0

Table 2 Area and production of sugarcane and their yield in the mill and non-mill zones in Bangladesh. *Source*: Anonymous (2015a)

Year	Area under sugarcane cultivation (Million ha)		Sugarcane production (MMT)		Yield (tha^{-1})	
	Mill zone	Non-mill zone	Mill zone	Non-mill zone	Mill zone	Non-mill zone
2005–2006	0.07	0.07	3.72	2.87	49.28	41.00
2006–2007	0.08	0.06	4.11	2.53	49.19	42.25
2007–2008	0.09	0.06	4.05	2.65	46.09	44.21
2008–2009	0.08	0.06	3.04	2.47	38.59	41.25
2009–2010	0.05	0.05	2.38	1.86	45.75	37.20
2010–2011	0.07	0.06	3.04	2.42	46.52	40.35
2011–2012	0.06	0.07	2.95	2.96	46.14	42.30
2012–2013	0.06	0.04	3.10	1.64	47.90	41.23
2013–2014	0.07	0.05	3.26	1.89	46.30	37.85
2014–2015	0.06	0.05	2.66	2.12	42.35	42.56
Mean	0.07	0.05	3.23	2.34	45.81	41.02

making is caused for higher jaggery price in the market. During the last 10 years (2005–2006 to 2014–2015), the sugar industry of Bangladesh produces on average 0.10 MMT of sugar at the rate of only 6.85% sugar recovery (Table 1). As a result, the sugar industry is incurring huge losses in every year. The total losses of 15 sugar mills for 7 years during 2006–2007 to 2012–2013 is 13856.40 million taka which is equivalent to 177.64 million US$ (Anonymous 2011–2012; Anonymous 2012–2013). Losses are mainly due to low sugar recovery percent, inadequate supply of sugarcane, lower yield of cane per unit area, higher cane price offered by the jaggery maker in the mill zone and underutilized capacity of the mills and which resulted per unit overhead cost of production increases too much.

Demand and Shortage of Sugarcane, Sugar and Jaggery in Bangladesh

Sugarcane is the main source of white sugar and jaggery in Bangladesh. According to FAO recommendation, the minimum per capita annual consumption of sugar should be 13.0 kg. Therefore, based on the FAO recommendation for 163 million people of Bangladesh, the total annual requirement of sugar is 2.12 MMT. However, during 2014–2015, only 0.07 MMT sugar and 0.30 MMT jaggery have been produced in the country. The shortfall of sugar is 1.75 MMT, and this big demand is met from importation. Jaggery consumption is traditionally popular in Bangladesh which causes higher price of it. Due to increasing of population, the per capita jaggery consumption is getting

Fig. 2 Sugarcanes are supplied in the sugar mill

reduced. However, the shortfall of jaggery cannot be met from importation, because jaggery is not available in the international market. Therefore, there is an ample scope of increasing the production of sugarcane, sugar and jaggery and their by-products through research and extension. The domestic production of sugar and jaggery will not only meet our sugar demand but also save the valuable foreign currency. Moreover, sugar industry plays an important role to develop infrastructure in rural area, rural employment, income of the farm families, contribution to national exchequer, foreign exchange saving and value addition to the sugar, jaggery and as well as by-product industries.

Progress of Bangladesh Sugarcrop Research Institute (BSRI)

Development of High Yielding and High Sugar Content Varieties

Bangladesh Sugarcrop Research Institute (BSRI) has developed and released so far 45 high yielding sugarcane varieties that are resistant to major diseases and insect pests. Among them, the important varieties now under cultivation are: Isd 2/54, LJC, Isd 16, Isd 19, Isd 20, Isd 21, Isd 22, Isd 24, Isd 25, Isd 26, Isd 27, Isd 28, Isd 29, Isd 30, Isd 32, Isd 33, Isd 34, Isd 35, Isd 36, Isd 37, Isd 38, Isd 39, Isd 40, BSRI Akh 41, BSRI Akh 42, BSRI Akh 43, BSRI Akh 44 and BSRI Akh 45. Presently, BSRI-released sugarcane varieties have covered almost 99% areas of the mills zones and about 55% areas of the non-mills zones (Table 4).

Sugar Recovery

BSRI has developed so many varieties having more than 12.0% sugar content. Surprisingly, when the varieties are processed under the sugar mills, the recovery goes below

Table 3 Production capacity, actual production and capacity utilization of 15 sugar mills during 2005–06 to 2014–15. *Source*: Anonymous (2015b)

Production year	Annual sugar production capacity (MMT)	Sugar produced (MMT)	Capacity utilization (%)
2005–2006	0.21	0.13	61.90
2006–2007	0.21	0.16	76.19
2007–2008	0.21	0.16	76.19
2008–2009	0.21	0.08	38.09
2009–2010	0.21	0.06	28.57
2010–2011	0.21	0.10	47.62
2011–2012	0.21	0.07	33.33
2012–2013	0.21	0.10	47.62
2013–2014	0.21	0.12	57.14
2014–2015	0.21	0.07	33.33
Mean	0.21	0.10	50.00

7.0% of sugar. Therefore, there is a wide gap between potential and actual sugar recovery achieved by the sugar mills. This low sugar recovery percent by the sugar mills of Bangladesh causes high cost of production and enormous losses. The BSRI scientists have firmly believed that the proper agronomic management with the application of recommended fertilizer dose, proper disease and insect pest management can provide at least 9.0–10% sugar recovery from the existing sugarcane varieties. However, the following recommendation should be considered for achieving the potential sugar recovery in the sugar mills:

- By adopting scientific agronomic cultural management from planting to harvesting of sugarcane.
- To increase the cultivation of early high yielding varieties.
- Increase the cultivation of early high yielding varieties.
- Strengthening of clean seed program.
- Better and intensive ratoon cane cultivation/management program.
- Thrust on spaced transplanting (STP) method for sugarcane production.
- Proper surveillance and management of diseases and pests.
- Reduction in field and process losses of sugar through better management and technical efficiency.
- Discourage the supply of stale and un-cleaned canes to the factory.
- Reduce the late application of nitrogen fertilizer.
- Practice of irrigation before harvesting of cane should be stopped.
- Enforcing maturity-wise harvesting schedule.
- Discouraging late planting of cane.

Table 4 Some popular varieties of BSRI and their yields, sugar content and maturity status. *Source*: Anonymous (2016a, b)

Variety	Year of release	Yield (tha^{-1})	Sugar content (pol %)	Maturity status
Isd 2–54	1967	83.0	12.43	Medium
Isd 16	1981	92.0	14.07	Early
LJC	1982	79.0	12.20	Medium
Isd 20	1990	72.0	12.36	Medium
Isd 21	1990	71.0	12.22	Early
Isd 26	1995	60.0	12.78	Early
Isd 28	1996	78.0	13.65	Medium
Isd 29	1998	71.0	12.91	Medium
Isd 30	2000	78.0	13.85	Early
Isd 32	2002	104.0	11.77	Medium
Isd 33	2002	99.0	12.38	Early
Isd 34	2002	93.0	11.64	Medium
Isd 35	2003	94.0	13.54	Early
Isd 36	2003	89.0	13.69	Early
Isd 37	2006	101.0	13.36	Early
Isd 38	2007	110.0	13.67	Early
Isd 39	2009	101.0	14.23	Early
Isd 40	2009	103.0	14.86	Early
BSRI Akh 41	2012	139.0	12.10	Medium
BSRI Akh 42	2014	169.0	11.11	Early
BSRI Akh 43	2014	118.0	13.72	Early
BSRI Akh 44	2014	106.0	13.35	Early
BSRI Akh 45	2016	105.0	13.94	Early

- Sugarcane price to be fixed based on its recovery percent instead of its weights.
- Special management techniques for flood and water-logged-prone areas.

Spaced Transplanting (STP) Technology

Lower germination is mainly caused by low temperature, and soil water stress during the major planting season (November–February) caused gappy and inadequate plant population. As a result, low millable canes and finally low yield obtains. To cope with this situation, transplanting the sugarcane settlings instead of sugarcane setts help to maintain the optimum plant population per unit area of land and to increase the ultimate yield. This planting method is named as Spaced Transplanting (STP). In this method, sugarcane settlings are raised in nurseries for 4–6 weeks before transplanting to the main field by spacing optimal distances. The settlings can be raised in soil beds or polybags. STP requires only 40% seed cane than conventional planting. STP ensures optimal mother plant population, uniform crop stand and higher stalk weight which produces higher yields and increases more profits for sugarcane growers. This method increases seed multiplication ratio (1:30) over conventional method (1:8). Therefore, it is very suitable for spreading of new variety and clean seed within a short period. Moreover, STP technology generates rural employment.

Intercropping with Sugarcane

Being a long duration crop, sugarcane requires 12–14 months to get its final return. It is difficult to afford for the poor marginal farmers to get the return after a long period. On the other hand, sugarcane requires 3–5 months for its full canopy development. Therefore, short-duration high-valued winter crops such as potato, onion, garlic, lentil and cabbage can be grown successfully between free spaces of two cane rows. To make sugarcane cultivation profitable as well as to increase total production including getting quick return from sugarcane field, the practice of intercropping with sugarcane has been introduced. While the area under sugarcane especially high lands and medium high lands is being reduced considerably due to high pressure of short-duration high-valued crops, the intercropping with sugarcane can help to overcome the situation. The additional income from intercrop can attract the poor marginal farmers to grow sugarcane in the high and medium high lands (Figs. 3, 4).

Fig. 3 Intercropping of potato with sugarcane

Fig. 4 Intercropping of lentil with sugarcane

Ratoon Management

Ratoon cane needs lower cultivation costs and mature earlier than plant cane. Under optimum ratoon management practices, higher yield of cane and higher sugar can be obtained. BSRI has recommended a complete package of ratoon management which includes optimal harvest time (October to mid-November and February), stubble shaving, gap filling by STP settlings, adequate fertilizer application, pest and disease management and other cultural practices. About 25% higher yield of ratoon cane can be obtained by gap filling with STP settlings at early stage of rationing. Almost 0.5 to 1.0 unit higher sugar recovery is obtained from properly maintained ratoon crop.

Updating the Fertilizer Dose for Sugarcane

BSRI has updated the fertilizer recommendations for sugarcane and its intercrop based on research findings for 12 agro-ecological zones (AEZs) where sugarcane is being cultivated intensively.

Insect Pest Management

Notable research contributions in sugarcane entomology include cultural, mechanical, chemical and biological control of sugarcane insect pest. The recommended technologies of Entomology Division of BSRI are management of sugarcane top shoot borer, sugarcane stem borer, sugarcane rootstock borer, sugarcane early shoot borer, sugarcane white grub, sugarcane termites and sugarcane pyrilla leafhopper. Screening of promising sugarcane clones against major insect pests is the routine work of Entomology Division. Other works include loss assessment due to borer pest, use of botanical products in controlling major insect pest etc. Entomology Division has also recommended chemical and biological control method for sugar beet caterpillar. They develop a sugarcane insect pest calendar for Bangladesh. Moreover, this division recommended the biological control of sugarcane stem borer using *Trichogramma chilonis*.

Sugarcane Disease Management

The major achievements of Pathology Division of BSRI include development of red rot, wilt and smut disease resistant varieties, control measures for sett-borne diseases of sugarcane like red rot, white leaf, smut and leaf scald by Moist Hot Air Treatment (MHAT) of seeds, control of ratoon stunting disease by hot water treatment, control of striga weed by spraying urea solution and control of sett rot diseases by treating with carbendazim fungicide. The research works are going on management of pineapple disease through biological means, integrated management of diseases of tropical sugar beet, date palm and palmyra palm. Moreover, the Pathology Division identified and recorded 40 sugarcane and 9 tropical sugar beet diseases in Bangladesh including development of a sugarcane disease calendar.

Sugarcane Abiotic Stress Management

BSRI has screened and released a good numbers of varieties of sugarcane for stress-prone areas in Bangladesh. Among them, the drought-tolerant varieties are Isd 20, Isd 22, Isd 35, Isd 36, Isd 37, Isd 38, Isd 39, Isd 40, BSRI Akh 43, BSRI Akh 44 and BSRI Akh 45. The waterlog-tolerant varieties are Isd 20, Isd 34, Isd 37, Isd 39, Isd 40, BSRI Akh 43, BSRI Akh 44 and BSRI Akh 45. The saline-tolerant varieties are Isd 39, Isd 40, BSRI Akh 44 and BSRI Akh 45. As Bangladesh encounters heavy flood almost in every year, therefore considering this aspect, BSRI has also recommended couples of flood-tolerant sugarcane varieties and the varieties include Isd 20, Isd 33, Isd 34, Isd 36, Isd 37, Isd 38, Isd 39, Isd 40, BSRI Akh 43, BSRI Akh 44 and BSRI Akh 45.

Sugarcane Varieties Suitable for Quality Jaggery Production

BSRI has released some sugarcane varieties which are not only for sugar but also suitable for manufacturing of golden or light brown color jaggery. The varieties suitable for jaggery production are Isd 16, Isd 21, Isd 22, Isd 24, Isd 26, Isd 30, Isd 32, Isd 35, Isd 36, Isd 37, Isd 38, Isd 40 and BSRI Akh 43. The golden/light brown color of jaggery manufactured from these varieties is superior in texture and color and commands more prices. Therefore, the producers can get higher return. These varieties will increase jaggery production in the mill zones as well as non-mills zones. Farmers and jaggery manufacturers will get more benefit by adopting these varieties for jaggery production.

Clarification of Jaggery During Manufacture and Preservation

In Bangladesh, during jaggery preparation, the producers add some health hazardous chemicals for getting attractive color for jaggery as normally produced jaggery does give good color. The extract of wild okra has been recommended to use during jaggery preparation by BSRI. For this, 350–500 g mature plants of wild okra after crushing dissolved in 2–3 l of water is used for one pan (200 l) of cane juice. The extract of wild okra is performing as excellent clarifying agent for jaggery preparation. Usually, jaggery is manufactured during September–March and consumed all over the year. Because of its hygroscopic nature, jaggery deteriorates rapidly with the starting of monsoon. In order to overcome this problem, BSRI has developed couple of methods of jaggery preservation for longer period. Semi-solid jaggery can be preserved for longer period in a paint-coated earthen pitcher with its neck sealing with wax. Solid jaggery can be preserved in granular form followed by packing in polythene bag.

Development of Agricultural Implements

BSRI has developed some important agricultural implements for sugarcane cultivation. The implements include the power tiller mounted trencher which can provide furrow depth 12–14 cm and the field capacity is 0.75 ha/day. The operation cost of this trencher is almost 2.5 times less than the cost incurred by human laborer with spade. The BSRI power weeder is another important implement of BSRI which is used for weeding of sugarcane field. It is just rotovator with some modification in the placement of rotary tine driven by power tiller (Figs. 5, 6).

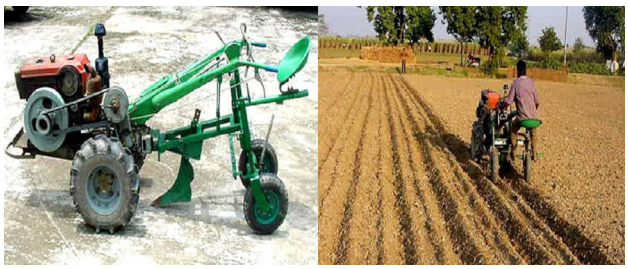

Fig. 5 Power tiller mounted trencher with operation

Fig. 6 BSRI power weeder during operation

There is a space adjustable mechanism to adjust the distance between two furrows. The field capacity of this weeder is 1.0 ha/day. It can save 60% cost of manual weeding. For sett cutting, a sett cutting machine has been developed by BSRI. Manually, 1200 setts of single bud and 2000 setts of double bud can be cut per hour, but at least 7500 setts of single bud and 8500 setts of double bud can be cut by the BSRI-developed sett cutting machine. BSRI has also developed a paired row trencher which is a device of attachment with the tractor which consist a trencher to make furrow having depth control mechanism to control depth of furrow. It can make a furrow of 60 cm width and 20–25 cm depth. The field capacity of this trencher is 0.29 ha/h. The bud chip cutter is another device among BSRI-developed implements, which is used for cutting the bud chips from sugarcane seed. After separating the bud chip, almost the full cane can be used for juice extraction. The bud chips are used as seed for sugarcane production. A laborer can cut about 1100 bud chip per hour by this machine. Finally, a pedal pump has been developed by BSRI which can operate just like a bicycle. Water lifting capacity is 60–100 l/min depending on suction head and aquifer properties, and the irrigation capacity is about 0.20 ha/day (Fig. 7).

Fig. 7 Paired row trencher during operation

Fig. 8 Tropical sugar beet field

Biotechnological Research

The research progress of Biotechnology Division BSRI includes transformation of salt and drought-tolerant genes in sugarcane, micro-propagation of sugarcane for clean seed production, molecular characterization and documentation of BSRI-released sugarcane varieties by using SSR markers, callus culture for sugarcane variety development, meristem and shoot culture of stevia.

Training and Technology Transfer

Conducting short- and long-duration residential training programmes for extension officers and workers of sugar mills, Department of Agricultural Extension (DAE) and NGO's on latest developed technologies of sugarcane production, conducting short-duration training programmes on station and in the field for sugarcane farmers under mill zones and non-mill zones. For disseminating BSRI-recommended mature technologies in farmers' field, result and method demonstrations are being organized and conducted as a part of technology transfer. Carrying out of technology transfer programs by using mass media such as radio and television; preparing print media such as leaflets, booklets, posters; preparing and representing the video films, slide shows; organizing field days and campaign. Organizing workshops, seminars and study tours for the extension and research personnel as well as sugarcane growers.

Progress in Sugarcane Cultivation Research in River Basins (*Char* Lands), Plain Land of Hilly Areas and Saline Areas

In Bangladesh, the *char* lands and plain lands of hilly area are covered almost 0.20 and 0.15 million ha, respectively. BSRI has been working for a couple of years in these areas. The results show successful sugarcane production. Very few the insect pest and diseases infestations are found in the hilly areas and provided very high yield per unit areas. In addition to char lands and hilly areas, the saline-prone areas of Bangladesh occupy about 3.1 million ha of land where almost any crops are not grown. BSRI has done some trials in the saline-prone areas and some BSRI-recommended varieties gave successful production of sugarcane and jaggery. Since the cultivated area under sugarcane is getting reduced day by day, there is a wide scope of introducing sugarcane in the huge lands of *char* lands, plain lands of hilly areas and saline-prone areas in Bangladesh. The government of Bangladesh is giving thrust to increase areas under sugarcane cultivation in these above areas.

Progress of Tropical Sugar Beet Research in Bangladesh

BSRI has been doing research on tropical sugar beet since 2002–2003. Meanwhile, a pilot project on sugar beet cultivation has been conducted (Fig. 8).

Under this project, total 17 germplasms were tested in 12 agro-ecological zones of Bangladesh including 12 sugar mill zones, non-mill zones and saline areas. In the saline area, the sugar beet trials gave satisfactory yield and sugar content. Moreover, research on management practices on different insect pests and diseases of sugar beet has been conducted. On the basis of research, for commercial cultivation, 10 sugar beet germplasms will be recommended for releasing as variety. Bangladesh government has approved a project to modify a sugar mill to extract experimentally sugar from sugar beet simultaneously from sugarcane. The germplasms ready for recommendation as variety are presented in Table 5.

Table 5 Recommended germplasms of sugarbeet at BSRI, Bangladesh. *Source*: Agronomy and farming systems division, BSRI

Germplasms of sugar beet for recommendation	Average yield (tha^{-1})	Sugar content (pol %)	Seed supplied company
Shubhra	100.00	13.90	Syngenta (Bangladesh) Ltd
Cauvery	75.57	13.13	Syngenta (Bangladesh) Ltd
HI 0044	80.00	15.86	Syngenta (Bangladesh) Ltd
HI 0473	80.50	14.60	Syngenta (Bangladesh) Ltd
SZ 35	95.80	13.50	Ses Vanderhave (Belgium)
PAC 60008	95.57	14.41	Ses Vanderhave (Belgium)
SV 891	107.57	13.37	Ses Vanderhave (Belgium)
SV 892	100.87	14.22	Ses Vanderhave (Belgium)
Aranka	108.87	12.89	KWS (Germany)
Natura	101.33	12.39	KWS (Germany)

Conclusion

In the increasing population, gradually the demand of sugar is getting higher. The white sugar production of Bangladesh is quite low compared to requirement. The main causes of low sugar production by the industry are insufficient supply of sugarcane in the factory and very poor recovery of sugar. Besides this, the yield of cane per unit area is also lower compared to other countries. Lack of following modern production technologies properly is one of the main reasons for this lower yield. In the non-mill zone, where sugarcane is used for jaggery production occupied almost 50% of total area. In this area, the yield of cane is much lower than mill zone. It is also caused due to lack of modern production technology. Therefore, it is important to overcome the insufficiency of sugar and jaggery; the BSRI-recommended sugarcane production technology must be followed properly in both in the mill and non-mill zones in Bangladesh. Simultaneously, the causes of low recovery of the factory also should be indentified and eliminated. On the other hand, a vast area of the country is under *char* land, plain land of hilly area and saline-prone areas can be taken under sugarcane cultivation. Moreover, as the farmers are not interested to grow long-duration sugarcane crop solely, intercropping of recommended short-duration high-valued crops can be practiced. Furthermore, after modification of duel purposes crushing of sugar mills, sugar beet cultivation can be introduced.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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