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Sugarcane Research and Development in Punjab : Historical Perspective

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ABSTRACT

Sugarcane has a rich, long, fascinating history in India as well as in Punjab. Since its domestication it is used for producing various products for human use. During British rule, sugarcane cultivation expanded significantly in Punjab with the introduction of world's first commercially successful inter-specific hybrid, Co 205 in 1922 and later another hybrid 'Co 312' in 1928. Before 1934, the state was only involved in testing and selecting varieties developed by the Sugarcane Breeding Institute, Coimbatore. Later, Punjab initiates its own varietal development programme with the establishment of Sugarcane Research Station near Lyallpur (now in Pakistan) under Punjab Agriculture College and Research Institute. Partition only shifts its location not its objectives. Starting from CoL 9 and CoL 29 before independence, it developed more than 38 varieties which have significant influence in cane economy of Punjab over the decades. Sugarcane research gears up in Punjab with the implementation of AICRIP system throughout the country. Epidemic of red rot on existing varieties cause heavy dent in sugar industry after 2000 A.D. make it less remunerative avenue which ultimately impedes present research objectives. Only sugar production by mills make them more prone to economical vulnerabilities. Hence mills are to be upgraded by adding units like distillery and Bio- ethanol plants for future sustainability to boost the economy and energize environment by cutting down on carbon emissions.

Keywords : Cane economy, Punjab, Sugarcane research, Sugarcane

Introduction

Sugarcane (*Saccharum* spp.) is a tall perennial tropical grass which is an allopolyploid with genome contributions from *Saccharum oficinarum* and *S. spontaneum*, is having high chromosome number of 2n=100 to 130 in different cultivars. The 'Saccharum complex' has species with varying ploidy level. The high polyploidy and heterozygosity due to hybridization has restricted the classical genetic studies in sugarcane. It belongs to the grass family Gramineae and genus *Saccharum* L. It is believed to have been introduced to India by Austronesian traders around 1200 to 1000 BC (Bremer, 1966). Over time, it became a staple crop in sub- tropical region, including Punjab. Sugarcane has long history from its origin in Malasia -Indonesia- Papua- New Guinea region or in the islands of Polynesia or Melanesia groups to its evolution in Indian

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subcontinent or Southeast Asia. *Saccharum oficinarum* L. a thick-stalked cane is domesticated from the wild species *i.e.*, *S. robustum* Brandos *et* Jeswiet ex Grassl. around 8000 years ago. Then, *S. oficinarum* appeared in India, where it hybridized to native *S. spontaneum* and other wild grasses to give rise to the indigenous sugarcanes of India classified as *S. barberi* Jeswiet (Bremer, 1966). It further transported to China on hybridization with wild-grasses gave rise to China's indigenous sugarcanes classified as *S. sinense* Roxb. emend. Jeswiet. These ancient sugarcanes subsequently spread from India to the Middle East, the Mediterranean, and eventually to the New World beginning with the second voyage of Columbus in 1493. Throughout the world during the nineteenth and twentieth centuries, the ancient varieties were gradually replaced with man-made 'Noble' hybrids beginning in Barbados and Java in 1888 (Barber, 1919). Today, all cultivated sugarcanes are derived from those man-made late nineteenth century interspecific hybrids.

Sugarcane Era- An Indian Perspective

Sugarcane has a long and fascinating history in India, deeply intertwined with the country's agricultural and cultural development. Sugarcane cultivation in India dates back to around 5000 BC. Initially, it was chewed as a sweet treat, but by around 1000 BC, Indians began extracting juice from the cane and producing sugar. The references of sugarcane and its products, such as jaggery (*gur*) and crystalline sugar (*sharkara*), are found in ancient Indian texts like the *Athervaveda* which is 5000 years old. Indians discovered how to crystallize sugar during the Gupta dynasty, around 350 AD, while the famous historians like Herodotus mentioned about the crop in their works. Ibn Battuta and Francois Bernier were other famous voyagers who wrote about the sugarcane cultivation in Kerala and Bengal. Tamil literature also has several references about sugarcane. The technique of boiling sugarcane juice to extract sugar was first discovered in India during the first millennium BC. Mention of establishment of first sugar factories in India can be found as early as 1610 at Masulipatnam and Coromandel Coast. These texts highlight the importance of sugarcane in rituals and daily life. India became a major center for sugar production and trade (Solaman and Swapna, 2022). The process of crystallizing sugar was a closely guarded secret, giving Indian traders a significant advantage. It is said that a French people at *Aska* in Orissa established the first sugar plant in India in 1824 and it stopped its operation around 1940. The modern sugar processing industry in India made its beginning in 1904 when the first vacuum pan process sugar plant was set up at Saran in Marhowrah in Bihar (Dhawan, 1972). The growth of the industry was slow till 1930 with only 30 sugar mills. By 1931-32, there were 31 sugar factories in India, all of which were in the private sector. The total production of sugar at that time was only about 1.5 lakh ton, whereas the consumption was about 12 lakh ton. To meet the domestic demand of sugar, India had to import sugar mainly from Java (Indonesia). In 1931, a Tariff Board was set up and the sugar industry was brought under protection. Since then, sugar

industry in India has experienced a long journey (Mishra, 2018). This period saw the establishment of large-scale sugarcane plantations and the introduction of new varieties of sugarcane. The credit of modern classification of sugarcane goes to C.A. Barber, British botanist, Founder Director of Sugarcane Research Station, Coimbatore and Jacob Jeswiet, Dutch botanist, Chief of Cane Breeding Department, Sugar Experimental Station, Java, Netherlands Indies (Later Indonesia). Over a decade, Barber collected sugarcane clones from north India distributed though Punjab, UP, Bihar, Bengal and Assam. Based on vegetative characters those canes were classified into five groups- Mungo, Nargari, Saretha, Sunnabile and Pansahi. The clones in Saretha group (Chunee, saretha, kansar) was found in Punjab and between Assam and Bihar, Mungo and Nargari were distributed in waterlogged areas of Bihar. Sunnabile group was dominant in Assam while Pansahi group (Uba, Tekcha) was distributed between Bihar and Bengal (Pandey *et al.,* 2010).

Saccharum barberi, the indigenous subtropical form of North India (named after CA Barber), were used for sugar production for centuries and were considered to be evolved and grown since earliest recorded times. *S. barberi* developed from introgression of *S. oficinarum* with *S. spontaneum* in India. It was in the Saretha group (Chunee and Kansar) that the most useful breeding canes of *S. barberi* had been extensively used to develop breeding lines/varieties for subtropics. The Saretha group was the only group with clones that flower and involved in the breeding of the sugarcane. Irvine (1999) considered only two species in the genus *Saccharum*- the wild species *S. spontaneum* and the cultivated species *S. oficinarum*. The rest of the four species viz., *S. barberi, S. sinense, S. robustum* and *S. edule* have been placed as the natural hybrids of *S. oficinarum* and *S. spontaneum*. Probably such natural crossing took place around 1000 BC.

Beginning of Sugarcane in Punjab

Sugarcane has a rich history in Punjab, played a significant role in the region's agriculture and economy. Sugarcane is being cultivated in sub-tropical region since *Vedic* times. Since its domestication sugarcane is used for its products like cane juice, jaggery cakes (*gur*), powered jaggary (*shakkar*), molasses and ethanol. The bagasse is burnt to provide heat, and it is also used as raw material in making of utensils, because of its high cellulose content. The press-mud is used as manure and the sugarcane tops as fodder for animals. The hard and thin north Indian canes are held to be indigenous to Punjab. The mention of sugarcane in early historical records or mythological legends is believed to refer only to north Indian canes. Indigenous domesticated thin reed like canes were under cultivation, namely *Katha, Lalri, Kansar, Dhaula, Teru* and *Ekar* etc. their yields and sugar recovery were low but have high tolerance for various biotic and abiotic stresses (Bremer, 1966).

During British rule, sugarcane cultivation expanded significantly in Punjab. Earlier, it was primarily processed into non- centrifugal sugar, known locally as *gur* and *shakkar*. The indigenous domesticated varieties of sugarcane in Punjab possessed thin canes, low sugar and poor yield. They had high fiber content

and good resistance to many diseases and pests. Varietal improvement work on sugarcane crop in Punjab was taken up in 1918 when the first batch of Coimbatore (Co) hybrid canes bred at the Sugarcane Breeding Station (now Sugarcane Breeding Institute), Coimbatore was received and tested at the Government Agricultural Farm, Gurdaspur. Out of this batch of varieties, the first commercially successful inter-specific hybrid in the world, Co 205, a hybrid between cultivated sugarcane (*Saccharum oficinarum*) and wild grass (*Saccharum spontaneum*) was selected, evaluated, multiplied and approved for cultivation in Punjab province in 1922 as it stood out prominently over the poor class of indigenous canes grown in the Punjab province (Parthasarathy, 1948). In 1928, another hybrid 'Co 312' was released which dominated as one of the most popular varieties in subtropical India for the next three decades (Dutta and Rao, 1956). The Sugarcane Breeding Institute, Coimbatore continued to supply a set of 'Co' varieties for testing and selection at the Government farm of the Department of Agriculture, Punjab till 1933.

Sugarcane Research and Development in Punjab

Punjab has a significant and a glorious history of sugarcane research since pre-independence. In 1934, Punjab begins its systematic sugarcane varietal development programme with the establishment of Sugarcane Research Station at Risalewala near Lyallpur (Pakistan) under Punjab Agriculture College and Research Institute, Lyallpur, Punjab and the Sub-Station at Jalandhar with financial assistance from the Imperial Council of Agricultural Research (now IARI) (Anonymous, 2009). Sardar Harbans Singh was the first sugarcane specialist appoint to sugarcane breeding research work at Punjab Agriculture College and Research Institute, Lyallpur, Punjab (Mohan, 2018). Sugarcane seedlings were raised from the fluff of the crosses received from Sugarcane Breeding Station, Coimbatore. Further selection of the clones possessing desirable traits in a clonal population was taken up by the Punjab Agricultural College, Lyallpur, Punjab (Pakistan). Two sugarcane varieties namely CoL 9 and CoL 29 from the breeding material developed at Lyallpur were released in Punjab before independence (1945) and after independence (1953), respectively. After partition in 1947, the Sugarcane Research Sub-Station in Jalandhar was upgraded as main Sugarcane Research Station in Punjab to conduct research on sugarcane varietal improvement, agronomic management, and plant protection under the Department of Agriculture. The Sugarcane Research Station, Jalandhar was transferred to Punjab Agricultural University, Ludhiana after its establishment in 1962. Since then, research infrastructure and facilities had been strengthened. The All India Coordinated Research Project on sugarcane was implemented in 1970, which helped to gear up research on sugarcane at Sugarcane Research Station Jalandhar. In 1971, around 75 acres land of Sugarcane Research Station, Jalandhar were taken by the Central Government for Boarders Security Forces and remaining 164 acres were taken by the Punjab Government for Medical College in 2001, closed a historical sugarcane research

station of Punjab. Till its closure, the Sugarcane Research Station, Jalandhar had developed and released twelve sugarcane varieties namely CoJ 39 (1960), CoJ 46, (1962), CoJ 58 (1969), CoJ 64 (1975), CoJ 81 (1988), CoJ 79 (1989), CoJ 84 (1992), CoJ 83 (1992), CoJ 82 (1995), CoJ 86 (1999), CoJ 85 (2000) and CoJ 88 (2002). The landmark achievement of sugarcane research at Punjab was the development and release of wonder variety CoJ 64 with high sugar, early maturing but susceptible to top borer. Due to this, it could not be released in 1970 for cultivation in Punjab for the want of top bore control. In 1972, a top borer control strategy was developed at the Sugarcane Research Station in Jalandhar and CoJ 64 was released in 1974 for general cultivation in Punjab and later, this variety was also released in Haryana, UP, Rajasthan and even in Pakistan. There were 6 Sugar Mills in Punjab at the time of adoption of this variety. The average sugar recovery of the Punjab increased by 1.5 units after release of CoJ 64. On a recovery basis, Punjab got 16 new licenses of Sugar Mills from the Ministry of Agriculture, Government of India. Realizing the importance of sugarcane crop in Punjab state, Indian Council of Agricultural Research sanctioned another all India coordinated research project (AICRP) on Sugarcane at Regional Research Station, Faridkot in 1995. During nineties, Punjab became self-sufficient in sugar and also started exporting sugar to other states. CoJ 64, wonder variety revolutionized the sugar industry and defines an early maturing group in sugarcane. After closure of Sugarcane Research Station, Jalandhar in 2001, sugarcane research was shifted to U.S.F. Ladhowal and became a part of the Department of Plant Breeding & Genetics. Later, in 2012 sugarcane research was shifted to Regional Research Station Kapurthala. The farm of Regional Research Station Kapurthala was established by Maharaja of Kapurthala state for agricultural and allied activities with formation of PEPSU (Patiala and East Punjab States Union). In 1948, the farm was transferred to Department of Agriculture and named as Kapurthala Farm. After merging of PEPSU into Punjab state 1956 these farms were used for seed production by Agriculture Department. In 1958, Kapurthala farms were converted into experimental station for cereals and pulses. In 1959, the Oilseed Sub-station was started at Kapurthala Farm and shifted to Punjab Agricultural University, Ludhiana in 1962. Same year, the Rice Research was shifted from Gurdaspur to Kapurthala Farm under Regional Rice Research Scheme. The Rice Research Station, Kapurthala was the one of the contributors of golden era of green revolution. In 2001, rice research was shifted from Regional Rice Research Station Kapurthala to Department of Plant Breeding & Genetics, PAU, Ludhiana. After that the Kapurthala station acted as University Seed Farm for a decade till shifting of Sugarcane Research from PAU, Ludhiana in 2012. Since 2012, around six varieties of sugarcane were released from Regional Research Station, Kapurthala. The concerted efforts of sugarcane scientists developed, evaluated and released many varieties of sugarcane resistant to diseases and insect pests with good traits like high sugar, early maturing, high yield and good ratooner. Suitable

agronomic practices, integrated pest management of insect pests and diseases, biological control of insect pests were developed and recommend for the successful cultivation of sugarcane**.** The detail of sugarcane varieties released in Punjab region since pre-independence till now is compiled in Table 1.

Table 1. Sugarcane varieties released in Punjab region since pre-independence

Sl No	Variety	Parentage release	Year of	Maturity group	Salient features
1.	Co 205 (Java)	Vellai x *S. spontaneum*	1918	--	First commercial hybrid of sugarcane in India. High sucrose; Resistant to drought & water logging
2.	Co 285	Green sport x *S. spontaneum* (Coimbatore)	1928	--	Good yielder; Appreciable ratoons; Released for water-logged soils; Resistant to drought, frost & water logging
3.	Co 312	Co 213 x Co 244	1932	--	High yielding; Rich in sucrose; Late maturing; Soft thick canes; Susceptible to borers & *Pyrilla*; Drought resistant
4.	Co 313	Co 213 x Co 244	1935	Early	Heavy yielder; Good sucrose; Moderately resistant to pests; Susceptible to frost & mosaic
5.	Co 421	PoJ 2878 x Co 285	1934	Late	Heavy yielder; Rich in sucrose; Resistant to pests & diseases
6.	CoL 9	Co 312 x Co 205	1945	Mid	High yielder,
7.	Co 453	Black Cheribon x Co 285	1953	Late	High yielder, Good ratooner
8.	Co L 29	Co 312 x Co 205	1953	Early	Medium thin canes; Average yielder; Medium ratooner; Susceptible to red rot
9.	CoJ 39	Co 312 x Co 453	1960	Late	High yielder
10.	Co J 46	Co 312 x Co 421	1962	Late	Good ratooner; Medium thick canes; erect habit; Non- lodging

11.	Co 1148	PoJ 4383 x Co 301	1967	Late	Heavy yielder; excellent ratooner; good quality
12.	CoJ 58	Co 312 x Co 421	1969	--	Good yielder; Average ratooner; High tillering; Erect , non-lodging, medium thin canes
13.	Co 975	Co 527 x Co 617	1969	Mid	Medium thick canes; Average ratooner; Good sucrose; Tolerant to frost and water logging.
14.	Co 1158	Co 421 G.C.	1969	Mid	Average yielder; Good ratooner; Medium thick solid canes
15.	Co J 64	Co 976 x Co 617	1975	Early	Excellent quality; High yielder; Good ratooner
16.	Co J 81	Co 798 x Co 775	1988	Late	Thick canes; Good yielder; Poor ratooner; Good in quality
17.	CoJ 79	NCo 310 x CoJ 64	1989	Mid	High yielder; Good germinator; Average ratoons;
18.	CoS 767	Co 419 x Co 313	1991	Late	Very high yielder; excellent ratooner; Average quality; Matures by Feb. end
19.	CoJ 84	Co 1148 x Co J 65	1992	Mid	Excellent yields in plant crop and ratoon; Good in quality
20.	CoJ 83	CoJ 64 x Co 1148	1992	Early	Good yields; Average stalk population; Performs better under high fertility soils with frequent irrigation; Possesses tolerance to red rot.
21.	CoPant 211	Co 6806 x Co 6912	1993	Early	Good yielder; Shy tillering; Tall, medium thick canes; Resistant to red rot
22.	CoJ 82	CoJ 64 x CoJ 75	1995	Mid	Excellent quality; Good plant crop yields; Average ratooner; Medium thick canes

23.	CoJ 86	Co 6912 x Co 7201	1999	Early	Good quality; High tillering and good ratooner; Tolerant to red rot
24.	CoJ 85	Q 63 x CoJ 70	2000	Early	Excellent quality; High cane yields
25.	CoS 8436	MS 6847 x Co 1148	2000	Mid-late	Thick canes; High yields & good quality; Non- lodging; Performs better under high fertility soils
26.	CoJ 88	CoJ 82315 x Co 1148	2002	Mid-late	Medium thick canes; Good ratooner; Excellent for gur production; Tolerant to red rot and wilt
27.	CoPb 91	CoH 110 x ISH 69	2014	Mid-late	Thick canes; Good ratooner; High yielding; Tolerant to red rot and wilt
28.	Co 0118	Co 8347 x Co 86011	2015	Early	Thick canes; Shy tillering; Good ratooner; Tolerant to red rot
29.	Co 0238	CoLk 8102 x Co 775	2015	Mid-late	Medium thick canes; Good ratooner; High yielding; Tolerant to red rot and wilt
30.	CoPb 92	Co 89003 (PC)	2017	Early	Medium-thick canes; High cane yield; High tillering and good ratooner
31.	CoPb 93	Co 1158 (GC)	2017	Mid-late	Thick canes; Good ratooner; High yielding; Tolerant to red rot and wilt
32.	CoPb 94	Co 1148 (GC)	2017	Mid-late	Thick canes; Good ratooner; High yielding; Tolerant to red rot and wilt.
33.	CoPb 95	CoLk 8102 (PC)	2021	Early	High cane yield, Good ratooner, Moderate susceptible to red rot and wilt
34.	CoPb 96	Co 0238 (GC)	2021	Early	High cane yield, Medium thick cane, Tolerant to red rot and wilt

35.	Co 15023	Co 0241 x Co 8347	2021	Early	Medium cane; High quality, Good for Gur, Tolerant to red rot and wilt
36.	CoPb 98	CoS 8436 (PC)	2021	Mid-late	Thick canes; Good ratooner; High yielding; Tolerant to red rot and wilt
37	CoPb 99	CoJ	2023	Mid-late	Thick canes; Good ratooner; High yielding; Tolerant to red rot and wilt
38	CoPb 100		2025	Mid-late	Thick canes; Good ratooner; High yielding; Tolerant to red rot and wilt

Sugar Industry Scenario in Punjab

Sugar industry has played an important role in prosperity of Punjab. The rise of sugar industry in Punjab coincides with the development of sugarcane research in Punjab. The history of cane cultivation in Punjab and open pan sugar industry developed simultaneously which was common tradition of Punjab. The first centrifugal sugar mill was established at Rahwali, Punjab in 1936. At the time of independence in 1947, Punjab had two sugar mills one at Rahwali, Gujranwala (Pakistan) in the Punjab and the other in Takht Bhai in North West Frontier Province (Pakistan) which produced 9,510 tons of sugar in 1948 (Anonymous, 2009). The improved sugarcane varieties had brought the tremendous change in the cane production and productivity in Punjab (Table 1). As a result in First five-year plan, 1954 the Bhogpur Co-operative Sugar Mills was sanctioned and registered under the Punjab Cooperative Society Act-II 1912 in the name of "The Janta Cooperative Sugar Mills Ltd. with 800 TCD (tons of cane per day) which was enhanced to 1016 TCD in 1988. Since then, the area under sugarcane which was around 1,56,000 ha in 1966-67 reached 2,30,000 ha in 1996-97. Cane yield also showed a substantial increase of over 55.3 t/ha from a mere 27.9 t/ha in 1966-67 to 83.2 t/ha in 2023-24. Sugar recovery too recorded a remarkable increase from 8.32 per cent in 1966-67 to 10.97 per cent (the highest ever recorded) during 1982-83. Punjab State, which was hitherto in the low sugar recovery zone of the country, was placed in the high recovery zone of the country. To cope with the increased cane production due to increase in area and productivity, sugar industry also expanded nearly by over four

times during this period. Number of sugar mills in Punjab increased from only five in 1966-67, with crushing capacity of 6750 tons cane per day (TCD), to 10 in 1985-86 with crushing capacity of 13,000 TCD and 22 in 1992-93 with crushing capacity 36800 TCD. The crushing capacity of 22 sugar mills had been further enhanced to 49260 TCD. The marketing federation of Punjab commissioned a sugar mill at Malout in 2001. In 2019-20 the crushing capacity of the oldest cooperative sugar mill, Bhogpur enhanced from 1000 TCD to 3000 TCD with the shifting of The Faridkot Coop. Sugar Mills Plant & Machinery at Bhogpur Coop. Sugar Mills. In spite of remarkable achievements in cane productivity and sugar recovery from mid-1970's to 1980's, cane productivity in the state stabilized between 55 to 65 t/ha and sugar recovery decreased to about nine percent during 1990's and remains fluctuating between 8.5 to 10.0 since then. During 1995-96, with release of CoJ 82 and CoJ 84 there was sudden increase in area of sugarcane in Punjab from 140 thousand ha to 230 thousand ha. From 2000 onwards the epidemic of red rot on CoJ 64 sugarcane variety cause heavy dent in the sugar industry of the Punjab. About six sugar mills had been shut down from 2000 to 2023 (Randhawa and Gupta 2013). Currently, 15 sugar mills are operating in the state out of which nine are Co-operative sugar mills and rest six are private sugar mills (Table 2). The combined crushing of all sugar mills in Punjab is around 57250 TCD. The sole sugar production by sugar mills does not make them economically viable hence the sugar mills are upgrading by additional units like distillery and Bio-ethanol plants. The sugar industry in Punjab is facing several challenges. One significant challenge is the high cost of sugar production in Punjab. The inefficient infrastructure, outdated technology, and contribute to elevated expenses. Despite being the "granary of India" for wheat and rice, Punjab contributes only a small fraction (around 1.48%) to India's total sugar production. The sugar mills in Punjab works only three-four months a year due to non-availability of sugarcane. The sugar industry faces volatility in sugar prices. In recent years, prices have hovered around a six-year low, impacting the financial viability of sugar mills. Simultaneously, raw material costs continue to rise, exacerbating the situation. The worst phase for Punjab's sugar industry was observed during 2014-15, with mounting losses and debt. These financial burdens affect not only the mills but also the livelihoods of sugarcane farmers and mill workers (Randhawa and Gupta, 2013). The sugar industry plays a vital role in rural livelihoods, and overcoming these hurdles is crucial for its sustained growth. These sugar mills play a significant role in diversification of agriculture. It helps in increasing the farm income of sugarcane growers.

Conclusion

During domestication, the wild fibrous grass sugarcane has been transformed into a luscious, sweet crop. Sugarcane's traits have been further refined by traditional breeding methods and research initiatives, making it a highly productive and resilient crop. Sugarcane is a major source of sugar and other sugar products (*Gur, shakker, khandseri etc.*).

Table 2. List of Total Cooperative and Private Sugar Mills of Punjab and their Operational Status

Sl. No.	Sugar Mill	Location	District	TCD	Govt./ Private	Operational Status
1	The Ajnala Cooperative Sugar Mills Ltd.	Ajnala	Amritsar	2500	Govt.	Working
2	Rana Sugars Ltd.	Butter Seviyan	Amritsar	5000	Private	Working
3	The Tarn Taran Cooperative Sugar Mills Ltd.	Tarn Taran	Amritsar	1250	Govt.	Closed
4	The Budhala Cooperative Sugar Mills Ltd.	Mansa	Bathinda	1250	Govt.	Closed
5	The Fazilka Cooperative Sugar Mills Ltd.	Fazilka	Fazilka	1250	Govt.	Working
6	The Faridkot Cooperative Sugar Mills Ltd.	Faridkot	Faridkot	2500	Govt.	Closed
7	The Zira Cooperative Sugar Mills Ltd.	Zira	Ferozpur	2500	Govt.	Closed
8	The Batala Cooperative Sugar Mills Ltd.	Batala	Gurdaspur	1500	Govt.	Working
9	The Gurdaspur Cooperative Sugar Mills Ltd.	Paniar	Gurdaspur	2000	Govt.	Working
10	Chadha Sugars and Industries Pvt. Ltd.	Kiri Afgana	Gurdaspur	7500	Private	Working
11	A.B. Sugars Ltd.	Dasuya	Hosiarpur	9000	Private	Working
12	Indian Sucrose Ltd.	Mukerian	Hosiarpur	9000	Private	Working
13	The Bhogpur Cooperative Sugar Mills Ltd.	Bhogpur	Jalandhar	3000	Govt.	Working
14	The Nakodar Cooperative Sugar Mills Ltd.	Nakodar	Jalandhar	1250	Govt.	Working
15	Golden Sandhar Mills Ltd.	Phagwara	Kapurthala	5000	Private	Working
16	The Budhewal Cooperative Sugar Mills Ltd.	Budhewal	Ludhiana	1250	Govt.	Working
17	The Jagraon Cooperative Sugar Mills Ltd.	Jagraon	Ludhiana	2500	Govt.	Closed

18	Markfed Sugar and Allied Industries Ltd.	Malout	Muktsar	2500	Govt.	Closed
19	The Patiala Cooperative Sugar Mills Ltd.	Rakhra	Patiala	1250	Govt.	Closed
20	Nahar Industrial Enterprises Ltd.	Amloh	Patiala	4000	Private	Working
21	Piccadily Sugar and Allied Industries Ltd.	Patran	Patiala	2500	Private	Closed
22	The Morinda Cooperative Sugar Mills Ltd.	Morinda	Roopnagar	2500	Govt.	Working
23	Bhagwanpura Sugar Mills	Dhuri	Sangrur	3500	Private	Closed
24	The Nawanshahr Cooperative Sugar Mills Ltd.	Nawan-shahr	SBS Nagar	2500	Govt.	Working

Apart from being a raw material for the sugar industry, this C4 crop could potentially fuel the industry, which would boost the economy and energize the environment by cutting down on carbon emissions. Sugarcane has covered a long way from domestication since its commercial use. The systematic varietal development in India by CA Barber contributed in nobilization of Indian Sugarcane. The emergence of sugarcane industry significantly backed by sugarcane research and development. The new avenues in sugarcane industrial sectors like production of biofuel has opened novel vistas for further growth of sugar cane industry. The sugar industry is a perfect example of an emerging technologies in the sugarcane and sugar production system along with the scope for diversification has made the global as well as the local sugar industries, the flag bearers of the concept of sustainability and profitability with self-reliance. This is evident from the remarkable growth of the Indian sugar industry from the early 30's till date and its transformation into a major sugar producing nation with a strong global presence.

The future of sugarcane research in Punjab holds both challenges and exciting opportunities. Punjab's reliance on natural resources (such as water) affects both sugarcane cultivation and sugar production. Sustainable resource management is essential for long-term viability. Climate change poses a significant threat to agriculture, including sugarcane. The sugarcane breeders are actively studying how changing weather patterns impact sugarcane production. Sugarcane breeding programs continue to play a crucial role in continuous development of the sugarcane. The numerous improved sugarcane varieties have been identified and notified for commercial cultivation in the Punjab over the period. These varieties offer higher

yields, disease resistance, and better quality. The changing trend similar to how the U.S. corn industry shifted a significant portion of its output to ethanol production, India is exploring using sugarcane for renewable energy so as the Punjab. Sugar mills are upgraded to produce bio-ethanol for blending in petrol and diesel. Sugarcane-based ethanol can contribute to energy independence and reduce greenhouse gas emissions. This transition aligns with sustainability goals and opens up new avenues for research and innovation (Chauhan *et al.,* 2022). The sugarcane improvement is not individual task, adopting interdisciplinary approaches is a key requirement to achieve the desired targets. The collaborative efforts of genetics, biotechnology and molecular biology to enhance sugarcane productivity, tolerance towards biotic and abiotic stresses. Whether it's precision farming, marker-assisted breeding or genomic selection, these integrated efforts will shape the future of sugarcane research. Sustainable sugarcane cultivation requires optimal nutrient management and soil health. Sugarcane research will be focused on efficient fertilizer use, organic amendments, and soil conservation practices to maintain long- term productivity. Developing varieties resistant to pests and diseases remains critical. Sugarcane researchers continue to explore biological control methods, disease- resistant genes, and eco-friendly pest management strategies further development of sugarcane. Beyond sugar, researchers are exploring value-added products from sugarcane such as bioethanol, bioplastics, and nutraceuticals. Diversifying the market ensures the crop's economic viability and sustainability (Tyagi *et al.*, 2023). In summary, the future of sugarcane research in Punjab is dynamic and forward-looking. It involves adapting to climate challenges, improving varieties, and contributing to both food security and renewable energy.

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