Agric Res J **61** (2): 318-321, *April* 2024
DOI: 10.5958/2395-146X.2024.00041.8

Perspective Paper

ETHANOL FROM MAIZE: A STRIDE TOWARDS CROP DIVERSIFICATION STRATEGY OF PUNJAB STATE

S Sandhu[1]*, G S Kocher[2] and A S Dhatt[3]

[1]*Principal Maize Breeder, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana-141 004, India*
[2]*Former Head, Department of Microbiology, Punjab Agricultural University, Ludhiana-141 004, India*
[3]*Director of Research, Punjab Agricultural University, Ludhiana-141 004, India*

With a population exceeding 1.4 billion, India heavily relies on imports to meet approximately 84% of its crude oil demands, positioning it as the third-largest oil consumer and importer globally. However, the nation faces formidable challenges stemming from rising oil prices, increased imports, and a decline in domestic oil production, resulting in a steep surge in crude oil import bills. Over this period, the country has witnessed a manifold increase in imports from select nations. Furthermore, India's reliance on imported crude soared to a historic high of 87.3% of domestic consumption in 2022-23, compared to 85.5% in the previous year and 84.4% in 2020-21. This spike can be attributed to burgeoning demand for fuel and other petroleum products alongside a decline in domestic crude oil output. Nonetheless, there is a hope for reducing import dependency and achieving sustainability goals. India initiated its biofuel policy in 2002-03 with the objective of blending ethanol @ 5% starting January 2003. The recent amendment to biofuel policy of 2018 ratified in 2022 permits the use of sugarcane juice, sugar containing materials like sugar beet, sweet sorghum, starch containing materials like corn and cassava as well as damaged food grains like wheat, broken rice and rotten potatoes, unfit for human consumption, for ethanol production. The government is actively promoting the production of indigenous biofuels to achieve net-zero targets and curtail imports. In a proactive move, the government has advanced its target to achieve 20% ethanol blending in petrol by 2025-26 instead of initially stated 2030. With a resolute target of achieving a 20% ethanol blending with petrol by 2025, the government's efforts have yielded significant results. In the fiscal year 2022-23, ethanol production soared to approximately 502 crore litres, translating to a staggering saving of ₹24,300 crores in foreign exchange. This milestone highlights India's prowess in navigating towards sustainable energy solutions while fostering economic resilience. *Niti Aayog*'s projections indicate a requisite production capacity of 7.6 billion litres through sugarcane-based distilleries, with an additional 7.4 billion litres from grain-based counterparts. This diversification in feedstocks not only mitigates risks associated with dependency on a single crop but also aligns with sustainable development goals. The trajectory of ethanol production highlights a paradigmatic shift towards maize utilization, with 0.8 million tonnes earmarked for ethanol production in 2023-24. This figure is poised to escalate to 3.4 million tonnes by 2024-25, eventually reaching 10 million tonnes by 2027-28. The national mandate for 20 % ethanol blending in petrol has sparked interest in maize as a promising bioethanol feedstock in the country due to its abundance, high starch content and success story in US. Currently, grain-based distilleries primarily rely on rice for ethanol production. Although paddy has great potential among cereals, its cultivation contributes to depletion of natural resources such as groundwater and is responsible for enhanced methane emissions. Maize is preferred crop for bioethanol production because it is available practically throughout the year (maize is cultivated during three seasons, namely *kharif*-rainy, *rabi*, spring), and the crop has high productivity potential, lesser water requirement, and no issues of residue management. Moreover, its use for ethanol production is not expected to have any effect on food security.

In the fiscal year 2024-25, targeted production of 250 crore litres of ethanol from maize will necessitate 66 lakh tons of maize grains (100 kg of maize grains produce 35-42 litres of bioethanol). At present, the area under maize is 102 lakh ha with production of 359 lakh tons at productivity level of 3.49 t/ha (2022-23) in the country. Therefore, the union government has set a target to raise maize production by 100 lakh tonnes over the next five years to meet the growing demand for ethanol production, besides higher demand from the poultry, dairy and starch industry.

Punjab, a traditionally maize growing state, has the potential to seize this new opportunity and thereby replace paddy and move towards much needed crop diversification. During pre-green revolution era, maize and cotton were the major *kharif* crops in the state. Maize and cotton were grown on 3.72 and 4.46 lakh ha,

*Corresponding author: surindersandhu@pau.edu
Date of receipt: 14.08.2023, Date of acceptance: 26.04.2024

respectively, during 1960-61. Maize had record acreage of 5.77 lakh ha during 1975-76 but at the present, it is cultivated over 93.3 thousand ha with average yield of 17.78 quintal/acre (4.39 t/ha). Since the advent of green revolution, the area under paddy-wheat cropping system has continuously increased. The intensive input-based cultivation specifically that of paddy has raised major concerns for sustainable agriculture. The ground water resource has depleted alarmingly, the burning of paddy straw has led to environmental and health hazards, and physical and microbial health of soil has been adversely affected. In this scenario, crop diversification is the top-most priority. Maize has almost one-third water requirement as of rice and less than one-fourth of sugarcane, with shorter crop duration (95-100 days) than rice (120 days). One kg of maize grain requires 800-1000 litres of water as against 3000-3500 litres of water for one kg of rice production. Its residue, with a higher Carbon: Nitrogen (C: N) ratio than rice, enhances soil health by promoting organic carbon accumulation and decomposition. Moreover, maize offers versatility, serving as food, feed, fodder, and a source for more than 3,500 industrial/processed products, fostering potential industrial development and entrepreneurship in the state. With its high yield potential and better adaptation to climatic change as a C4 plant, maize presents an opportunity to discourage rice farming and promote maize cultivation, during the *kharif* season. Maize can serve as a viable substitute for rice and broken rice in distilleries provided we can ensure raw material availability to the industry

Punjab has ample capacity and facilities for maize processing with state of art industrial units which can procure whole of the maize produce. The ethanol production capacity of units in Punjab is about 3860 Kilo Litres /Day (KLD) as the current capacity is 2260 KLD with upcoming capacity of 1600 KLD. With this capacity, distilleries alone would need 3.67 million tons of maize, keeping aside the need for poultry and starch, the other major domains of maize consumption in Punjab. For this much requirement, Punjab needs about 6 lakh ha area under maize cultivation. Most of the area under maize in the state falls in the districts of Hoshiarpur, Rupnagar, Shaheed Bhaghat Singh Nagar, Pathankot, Jalandhar and Sahibjada Ajit Singh Nagar (Mohali) with wide district-wise variability in productivity *viz*., 5.2 t/ha (highest) in Kapurthala and 2.69 t/ha (lowest) in Pathankot. It is pertinent to mention that Punjab Agricultural University, Ludhiana has released six *kharif* maize hybrids *viz*., PMH 14 (2023), PMH 13 (2021), PMH 11 (2019), Private sector hybrid Adv 9293 (2021), DKC 9144 (2024) and Bioseed 9788 (2024) in last five years with average grain yield of these hybrids 24-25q/acre (about 6 t/ha).

While, Punjab Agricultural University (PAU) bred hybrids have a yield potential of 6-7 tons/ha, our average yield is 4.39 t/ha. No other cereal crop exhibits such a significant disparity of approximately 2t/ha between potential and actual yield in farmers' fields, a gap that must be addressed to ensure maize's economic viability as a crop. Challenges for maize such as better crop options, pushing of maize cultivation on marginal lands with low to average soil fertility, moisture stress, erratic rainfall patterns, and low adoption of high yielding single cross hybrids and recommended agronomic practices have hindered the realization of yield potential (6-7 t/ha). Several factors contribute to this significant gap between potential and realized yield at farmers' fields, including low plant population per acre, water logging stress during the monsoon season coupled with high biotic stress, the high cost of quality seed from the private sector, limited availability of high quality hybrids seed from public agencies, lesser mechanization, non-allocation of fertile lands to maize by farmers due to poor return and farmers' preference for paddy cultivation on fertile soils due to secure procurement. Plant population, which generally remains 20,000-22,000 per acre in *kharif* season, need to be maintained at the optimum level of 33, 000 plants per acre by sowing using pneumatic planter and proper cultural practices to achieve productivity potential. Laser levelled fields with good drainage to avoid water logging stress, restricting to the recommended sowing window of May 20 to end June so that germination duration does not coincides with onset of monsoon, sowing on raised beds are important steps to achieve the goal. Here, PAU research teams for technology development and State Agriculture Department for technology dissemination has to take long strides to make maize a profitable venture. The availability of quality seed of high yielding hybrids at controlled rates; availability of pneumatic planters for sowing; extensive cluster demonstrations for complete package of practices to optimize the maize yields of state are mandatory steps.

According to the Commodity Outlook Report on Maize, 2023, published by Agricultural Marketing Innovations, Research and Intelligence Centre (AMIRIC), Department of Economics and Sociology, PAU, the lower profitability of maize compared to paddy and the relatively higher price fluctuations are major deterrents to expanding the area under maize cultivation in Punjab. The net returns of maize crop (Rs. 26,583/acre) are lower than cotton (Rs. 36,917/acre) and paddy (Rs 37,546/acre) based on MSP in year 2022-23. The increase in productivity of maize and reduction in potential and farmers field yields can overcome this barrier. Our cost of cultivation is also higher. Major maize producing states of India such as Karnataka, Madhya Pradesh, Tamil Nadu and Uttar Pradesh have much lower cost of production ranging from Rs 1170 per quintal to Rs 1214 per quintal whereas the cost of production is Rs 1447 per quintal in Punjab. To achieve economic viability for ethanol production from maize, it is essential to increase state productivity from 3.93 t/ha to 6 t/ha and to expand maize cultivation to the highly fertile soils of the central districts of Punjab and to enhance the ethanol production potential from 38 % to 40%. Therefore, we need to strengthen our research efforts in these directions.

Following are some key areas that warrant further research:

- Development of hybrids with longer maturity duration (100-105) exceeding the current range of 95-97 days duration, holds the potential to significantly enhance grain productivity. The long duration hybrids should also exhibit rapid dry down of ears/grains after grain filling.
- One of the breeding objectives to support the ethanol production industry, particularly for achieving a 20% Ethanol Blended Petrol (EBP), is to increase the total amount of extractable starch during wet and dry milling processes. The development of high starch content hybrids directly enhances the ethanol production potential of maize. While a longer vegetative phase and cooler environmental conditions during crop cultivation favour high starch accumulation, concerted efforts can feasibly achieve >67-68% starch contents during the *kharif* season in Punjab.
- To protect the maize grains from aflatoxin contamination, it is imperative to dry them to a 14% moisture level. Large capacity maize dryers have been provided in some *mandis* in Punjab such as *Saila Khurd* and *Phuglana* in Hoshiarpur District, Nawanshahr in SBS Nagar district, Nakodar and Bhogpur in Jalandhar district, Machhiwara in Ludhiana district and in Kapurthala. The capacity of dryers installed at these places ranges from 24–64 tonnes per batch. However, these remain under-utilized due to insufficient maize grain availability. To address this issue, there is a need to develop medium capacity potable dryers and to test and demonstrate their utility at a large scale in *mandis*.
- There is a need to boost ethanol production potential from 38 to >40%. For this it is essential to understand the process involved.

Maize contains about 70% starch and about 2% simple sugars, both fermentable into ethanol. Commercial fuel ethanol production typically follows a basic process: breaking down the starch present in corn into fermentable sugars (starch saccharification), feeding these sugars to yeast (fermentation), and then recovering (downstream processing) the main product (ethanol) and recovering the byproducts (animal feed, carbon dioxide, oil and even protein). Two primary industrial methods for starch saccharification are wet milling and dry milling. Dry milling ethanol production represents the majority of commercial ethanol processing in the distilleries. In wet milling, as name indicates, the grain is soaked in water (steeping) to soften it and make it easier to separate (fractionate) the various components of the corn kernel. Fractionation, which separates the starch, fiber, and germ, allows these various components to be processed separately to make a variety of products. The major byproducts of wet-mill ethanol production are two animal feed products, corn gluten meal (high protein, 40%) and corn gluten feed (low protein, 28%), and corn germ, which may be further processed into corn oil. Removing the germ from starch is a major task in wet milling process which makes this process capital intensive. Post fractionation, the starch is saccharified into simple sugars which are fermented with the yeast, *Saccharomyces cerevisiae* to produce ethanol. The latter is distilled and dehydrated to recover ethanol. On the other hand, in dry-grind ethanol process, the entire grain undergoes milling followed by enyzymatic saccharification and fermentation similar to wet milling. However, dry milling generates value added byproducts like Distillers Dried Grain Solubles (DDGs) and carbon dioxide, making this process economical.

Given the National Biofuel Policy (2018), which permits the utilization of first generation (1G) feedstocks, it is relevant to compare prices between molasses (traditionally used but with limited availability as a byproduct), sugarcane juice and grains. Below are the provided comparisons:

A well-defined policy must encompass the development of high yielding hybrids.

The actionable points are:

1. **Assured procurement and price stability**: Price fluctuation in maize is one of the major deterrents in large-scale adoption of maize. Assured procurement of maize at MSP (as in paddy) is the foremost desired step. The vicious cycle of low market price of maize grain and poor resource allocation to the crop can only be broken by making the maize-based cropping system economically viable through a shift in the usual business practice. When maize farmers will receive better prices, they will be inclined to invest more.
2. **Government initiatives and support:** Detailed recommendations are to be worked on subsidies for maize cultivation and biofuel production; financial incentives for farmers transitioning from paddy to maize cultivation and investment plans in R&D for improving maize yield and ethanol production efficiency. Raising awareness about the

Table 1. Estimated bioethanol production costs from sugarcane, maize and rice grains

S. No.	Parameter	Sugarcane	Maize	Rice
1.	Ethanol production [a] (litres/ton)	95	400	475
2.	Ethanol production, litres/ ha (productivity, ton/ha)	7600 (80)	2200 (5.5)	2135 (4.5)
3.	Processing cost (Rs/litre)	10	15	15
4.	Production cost (Rs/ha)	76,000	33,000	32,025
5.	Raw material cost, Rs/ha (Procurement cost, Rs/q)	3,28,000 (410)	1,10,000 (2090)	98,235 (2183)
6.	Total ethanol cost (Rs/ ha)	4,04,000	1,43,000	1,30,260
7.	Ethanol cost (Rs/litre) [b]	53.15	65.0	61.0
8.	Other revenue sources from the field	- Bagasse (30%)-(used as fuel and for making pulp/ paper/ board) - Press mud (5%)-(used as soil conditioner)	- Distillers dried grains- 32%, (used as animal feed) - CO_2-32%, (used as dry ice etc.)	Similar as with maize

[a]One tone of sugarcane yields about 750 litres juice which has 18-20% sugar. At a conversion rate of 0.511, there is potential of 95.

[a]One tonne of maize (assuming 15% moisture and 68% starch content) would yield 578 kg starch which converts to 635 kg sugar (@ 1.1% conversion rate) which can yield 325 kg of ethanol (conversion factor of 0.511) or 400litres of ethanol.

[a]One tonne of rice (assuming 15% moisture and 80% starch content) would yield 680 kg starch which converts to 748 kg sugar (@ 1.1% conversion rate) which can yield 382 kg of ethanol (conversion factor of 0.511) or 475 litres of ethanol.

[b]Govt. purchase rates for ethanol: Rs 65.61/L from sugarcane juice and Rs 60.73/L from B-Heavy molasses; Rs 56.35/L from maize and Rs 58.5/L from rice.

need for crop diversification, the ecological benefits of maize compared to paddy, and the adoption of improved technologies to optimize yield can be highly beneficial.

3. **Infrastructure development:** Farmer cooperatives equipped with proper drying and storage facilities can serve as effective aggregators, ensuring industries receive high quality grains while farmers secure better prices. Industry needs dry maize grain. In Punjab, most of maize is harvested at 20-25 percent grain moisture and the produce is directly taken to *mandis*. This not only leads to heavy post-harvest losses (upto 20-30 percent) but also the grains get infected with fungi which produce aflatoxin. The drying of maize to bring the moisture level to 14% is mandatory to protect the grains from aflatoxin infestation. There is an immediate need of small/medium capacity dryers coupled with moderate capacity *silos* at block level for proper drying and storage of maize grains.

4. **Capacity building and education**: Conduct of training programs for farmers on maize cultivation techniques and benefits, on policy advocacy and to raise awareness about the environmental and economic benefits of maize-based biofuels. Raising awareness about the need for crop diversification, the ecological benefits of maize compared to paddy, and the adoption of improved technologies to optimize yield can be highly beneficial.

5. **Linking industries with maize growers**: Growing maize in command areas of distilleries will reduce the transportation costs and ensure the timely availability of raw material to industry. In Punjab, the majority of maize cultivation is confined to two districts namely Hoshiarpur (50%) and Rupnagar (20.2%). In first phase, efforts should prioritize farmer collection centres and medium capacity dryers in these *mandis.* Setting up of controlled temperature and humidity storage houses will facilitate the year-round availability of maize.

6. **Supportive Framework:** A regulatory framework which encourage public-private sector participation in quality seed production and distribution, technology dissemination and biofuel production, is to be well in place.

To sum up, maize stands out as a highly viable option for diversifying paddy cultivation in Punjab. Its potential is reinforced by the rising demand, the proliferation of grain-based distilleries and processing units in Punjab, and the Union government's decision to procure maize at the minimum support price (MSP). The time to seize this opportunity is now.