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Explained: The green revolution in maize

Maize production in India has more than tripled over the last two decades, making it a private sector driven green revolution success story. Maize has now gone from being a feed crop to a fuel crop

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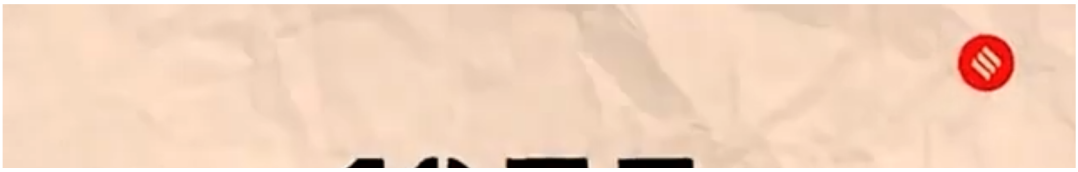
India's maize production peaked in 2022-23 at just over 38 mt. (Express Archive Photo)

The Green Revolution was largely about wheat and rice. India became self-sufficient, if not surplus, in these two cereal grains, thanks to high-yielding varieties bred by institutions such as the Mexico-based CIMMYT (International Maize and Wheat Improvement Center) and the Indian Agricultural Research Institute (IARI) in New Delhi, under the leadership of scientists like Norman Borlaug and M S Swaminathan.

There is, however, another less celebrated revolution that has taken place in India — in maize. Between 1999-2000 and 2023-24, its annual output has more than tripled, from 11.5 to over 35 million tonnes (mt), with average per-hectare yields also rising from 1.8 to 3.3 tonnes.

Maize, unlike rice and wheat, isn't much of a food grain. Hardly a fifth of India's maize production is used for direct human consumption. An estimated 60% goes as feed for poultry birds and livestock. Such maize is indirectly consumed as food by households – in the form of chicken, egg or milk.



The chicken that one eats is basically “maize with wings”. A market-ready broiler bird weighing 2-2.5 kg consumes some 4 kg of feed during its rearing cycle of 40-42 days, from a 35-40 gm day-old chick. Broiler feed itself contains 55-65% maize by weight, with these at 50-60% for egg-layer feed, and 15-20% in cattle feed. Maize supplies carbohydrates, the principal energy source for poultry and livestock. Other feed ingredients include protein sources (soyabean meal and other oilseed cakes), mineral and vitamin supplements, and additives.

Starch and ethanol

Food and feed apart, 14-15% of India’s maize utilisation is for industrial purposes. Maize grains have 68-72% starch, and 1-3% of other simple carbohydrates (sucrose, glucose and fructose). Starch has applications in the textile, paper, pharmaceutical, food and beverage industries.

More recent is maize emerging as a feedstock for ethanol that is used for blending with petrol. Distilleries run on sugarcane molasses and juice/syrup during the crushing season (November-April). In the off-season (May-October), when cane isn’t available, they use grains. That, until recently, was mainly surplus rice from the Food Corporation of India. But with the government stopping its supplies on concerns over depleting stocks and “food security”, the focus has shifted to maize.

That's where the role of research comes in. IARI has bred India's first "waxy" maize hybrid with high amylopectin starch content, making it better suited for ethanol production. The starch in maize is a mixture of two polymers, comprising glucose molecules bonded together in a straight chain (amylose) and in branched form (amylopectin).

Normal maize starch has 30% amylose and 70% amylopectin. The starch from IARI's waxy maize hybrid (AQWH-4) has 93.9% amylopectin. Amylose starch imparts hardness in the grain, while amylopectin causes softness. That, in turn, affects starch recovery and fermentation rates. Normal maize grains have 68-72% starch, but only 58-62% is recoverable. The grains from the new Pusa Waxy Maize Hybrid-1, as it is proposed to be called, have 71-72% starch with 68-70% recovery.

"Softness ensures better grinding of the grains fed into the mill for making flour. Granules with higher amylopectin are also easily accessible by alpha-amylase, the enzyme that hydrolyses or breaks down the starch into smaller glucose units. The glucose is, then, fermented into ethanol using yeast," Firoz Hossain, principal scientist at IARI, said.

The IARI-developed hybrid, having an average grain yield of 7.3 tonnes per hectare and potential of 8.8 tonnes, has been identified for release under the All-India Coordinated Research Project on Maize. "We'll soon be going to the Central Variety Release Committee. Once they approve, the hybrid will be officially released and notified (for commercial cultivation)," Hossain said.

IARI has signed a memorandum of understanding with the Uttar Pradesh Distillers' Association for field trials of its waxy maize hybrid. "We get roughly 390 litres of ethanol from one tonne of normal maize grain. The higher recoverable starch from waxy maize should take that to 415-420 litres," S K Shukla, business head at India Glycols Ltd's distillery in Gorakhpur, said. The company is promoting the cultivation of improved maize hybrids for ethanol production by farmers in eastern UP's Gorakhpur, Maharajganj, Sant Kabir Nagar and Basti districts.

New breeding strategies

Meanwhile, CIMMYT has opened a maize doubled haploid (DH) facility at Kunigal in Karnataka. Established in partnership with the University of Agricultural Sciences, Bangalore, it produces 100% homozygous (i.e. having two identical copies of a single gene), and genetically pure inbred lines of maize that can be used as parents for further crossing and breeding of hybrids.

"In the conventional process, inbred lines are formed by continuous self-pollination for 6-8 generations. DH technology enables production of completely uniform lines after just two cropping cycles. It speeds up inbred line development, thereby improving the efficiency of maize breeding and shortening the process," CIMMYT's director-general Bram Govaerts told The Indian Express.

The Kunigal facility, set up in December 2022, produced and shared 29,622 maize DH lines last year. "We have many high-yielding lines tolerant to drought, heat and water-logging, besides those that are nutrient-use efficient and resistant to pests and diseases such as fall armyworm and maize lethal necrosis," added Govaerts.

The Green Revolution in wheat and rice was a result of farmers cultivating high-yielding varieties mostly bred by CIMMYT, IARI and other public sector research organisations. Being self-pollinating plants – their flowers contain both the male and female reproductive organs – these crops aren't amenable to hybridisation. This is as against maize, whose cross-pollinating nature (the male and female parts are located in different areas of the plant) makes hybrid breeding commercially viable.

Private sector-bred hybrids account for more than 80% of the 10 million hectares-plus area planted to maize in India. Their higher yields, from crossing two genetically dissimilar inbred plants, are limited to the first generation. Farmers cannot harvest the same yields if they save the grains from these and reuse as seed.

In maize, CIMMYT is sharing its improved inbred lines with both public sector institutions and 25-odd private seed companies. These include Mahyco, Shriram Bioseed, Advanta Seeds, Nuziveedu Seeds, Kaveri Seeds, Mahindra Agri Solutions, Rasi Seeds and Indo-American Hybrid Seeds.

The Green Revolution in maize has been, and continues to be, a private sector-led one.

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