

INDOLA: Development and utilization of quality mustard (*Brassica juncea*) oil

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Oilseed Brassica commonly known as rapeseed mustard is the most important source of edible oil in India next to soybean. The proportion of different fatty acids in edible oil determines its suitability for consumption. Erucic acid is a nutritionally undesirable fatty acid present in the rapeseed-mustard seed oil, reported to cause heart-related diseases. De-oiled seed meal is an excellent source of animal/poultry feed due to its high-quality protein content but glucosinolates, another anti-nutritional factor diminishes the value of the de-oiled cake. After a lead from the Canadian plant breeders, Indian researchers initiated the efforts to reduce these two anti-nutritional factors in Indian mustard to Canola/double zero standards (having erucic acid <2% in oil and glucosinolates <30 µmoles/g in defatted seed meal) and subsequently developed a good number of varieties. We proposed the name of these indigenously developed double zero varieties/genotypes as INDOLA. To meet the increasing demand for quality edible oil and to reduce the expenditure on the import of Canola oil, a lot of innovations spanning over research, extension, and policy framework are needed for the development and utilization of INDOLA varieties.

Keywords: Canola, Erucic acid, Glucosinolates, INDOLA, Mustard, Oil quality

IN India, demand for oilseeds is ever increasing. During 2020–21, India imported edible oils worth ₹1.17 lakh crore, an all-time high. Rapeseed-mustard belongs to the genus *Brassica* comprising of six cultivated species, viz. *B. rapa*, *B. leigra*, *B. oleracea*, *B. juncea*, *B. napus* and *B. carinata*. In India, Indian mustard (*Brassica juncea*), is the predominant species among the rapeseed-mustard group of crops and accounts for more than 85% of its total acreage. India has a 40% share in the total rapeseed-mustard production in Asia. It is cultivated mainly in Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana, West Bengal, Assam, and Gujarat which contributes maximum to its production (>93%) and acreage (>91%). In India, rapeseed-mustard has about 24% share in total oilseed production ranking second after soybean.

Erucic acid and glucosinolates

Oil quality being a complex character is determined by many dependent and independent parameters such as shelf-life, palatability, nutritional profile, suitability for cooking and industrial utility, etc. Fatty acid profile (types and proportion of different fatty acids in oil) and amount of essential amino acids determines the nutritional quality of edible oil. Conventional varieties of Indian mustard contain a high proportion of erucic acid (40–50%) in seed oil, which is nutritionally undesirable as it is reported to cause heart-related ailments in humans. High erucic acid in mustard oil is not metabolized and is reported to impair the peripheral vascular system, decrease coagulation time and increase blood cholesterol.

Similarly, oil-free mustard seed meal cake is an excellent source of animal nutrition as it contains about 40% high-quality protein and

balanced amino acid composition. According to FAO statistics, India is third-largest producer of mustard cake (9.255 MT) in the world. Despite being a rich source of good quality proteins, the mustard cake has limited export potential to European and other developed countries as the conventional Indian mustard has internationally unacceptable levels of glucosinolates (80–160 µmole glucosinolate/g of oil-free seed meal) in the seed meal. Glucosinolates are a group of sulfur-containing compounds that are hydrolyzed by endogenous enzyme, myrosinase to yield active metabolites, viz. thiocyanate, isothiocyanate, and nitrile. The cleavage products are reported to be associated with the alterations of the size, structure, and function of the thyroid gland and damages of the liver and kidneys. In addition, high amount of glucosinolates in the seed meal of traditional varieties of Indian mustard causes bitterness

and reduces the palatability of seed meal.

Single zero and double zero/INDOLA varieties of Indian mustard

To create value and to increase the acceptance of mustard seed oil and meal, reduction of anti-nutritional erucic acid in oil and glucosinolates in the de-oiled cake are the two important breeding objectives of paramount importance. The rapeseed-mustard varieties fulfilling the requirements of low erucic acid (<2%) are called single zero whereas, single zero varieties having glucosinolate content <30 $\mu\text{mol/g}$ of oil-free cake are known as double zero or simply as INDOLA quality type and fetch a premium price in the international market. To provide a distinct identity from the imported Canadian double low (Canola) oil, we proposed the INDOLA name to the indigenously developed double zero varieties.

Development of single zero and Canola rapeseed-mustard

Genetic improvement of rapeseed for Canola quality is a key milestone in the history of breeding for oil and meal quality enhancement and was first initiated in Canada. During the second world war, the Canadian government started to introduce the cultivation of rapeseed in Canada to meet the domestic demand through the seeds sourced from Poland (*B. rapa*) and Argentina (*B. napus*). Due to the good adaptation to Canadian

prairies, over the next 20 years, *B. napus* and *B. rapa* became major oilseed crops in Canada. However, during 1956, the nutritional aspects of rapeseed oil were questioned, especially the high proportion of erucic acid in the fatty acid profile of the oil. Canadian plant breeders initiated the effort to reduce erucic acid and their efforts were greatly facilitated by the contemporary development in the field of gas chromatography which enabled the study of the fatty acid profile. The first breakthrough came with the discovery of natural mutants almost free of erucic acid in *B. napus* (1961) and *B. rapa* (1964) by Baldur Stefansson and Keith Downey, respectively. In 1968, Agriculture and Agri-Food Canada (AAFC) released 'Oro' and 'Span', the world's first low erucic acid *B. napus* and *B. rapa* cultivars, respectively.

The development of low erucic acid cultivar increased the value of rapeseed oil for edible oil purposes. Nevertheless, due to the presence of glucosinolates, the nutritional value of oil-free seed meal was limited. Extensive screening of rapeseed germplasm by Canadian breeders at AAFC resulted in the isolation of Bronowaski, a natural mutant in 1967 only to become the single genetic source of low glucosinolates trait to develop the low glucosinolates *B. napus* and *B. rapa* cultivars throughout the world. The world's first double low (Canola) *B. napus* cultivar 'Tower'

was developed by Dr. Baldur Stefansson and released in 1974 at the University of Manitoba. The first double low *B. rapa* cultivar 'Candle' was developed by Dr. Keith Downey at AAFC and was released in 1978. Due to their incredibly important contributions to Canola breeding, Dr. Stefansson and Dr. Downey are known as the 'Fathers of Canola'. The reduction in the amount of two anti-nutritional factors in seed oil and meal augmented a significant value for rapeseed (*B. napus* and *B. rapa*) globally. However, Indian mustard (*Brassica juncea*) is a more productive oilseed than rapeseed (*B. napus* L.) in tropical and dry conditions of India. Indian mustard genotypes with low erucic acid in their seed oil were first discovered in Australia in 1980 by Kirk and Oram in two commercial mustard samples. The zero erucic/low eicosenoic acid components of these two samples were designated Zem 1 and Zem 2, and were widely distributed to mustard breeders around the world, including India.

Development of INDOLA mustard

Breeding efforts have been underway in India since 1970 to reduce the erucic acid and glucosinolates in the rapeseed mustard to internationally accepted standard (erucic acid <2% in oil; glucosinolates <30 $\mu\text{moles/g}$ in oil-free seed cake). The indigenous efforts with the objectives to improve rapeseed-mustard oil and meal quality were strengthened with



PDZM-31: An INDOLA-quality variety of Indian mustard at IARI farm, New Delhi



PDZM-33: An INDOLA-quality variety of Indian mustard at IARI farm, New Delhi

various international collaborative projects such as the Indo-Swedish collaborative project (1975–1988), Indo-Canadian collaborative project (1979–94) and Indo-Australian project (2004–10). Through these international collaborations, 30 exotic single zero/canola lines including Zem-1 and Zem-2 of *B. juncea*; Torch, Tobin, Candle and Span of *B. rapa*; Tower, Altex and Westar of *B. napus* were introduced for testing in India. However, the introduced strains were low-yielding in Indian hot and dry growing conditions, therefore, initial efforts emphasized the development of genetic stocks for low erucic acid and/or low glucosinolate in the indigenous cultivars using exotic donor sources. As a result of vigorous efforts by Indian plant breeders, several low erucic strains were identified during this phase. During 1996–97, a National Network Project for Improvement of Oilseed Brassica Quality was established by ICAR to transfer improved quality traits from exotic germplasm into agronomically suitable cultivars of *B. juncea*. Since then, quality mustard breeding became an integral component of the All India Coordinated Research Project on Rapeseed-Mustard (AICRP-RM). The zero erucic mustard developed by Kirk and Oram (1981) has been utilized by Indian scientists for transferring zero erucic traits to Indian mustard varieties. The first low erucic acid variety Pusa Karishma of *B. juncea* was developed in 2004 and later on several varieties were developed by ICAR-IARI, New Delhi and released for different climatic conditions of India, viz. Pusa Mustard-21 (PM-21), PM-22, PM-24, PM-29, PM-30 and more recently (2020) PM-32 for Zone II [comprising of Rajasthan (Northern and Western parts), Punjab, Haryana, Delhi, Western Uttar Pradesh, Plains of Jammu & Kashmir and Himachal Pradesh]. Similarly, the first single zero bold seeded (1000 seed-weight: 5.38g) variety of Indian mustard PM-30 was released for Zone III (Uttar Pradesh, Uttarakhand, Chhattisgarh and Madhya Pradesh) of the

Table 1. Characteristics features of INDOLA varieties released from IARI

Variety	Release year	Avg. yield (q/ha)	Oil content (%)	Maturity (days)	1000 seed weight (g)	Recommended for Zone
PDZM-33	2021	26.4	38	141	3.9	Zone II comprising Rajasthan (Northern and Western parts), Punjab, Haryana, Delhi, Western Uttar Pradesh, Plains of Jammu & Kashmir and Himachal Pradesh
PDZM-31	2017	23.3	41	142	3.68	Zone II comprising Rajasthan (Northern and Western parts), Punjab, Haryana, Delhi, Western Uttar Pradesh, Plains of Jammu & Kashmir and Himachal Pradesh

country. These low erucic varieties have received an overwhelming response from the farmers and industry. Nevertheless, to address the issue of anti-nutritional glucosinolates in seed cake, India's first INDOLA variety, Pusa Double Zero Mustard-31; developed by ICAR-IARI was released in 2017. Very recently (2021) another high yielding (avg. yield: 26.4 q/ha) INDOLA variety of Indian mustard, Pusa Double Zero Mustard-33 was developed by ICAR-IARI.

Apart from these, Punjab Agricultural University (PAU), Ludhiana has also released single low erucic acid (GSC5), double low varieties (GSC6, GSC7) of *Brassica napus* and single low (RLC2), double low varieties (RLC3) of *B. juncea*. PAU is also credited with the development of the first double zero hybrid (RCH-1) of Indian mustard. The characteristic features of INDOLA varieties developed by ICAR-IARI are presented in Table 1.

Challenges and opportunities in development and utilization of INDOLA mustard

Development and utilization of INDOLA mustard varieties in India is facing a lack of consumer awareness, absence of proper policy framework and technologies related constraints. In India, mustard is grown mainly on marginal land under low input orientated rainfed conditions which is a major barrier in the realization of potential oil and seed yield of most of the released single zero and INDOLA varieties. Further, at present, the cultivation of INDOLA varieties

accounts for less than 1.0% of the total area under rapeseed-mustard cultivation. The segregation of quality mustard with conventional mustard is itself a daunting task at all the stages of crop production and marketing. In the Krishi-mandis, at present, farmers hardly get any incentive for the INDOLA-quality produce. Promotion of farmer produce organization (FPO), contract farming, and price support schemes are necessary as an incentive to promote the farmers for cultivation of INDOLA-quality varieties of rapeseed-mustard. The INDOLA-quality traits, especially the low glucosinolate are governed by multiple recessive genes and to combine all of them with high yield requires the support of modern plant breeding tools and techniques. Marker-assisted selection would help enhance precision and selection efficiency for double low traits. There is an urgent need for hands-on training of scientists and technicians involved in *Brassica* breeding and use analytical tools and techniques such as gas chromatography, spectrometry, etc. applicable in the breeding of Indian mustard varieties for INDOLA trait.

As per the economic survey 2021–22, India's cooking oil import will continue to grow at a high growth rate of 3.4% per annum till 2030 due to growing urbanization, and changing dietary habits with a shift towards highly processed foods with high content of vegetable oils. Due to a large gap in the demand and supply of edible oil, India relies heavily on the import of edible oil to meet its domestic requirements.

Plant breeding programmes with the objective of INDOLA-quality breeding should be given priority in resource allocation. Ensuring the availability of high-quality edible oil and meal plays a crucial role in the economy; thus, India could become a key contributor to the world's healthy rapeseed-mustard oil production.

SUMMARY

India meets a large share of its edible oil demand through import and at present enormous foreign exchange is being utilized to import edible oil, especially transgenic Canola oil. With the increased standard of living, the demand for healthy edible oil is expected to

increase further in the future. The widening gap between demand and supply of mustard oil has to be curtailed. Rapeseed-mustard being a traditional and indigenous crop is the most important source of edible oil in India. However, due to the presence of two anti-nutritional factors erucic acid and glucosinolates in seed oil and meal, respectively, the nutritional potential of rapeseed-mustard is limited. To address this challenge, low erucic acid and INDOLA-standard varieties have been developed in India. Successful breeding of nine low erucic and INDOLA varieties at ICAR-IARI with good yield potential has been able to thwart the biggest challenge of enhancing the value of rapeseed-

mustard to an internationally accepted level. The sustained plant breeding efforts not only have made rapeseed-mustard oil qualitatively superior for human consumption; the cake/meal obtained after extraction of oil, which is a rich source of protein, has also been made nutritionally superior by removing the undesirable glucosinolates. Addressing the challenges of INDOLA, development at the policy and technological level will help make India *atmanirbhar* in the field of edible oil production.

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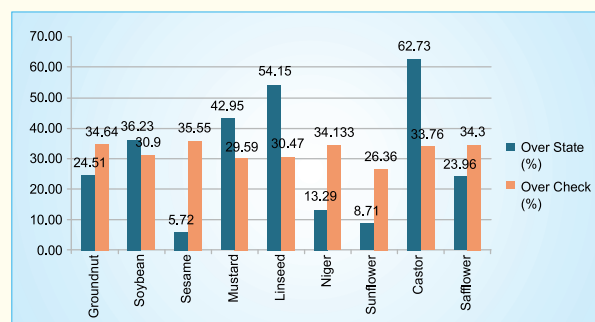
List of improved/released varieties/hybrids of Oilseeds

Variety	Area of adoption	Characters
Indian mustard (<i>Brassica juncea</i>)		
Pusa Mustard 32 (LES 54)	Rajasthan (Northern and Western), Punjab, Haryana, Delhi, Western Uttar Pradesh, Plains of Jammu & Kashmir, Himachal Pradesh	Low erucic acid (<2%) mustard variety, suitable for timely-sown irrigated condition, average seed yield 2.71 tonnes/ha, oil content 38%, maturity 145 days.
Radhika (DRMR 2017-15)	Jammu, Punjab, Haryana, Delhi, Rajasthan	Suitable for irrigated late sown conditions (November) under irrigated condition, average seed yield 1.79 tonnes/ha, oil content 40.7%, maturity 131 days, tolerant to high temperature at terminal stage.
Brijraj (DRMRIC 16-38)	Jammu, Punjab, Haryana, Delhi, northern Rajasthan	Suitable for late sown (November) under irrigated condition, average seed yield 1.73 tonnes/ha, oil content 39.9%, maturity 132 days, tolerant to high temperature at terminal stage.
SVJH 108	Haryana	Suitable for irrigated conditions under high and low fertility, average grain yield 2.4 tonnes/ha, oil content 41.3%, black and bold seed (6.1 g/1000-seed).
Azad Mahak [(KMR (E) 15-2)]	Uttar Pradesh	Suitable for timely sown irrigated conditions, average seed yield 2.05 tonnes/ha, oil content 41.6%, maturity 120–125 days, tolerant to high temperature.

Cluster Frontline Demonstration on Oilseeds

In all, 74,754 CFLDs on different pulse crops were organized covering 29,955.20 area (7,157.60 ha area and 17,740 demonstrations in *kharif*, 19,568.60 ha area and 48,711 demonstrations in *rabi* and 3,229.00 ha area and 8,303 demonstrations in summer).

Yield advantage through CFLDs of various oilseed crops over state and check yield was significant. In groundnut crop yield advantage through cluster frontline demonstrations over the state and check yield was 24.5 and 34.64%. The yield advantage was 36.23 and 30.9% in soybean; 5.72 and 35.55% in sesame; 42.15 and 29.59% in mustard; 54.15 and 30.47% in linseed; 13.29 and 34.13% in niger; 8.71 and 26.36% in sunflower; 62.73 and 33.76% in castor, and 23.96 and 34.3% in safflower over state and check yield, respectively.



Yield advantage through CFLDs of various oilseed crops

Source : ICAR Annual Report 2021-22