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Maize as emerging source of oil in India: an overview

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Abstract

India is the largest importer as well as the third largest consumer of edible oils. Over many decades maize has been meeting the requirements of human population for food, fodder, fuel and other innumerable number of industrial products such as oil, protein, starch, ethanol, etc. Due to ever-growing and increasing human population and its demands, the necessities and demands of oil is increasing at an alarming rate. In India, maize oil is used to blend with other oils, because of vast nutritional quality embedded in it such as vitamin E (tocopherol), sitosterol and linoleic acid which are indispensable essential fatty acids. Hence, there is a wider scope to emphasize research on maize hybrids that are not only rich in oil content but also having an array of beneficial nutrients. Maize has the highest productivity as compared to other crops. Therefore, the target of attaining self-sufficiency in oil can be fulfilled through this crop. To achieve this goal, the breeders have to develop best inbreds by various methods such as divergent recurrent selection or other such, which are being successfully conducted in the University of Illinois.

Keywords: India, germ, oil, QTL, *Zea mays*

Introduction

Maize provides food, feed, fodder and serves as a source of basic raw material for a number of industrial products viz, starch, protein, oil, alcoholic beverages, food sweeteners, cosmetics, bio-fuel, etc. Maize is the third most important food grain in India after wheat and rice and it is cultivated over ~8.12 mha area with an annual production of ~19.77 million tonnes (mt) and an average productivity of 2,435 kg ha^{-1} (Maize Atlas of India, 2009). It was introduced in India during the seventeenth century by the Portuguese. The Indian vegetable oil economy is the world's fourth largest after the US, China and Brazil, harvesting about 25 million tons of oilseeds against the world (India Law Offices). Edible oils most commonly employed in India are palm, soybean, mustard, sunflower, groundnut, cottonseed, coconut and olive oil. Maize oil is used to blend with other edible oils. It is not traditionally viewed as an oilseed crop but it is considered as 'minor' oil among traditional vegetable oils. The United States is the largest producer of maize oil. Brazil, China, Romania, countries of the former Soviet Union, former Yugoslavia and South Africa also produce maize oil (Orthoefer et al, 2003). It is a co-product of wet and dry milling industries, which essentially breaks down maize kernel into starch, oil, protein and some of the important vitamins and minerals (Duensing et al, 2003; Johnson and May, 2003).

Generally, maize kernel having an oil content of more than 6% is called as High Oil Maize. The maize kernel is a mixture of maternal tissues (eg. pericarp) and zygotic tissues (eg. embryo, aleurone and endosperm). The maize kernel, like other cereal grains, includes pericarp (6%), endosperm (82%) and germ which are about 12% (Watson, 1987). The typical maize kernel, on dry weight basis is composed of 61-78% of starch, 6-12% of proteins, 3.1-5.7% of oil, 1.0-3.0% of sugar and 1.1-3.9% of ash (Miller, 1958; Watson, 2003). The typical fatty acid profile of a maize kernel contains 57.9% of linoleic acid, <1% of linolenic acid, 25.2% of oleic acid, 11.6% of palmitic acid and 1.8% of stearic acid (Dunlap et al, 1995; White and Weber, 2003).

If we talk, about the fatty acids in maize oil, the unsaturated fatty acid is composed of about 80% of linoleic acid which is an indispensable fatty acid. It has the efficiency to reduce cholesterol content, soften blood vessels, enhance the function of cardiovascular system, prevent and improve the arteriosclerosis (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2011). Besides linoleic acid, maize oil is also rich in other useful products like sitosterol, vitamin E and other functional nutrients. Since maize oil is having 2.25 times more calorie per unit weight as compared to starch, hence, we can say that increasing the oil content of maize would obviously increase its energy value. Most of the oil is present in germ of the seed. Germ of ordinary corn contains about 30% of oil, whereas germs of high oil strains contain as much as 50% oil. The protein of high oil lines have better quality with subsequent increase in lysine content and higher proportion of yellow pigments (xanthophylls, carotenoid). Apart from this, it contains higher concentration of vitamin E (tocopherol) which is soluble in oil and protects double bonds from oxidation (acting as an antioxidant) thereby, increasing the shelf life of corn oil. In India, less attention has been paid on exploitation of heterosis towards quality

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traits like high oil and starch content in maize.

Status of high oil maize at global level

Hopkins (1896) in the University of Illinois initiated divergent selection for oil and protein concentrations in open pollinated cultivar 'Burr's White' (white endosperm) in corn kernel. After 70 generations of mass selection of ears with highest oil content, the oil content in Illinois High Oil Line increased 3.6 folds. This experiment established the fact that oil content is a heritable trait in maize. The classical report entitled "The structure of the corn kernel and the composition of its different parts" formed a basis for divergent mass selection by Hopkins et al (1903). They divided the corn kernel into six major parts viz, tip cap, hull (pericarp), horny glutinous part (aleurone), horny starchy part (horny endosperm), white starchy endosperm (soft starch) and germ. He estimated about 80 to 84% of total oil located in germ, about 12% in aleurone and 5% in endosperm. In 2005, 106 generations of selection had been accomplished for high oil and 105 for high protein (Dudley, 2007). The long-term selection experiment for high and low oil content has permitted testing of fundamental quantitative genetic principles that pertains to selection in plants and animals. Several high oil corn breeding programs at public institutions and commercial hybrid corn companies has been started since the late 1940s. One of the early high oil corn breeding programs was started by CM Woodworth and was continued by RW Jugenheimer at the University of Illinois. Funks Seed Co of Bloomington, IL started a high oil corn breeding program in the year, 1946. The objective of this breeding programme was to develop high oil inbreds to be employed in hybrid production. Watson and Freeman (1975) added another effort for high oil corn breeding at Funks Bros Seed Co and further it was purchased by CPC Inter Inc in 1968 (Lambert, 2001). Wolf et al (1952) observed that corn germ consists of scutellum and embryo, the latter containing the primary axis, plumule, coleoptile, mesocotyl, adventitious and primary roots and the coleorhiza. In general, scutellum is about 10 to 12% of total kernel dry weight but it contains 83-85% of total oil. The total oil in pericarp tip cap and endosperm ranges from 10 to 13% in the kernel. Some workers applied certain statistical analysis techniques to measure quantitative variation in oil concentration in the Illinois chemical strains (Winter, 1929).

The scutellum consists of epithelial, parenchyma cells and vascular tissue. Oil synthesis in developing scutellum tissue takes place through deposits of oil bodies or spherosomes in parenchyma cells. Bauman et al (1963) and Alexander et al (1967) reported that the unique feature of high oil corn breeding program was the appositeness of wideline Nuclear Magnetic Resonance Spectroscopy (NMR) to select single corn kernels which are high in oil concentrations. A high oil corn breeding programme implicates recurrent selection procedures to increase oil concentrations in synthetics followed by ear to row selection along with selfing to develop high oil inbreds (Alexander, 1956). Pfister Hybrid Corn Co, El Paso, Illinois started a high oil breeding program in the early 1970s and marketed high oil single cross hybrids since 1980s. In 1989, Pfister Hybrid Corn Co, Du Pont and the University of Illinois started a joint project to develop and release high oil corn hybrids for marketing. There were about 70 hybrid seed corn companies in 1997 producing and marketing topcross seeds. There were about 607,287 ha (1.2 million acres) of high oil corn grown in the US in the year 1998 (Lambert, 2001). On comparative analysis of rate of oil accumulation in high oil inbred and normal inbred, it can be concluded that during 15-45 days of pollination, high oil inbred can accumulate oil at a higher rate (Lambert et al, 1968). Lambert et al (1968) compared the rate of oil accumulation in kernels of high oil inbred and normal inbred and thus came to the conclusion that high oil inbred showed a higher rate of oil accumulation during 15 to 45 days after pollination. Both inbred had relatively constant rates of oil accumulation from 45 DAP to black layer. Wang et al (1984) estimated the size of spherosomes which ranges from 1.09 µm for ILO (at 0.5% oil) to 1.31 µm for IHO (at 18% oil). One inference that could be drawn from this is that the higher oil genotypes contain slightly larger and greater number of oil bodies.

Indian situation in global context

Since 1995, Indian share's in the world production of oilseeds has been around 10%. Although, India is a major producer of oilseeds, per capita oil consumption in India is only 10.6 kg annum^{-1}, which is low as compared to 12.5 kg annum^{-1} in China, 20.8 kg annum^{-1} in Japan, 21.3 kg annum^{-1} in Brazil and 48.0 kg annum^{-1} in the USA. Vegetable oil consumption has increased following a rise in household incomes and consumer demands. India imports half of its edible oil requirement, making India, the world's third-largest importer of edible oil and third largest consumer of edible oil due to ever growing population. Currently, India accounts for 11.2% of vegetable oil import and 9.3% of edible oil consumption (India Law offices). India is the largest importer and third largest consumer of edible oils. The sources of edible oil are palm, soybean, mustard, sunflower, groundnut, cottonseed, coconut and olive oil. Among industrial oils, rice bran oil and cotton seed oil are gaining importance. The corn oil emerged in the USA. The large scale production of corn oil began in the 1910s. Since 1950s, developed countries have taken up the production of corn oil. Presently, corn oil makes a major proportion of edible oil consumption. Corn oil is used in margarine, soup, soap, in emulsions and paints as rust preventative and in many more products.

In India, most of the corn is used for feed industry and starch extraction. Germ used to be a waste

Table 1 - List of Inbreds available in India for High Oil Maize in public sector (Sain et al, 2010).

Inbred	Pedigree	Kernel Colour	Kernel Texture	Maturity	Center
DHol 1	02POOL 33C24	Y	F	E	DMR
DHol 10	POBLAC 70 C1	Y	F	E	DMR
DHol 17	02POOL 17C10	Y	F	E	DMR
DHol 18	02POOL 33C25	Y	F	E	DMR
DHol 7	HIGH OIL POUPATION II	Y	F	E	DMR
DMHOC 5-1	Temp x TropHigh oil QPM-13	Y	F	E	DMR
DMHOC 5-2	Temp x TropHigh oil QPM-13	Y	F	E	DMR
DMHOC 6	CUBA 14	Y	F	E	DMR
DHol 13	Temp x TropHigh oil QPM	Y	F	E	DMR
DHol 20	POBLAC 61 C5	Y	D	E	DMR
DHol 8	POBLAC 61 C4	Y	D	E	DMR
DMHOC 8	SELECC H. OIL	Y	D	E	DMR
DHol 14	Temp.HOC 15	Y	D	E	DMR
DHol 15	TxT YD HO C 208	Y	D	E	DMR
DHol 16	TxT YD HO C 15	Y	D	E	DMR
DMHOC 14	POBLAC 69 C5	Y	D	M	DMR
DMHOC 9	HIGJ OIL POPULATION II	W	D	M	DMR
DHol 22	TLWD HO C8	W	F	M	DMR
DMHOC 3	HIGH OIL POPULATION II	W	F	M	DMR
Dholi Inbred-73	Talar	Y	F	M	Dholi
Dholi Inbred-75	Talar	Y	F	M	Dholi
Dholi Inbred-76	Talar	Y	F	M	Dholi
Dholi Inbred-79	Talar	Y	F	M	Dholi
Dholi Inbred-82	Shahid	Y	F	M	Dholi
Dholi Inbred-83	HOTLWC-C1-S	Y	F	M	Dholi
Dholi Inbred-84	HOTLWC-C1-S	Y	F	M	Dholi
Dholi Inbred-86	HOTLWC-C1-S	Y	F	M	Dholi
HKI 41-3-1	DMR41	Y	F	L	Karnal
HKI 48-3-2-1	DMR48	Y	F	L	Karnal
HKI SHD ER-10	Shahid	Y	F	L	Karnal
HKI SHD ER-12	Shahid	Y	F	L	Karnal
HKI SHD ER-16	Shahid	Y	F	L	Karnal
HKI SHD ER-6	Shahid	Y	F	L	Karnal
HKI Tal-1-2-1-3	Talar	Y	F	L	Karnal
HKI Tal-G-1-1	Talar	Y	F	L	Karnal
HKI Tal-G-1-2-1	Talar	Y	F	L	Karnal
HKI Tal-PF-1-2-1	Talar	Y	F	L	Karnal
Dholi Inbred-71	Talar	Y	F	L	Dholi
Dholi Inbred-72	Talar	Y	F	L	Dholi
Dholi Inbred-74	Talar	Y	F	L	Dholi
Dholi Inbred-77	Shahid	Y	F	L	Dholi
Dholi Inbred-78	Shahid	Y	F	L	Dholi
Dholi Inbred-80	HOTLWC-C1-S	Y	F	L	Dholi
Dholi Inbred-81	HOTLWC-C1-S	Y	F	L	Dholi
HKI Talar	-	Y	F	L	DMR
DMRHOC-51	SHD-1ER6	Y	F	L	DMR
Dholi Inbred-85	HOTLWC-C1-S	W	F	L	Dholi
DHol 5	HIGJ OIL POPULATION II	W	F	L	DMR
DHol 6	HIGJ OIL POPULATION II	W	F	L	DMR

Y: Yellow, W: White, F: Flint, D :Dent, E=Early, M: Medium, L: Late, DMR: Directorate of Maize Research, New Delhi

product obtained after starch extraction from seed. Currently, germ is in demand because of its high oil content and utilization as a byproduct. Refined corn oil is considered to be the best edible oil used internationally. Considering the large planting area under corn and high unit production, commercial interest is now arousing in corn oil production. Cost benefit ratio in maize is highest due to its high productivity. Through good cultivars, processing and comprehensive utilization, the value of high oil corn can be improved considerably.

In India, Directorate of Maize Research, New Delhi and its centers are working for High Oil hybrid and inbred development viz, New Delhi, Dholi and Karnal. List of High Oil Inbreds is given in Table 1.

Prospects and constraints

Limited breeding work has been done for exploiting the potential use of maize as a source of edible oil. Processors carry out blending of corn oil with olive oil and rice bran oil etc. Blending provides ideal levels of mono-unsaturated and poly-unsaturated fatty acids. This ensures excellent flavour stability as well as enhances the taste of food. Thus, in view of the need and relative advantages of high oil rich corn in order to ensure food which is rich in essential nutrients and palatability, developing country like India, must be focused on developing good hybrids by employing advanced breeding and molecular strategies.

Genetics of high oil maize

The number of loci controlling oil concentration in IHO and ILO ranges from 33 loci in cycle 28, 20 to 40 loci, 54 loci in cycle 76, 54 to 69 loci in cycle 90 (Dudley and Lambert, 1969,1992; Dudley, 1977; Lambert et al, 1997). As the number of loci controlling oil concentrations increased, the cycles of selection and progress also increased in IHO and ILO strains. These are the functions of selection progress and additive genetic variance. Exploitation of xenia effect is a well established fact for breeding in corn for high oil. Xenia describes any immediate effect; a pollen grain has, on the germ or endosperm of seed plants. Normal oil hybrids pollinated by high oil pollinator results in increase in germ weight and oil concentrations, percent reduction in endosperm and small changes in germ size without affecting yield. The pollinators need to be high in oil with good amount of pollen with increased duration of pollen shedding. Hence, prospecting germplasm for good pollinators is essential. Good normal corn inbred or elite single cross hybrid used as female line will impart good seed production. Elite single cross hybrid can be used as female after detasseling. Female parent has largest influence on kernel oil concentrations and pollen source (xenia) and a less effect on the oil levels (Miller and Brimhall, 1951). The self pollinated high oil hybrid had less oil content than high oil inbred hence Xenia effect is negligible but for exploiting more oil yield in high oil hybrid were pollinated by high oil inbred.

To determine the inheritance of oil levels in corn, Sprague and Brimhall (1949) were the first to evaluate segregating generations (F_2, BC_1 P_1, BC_2 P_2) involving crosses of IHO, ILO and normal inbreds. Segregating generations of crosses (IHO × ILO) showed dominance for low oil concentration; others showed partial dominance or dominance for high oil levels. Analysis of a diallel among the Illinois chemical strains has dominance for both high and low oil concentrations. Total genetic variance for oil concentrations in 'Reid Yellow Dent' has dominant genetic variance consisting of additive variance (Dudley et al, 1977; Moreno et al, 1975; Miller et al, 1981). In case of Linkage effects in IHO × ILO crosses, F_2 and F_6 generations by random mating with Design III and the additive genetic variance is about seven times larger than dominance variance in F_2 ($VA = 1.550$, $VD = 0.220$) and about four times larger in F_6 ($VA = 0.812$, $VD = 0.189$) because additive genetic variance in F_6 was about 50% of F_2. The lack of linkage effects on dominant genetic variance indicates, the loci with dominant genes which are distributed throughout corn genome are not linked, thus it can segregate independently. Some genes are dominant for low oil concentration and other genes are dominant for high oil concentration(s).

Spherosomes analysis

The oil bodies present in cell are called as oleosomes in maize, the shape of oleosomes is similar to shape of a 'sphere' hence also called as 'Spherosomes'. These spherosomes are bounded by olesins which is wall of spherosomes (Sorokin, 1967). These olesins are made up of proteins, vitamins and several minerals which are insoluble in triglycerides. In maize, these olesins are comprised of tryptophan, isoleucine, lysine etc. These oil bodies can easily be observed by biological stains, most commonly used stains or biochemical marker is Nile Red and Nile blue (Wei Chen et al, 2009). It stains spherosomes with red colour and olesins with blue colour.

Breeding for high oil maize

Breeders have been selecting germplasms for higher oil content in maize since many years. Limited breeding work has been done for exploiting the potentiality of maize as a source of edible oil. There is a positive correlation between oil content and germ size. Most of the genetic research work on maize kernel has been focused on total oil content rather than its composition. The inheritance of which is highly quantitative; however, several single gene mutations influencing fatty acid profile have been identified. Linoleic acid content is controlled by a single recessive mutation, *linoleic acid1* (*ln1*) (De la Roche et al, 1971). High oleic acid content (57% vs 27%) is due to the recessive mutation *oleic acid content1* (*olc1*) (Wright, 1995).

Heterosis breeding is the most successful approach among the different options available. The concept of heterotic groups was established by relating the level of heterosis with combining ability. Maize breeders have relied on exploitation of two or more heterotic groups in development of inbreds and hybrids including synthetics and composites all over the world. Therefore, a knowledge of gene action, combining abilities and heterosis for agronomic and quality traits governing the ultimate end product i.e. yield is essential before formulating appropriate maize improvement strategies.

Conventional selection can also lead to increase in oil kernels. Selection for high oil kernel increases the proportion of germ and further content of germ oil. The problems that overshadow successful production of high oil corn includes low grain yield potential, physiological cost of oil synthesis, low seed vigour, low kernel weight, shorter seed longevity and poor germination of high oil corn lines. Study of seed related traits at advanced level on seed germinability, setting, maturation and mobilization of oleosomes and oleosins can be done to overcome these demerits. The amenable proportion of embryo and endosperm in oily kernel can increase the level of nutrients especially in embryo without reducing starch in endosperm. A breeding programme to increase oil content in kernels should be considered to avoid grain yield reduction by accumulating positive alleles distributed among genotypes. Gathering of positive alleles from different genotypes can provide transgressive segregants with higher oil content. The two major factors affecting fatty acid composition of corn oil are genotype and environment. Lambert stated that Fatty acid compositions of commercial corn hybrids have varied to some extent over the years, but changes probably resulted from the use of different inbreds in corn hybrids rather than environmental effects. Genetic variation in fatty acid composition of corn oil has been determined by evaluating a series of corn hybrids or by conducting inheritance studies on corn genotypes that varies in the levels of a particular fatty acid(s).

Function of tocopherols or vitamin E in corn oil is to protect the double chemical bonds from oxidation as vitamin E is soluble in corn oil and prevents autoxidation, thus it can increase the shelf life of corn oil. Also, vitamin E is an essential component in animal diet, hence gaining more importance in human diet. The four tocopherol isomers found in corn oil are designated as α-, β-, γ- and δ-tocopherols.

In one of the study of four corn hybrids (2 normal, 1 high-oil, 1 opaque-2) about 70 to 80% of tocopherols were located in corn germ and 11% to 27% in endosperm (Grams et al, 1970). Most of the α-tocopherol (94 to 96%) and γ-tocopherol (93 to 96%) was concentrated in germ. α- and γ-tocopherols are positively correlated with total oil concentration (Levy, 1973). Similarly, a positive correlation ($r = +0.60$) is also there between the amount of linoleic fatty acid and vitamin E g^{-1} of oil for 18 dent corn hybrids. The broad sense heritability were $h^2 = 0.62 \pm 0.16$ for α- and 0.68 ± 0.15 for γ-tocopherol (Gallihar et al, 1985). Hence genetic variances clearly indicate, recurrent selection would be effective for changing the levels of α- and γ-tocopherols in RSSSC with appropriate monitoring procedures.

Molecular breeding approach

At present, the availability of molecular tools has widened the knowledge of genetics of oil and oil related traits in corn. Several types of molecular markers are being used to detect linkages between marker and Quantitative Traits Loci (QTL) to enhance the selection processes. QTL analysis has given information about several QTL regions governing quality and quantity of oil (Berke and Rocheford, 1995). Major QTL for oil concentration are located on chromosome 2, 5, 6 and 9. Among 31 loci, 22 has only additive effects, 8 has both additive and dominant gene effects and only one with dominant effect. Regarding quality of oil, there should be an increase in oleic acid concentration and simultaneously reduction of saturated fatty acid i.e., palmitic acid. Metabolism/pathways/enzymes involved in accumulation of oil, starch and protein in kernel can be utilized for studying beneficial correlation between fatty acids, carbon flow for oil, starch and protein synthesis and to improve the oil contents. Abundant information is available describing the synthesis of fatty acids and triglycerol. The regulatory role of ‘DGAT’ allele in determining seed oil content during seed maturation has been revealed (Yuchao Chai et al, 2011). Kernel oil content in maize is a complex quantitative trait. Phenotypic variation in kernel oil is due to its component traits such as oil metabolism and physical characteristics of kernel including embryo size and embryo-to-endosperm weight ratio. The QTL on chromosome 1 has largest effect on kernel oil content (qKO1-1) which is associated with embryo width. The QTL on chromosome 9 is for kernel oil content (qKO9) which is to EEWR (qEEWR9). Embryo oil concentration and embryo width are identified as the most important component traits controlling the second largest QTL for kernel oil content on chromosome 6 (qKO6) and a minor QTL for kernel oil content on chromosome 5 (qKO5-2) respectively (Yang et al, 2012). Recently, very remarkable study was done by Li et al (2012) in which they extensively examined the genetic architecture of maize oil biosynthesis in a genome-wide association study using 1.03 million SNPs characterized in 368 maize inbred lines, including ‘high-oil’ lines. They identified 74 loci significantly associated with kernel oil concentration and fatty acid composition ($P < 1.8 \times 10^{-6}$) which subsequently examined using expression quantitative trait loci (QTL) mapping, linkage mapping and coexpression analysis. More than half of the identified loci localized in mapped QTL intervals, and one-third of the candidate genes were annotated as enzymes in the oil metabolic pathway. The 26 loci associated with oil concentration could explain up to 83% of the phenotypic variation using a simple additive model. His results provide insights into the genetic basis of oil biosynthesis in maize kernels and may facilitate marker-based breeding for oil quantity and quality.

Genetic engineering and ‘omics’ approaches can give better understanding of plant metabolism mechanism. Marker assisted selection could allow more efficient breeding programs for this trait using QTLs with no or lower pleiotropic effects on grain yield. Favourable QTLs from elite and non-elite lines for high oil content are identifiable before flowering with marker-assisted backcrossing of QTLs with larger phenotypic variation. Cost effective marker-assisted selection are successful in plant breeding programmes. Development of genome sequencing and 'Chip technology' or 'Microarray' to determine gene function may lead to additional ways to enhance oil concentration in corn with associated enhancement in kernel size, starch concentration and grain yields.

Future strategies

Corn oil is gaining importance due to its numerous health benefits. Subsequently, non-traditional oils such as corn oil are entering the international market (Ambika et al, 2012). Development of high oil corn is one of the aspects that have been picked up recently in India as it is the largest importer and 3rd largest consumer of edible oils. Development of superior high oil inbred lines for commercial use in hybrid combination(s) is one of the major goals of today's maize improvement programmes. Contract farming of high oil maize will offer maize growers higher profits through the Indian markets. An assured market of high oil maize is to be created so that farmers receive good price for their products. High oil maize content is a desirable trait especially for starch extracting industries. In the coming years, emphasis will be on supporting corn oil to catch a formidable position in edible oil market. High oil is a useful, unique and specialty trait for plant breeders.

Conclusions

Selection of High Oil inbreds for improvement and development of High Oil hybrids to achieve self-sufficiency of oil in India is the latest concept. With respect to oil, Quality proteins are also increased as they are positively correlated. Hence selection for oil will also assist in the indirect selection of quality proteins. Utilization of xenia effect can be done for exploiting more oil content. Biological stains can be used as biochemical markers for oil. Kernel oil QTL identification through SNP's, SSR's can facilitate future cloning and/or functional validation of kernel oil content and helps to elucidate the genetic basis of kernel oil content in maize in India.

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Table 1- List of Inbreds available in India for High Oil Maize in public sector (Sain et al, 2010).

Inbred	Pedigree	Kernel Colour	Kernel Texture	Maturity	Center
DHol 1	02POOL 33C24	Y	F	E	DMR
DHol 10	POBLAC 70 C1	Y	F	E	DMR
DHol 17	02POOL 17C10	Y	F	E	DMR
DHol 18	02POOL 33C25	Y	F	E	DMR
DHol 7	HIGH OIL POUPATION II	Y	F	E	DMR
DMHOC 5-1	Temp x TropHigh oil QPM-13	Y	F	E	DMR
DMHOC 5-2	Temp x TropHigh oil QPM-13	Y	F	E	DMR
DMHOC 6	CUBA 14	Y	F	E	DMR
DHol 13	Temp x TropHigh oil QPM	Y	F	E	DMR
DHol 20	POBLAC 61 C5	Y	D	E	DMR
DHol 8	POBLAC 61 C4	Y	D	E	DMR
DMHOC 8	SELECC H. OIL	Y	D	E	DMR
DHol 14	Temp.HOC 15	Y	D	E	DMR
DHol 15	TxT YD HO C 208	Y	D	E	DMR
DHol 16	TxT YD HO C 15	Y	D	E	DMR
DMHOC 14	POBLAC 69 C5	Y	D	M	DMR
DMHOC 9	HIGJ OIL POPULATION II	W	D	M	DMR
DHol 22	TLWD HO C8	W	F	M	DMR
DMHOC 3	HIGH OIL POPULATION II	W	F	M	DMR
Dholi Inbred-73	Talar	Y	F	M	Dholi
Dholi Inbred-75	Talar	Y	F	M	Dholi
Dholi Inbred-76	Talar	Y	F	M	Dholi
Dholi Inbred-79	Talar	Y	F	M	Dholi
Dholi Inbred-82	Shahid	Y	F	M	Dholi
Dholi Inbred-83	HOTLWC-C1-S	Y	F	M	Dholi
Dholi Inbred-84	HOTLWC-C1-S	Y	F	M	Dholi
Dholi Inbred-86	HOTLWC-C1-S	Y	F	M	Dholi
HKI 41-3-1	DMR41	Y	F	L	Karnal
HKI 48-3-2-1	DMR48	Y	F	L	Karnal
HKI SHD ER-10	Shahid	Y	F	L	Karnal
HKI SHD ER-12	Shahid	Y	F	L	Karnal
HKI SHD ER-16	Shahid	Y	F	L	Karnal
HKI SHD ER-6	Shahid	Y	F	L	Karnal
HKI Tal-1-2-1-3	Talar	Y	F	L	Karnal
HKI Tal-G-1-1	Talar	Y	F	L	Karnal
HKI Tal-G-1-2-1	Talar	Y	F	L	Karnal
HKI Tal-PF-1-2-1	Talar	Y	F	L	Karnal
Dholi Inbred-71	Talar	Y	F	L	Dholi

Dholi Inbred-72	Talar	Y	F	L	Dholi
Dholi Inbred-74	Talar	Y	F	L	Dholi
Dholi Inbred-77	Shahid	Y	F	L	Dholi
Dholi Inbred-78	Shahid	Y	F	L	Dholi
Dholi Inbred-80	HOTLWC-C1-S	Y	F	L	Dholi
Dholi Inbred-81	HOTLWC-C1-S	Y	F	L	Dholi
HKI Talar	-	Y	F	L	DMR
DMRHOC-51	SHD-1ER6	Y	F	L	DMR
Dholi Inbred-85	HOTLWC-C1-S	W	F	L	Dholi
DHol 5	HIGJ OIL POPULATION II	W	F	L	DMR
DHol 6	HIGJ OIL POPULATION II	W	F	L	DMR