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An Overview of Various Quality Enhancement Strategies in Oilseeds and Summarisation of the Quality Parameters

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A B S T R A C T

This article focuses and reviews on the seed enhancement techniques in oilseeds, and highlights of new developments that may provide even more benefits in the future. Oilseed crops are grown primarily for the oil contained in their seeds. Oilseeds are rich in protein, the proteins in oilseeds can be fed either as part of the oil-intact seed, or as a meal from which the oil has been removed. Major objectives in oil crop improvement are enhancement of seed and oil yield, quality of oil according to its use, i.e. edible or industrial uses, breeding of varieties which fit in different cropping systems and breeding biotic and abiotic stress resistant/tolerant varieties. Oilseeds are in demand globally, and there is a need to identify and quantify the key issues for their seed enhancement to develop and support actions that will ensure a viable future of such crops.

Introduction

Oilseed crops are primarily grown for edible oil. Recently, oilseeds attracted more attention due to an increasing demand for their healthy vegetable oils, livestock feeds, pharmaceuticals (Sosa-Segura *et al.*, 2014), biofuels (Singh and Nigam, 2011), and other oleo chemical industrial uses. Seed oils can be used for different purposes: for human consumption as food (Mohamed Fawzy Ramadan, 2011) for cooking (Mounts *et al.*, 1994), as a source of bioactive compounds and/or nutraceuticals (e.g. vitamins, polyphenols) and for using in the pharmaceutical and cosmetic industries for preparation of different products. The increased interest resulted in an 82% expansion of oilseed crop cultivation areas and about a 240% increase in total world production over the last 30 years. Therefore, to satisfy the increasing world demand, sustainable oil production, through classic breeding efforts needs to be coupled with biotechnological approaches in order to expand oil yield per unit area. The expansion of oilseed growing areas can be another approach utilized to meet this increased demand. Genetic engineering of oilseeds will allow not only the sustainable production of oilseed crops but also enhanced nutritional value as well as enhanced quality for industrial purposes. TAGs, composed of various fatty acids, are the main component of vegetable oil. Many genes in TAG biosynthesis pathways have been identified and studied well. New biotechnology methods allow insertion or modification of genes involved in the biosynthesis of a desired fatty acid, in order to accumulate a higher level of fatty acid or even to produce a novel fatty acid. Genetic engineering started a new era for designer oil crops and has created opportunities for sustainable oilseed crop production around the world (Mukhlesur Rahman *et al.,* 2016). Oilseed crops play the second important role in Indian economy next to food grains in terms of area and production. The major oilseed crops grown worldwide are: soybean, rapeseed, cottonseed, peanut, sunflower seed, palm kernel, and copra (Daun *et al.,* 2011).

Enhancement strategies for quality in major oilseed crops

Various conventional methods have been exploited for enhancing the yield of oilseeds crops, however, for further improvement there is a need to adopt recent technologies, which will lead to improved sustainability.

Soybean

Soybean breeders have made significant progress in improving the overall yield of soybean, which translates into more protein and oil on a per ha basis. Despite this, minimal advancements have been made in the selection of high-yielding genotypes, with major shifts in carbon flux for improvements in total oil or protein content (Mahmoud *et al.,* 2006). On the other hand, implementing the tools of molecular biology and biotechnology has opened the door to the development of improved end-use quality of the oil for food, feed, and industrial applications. These have been achieved by directed modification of fatty acid biosynthesis to alter relative amounts of fatty acids naturally found in soybean or to produce novel fatty acids (Jaworski and Cahoon, 2003; Damude and Kinney, 2008). In case of Soybean high amount of polyunsaturated fatty acids is a major limiting factor in terms of quality. A possible approach for improvement of oil quality in soybean is the inactivation of fatty acid desaturase genes (*FAD-2-1* and *FAD-2-2*). (William Haun *et al.,* 2014). In a similar study conducted by Nicole Bachleda *et al.,* (2017) an attempt to improve oleic acid content in soybean seed which is considered to be key compositional trait that improves oxidative stability and increases oil functionality and shelf life. Using a marker-assisted selection method, near -isogenic lines (NILs) of G00-3213 were developed and yield tested for the high oleic trait. The results indicated that G00-3213 NILs with both homozygous mutant *FAD2- 1A* and *FAD2- 1B* alleles produced an average of 788 g/kg oleic acid content. The results also demonstrated that possessing these mutant alleles did not cause a problem in yield reduction. Unpleasant beany flavour is another problem in soybean (Nandanie *et al.,* 1987). This problem has been addressed through mutagenesis and one mutant lax-2 which totally inactivates the enzyme (Davies *et al.,* 1987). A study conducted by Kyung Jun Lee *et al.,* (2014) revealed the elimination of lipoxygenases can reduce the poor stability and off-flavors of soybean oil and protein products. In this study, a soybean mutant (H70) was selected in which the three lipoxygenases had been mutated using gamma rays. The results suggest that gene analysis based on DNA sequencing could be useful for elucidating the lipoxygenase content in soybean mutant lines. Additionally, the soybean mutant line selected in this study could be used to develop soybean cultivars with improved flavour.

Brassicas

The brassicas commonly known as rapeseed mustard are important group of edible oils and vegetables crops belonging to Brassicaceae or Cruciferae family. Rapeseed mustard is the third most important source of vegetable oil in the world and is grown in more than 50 countries across the globe. For breaking the yield barrier, population improvement programme was followed involving diverse parents. Through the intervention of biotechnological tools, yield QTLs are to be identified and can be introgressed in improved backgrounds using marker-assisted selection (MAS) (Yadava *et al.,* 2012). A major problem with mustard oil is that it contains large amounts of erucic acid (50%) and glucosinolates (80-160 micromoles/g), even though it is relatively stable by virtue of having less polyunsaturated fatty acids (Christine wendlinger *et al.,* 2014; Hussam *et al.,* 2017). Serap Durakli Velioglu *et al.,* (2017) in their study revealed a novel method to determine erucic acid in canola oil samples by using Raman spectroscopy and chemometric analysis. The oil mixtures were prepared at various concentrations of erucic acid ranging from 0% to 33.56% (w/w) through binary combinations of different oils. In order to predict erucic acid content, Raman spectroscopy and GC results were correlated by means of partial least squares analysis. The results revealed the potential of Raman spectroscopy for rapid determination (45 s) of erucic acid in canola oil. According to Katherine Cools *et al.,* (2018) three mustard seed cultivars from two seasons were processed into Dijon- and wholegrain-style mustard and glucosinolates and isothiocyanates were analysed. Canadian cv. Centennial tended to contain higher glucosinolates compared with the French cv. AZ147 and Ukrainian cv. Choraiva. Conversion of the mustard seed into a wholegrain condiment had less effect on total isothiocyanates and sinigrin content compared with the Dijon preparation. The Canadian mustard cultivars produced wholegrain-style mustard with higher total isothyocyantes and sinigrin compared with the French and Ukrainian cultivars. Therefore, results suggest that Canadian mustard seed cvs. Centennial and Forge, and wholegrain processing results in a condiment with greater bioactive composition. Hussam *et al.,* (2009) revealed that glucosinolates are sulfur-rich secondary metabolites characteristic of the Brassicales order. He studied, piecing together the glucosinolate pathway by presenting and critically analyzing all data on glucosinolate research. Furthermore, the data on glucosinolate transport is considered in the light of the newest findings on glucosinolate synthesis and distribution. The aim of this study was to provide a comprehensive and updated set of hypotheses which may prove useful in directing future research on glucosinolate transport.

Sunflower

Although hybrids in sunflower have recorded two times higher seed yield than the open pollinated varieties, a narrow genetic base is the major bottleneck in further improving the yields. Release of large number of hybrids in the past has broadened the base of hybrids in the country. Beside seed yield, oil content, which is between 35 and 40% in hybrids, is also equally important and needs to be improved up to 45% so that this crop may be made more profitable. Introgression of resistance against major insects like Heliothis and Spodoptera, Bt sunflower needs to be developed (Kambrekar, 2016). Identification of resistance/ tolerance sources for drought related traits and their subsequent transfer in the improved genetic background would help in achieving the stability of production in diverse rainfed areas (Saeed Rauf, 2008). According to Muhammad Ahsan Iqbal *et al.*, 2017 exploiting heterosis and combining ability of yield and oil content of sunflower will increase the oil percentage in crop. Sixteen hybrids grown in line x tester manner and were evaluated for seedling traits. Objective of this study was to evaluate the seedling traits and exploit heterosis, GCA and SCA of given genotypes for using them in better hybrid seed development. Results showed that lines and testers showed positive GCA effect for shoot length, root length and root fresh weight while hybrids have negative SCA effect for all the traits.

Groundnut

Aflatoxin contamination is a serious quality problem in groundnut. Aflatoxins are toxic substances produced by certain fungi called *Aspergillus flavus* and *Aspergillus parasiticus*. Permissible limit of aflatoxin is 30 mg/kg. A strategy to avoid to this contamination need to be developed. Shifa *et al.,* (2016) studied the antagonistic activity of *Bacillus subtilis* strain G1 and tested it against various isolates of *Aspergillus flavus in vitro*. A talc-based powder formulation of *B. subtilis* strain G1 was prepared and evaluated to control *A. flavus* infection and aflatoxin B1 contamination in groundnut under greenhouse and field conditions. The results showed that *B. subtilis* strain G1 could inhibit the growth of all isolates of *A. flavus* tested in dual culture assay and the growth inhibition ranged from 93 to 100%. Results of greenhouse and field experiments indicated that *B. subtilis* strain G1 when applied to groundnut as seed treatment and soil application significantly suppressed *A. flavus* population in the soil, *A. flavus* infection and aflatoxin B1 content in kernels and increased the pod yield. These studies show that *B. subtilis* strain G1 has potential as a biocontrol agent for control of aflatoxin contamination in groundnut. Waliyar *et al.*, (2014) studied Aflatoxin contamination in groundnut by *Aspergillus* section *Flavi* is a major pre- and post-harvest problem causing kernel-quality loss. Post-harvest aflatoxin contamination is caused initially by infestation of aflatoxigenic strains at the pre-harvest stage, resulting in reduced kernel quality after harvest. Improper handling of pods and storage methods after harvest lead to high moisture and ambient temperatures, directly causing aflatoxin contamination. Besides the major breeding objectives in this crop are development of high yielding cultivars of suitable duration to escape moisture stress with resistance to various biotic stresses and tolerance to different abiotic stresses (moisture stress). Short and medium duration and confectionery type varieties with multiple tolerance/resistance have been developed by ICRISAT as well as NARS in India. Novel techniques such as genetic transformation, molecular markers added selection and gene transfer from alien sources need to be exploited more for making an impact on groundnut research. (Vishwakarma *et al.*, 2017)

Sesamum

It is an important crop both in terms of area and production in the world. Higher yields, improved plant architecture, adapted crop duration, resistance to diseases and pests and indehiscent capsules are the major objectives in this crop. Among the various options available for increasing the productivity, heterosis breeding is perhaps the most important way for the vertical yield increase in this crop (Monpara *et al.,* 2016).

Table.1 Important fatty acid percentages in major oilseeds

Crop	Fatty acid %age					
	Saturated	Oleic	Linoliec	Linolenic	Eicosenic	Erucic
Groundnut	19	48	32	-	1	-
Safflower	10	14	75	-	1	-
Sunflower	12	17	70	-	1	-
Soybean	15	23	54	8	-	-
Palm	51	38	10	1	1	-
Corn	13	29	57	1	-	-
Cotton seed	27	18	54	1	-	-
Coconut	91	7	2	-	-	-
Mustard	7	12	14	9	8	**50**
Canola	**7**	**57**	**21**	**11**	**2**	**1-2**

Source: Banga *et al.*, 2000

The development of varieties with low or zero anti-nutritional factors like oxalic and phytic acids needs attention for its value addition. In addition, the efforts should also be made to develop low free fatty acid (<2%) varieties of Sesamum. Increase in oil content is also one of the important components in varietal improvement of this crop (Bülent Uzun *et al.*, 2008). According to the studies conducted by Varsha Thakur *et al.*, (2017) the fatty acid composition is a great significance for determination of the oil quality. The quality is especially based on the palmitic, stearic, oleic and linoleic acid. In this research, variation in oil content, oil yield, chemical composition and fatty acid composition of 7 different TKG-22, GT-10, PKVNT-11, PRACHI, HT-2, DSS-9 and TMV-7 sesame verities were investigated. The oil content varied 39.33 to 46.4. percentage content of, linoleic acid, palmitic, Stearic acids, oleic acid and linolinic acid in the seed oil ranged between 31.84–41.73 %, 8.33–10.15%, 5.34–7.0 respectively. Oleic acids 39.88–48.81%, linoleic acids 0.25–0.50% and palmitoleic 0.10–0.13 % acids were the minor fatty acids of sesame as sesame were about 24.3% which increases the suitability of the sesame oil for human consumption. The oil could be useful as edible oils and for industrial applications.

Linseed

The productivity of this crop is very low as it is grown under input starved and moisture stress conditions. The major diseases of this crop are wilt, rust, powdery mildew and Alternaria blight (Singh; 2016). Amongst the insects, bud fly is causing lot of losses to this crop. The average productivity of this crop at national (0.4 t/ha) as well as at global level (0.85 t/ha) is low in comparison to other oil crops like soybean, rapeseed mustard and groundnut. Hence, the breeding strategies for yield enhancement need immediate attention. Oil content is one of the important components in oil crops and it is around 28–30% in linseed varieties which has ample scopes for enhancement (Bertrand Matthäus *et al.*, 2017).

Fatty acids

A fatty acid is a carboxylic acid with a long aliphatic tail called a chain, which is either saturated or unsaturated. Most naturally occurring fatty acids have a chain of an even number of carbon atoms, from 4 to 28. Fatty acids are usually derived from triglycerides or phospholipids. When they are not attached to other molecules, they are known as free fatty acids. Saturated fatty acids (SFAs) are the fatty acids without any double bonds between the carbon atoms. Dietary SFA could be grouped as short and medium chain SFA (C2:0 to 16:0), depending on the carbon chain length. Milk and dairy products are the major sources of short- and medium-chain fatty acids, while meat, processed meat products, and vegetable shortenings/partially hydrogenated vegetable oil are the sources of long-chain SFA. Palmitic acid (C16:0) and stearic acid (C18:0) are the most abundant SFA in the diet. Fatty acids, like palmitic acid and stearic acid, are desaturated by SCD1, SCD2, or SCD4 to their respective MUFA, such as palmitoleic acid and oleic acid, or could be elongated to arachidic acid (C20:0) by elongases ELOVL6 (to C18:0) and ELOVL1, ELOVL3, and ELOVL7 (Guillou *et al.,* 2010) Monounsaturated fatty acids (MUFAs) are the fatty acids with a single double-bond between the carbon atoms. Oleic acid (C18:1 cis-9) and palmitoleic acid (C16:1n7) are the major dietary MUFAs consumed both from plant and animal sources. Diets rich in MUFAs have shown positive effects on insulin sensitivity (Soriguer *et al.,* 2004). PUFAs are the fatty acids with two or more double bonds between the carbon atoms. PUFAs are categorized primarily as n-3 or n-6, depending on the position of the double bonds from the methyl group in the carbon chain. Fish, fish oil, and nuts are the major sources of n-3 PUFAs, and vegetable oils are the main source of n-6 PUFAs. The effects of dietary PUFAs on the onset and progression of diabetes have been mixed. Several epidemiological studies have found no associations between dietary PUFAs to either type 2 diabetes or gestational diabetes (van Dam *et al.,* 2002; Bowers *et al.,* 2012; Brostow *et al.,* 2011; Kaushik *et al.,* 2009; Wu *et al.,* 2012), while few have reported an inverse relation between PUFA intake and diabetes incidence (Meyer *et al.,* 2001; Brostow *et al.,* 2011; Ebbesson *et al.,* 1999). In some studies, substituting SFA or *trans* FA with PUFA substantially reduced the risk of diabetes (Harding *et al.,* 2004; Meyer *et al.,* 2001; Salmeron *et al.,* 2001; Ebbesson *et al.,* 2007). However, the positive effects seen in those studies could also be mediated through reductions in SFA and *trans* FA in the diet. The Percentages of various fatty acids in oilseeds are summarized in Table 1.

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