



OAT GRAIN PRODUCTION FOR HUMAN CONSUMPTION: SUSTAINABLE OPTION UNDER TEMPERATE CLIMATIC CONDITIONS OF KASHMIR VALLEY

¹*Mushtaq Ahmad, ¹Gul-Zaffar, ²Intikhab Aalum Jehangir, ³Rukhsar Ahmad Dar, ¹Uzma Mehraj, ¹Ajaz A Lone

¹*Division of Genetics and Plant Breeding,

²Division of Agronomy, Faculty of Agriculture FOA, Wadura

³KVK Neyoma Leh, Ladakh India

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar-190025 (J&K), India

*Corresponding Email: drmuhtaqdarskuastk@rediffmail.com

ABSTRACT

Oat (*Avena sativa* L.), a grass species grown predominantly in temperate short-season regions, has received significant attention for its positive and consistent health benefits when consumed as a whole grain food. Oats are viewed by consumers as one of the wholesome, healthiest; natural food with the result there is rising global food demand for oats and increasing production, milling and trade. The protein of rolled (flakes) oats is generally greater than that found in other cereal grains. Oats is the only cereal containing globulin or legume-like protein, avenalin, as the major (80%) storage protein. Many of the vitamins and minerals found in oats are combined in the bran and germ. Most oat food products use the entire groat, making it a nutritious cereal grain. In fact the health effects of oat rely mainly on the total dietary fibre and beta-glucan content, which reduce postprandial blood glucose; insulin responses and lowers blood lipids, especially serum total and LDL-cholesterol. Medicinally, oats are used for patients suffering from diabetes, hypertension and high cholesterol. Besides, conventional breeding methods, molecular breeding (MB) approaches have made possible to identify and dissect -glucan content rich regions across oat genome, such approaches have enabled to accelerating improvement in oat grain quality and increasing the nutritional value of the crop for human consumption. Till date, the investigations undertaken by SKUAST-K the premier research institutes of Kashmir valley have focused on development of agro ecologically specific cultivars having high green forage yield with better nutritional quality for cattle but there has been very little investigations regarding screening of available germplasm resources for nutritional quality suited for human consumption. Keeping in view health benefits of oat grain, therefore, there is an urgent need of exploiting new research technologies to boost grain yield with desirable quality parameters and increasing the nutritional value of the crop for human consumption under temperate conditions of Kashmir valley in India. Here we review the health benefits of Oats (*Avena sativa* L.), and highlight the potential for future expansion in this field through various breeding methods and to develop an economically viable and sustainable crop production option.

KEYWORDS: beta-glucan, genome, molecular breeding, human consumption, temperate conditions, sustainable.

INTRODUCTION

Oats are one of a kind and irreplaceable! No other grain offers so many advantages for healthy nutrition and healthy crop rotations. At the same time oat production is particularly pollution free: due to the more efficient root system and the high disease resistance a minimum of fertilization and plant protection is sufficient for high yields. Quality Oats are increasingly in demand and in many places a highly-profitable market grain. In addition, margins compare favorably with wheat and finally, very small production costs and the enormous following crop. Close crop rotations with high winter grain portions have become increasingly under pressure in recent years: The yields vary ever more strongly, the costs rise, also increasing resistance problems with plant protection products require integrated cultivation procedures with “healthy” crop rotations. The genus *Avena* is large and diverse containing both wild and cultivated polyploidy series with a basic chromosome number of $n=7$ (Table 1). Three naturally occurring ploidy levels are known with the genus, diploids ($2n=2x=14$), tetraploid ($2x=4x=28$) and

hexaploid ($2n=6x=42$). Oat ($2n=6x=42$) is a natural allopolyploid evolved through cycles of interspecific hybridization and polyploidization combining three distinct genomes. Availability of the genetic variability for the component characters was a major asset for initiating a fruitful crop improvement program. Oat is a multipurpose cereal crop grown worldwide for human food and animal feed (Dubey *et al.*, 2014). The exact time and place of the introduction of oats as a crop to India cannot be ascertained with certainty but there are references to oat cultivation in Ain-I-Akbari written by Abul Fazal, the court historian of Mughal king Akbar, in 1590. Large-scale oat growing started in the early nineteenth century, when the British established remount depots for the Indian Army. Oats have developed as important winter forage in the irrigated plains of northern India, but extension of oat growing in the Himalaya is comparatively recent. Oats were first introduced in the Jammu and Kashmir State by the then King, Maharaja Hari Singh (1925-1947) on his stud farms, with seed imported from Europe. During this period, oat growing was confined to the King’s farms;

local farmers did not use oats. Its introduction in general in the Himalayan region started in earnest in the late 1970s, with the the establishment of an Agrostology wing of Jammu and Kashmir Department of Agriculture, Himachal Pradesh Agricultural University at Palampur and G. B. Pant Agricultural University at Pantnagar, and organized research on oats in the Himalayan region also started. These activities were strengthened by extensive research on production technology and varietal development of oats at the Indian Grassland and Fodder Research Institute

(IGFRI) and Indian agricultural universities in the plains. In these areas, berseem (Egyptian clover; *Trifolium alexandrinum*) is very popular but can only be grown under irrigation. To find alternative forage for rainfed areas, research on oats began and is continuing for the purpose of increasing livestock population, now this crop gaining the importance for human consumption after the nutritional scientists around the world report on the health-promoting effect of oats. Internationally the employment of oats for food purposes has risen for several years.

TABLE 1: Avena species – genome constitution and chromosome number

Classification	Chromosome no.	Genome constitution
Section Avenotrichon		
<i>A. macrostachya</i>	4x=28	
Section ventricosa		
<i>A. clauda</i>	2x=14	C _p C _p
<i>A. eriantha</i>	2x=14	C _p C _p
<i>A. ventricosa</i>	2x=14	C _v C _v
Section Agraria		
<i>A. brevis</i>	2x=14	AA
<i>A. Hispanica</i>	2x=14	AA
<i>A. nuda</i>	2x=14	AA
<i>A. strigosa</i>	2x=14	AsAs
Section Tenaicarpa		
<i>A. agadiriana</i>		
<i>A. atlantica</i>	2x=14	AsAs
<i>A. barbata</i>	4x=28	AABB
<i>A. canariensis</i>	2x=14	AcAc
<i>A. damascena</i>	2x=14	AdAd
<i>A. hirtula</i>	2x=14	AsAs
<i>A. longiglumis</i>	2x=14	AiAi
<i>A. lusitanica</i>	2x=14	AA
<i>A. matritensis</i>	2x=14	
<i>A. prostrata</i>	2x=14	A _p A _p
<i>A. wiestii</i>	2x=14	AsAs
Section Ethiopica		
<i>A. abyssinica</i>	4x=28	AABB
<i>A. vaviloviana</i>	4x=28	AABB
Section Pachycarpa		
<i>A. moroccana</i>	4x=28	AACC
<i>A. murphyi</i>	4x=28	AACC
Section Avena		
<i>A. atherantha</i>	6x=42	AACCDD
<i>A. fatua</i>	6x=42	AACCDD
<i>A. hybrid</i>	6x=42	AACCDD
<i>A. occidentalis</i>	6x=42	AACCDD
<i>A. sativa</i>	6x=42	AACCDD
<i>A. sterilis</i>	6x=42	AACCDD
<i>A. Trichophylla</i>	6x=42	AACCDD

Health issues related to diet have become a major problem facing developing countries over the past few decades. In many countries this problem is more emphasized in teens where levels of obesity and cases of type-2 diabetes have been on the rise. Consumption of oats as a whole grain has consistently been shown to have a positive impact on cholesterol, diabetes, and obesity. The positive health benefits of consuming oats as a whole grain food are attributed in part to beta glucan, a soluble fiber found in the cell walls. Oat is considered to be a nutritious source of protein, carbohydrate, fibre, vitamins, and minerals as well as of compounds with beneficial effects on health. The protein of rolled (flakes) oats is generally greater than that found in other cereal grains. Many of the vitamins and minerals found in oats are combined in the bran and germ.

Oat protein is nearly equivalent in quality to soy protein, which has been shown by the World Health Organization to be equal to meat, milk, and egg protein. As food oats are mostly preferred in breakfast items. Oats are viewed by consumers as one of the wholesome, healthiest; natural food with the result there is rising global food demand for oats and increasing production, milling and trade. Out of cereals, the highest amounts of β -glucans are found in barley and oat grains (Ahmad and Zaffar, 2014). Literature data indicating the yields of β -glucans in different cultivars and fiber content of oat food products are listed in (Table 2 & 3). The popularity of oatmeal and other oat products again increased after a January 1998 decision by the Food and Drug Administration (FDA), when it issued a final rule that allows food companies to

make health claims on food labels of foods that contain soluble fibre from whole oats (oat bran, oat flour and rolled oats), noting that 3.0 grams of soluble fibre daily from these foods may reduce the risk of heart disease. Oats is the only cereal containing globulin or legume-like protein, avenalin, as the major (80%) storage protein. The globulins are characterized by their solubility in dilute saline. The more typical cereal proteins, such as gluten and zein, are prolamines (prolamins). The minor proteins in oats include prolamine and avenin. The protein content of hull-less oats kernels (groat) ranges from 12-24% which is highest amongst the cereals (Lasztity, 1999). So, there is an urgent need of exploiting new research technologies to boost high grain yield to meet the world demand by using oats as a food. Hence, such approaches have enabled to map and to dissect these genomic regions, accelerating improvement in oat grain quality and increasing the nutritional value of the crop for human consumption (Ahmad *et al.*, 2015b). During year 2013-2014 the state had 29,400 ha under oats cultivation and about 80 percent of the cultivated fields in Kashmir used to remain barren

during winters because of the severe cold conditions (Anonymous, 2014). This indicates there a lot of scope for quality oat cultivation to improve the economic condition of small and marginal farmers after utilizing this barren land during severe cold. The investigation was undertaken at SKUAST- Kashmir valley ("Fig. 1", 2") experimental material comprised of ten oats (*Avena sativa* L.) genotypes and their 45 F₁ crosses evaluated for grain protein content, beta glucan % and grain yield (kg ha⁻¹). The highest grain protein content (10.75%) and beta glucan (8.56 %) were recorded for SKO-208, followed by SKO-209 and SKO-207. The cross combination SKO-208 x SKO-209 recorded the highest beta glucan (10.23 %) and highest grain yield (43.22 kg ha⁻¹). The cross combinations SKO-204 x SKO-208, SKO-205 x SKO-209, SABZAAR x SKO-209, SKO-207 x SKO-208 and SKO-208 x SKO-213 were observed desirable with respect to all parameters studied, need critical evaluation during subsequent generation for isolating desirable transgressive segregants. Parents *viz.*

TABLE 2: Content of β -glucans in oats according to literature data

	β -glucans (g/100g dry wt)	Method of determination	Reference
	10.9–1.0 ^b	Enzymic	Lambo <i>et al.</i> (2005)
	4.0 \pm 0.1 ^a	enzymic + HPAEC-PAD	Johansson <i>et al.</i> (2004)
	4.1 \pm 0.19 ^a	Enzymic	Genc <i>et al.</i> (2001)
	10.37 ^b	Enzymic	Dongowski <i>et al.</i> (2003)
	8.5 ^b	alkaline extraction	Bhatty (1995)
	4.0 ^a	Enzymic	Virkki <i>et al.</i> (2005)
Oats	3–5 ^a	-	Anttila <i>et al.</i> (2004)
	2.47–3.45 ^a	Enzymic	Weightman <i>et al.</i> (2004)
	1.73–5.7 ^a	Enzymic	Havrlentova and Kraic (2006)
	13.79–33.73 ^b	enzymatic-gravimetric	Gajdošova (2007)
	Beta-glucan %		
	3.77-8.56(Parents)	Enzymic	Ahmad and Zaffar (2014)
	3.98-10.23 (F ₁ s)	Enzymic	Ahmad <i>et al.</i> (2015c)

^asoluble β -glucan, ^btotal β -glucan; HPAEC-PAD – high performance anion exchange chromatography with pulsed amperometric detection

TABLE 3: Fibre content in different oat-based food products

	Food products	Soluble β -glucans (g/100g dry wt)	Reference
	whole meal	2.66	Gajdošova (2007)
		4.51	Grausgruber <i>et al.</i> (2004)
Oats	Groat	3.16	Gajdošova (2007)
		3.5-5.0	Malkki and Virtanen (2001)
	bran concentrate	7.48	Gajdošova (2007)
		11.5-17.0	Malkki and Virtanen (2001)
	Flakes	2.64-4.6	Havrlentova and Kraic (2006)



FIGURE 1: Crossing programme at SKUAST-Kashmir valley for quality study in oats for human consumption (Ahmad and Zaffar, 2014)

SKO-208, SKO-209 and SKO-207 identified for human consumption on the basis of higher beta-glucan content, protein content and seed yield need to be evaluated again for confirming this seed yield potential over the environments and identifying specific agro-ecological niches for taking up commercial cultivation, which can be a remunerative venture (Ahmad and Zaffar, 2014; Ahmad et al., 2015c; Ahmad et al., 2015b). Quality Oats imported by India about 5 to 6 tons from Australia, Russia and Canada for human consumption involved a huge amount of money, instead of this if we conduct research under temperate conditions of Kashmir valley for development high seed yielding with desirable nutritional quality



FIGURE 2: Crossing programme at SKUAST-Kashmir valley for quality study in oats for human consumption (Ahmad and Zaffar, 2014; Ahmad *et al.*, 2015c)

Oats are simple to grow

Oats are a simple crop to grow, or perhaps their cultivation is similar to that of wheat and barley, which are major crops in climates suitable for oats; techniques and equipment for wheat also suit oats. Each zone and farming system has adopted the methods that best suit it - from the simplest hand cultivation on small farms in developing countries to up-to-date mechanized systems in areas of large-scale farming. They are an excellent small holder crop. Seed rates vary from country to country, and fertilizer practice is largely dependent on soils. A less usual method of growing oats, in areas of mild winters, is sod-seeding them into winter-dormant pastures in autumn. Sowing dates are also dependent on the climate, on the cropping pattern when two crops are taken yearly, and when the forage is needed - or when weather is likely to suit haymaking. The place of fodder oats in rotations varies, but in cereal-growing zones they are a useful break crop. Development of oat cultivars using specific end product characteristics as part of the screening criteria is in its early stages, relative to other crops such as wheat and corn that have long been a staple in the human diet. Traditionally, oat improvement programs have focused on agronomic characteristics first, testing a limited scope of quality characteristics once the breeding material is at an advanced stage of development. With the increase in human oat consumption in recent years, quality aspects of oat products are becoming more clearly defined. Oat mills that supply the food industry with oat flakes, flour and oat fractions, are close to consumers in the value chain and have gained an understanding of consumer preferences for oat products through customer feedback and sensory

parameters so that India become self sufficient and full fill the demand of quality oats for human consumption, particularly with high protein content and beta glucan (%). Therefore, there is an urgent need of exploiting new research technologies to boost grain yield with desirable quality parameters. For scientific utilization of elite allelic resources present in the exotic gene pool of oats through hybridization and subsequent selection of recombinants possessing high grain yield potential together with high -glucan, it is imperative to characterize these genotypes on scientific basis and used in breeding programmes for increasing the -glucan content of adapted local germplasm (Ahmad *et al.*, 2015c).

evaluation. Information defining oat end product quality will be valuable to breeders, but it is just the first step towards going beyond traditional oat breeding priorities. If end-product quality is to become a true breeding priority it needs to start in early generations. Traditionally, breeders select for agronomic suitability early on, waiting several generations before selecting for quality attributes even if a quality based trait such as -glucan is a major objective. This reduces the numbers advanced but means poor quality lines are carried forward unnecessarily. Greater improvements in quality could be made if end product quality could be tested earlier.

Beta glucan

Beta Glucan is a polymer of D-glucose linked with glycosidic bonds at (1 3), (1 4), (1 6) (Fig 3) and is typically found in the endosperm cell wall in oats and barley. Beta glucan is commercially derived from oats, barley, mushrooms and some microorganisms. In microorganisms and mushrooms, these compounds are found to have a linear chain of D-glucose linked in the (1 3) position with various sized D-glucose branches linked to the main chain by (1 6) linkages. Beta glucans derived from cereals are polymers of D-glucose with (1 3) and (1 4) linkages (Figure 1). Beta glucan constitutes 1 % of wheat grains, 3- 10% of oats and 5-11% of barley (Skendi et al., 2003).

Major Beta glucan Sources

Barley (*Hordeum vulgare*)

Barley, one of the ancient crops in the world, belongs to the genus *hordeum*. It is used as animal feed, and for malting as brewing substrates for whiskey and beer fermentation and adjuvants for bread flour.

Oat (*Avena sativa* L.) Oats belong to the genus *Avena* and are considered a minor cereal crop based on annual production. It is primarily used as an animal feed, but it is gaining popularity as a breakfast cereal in forms like oat

meal, ready-to-eat cereal and cereal bars. Oats are a good source of beta glucan and as such a good source of dietary fiber (Weightman *et al.*, 2002, 2004).

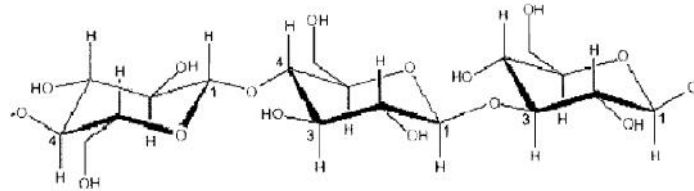


FIGURE 3: Structure of (1-3) beta glucans with branched (1-4) present in oats and barley (Mantovani *et al.*, 2008)

Genuine and perceived health benefits of oats

In discussing the health benefits of particular foods, it is important to distinguish between foods and diets. It appears self-evident that there are neither good foods nor bad foods, just good and bad diets. However, the argument can be advanced that a significant inclusion of a particular food in a diet will promote better long-term health. Health claims for particular foods – and there are very many – are tacitly based on this argument, but the notion that a particular food is intrinsically healthy is what the public at large is bombarded with. The sources of these claims are usually the commercial organizations seeking to increase sales of their product, such as American Oats, Inc. However, in many if not all cases, other related foods may fulfill the same role. For example, many or most of the ‘health benefits’ of oats are shared by other grains perhaps represented by commercial interests with smaller promotional budgets. Oats are valued as a nutritious grain which offers considerable health benefits. First of all, oats contain a high concentration of dietary fibre. Studies have shown that oat bran can help lower blood low density lipoproteins (‘bad’ cholesterol), and reduce the risk of heart disease. The soluble fibre (called beta-glucan) from oats also helps stabilize blood glucose levels, which can benefit people with non-insulin-dependent diabetes. Research result from (Saltzman *et al.*, 2001) at Tufts University in Boston showed that blood pressure and total cholesterol level may be lowered in six weeks by consuming oats-rich diets. A high percentage of desirable complex carbohydrates in oats may reduce the risk of colon, breast, and prostate cancer, and lower bowel problems such as constipation (Hill, 1997). Crop improvement for increased nutritional value is an important objective for breeding programs. In oat (*Avena sativa* L.), breeding for mixed-linkage-(1, 3;1,4)-Dglucan (referred to as β -glucan) content has been an objective for over two decades in North America (Peterson, 2001). Food agencies from Sweden, United Kingdom, Finland, and the Netherlands have approved the claim that β -glucan reduces blood cholesterol levels while the United States-Food and Drug Administration approved the claim that β -glucan decreases the risk of coronary heart disease (Tiwari and Cummins, 2011). New research has also discovered that the antioxidants found in oats reduce cholesterol by reducing the ability of blood cells to stick to the inside of artery walls Ruxton and Derbyshire, 2008; Cui and Wang, 2009). As the beta-glucan in the soluble fiber of oats is digested, it forms a gel, which causes the viscosity of the contents of the stomach and small intestine

to be increased. This in turn slows down digestion and prolongs the absorption of carbohydrates into the bloodstream. This means dramatic changes in blood sugar levels are avoided (Kim *et al.*, 2009). A daily serving of whole oats rich in soluble fibre can reduce hypertension, or high blood pressure, and so reduce the need for anti-hypertensive medication.

Additionally, the high lipids (fats) content in oats provides a high level of energy value. The fatty acid composition of oat lipids is of considerable interest because of the nutritional significance of unsaturated fatty acids (normally esterified as triacylglycerols), which are essential fatty acids in human diets (Peterson, 2001), and have been connected with long life and general good. The statements presented below must be seen in light of these concepts. Beta glucan is a soluble fiber readily available from oat grains that has been gaining interest due to its multiple functional and bioactive properties. Its beneficial role in insulin resistance, dyslipidemia, hypertension, and obesity is being continuously documented. In addition to β -glucan soluble fiber, oats also contain unique, low molecular-weight, soluble phenolic compounds called avenanthramides (a type of antioxidants), which are not present in other cereal grains. These compounds are anti pathogens, which are produced by the plant in response to exposure to pathogens such as fungi. For some time, oatmeal has been recognized as a remedy for the treatment of poison ivy, sunburn, eczema, and psoriasis. Oat colloidal extract containing avenanthramides has also proved to have antihistamine and anti-irritation activity. While the anti-itching property of oats and oatmeal has been known for centuries, a recent report provided molecular evidence for the mechanism by which oat avenanthramides may exert their soothing effect on irritated skin (Peterson *et al.*, 2002; Mattila *et al.*, 2005). Oat beta glucan also appears to help speed up response to infection, which may result in faster healing. According to a new study, it was discovered that beta glucan can enhance the ability of certain human immune cells to navigate to the site of a bacterial infection, resulting in faster healing. Oats contain a good balance of essential fatty acids, which have been linked with longevity and general good health, and also have one of the best amino acid profiles of any grain. Amino acids are essential proteins that help facilitate optimum functioning of the body. Oats are a good source of essential vitamins such as thiamin, folic acid, biotin, pantothenic acid and vitamin E. They also contain zinc, selenium, copper, iron, manganese and magnesium (Table 4). Oatmeal or gruel is an ideal

food for convalescents and can be flavored with raisins, lemon, butter, or maple syrup. It is easily digested and is a soothing food for those with fever and a good first food for those who have experienced intestinal illnesses or food poisoning. These effects of oat β -glucan were well reviewed by Ulmius *et al.*, 2011; Ahmad *et al.*, 2014a). The fermentation ability of β -glucan and their ability to

form highly viscous solutions in the human gut may constitute the basis of their health benefits. Consequently, the applicability of β -glucan as a food ingredient is being widely considered with the dual purposes of increasing the fiber content of food products and enhancing their health properties.

TABLE 4: Oats nutritional value per 100 grams

Vitamins		Amino Acids	
Vitamin C	0 mg	Tryptophan	0.234 g
Thiamin (B1)	0.763 mg	Threonine	0.575 g
Riboflavin (B2)	0.139 mg	Isoleucine	0.694 g
Niacin	0.961 mg	Leucine	1.284 g
Pantothenic acid	1.349 mg	Lysine	0.701 g
Vitamin B-6	0.119 mg	Methionine	0.312 g
Total folate	56 mcg	Cystine	0.408 g
Vitamin B-12	0 mcg	Phenylalanine	0.985 g
Vitamin A	0 IU	Tyrosine	0.573 g
Retinol	0 mcg	Valine	0.937 g
		Arginine	1.192 g
		Histidine	0.405 g
		Alanine	0.881 g
		Aspartic acid	1.448 g
		Glutamic acid	3.712 g
		Glycine	0.841 g
		Proline	0.934 g
		Serine	0.750 g

Data source: USDA National Nutrient Database

Economics of fodder oats vs quality oats

Cost benefit analysis of fodder oats vs quality oats grain production

Cost of cultivation/ha for green fodder purpose

Seed cost (1q/ha) = Rs, 2000

Fertilizer cost/FYM = Rs, 4300

Ploughing cost = Rs, 3000

Weeding/Hoeing/Harvesting = Rs, 5000

Total = Rs, 14300

Yield(350 q/ha) = Rs, 60,000

Net returns = Rs, 45,700

B.C ratio = $\frac{\text{Net returns}}{\text{Total cost of cultivation}} = \frac{45,700}{14,300} = 3.19$

Seed production using quality oat varieties

Yield 25q/ha (Rs, 60/kg) = Rs, 15000, 00

Net returns = Rs, 104,300

B.C ratio = 7.29

Cost-benefit ratio (C/B ratio) suggested that formers can get higher profit from oat production for grain yield with desirable quality parameters as its C/B ratio is maximum (7.29) much higher than fodder oats (3.19). Thus, farmer will be most benefited by cultivating quality oat seed.

Breeding methodology for oat quality improvement

Presently, most breeding approaches are in the domain of introduction, selection and hybridization (inter-varietal as well as interspecific) followed by pedigree, backcross, bulk and single seed descent methods. Certain other modifications like use of North Carolina designs I and II, Biparental matings among genotypes within and between segregating F_2 s have also been useful in isolating superior plant populations for grain quality and forage production (Mishra *et al.*, 1982; Pant *et al.*, 1992). Scope of recurrent selection also appears fruitful. The reports on the positive

health implications of oats when consumed as a whole grain are happening as plant breeding technologies are also rapidly evolving. Foremost are rapid and high density genotyping technologies (*e.g.* DArT markers, (Tinker *et al.*, 2009) and new statistical approaches to analyze the large amount of data that is being generated. The availability of high density marker data enables high resolution mapping of QTL controlling complex traits like β -glucan. Although traditional QTL mapping for β -glucan has been conducted in biparental oat populations (Kianian *et al.*, 2000; De Koeber *et al.*, 2004), Genomewide association studies (GWAS) has yet to be implemented for QTL detection in elite oat germplasm.

Selection

Genotypes having high β -glucan content are selected and bulked from the source population. Replicated trials for

quality and other characteristics are carried and superior ones are carried forward. Genotypes with high β -glucan are then released. Selection for greater β -glucan content improves grain yield simultaneously, because there is a positive and significant correlation between beta glucan and grain yield (Ahmad and Zaffar, 2014). Phenotypic selection for greater oat β -glucan content will be effective for developing cultivars with elevated β -glucan contents. β -glucan concentration is amenable to early generation selection (Cervantes-Martinez *et al.*, 2001). Early generation selection by determination of β -glucan content is done by following methods such as enzymatic method, near infrared reflectance spectroscopy (NIRS), automated flow injection analysis (FIA) and calcoflour flow injection analysis (FIA).

Pedigree method

Genotypes having high β -content are crossed and from F₂ generation individual plant selection is continued till the progenies become virtually homozygous and show no segregation for β -glucan content. Selection is done among the progenies because there would be no genetic variation within the progenies. Seeds from superior genotypes are bulked and then released for multi-location testing, licensing, seed multiplication and cultivar release.

Backcross method

Genotypes globally identified as donors for high β -glucan content are used in back cross programmes *e.g.*, Marion has high β -glucan content (Kianian *et al.*, 2000). HiFi oats which are having about 50% greater β -glucan content than other oats (bred by USDA and NDSU) are also used in back cross programmes to increase the β -glucan content of other local adaptable elite cultivars. In each backcross generation discard ~50% of first back cross generation. (BC₁) and visually select BC₁ progeny that resemble recurrent parent along with having high quality. Process repeated until BC₆ so that recurrent parent genome is recovered. Additional back crosses are used till the linkage drag is minimized. If conditions allow marker assisted backcross breeding (MABB) can be used because MABB allows: efficient and accurate selection of target loci of gene of interest, reduces linkage drag and accelerating recovery of recurrent parent thus enabling effective use of resources.

Single seed descent method (SSD)

Genotypes having high β -glucan content are crossed in a crossing block and in F₂ generation seed from each single plant is bulked and grown for next generation. Process is carried till F₅ or F₆ till the individual plant progenies become completely homozygous and are referred to as recombinant inbred lines (RILs). In each year, two-three generations may be raised in off season nurseries or mostly in greenhouses. Thus, this method (SSD) saves time, resources, and rapidly advances homozygosity. Each F₂ plant which is a unique combination of two diverse parents is carried till the end population. But the disadvantage of this method is that the size of the end population is very small and no selection is carried till the plants become completely homozygous so the variation is carried as such. After F₅ or F₆ selection among progenies is done and then the superior ones are evaluated for quality and other characteristics such as preliminary yield trials (PYTs) and coordinated yield trials (CYTs) are done and best genotypes released for seed multiplication.

Use of wild species in breeding programmes

For cultivated *A. sativa*, oat β -glucan content usually ranges from 1.8 - 6% (Cervantes-Martinez *et al.*, 2001). Oat β -glucan concentration showed very wide variation in *A. atlantica*, *A. damascena* and *A. murphyi* genotypes (2.2 to 11.3%). The highest β -glucan concentrations were found in genotypes of *A. atlantica* (Welch *et al.*, 2000). Henceforth, *A. atlantica* genotypes may be useful source for increasing the β -glucan content of cultivated oats. Complete and regular chromosome pairing affinities of interspecific hybrids involving the newly discovered species *A. atlantica* with *A. sativa* are described due to the AsAs genomic group.

Oat quality improvement through molecular and biotechnological interventions

Marker assisted selection (MAS) are much precise and easier as compared to conventional plant breeding. In MAS breeding, tightly linked markers to the target loci or gene of interest are utilized. Therefore, there is an effective and accurate selection of genotypes having target loci or gene of interest. By this method genotypes can be selected at the seedling stage and therefore, there is effective usage of resources. In conventional plant breeding phenotypic selection takes place in field trials and glasshouse trials for many generations which is time consuming and is less effective for accurate selection of genotypes having the gene of interest or target loci. In MAS breeding the only limitation is of high cost. Advances in genomic analysis and application of marker-assisted selection to oat genetic improvement is currently limited by a lack of genomic information and molecular genetics tools, particularly user-friendly molecular markers adapted to high-throughput technology. Identification of such markers in large numbers would allow oat breeders and geneticists to take advantage of the services of recently established regional marker labs, thus enabling much more ready trait marker association identification and application of marker-assisted selection. Single-sequence repeat (SSR) markers are marker-of-choice for many situations because they are often co-dominant and multi-allelic. However, they are arduous and expensive to develop. Only a limited number of genomic SSRs have been reported to date for oat and the amount of polymorphism detected among cultivars has been disappointingly low (Jannink and Gardner, 2005). Identification of SSR sequences in expressed sequence tag (EST) sequences in GenBank and other data bases have been a less expensive source of these markers, but only a few thousand ESTs have been reported in oat limiting the number of oat EST-SSRs identified (Brautigam *et al.*, 2005). Genome sequence similarities among grasses allow some cross-detection of markers across species, particularly for EST-SSR markers (Varshney *et al.*, 2005), providing opportunities for identification of markers from wheat, barley, lolium, fescue, and other grasses that are useful in oat. Communication and coordination among researchers are needed to make screening markers from other species on oat more efficient. Other type markers (*e.g.*, RFLPs, AFLPs) found associated with genes or QTLs of interest, or even candidate genes, have been converted to PCR-based markers to increase their efficiency, but again in limited numbers (Rines *et al.*, 2006). Several new technologies for identification and

scoring of SNPs and other markers have arisen. A most promising technology, Diversity Array Technology (<http://www.Diversityarray.com/applicationsdart.html>), which could provide genome-wide finger-printing for several hundred markers rapidly and at a low per-marker cost, currently is being pursued by an international consortium of oat researchers. This paper is intended to promote a discussion of how oat workers can best coordinate their efforts to improve opportunities for marker development and use in oat improvement. Gene transfers of microbial 1, 3- β -glucan synthases (Inoue *et al.*, 1995). In a case study this was accomplished by using particle bombardment (Wan and Lemaux, 1994). Advanced backcross – Quantitative trait loci (AB-QTL) analysis is a directed approach to introduce QTLs for β -glucan content from a gene bank accession (wild species) into elite cultivar breeding programmes (Tanksley and Nelson, 1996). TILLING (Targeting Induced Local Lesions IN Genomes) this method combines high frequency mutagenesis (with a chemical mutagen viz., ethyl methane sulfonate) along with molecular based, high precision selection technique that identifies single base mutations in a target gene. TILLING is a good alternative to more direct DNA modifying techniques since seed mutagenesis is easy to apply and relatively independent of genome size and organization (Henikoff and Comai, 2003). Moderately high density and throughput markers would allow the oat community to go beyond QTL mapping in experimental populations to estimating QTL effects in breeding populations, making the estimates immediately useful in selection decisions. For this approach to be effective, continued community cooperation in the effort will be essential. This cooperation will allow us to bring together into a single analysis enough lines so as to be able to detect and reliably estimate the effects of QTL useful to marker assisted selection. As a community, we should also devise plans to evaluate the levels of linkage disequilibrium between the markers we are developing, and to determine the level of population structure that exists between our breeding programs. Identification of QTL controlling beta glucan content has been limited in oat (Kianian *et al.*, 2000; De Koeber *et al.*, 2004). Fortunately, a comparative genomics approach can give some insight into candidate genes from other grass species (Fincher, 2009). First identified in barley (Han *et al.*, 1995) and later identified on chromosome seven of rice (Burton *et al.*, 2006), the CslF gene family is known to have beta glucan synthase function. Thus, this gene family is an important candidate for QTL detection for increased beta glucan content in oat. There are numerous QTL mapping studies that have utilized linkage-based analysis of bi-parental populations in oat (e.g. reviewed by Holland (2007). Although this has proven to be a powerful approach for QTL detection, it delivers low-resolution, population specific QTL, and samples only a small portion of the allelic diversity present in the germplasm available (Zhu *et al.*, 2008). Genome-wide association studies (GWAS) attempt to overcome the pitfalls associated with linkage mapping in bi-parental populations. Genome-wide association studies have the ability to identify useful allelic diversity and to map this diversity with high resolution within complex plant pedigrees that are typical of breeding programs (Jenkins *et*

al., 2002). From a practical perspective, GWAS have been applied in many grain crops, including rice, maize, barley, and wheat (Bel *et al.*, 2008; Zheng *et al.*, 2009). Implementation of GWAS in oat for QTL detection could be valuable to the oat community. The ability of GWAS to deliver high-power, high-resolution results is largely dependent on the extent of linkage disequilibrium (LD) within the working population. Also known as gametic phase disequilibrium, LD is defined as the non-random association of alleles at two loci (Falconer and Mackay, 1996) and is affected by mutation, admixture, selection, drift, population structure associated with breeding history, and reproductive biology (reviewed by Flint-Garcia *et al.* (2003)). Additionally, since the mechanisms mentioned may differentially affect different genomic regions, this can introduce LD heterogeneity across the genome. This makes the power and resolution achieved in GWAS highly dependent on the species and the population being evaluated. The extent of LD among the common grass species varies with respect to the crop and the population chosen for evaluation. For example, in maize, an allogamous species, LD decays over relatively shorter distances compared with autogamous crops. Remington *et al.* (2001) reported that LD (measured as r^2) declined to 0.1 within 1,500 basepairs (bp) in a set of 102 maize inbred lines representing breeding germplasm from temperate and tropical regions. Tenaillon *et al.* (2001) found similar results in a group of 25 maize lines consisting of 16 landraces and nine elite inbreds: LD decayed to 0.15 at 500 bp for the combined dataset. Unlike maize, barley is a self-pollinated crop with strong population structure due to variation in growth habit and kernel row number. Zheng *et al.* (2009) reported that LD extends to 2.6 cM at r^2 equal to 0.2 for a group of elite Canadian lines. This is in agreement with Hamblin *et al.* (2010) in a study of North American elite germplasm. Similar to barley, oat is a self-pollinated species; thus it is expected that LD decay will occur over relatively long map distances. In addition to LD, the power and resolution of GWAS is also dependent on marker density. Until recently, the lack of genetic markers and a method to deliver high-throughput genotyping have limited the options for identifying QTL in oat. Diversity Array Technology (DART) markers developed recently for oat have greatly increased the density of available (Tinker *et al.*, 2009). These markers were developed based on random clones isolated from 60 elite varieties of diverse global origin, making them useful in diversity analysis as well as in linkage mapping. Since they can be applied in parallel using a cost effective assay, they show good potential for use in QTL detection, comparative mapping, marker-assisted selection (MAS), and genomic selection.

CONCLUSION

Various strategies are used to combat diseases and potential health risks. In addition to pharmaceutical approach, diet based strategies are also considered suitable to prevent various disorders. In the developing countries, increased cost of medication, duplication and their side effects are of great challenge to general public; opening new channels of pharmacological investigations focusing on natural medication and diverting human trends toward natural cure. Thus, oats contain several bioactive

compounds and soluble fibre (β -glucan) may contribute to the health effects and are easily available for consumption to increase the nutrition status as well as act as safeguarding against possible deficiencies as well as nutritious grain which offers considerable health benefits. The climate prevailing in Western Himalayas particularly in Kashmir valley is ideally suitable for oats cultivation. This reveals there is a tremendous scope for development of high yielding oat varieties together with high richest dietary sources of the soluble fibre β -glucan, high in protein and fibre than other cereal. Therefore, it has been proposed as a target trait in oat breeding programs so as to double its concentration, it is imperative to characterize these genotypes on scientific basis. Genotypes having high β -glucan content can be used in breeding programmes for increasing the β -glucan content of adapted local germplasm. Besides, conventional breeding methods, molecular breeding (MB) approaches viz., MAS, MABB, AB-QTL and genome wide association studies (GWA) along with mutagenesis (TILLING) have made possible to identify and dissect β -glucan content rich regions across oat genome, such approaches have enabled to map and to dissect these genomic regions, accelerating improvement in oat grain quality and increasing the nutritional value of the crop for human consumption in temperate conditions of Kashmir valley and becomes India self sufficient.

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