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RECENT ADVANCES IN YIELD AND QUALITY OF DUAL PURPOSE OAT

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SUMMARY

Oat is a dual-purpose *Rabi* cereal that emerged as a valuable crop because of its utilization as quality fodder for livestock. The multi-cut nature of oat crop with high regeneration capacity, fast-growing plant habit, palatable, succulent and nutritious fodder make it more suitable for livestock sustainability. In recent years, the grain component of oat gained accelerative attention due to its growing popularity as healthy food and ultimately in the food industry. The potential nutritional characteristics, health promoting and therapeutics benefits offered by oat grains make it “super-grain” as it contains all the principle nutritional components including carbohydrates, protein, vitamins, minerals, antioxidants, and soluble fibre. The expansion of cultivated area under forage crops is not possible due to pressure of more remunerative and commercial crops like rice, wheat and barley. Therefore, the alternative way to meet the demand for quality fodder is through increasing productivity. Earlier oat was grown by farmers solely as fodder crop but more focus is to tailor dual-purpose (forage-cum-grain) oat genotypes adaptable under changing climatic conditions. The dual-purpose oat presents extra advantage of the nutritional value of the crop for human consumption as well as burgeoning livestock production.

Key words : Beta-glucan, dual-purpose, forage, oat, sustainability

Forage crops have been uniquely linking agriculture and animal husbandry for supporting the rural economy and in generating employment since the domestication of animals and plants began in human civilisation. Livestock is critical to agricultural sustainability, which is dependent on the availability of high-quality fodder. The global area under oat cultivation covers 10.12 million hectares with a production of 25.56 million metric tons (USDA, 2021). India covers an area of about one million hectare with fodder productivity of 30-45 t/ha (FAO 2012). The distribution of the area under crop acreage shows Uttar Pradesh (34%) is the leading crop grown state followed by Punjab (20%), Bihar (16%), Haryana (9%) and Madhya Pradesh (6%) (Anonymous, 2019). Oat is a multi-purpose winter annual crop used for forage, grain and pasture. Avena sativa, the most important commercial oat, is a hexaploid species (2n = 6x = 42) with AACCDD genomic constitution (Rines et al., 2006). A-type genomes of diploid species show metacentric chromosomes, and in C-type genomes most chromosomes are subterminal. The wild ancestor of *Avena sativa* is the *A. Sterilis. Avena sativa* L. and *Avena byzantina* K. also known as white oat and red oat, respectively, are the main oats grown for fodder and grain. The genome size is estimated to be 12.3 Gb. Annuals belong to either of three groups based on their chromosome number-diploid 2n = 14 chromosomes (*Avena strigosa; Avena strigosa* brevis; *Avena clauda; Avena longiglumis*), tetraploid 2n = 28 chromosomes (*Avena strigosa* weistii; *Avena barbata*) and hexaploid 2n = 42 chromosomes (*Avena sterilis; Avena byzantina; Avena fatua; Avena sativa*).

Livestock production and agriculture are linked as both are crucial for food security due to their dependence on one another. Livestock being sub-sector of agriculture plays important role in the Indian economy. Oat along with the provision of grain has enormous potential for fodder and is one of the rapidly emerging and promising crop for dual purpose. The continued big lag between the demand and supply of green fodder for animals and grain for human consumption needs to be mitigated. For this conventional cereal crops should be grown for dual purpose under the irrigated farming system (Naveed, 2013; Dove and Kirkegaard, 2014; Jarial, 2014). Dual-purpose varieties help in ensuring fodder and feed security. In recent years oat grain has been used as livestock feed

(Nikolaudakis, 2016). The lodging problem among the fodder cereal i.e. oat can be overcome by taking one fodder cut and then one cut for grain. For this, it is important to identify geographic-specific varieties which are appropriate for dual purpose along with the cutting management schedule (Singh *et al.,* 2014). Oat has a well grown rooting system having a greater penetrating ability. Oat has proven beneficial in crop rotation since it uses nutrients and soil moisture in better ways.

A study on performance of dual purpose cereals (wheat, barley and oat) under different cutting management purposed that oat is suitable for dual purpose but the selection on a crop should be based on the priority of send user. If from the first cut green fodder has to be prioritized, oat could be first choice followed by barley and wheat (Godara *et al.,* 2019). Various studies have proven the economic importance of dual purpose oat in terms of high cross monetary terms when other dual purpose cereals like wheat, barley are taken into consideration (Rana *et al.,* 2002; Patel *et al.,* 2003 and Pathan *et al.,* 2020). Molecular diversification of dual purpose oat genotypes by studying clustering patterns has also been elucidated in various studies (Ruwali *et al.,* 2013). The potential health-promoting characteristics and nutritional benefits offered by oat make it super-food because it contains all the principle nutritional components *viz.* carbohydrates, protein, vitamins, minerals, antioxidants, and soluble fibre.

Need for dual-purpose oat

The oat crop has not been preferred earlier but now it is cultivated in cropping areas not optimal for wheat, barley or maize. Green fodder oat is grown either as single cut or as multi-cut depending on the requirement of green fodder. The single cut oats are generally harvested at days to 50% flowering to get high green fodder yield while multi-cut varieties are taken at different times for the supply of green fodder during the entire season. The uniqueness and advantages offered by oats over other popular cereals, due to their highly valuable nutritional characteristics, have been well studied and reported, opening new market "niches" for oats. Even though, the status of the oat crop is still fragile, with very less area under this crop compared with other cereals and therefore commercial efforts in oat breeding are less. Oat groat yield is lower than other cereals such as wheat and the nutritious uniqueness has not been reflected in agreeable market prices. The absence of visible market competitiveness, and some of the oat biological drawbacks, including low grain yield, keep the oat crop as a lower profitability minor crop (Gorash *et al.,* 2017). The utilization and beneficial effects of oats are depicted in Fig. 1.

To combat common oat illnesses that can kill tissue and decrease the quality, forage oats are also selected for softer stems with less lignin, as well as

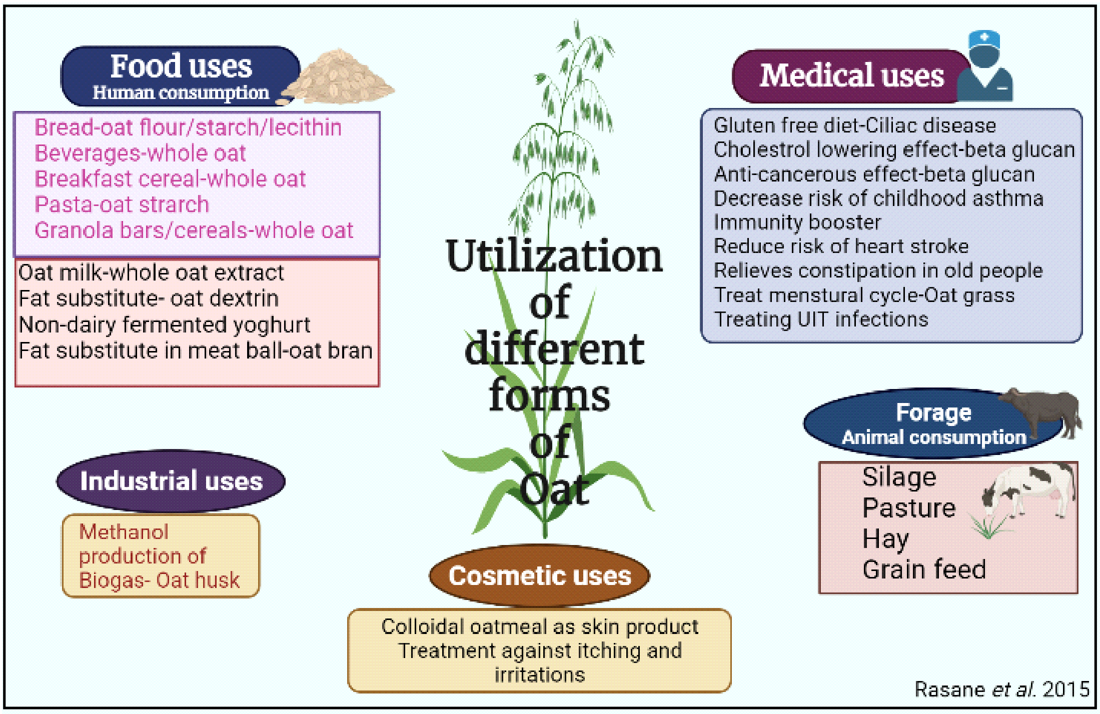

Fig. 1. The utilization and beneficial effects of oats (created by Biorender. com).

disease resistance. Grain oats have more rigid stems to support a grain-filled panicle. In addition, shorter stems avoid lodging in high-yielding cultivars that are heavily irrigated. For fodder, multi-cut cultivars (3-5 cuts) are typically used to provide green fodder throughout the season. To achieve high regeneration and improved plant stand, the cuts are usually made 15-20 am above ground level after each cut. However, oats with the capacity to regrow and set seed which leads to the dual-purpose utilization of this crop globally by adopting suitable high yielding varieties under changing environmental conditions (Francia *et al.,* 2006). There are several fodder quality traits such as fodder crude protein, IVDMD, leaf:stem ratio, green fodder yield, dry matter yield, and durability of availability of green herbage, whereas grain characters include seed crude protein, seed yield, bold grain size, groat percent grain hardiness, grain plumpness, taste, dehulling ease, and, most notably, beta-glucan content is crucial for direct and indirect improvement for the particular objective. Individually planning breeding with distinct purposes can be overcome by screening genotypes that perform better for dual-purpose varieties (Sharma, 2002; Ahmad *et al.,* 2014; Kaur *et al.,* 2018).

Oat as fodder

Fodder crops are plants that are cultivated and harvested for feeding the animals. Green fodder contains about 10 to 13% protein and 30 to 35% dry matter. Oat is usually cut green and fed fresh to the livestock during the summer season. Surplus is made into silage (preserved under anaerobic conditions) or hay (dehydrated green fodder) for it to be used during lack of fodder availability (Suttie and Reynolds, 2004). Due to its good growth habit, quick regeneration ability, high palatability, succulence and high nutritive value oat is considered excellent for fodder purposes. Its straw is important bedding for livestock, as well as good roughage. During dry summer conditions, the yield from other conventional fodder crops is limited. Oats can be grazed when the plants are young and reach a height of 20-25 cm because of their high crude protein content, low cell wall fibre level and high digestibility. Due to its good water-soluble carbohydrates content particularly before grain formation qualifies oat as good silage (Peterson *et al*., 2005).

Oats are often produced as a sole crop, but they can also be intercropped with berseem or legumes to produce a more nutritious feed. Farmers are forced to feed their cattle dry pearl millet stalks, wheat bhusa, or paddy straw (parali) due to a lack of forage throughout the winter. The oat crop thrives in these conditions and can compensate for the lack of green feed. It can be utilized as green fodder during the growing season or as hay or silage during the off-season to provide high-quality fodder (Poonia *et al.* 2020). For hay purpose, oat is cut before full grain formation to avoid grain loss during manipulation and baling. It is because of this reason, hay making can only be used in countries which fulfil the condition of enough warmth needed during the haymaking time span. Oat straw and chaff are softer and finer than the straw of the other white-straw cereals and have a higher nutritive value. Oat has dry matter digestibility over above 75% (Burgess *et al.,* 1972).

Fodder quality

The amount of nutrition in the forage is revealed by its quality (biochemical) composition, palatability, digestibility and antimicrobial properties associated with dietary parameters with cattle performance (Ingalls *et al.,* 1965). Different parameters contribute to the quality of fodder among which crude protein (CP) content is the most important criteria. (Caballero *et al.*,1995; Aseefa and Ledin, 2001). The green fodder oat contains more crude protein in first cut (12.10- 15.63 %) than the lower content of crude protein was observed in second cut (9.63-13.57%; Poonia and Phogat, 2017). The research studies have shown a positive and significant correlation of seed crude protein with fodder crude protein. (Poonia *et al.,* 2017). Some studies revealed that crude protein was observed to have a negative association with green fodder yield (Ahmad *et al.* 2010; Mushtaq, 2013) and also it was found negatively correlated with grain yield (Humphreys & Mather, 1996). Naked oat cultivars had higher fat content than hulled cultivars (Kourimska *et al.,* 2018).

Oat as a healthy substitute

When the feeding value and composition of oat grain are compared to wheat, maize, and barley, oat has the highest oil content, crude fiber, and gross energy value. Oat provides a lot of nutritional and health benefits for humans, especially in the form of cereal porridge, muesli components, and oat cakes. For human consumption, it is utilized as flakes, flour, coffee substitute, and meal. Oat, on the other hand, has a very low gluten concentration, rendering it unsuitable for bread production. Because it is a good source of protein and the only cereal with a globulin, avenin, as the primary (80%) storage protein, oat grain may be a good source of protein (Bityutskii *et al.,* 2019). Oats, after maize, have the highest lipid content of any cereal. These are also rich in starch and vitamins (B1, B2). Oats are rich in carbohydrates and fiber, but also higher in protein and fat than most other grains. They are also high in many vitamins and minerals. Oats are rich in antioxidants like alpha-tocopherol, ferulic acid, alpha-tocotrienol and avenanthramides (having anti-inflammatory and anti-itching effects) and rich in total dietary fibre (Oliver *et al*., 2010; Peterson, 2005; Rasane *et al.,* 2015; Van den Broeck *et al.,* 2016). Lactose intolerance is major problem in many humans. Oat milk is rich in vitamin E, fibre, low fat and lactose free can be used as a milk substitute. Oats are also occasionally used in several different drinks like for brewing beer and oat meal stout is also a delicacy in some countries. As compared to oat bran (13µg/g), oat flakes (27µg/g) have more avenanthramides (Mattila *et al.,* 2005). Different types of micronutrients and quality parameters studied in oat grains recently by (Poonia *et. al.,* 2022) given in Table 1.

TABLE 1
Amount of micronutrients and quality parameters in grains of oat genotypes

Trait Name	Mean	Minimum	Maximum
Phenol (mg/g)	11.90	1.70	31.30
Protein (mg/g)	138.70	127.0	160.50
Phytic (mg/g)	3.70	1.00	8.00
β-glucan (mg/g)	31.00	13.80	53.50
Ca (mg/g)	2.51	1.91	4.34
Mg (mg/g)	1.28	0.82	2.23
Cu (mg/100g)	0.83	0.12	1.31
Zn (mg/100g)	4.96	3.80	6.50
Fe (mg/100g)	2.48	0.66	4.89
Mn (mg/100g)	4.04	2.88	8.00

Phenolic compounds

Among the phenolic substances, phenolic acid especially ferulic acid (250 mg/kg), is predominantly found in oat. It is present in free state but mainly is found in bounded state with cell wall components through ester or ether bonds. There is around 61% of the total flavonoid content in oat which is concentrated in structures bound to the cell wall (Adom and Liu, 2002). Emmons and Peterson (2001) examined the effects of location on phenolic contents and antioxidants activities from oat groats. The study showed that location significantly affects the concentration of five of the phenolic and total free phenolic compounds.

Beta-glucan

Oat is an excellent source of the dietary soluble fibre β-glucan making it well accepted for human nutrition (Premkumar *et al.,* 2017; Varma *et al.,* 2016), providing 5.0 g (oatmeal) to 7.2 g (oat bran) per 100 g serving (Glore *et al*., 1994). Nutrition experts believe that β-glucan, can help to inhibit cholesterol build up and ultimately reducing low density lipoprotein and total cholesterol level thus reducing heart diseases (Brown *et al.,* 1999; Whitehead *et al*., 2014). It was also found to be effective to reduce blood sugar (type II diabetes) and insulin response (Tapola *et al.* 2005; Priebe *et al.,* 2008). It helps in increasing the feeling of fullness and increasing the growth of good bacteria in the digestive tract. Therefore it prevents inflammation in arteries, damages tissues and can raise the risk of heart attacks and strokes (Joyce *et al.,* 2019; Mellen *et al*., 2008).

One study reports that feeding oats to infants before the age of 6 months is linked to a decreased risk of childhood asthma (Nwaru *et al*., 2012). Cui and Wang (2009) studied the distribution pattern of beta-glucans in the oat groat and found that it concentrated more in the bran fraction as compared to the endosperm. Oat bran, the fibre rich outer layer of the grain, helps relieve constipation in older people (Sturtzel and Elmadfa, 2008). Oat grass has been used traditionally for medicinal purposes, including the balance of menstrual cycle, treating dysmenorrhoea and for osteoporosis and urinary tract infections (Duke, 2009). Beta-glucan was found to be correlated with different characters studied in oat.

Screening of genotypes for Dual-purpose

Dual purpose oat accessions aim to achieve green fodder yield for livestock sustainability as well as seed production for human consumption. Radcliffe *et al*., 2012 advocated the principles for the development of dual purpose cultivars of oat, triticale and other cereals and recommended plant breeders to adopt the following principles:

- Initially, little focus should be given to the

green fodder production
- Evaluation and selection for the genotypes with winter habit because these genotypes will show delayed reproductive development
- Evaluation of the genotypes for grain yield and quality along with early generation selection for biotic and abiotic stress
- Genotypes performed better than checks based on the "grazability" should be conserved as advanced lines and advance trials should be conducted.

The cut for green fodder is usually taken 60-70 days after sowing 10-15 cm above ground level and the crop is left for seed production. The seeds are harvested at maturity as soon as the plants turn brown colour. The genotypes which produce higher green fodder yield, dry matter yield and seed yield can be considered ideal for dual purpose. Many kinds of researches have shown a positive and significant correlation between seed yield and green fodder yield (Ahmad *et al.*, 2013; Poonia *et al.*, 2017). Molecular approach can also be used to study diversity using clustering patterns. The studies were based on different marker systems (RAPD, SSR, ISSR or can be used in combination). A study showed that the clustering pattern of the varieties appeared such that it can be grouped in the genotypes suitable for the fodder purpose and the dual purpose varieties separately (Ruwali *et al.*, 2013).

CONCLUSION

The demand of oat has been increasing especially for mining of its health benefits including dietary benefits and beta-glucan. Focusing on small and divided farming land, it is important to develop dual-purpose oat varieties so that farmers can have sufficient grain yield and fodder yield from the same crop. Due to its quick regeneration capacities, oat can be managed for seed production after taking first cut for green fodder. The multi-cut nature of this crop makes it more suitable to get green fodder yield during fodder scarcity period. Exploitation of the available germplasm will help to improve the oat varieties for dual purpose. Extensive research on quality parameters of oat grains is the need of the time. The selection of superior dual-purpose oat genotypes provides better solution for the food insecurities and livestock sustainability under changing climatic conditions.

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