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Review Article

Taxonomy, domestication, and global significance of oats (Avena spp.) with emphasis on Ethiopian production and research: A review

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Abstract: *Oat (Avena sativa L.) is a vital cereal crop belonging to the Poaceae family, with significant agricultural, nutritional, and economic importance. Taxonomically, oats are classified under the genus Avena, which includes diploid (AA), tetraploid (AABB), and hexaploid (AACCDD) species, with A. sativa and A. byzantina being the most widely cultivated. Oats originated in the Mediterranean and Near East regions, later spreading to Europe and other temperate zones as a weed before domestication around 4,000 years ago. Today, oats serve dual purposes as livestock feed and human food, offering high nutritional value, including protein, β-glucan, antioxidants, and essential minerals. They play a crucial role in reducing cholesterol, regulating blood sugar, and improving digestive health. Globally, oats rank sixth among cereals in production, with Europe leading at 54.4% of total output. In Ethiopia, oats are predominantly grown in highland areas (1,750–3,000 m elevation) for forage and grain, though adoption remains limited due to low extension support and environmental constraints such as waterlogging, soil acidity, and frost. Despite challenges, Ethiopia has released several high-yielding oat varieties, with forage yields ranging from 7.5 to 19.5 t/ha and seed yields between 1.5 and 4.1 t/ha. Research efforts by institutions like the Ethiopian Institute of Agricultural Research (EIAR) and the International Livestock Research Institute (ILRI) have focused on germplasm evaluation, varietal development, and promotion, yet farmer awareness and adoption rates remain low. Enhancing extension services, improving seed systems, and addressing production constraints could boost oat productivity and utilization in Ethiopia's livestock and food systems.*

Keywords: Livestock feed, Oats research, Oats species, Oats taxonomy, Uses of oats

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1. Introduction

Ethiopia's feed resources include natural pastures, crop residues, stubble grazing, cultivated forages, agro-industrial by-products, grains and grain screenings, and compound feeds. Ethiopia's feed resources include natural pastures, crop residues, stubble grazing, cultivated forages, agro-industrial by-products, grains and grain screenings, and compound feeds. Natural pastures constitute the largest share (54.5%) of the feed supply, followed by crop residues (31.1%) and hay (7.4%) (CSA, 2021). The remaining portion consists of agro-industrial by-products (2.0%), improved forage crops (0.6%), and non-conventional feed resources such as animal by-products, vegetable, and fruit wastes (4.4%).

Livestock feeding in Ethiopia primarily relies on natural pasture and crop residues, both of which have low nutritional quality (Adugna et al., 2012; Alemayehu et al., 2017). The nutritive value of crop residues varies depending on crop species and variety, harvest timing, and handling and storage conditions. Fibrous agricultural by-products mainly from cereals and pulses are typically low in nutrients, high in fibre, and have poor digestibility and voluntary intake by animals (Getu, 2019). Grazing land is shrinking due to the expansion of arable farming, urbanization, and industrial development. As a result, pastures are now largely confined to areas unsuitable for cropping due to topographic, edaphic, and climatic constraints, further limiting pasture yield and quality (Fekede et al., 2015; Alemayehu et al., 2016). Agro-industrial by-products derived from flour mills, sugar factories, edible oil processors, breweries, and abattoirs are less fibrous and richer in energy and/or protein compared to other feed resources. They also exhibit higher digestibility and energy values (FAO, 2019a). These by-products play a crucial role in urban and peri-urban livestock systems. However, their contribution to total dry matter (DM), crude protein (CP), and metabolizable energy (ME) availability in Ethiopia remains low at 1.08%, 3.08%, and 1.42%, respectively (FAO, 2019a). Overall, livestock production in Ethiopia is constrained by inadequate availability and supply of cultivated forages, supplements, premixes, and feed additives (EIAR, 2017).

When livestock rely on crop residues and low-quality roughage, significant energy is lost in the form of methane emissions. This leads to reduced feed efficiency, poorer animal performance, and higher greenhouse gas (GHG) emissions per unit of product. In Ethiopia, cattle alone emit an estimated 192.4 million tons of CO_2-equivalent GHG annually (FAO, 2019b), but improved feed quality can substantially reduce these emissions (Aemiro, 2016). Improved forage crops play a vital role in enhancing farmers' livelihoods by boosting livestock productivity while promoting economic and environmental sustainability. They improve soil fertility, sequester more CO_2, and produce high-quality forage, thereby reducing GHG emissions. Enhancing feed quality and utilization efficiency also supports Ethiopia’s Climate-Resilient Green Economy strategy (FDRE, 2011). By adopting improved forage crops, food security and climate resilience can be achieved, as these forages enhance feed conversion efficiency, increase livestock productivity, and lower GHG emissions. Strengthening feed production through cultivated forage crops alongside natural pasture and crop residues can significantly improve livestock output (Fekede et al., 2015). The use of improved forages is further necessitated by the shrinking availability of productive pasturelands in mixed crop-livestock systems (Muluneh et al., 2012). While their productivity varies by species, variety, soil, weather, and management, improved forage crops consistently outperform natural pastures. Under rainfed conditions, they yield 3 to 10 times more biomass per harvest than seasonally rested or continuously grazed pastures, respectively (Fekede et al., 2015). With irrigation, perennial forages can achieve even higher yields through multiple harvests. Comparative studies show that improved forage crops produce significantly higher dry matter (DM) yields than natural pastures: grasses average 13 tons/ha, legumes 8 tons/ha, and browse trees 11 tons/ha, while seasonally rested and continuously grazed pastures yield only 4 and 1 ton/ha, respectively.

Over the past five decades, the adaptability and yield performance of improved forage crops have been evaluated across altitudes ranging from 600 to 3000 meters above sea level, leading to the identification of promising species suited to high, medium, and low elevations (Getnet and Gezahagn, 2012; Alemayehu et al., 2017). These selected forage crops exhibit strong adaptation to diverse agro-ecologies, yielding more abundantly and offering superior nutritional quality compared to natural pasture (Getnet et al., 2012; Fekede et al., 2015). Among the improved forage crops recommended for Ethiopia’s agro-ecological zones, oat (*Avena sativa* L.) stands out as a valuable annual forage crop widely cultivated in the central highlands (Gezahagn et al., 2016). Oat has been recognized as a key fodder crop for livestock feed in Ethiopia for approximately fifty years. Its resilience under stressful conditions such as poor soil fertility, acidity, waterlogging, and frost with minimal management inputs has made it a preferred choice among farmers (Getnet, 1999; Fekede, 2004; Gezahagn et al., 2016). Notably, oat thrives in environments where other crops struggle, such as in North Shewa, where challenging growing conditions have further elevated its agricultural significance. It serves as a versatile livestock feed, utilized as hay, silage, green forage, or grazing material, providing high-quality forage during periods when other protein-rich feeds are scarce. Additionally, oat grain contributes to human diets in regions like Selale, Debre-Berhan, Sheno, Arsi, and Gojam (Fekede, 2004; Getnet et al., 2004). Farmers find oat cultivation straightforward, as its production practices align with those of other cereals like barley and wheat. Given its potential to address feed shortages, oat could play a transformative role in Ethiopia's livestock sector, which faces persistent constraints due to inadequate feed quantity and quality. These limitations contribute to low livestock productivity and perpetuate a low-input, low-output production system (Getahun, 2019). This review aims to provide a comprehensive and systematic overview of oats (*Avena spp*.), covering its taxonomy, botany, origin, domestication, and economic importance, with a focus on production status, genetic diversity, morphological traits, nutritional benefits, and agricultural significance—particularly in Ethiopia.

2. Methods

This narrative review article synthesized existing peer-reviewed articles, books, conference proceedings, and grey literature on oats (*Avena spp*.), with a specific emphasis on taxonomy, domestication, global distribution, and production dynamics within the Ethiopian context. A comprehensive literature search was conducted using the following electronic databases: Google Scholar, Web of Science, Scopus, PubMed, and FAO databases. Other related websites and thesis research reports were searched using Google search engines and university websites. Additionally, institutional repositories from Ethiopian universities and the Ethiopian Institute of Agricultural Research (EIAR) were manually searched to capture region-specific studies. Articles were screened by title and abstract for relevance, and then fully reviewed. Relevant information was extracted and organized thematically according to the review's sub-topics.

3. Biology of oats

3.1. Taxonomy of oat

Oats belong to the genus Avena and are taxonomically classified as follows: Phylum—Spermatophyta, Class—Monocotyledons, Order—Cyperales, Family—Gramineae/Poaceae, and Tribe—Aveneae (Atman, 2017; Fu, 2018). The genus Avena, commonly referred to as oats, includes approximately 70 species (Table 1), only a few of which are cultivated (Atman, 2017; Harshita, 2018). This genus is highly diverse, encompassing diploid, tetraploid, and hexaploid species, all with a base chromosome number of seven (Atman, 2017; Kaur and Kapoor, 2017; Ashenafi, 2018; Harshita, 2018). While most diploid and tetraploid species are wild, other ploidy levels—such as triploids, pentaploids, and octaploids—can arise through hybridization and chromosome doubling, though they are rare in nature (Sanjeet, 2018). Two well-known diploid species ($2n=2x=14$) within the genus are *Avena strigosa* and *Avena nuda* (Atman, 2017), both sharing the same genomic designation (AA) (Leggett and Thomas, 1995). *A. strigosa*, also called bristle-pointed oat or black oat, is utilized as a winter cover crop and forage in subtropical and temperate regions (Atman, 2017). While *A. strigosa* is typically hulled, a naked variety exists, whereas *A. nuda* is a less commonly cultivated diploid naked oat. Tetraploid species ($2n=4x=28$), such as *A. abyssinica* H. and *A. vaviloviana* M., possess the genomic constitution AABB (Leggett and Thomas, 1995; Ashenafi, 2018) and are native to Ethiopia (Ladizinsky, 1975; Leggett and Thomas, 1995). *A. abyssinica* exhibits an erect growth habit, reaching up to 1.5 meters in height, while *A. vaviloviana* ranges from prostrate to erect, growing up to 1.1 meters (Ashenafi, 2018). The hexaploid species ($2n=6x=42$) are *A. sativa* L. (common or white oat), *A. sterilis* L. (sterile oat), *A. fatua* L. (wild oat), and *A. byzantina* C. (red oat) (Atman, 2017; Ashenafi, 2018).

Table 1: Lists of some oats species and their descriptions

Common name	Scientific name	Description	Reference
Common oat	*Avena sativa*	The most widely cultivated oat species, used for human food (oatmeal, rolled oats) and animal feed. It has a high nutritional profile, including beta-glucans, which support heart health. Tolerates cooler climates.	Linneaus, 1753
Red oat	*Avena byzantina*	Also known as Byzantine oat, it is similar to *A. sativa* but more heat- and drought-tolerant. Primarily grown in Mediterranean and Middle Eastern regions. Used for forage and grain.	Gill et al., 1964
Black oat	*Avena strigosa*	A diploid species used as forage and green manure. Grown in South America and Europe. Tolerates poor soils but has lower grain yield than *A. sativa*.	Restelatto et al., 2014
Naked oat	*Avena nuda*	A hull-less oat variety where the grain threshes free from the husk. Easier to process for human consumption and has higher fat content than common oat.	Valentine, 1995
Wild oat	*Avena fatua*	A weedy species, often considered invasive in cereal crops. It has high genetic diversity and is used in oat breeding programs for disease resistance. Seeds shatter easily, reducing yield in cultivated fields.	Thurston, 1951
Sterile oat	*Avena sterilis*	A wild ancestor of cultivated oats, found in the Fertile Crescent. Used in breeding programs for disease resistance (e.g., crown rust). Produces large seeds but it has strong seed dormancy and shattering traits.	Thurston and Phillipson, 1976
Slender oat	*Avena barbata*	A wild oat species found in Mediterranean climates. It has a slender panicle and is drought-resistant. Sometimes used in breeding for stress tolerance.	Carson, 2009
Ethiopian oat	*Avena abyssinica*	A tetraploid species found in Ethiopia, used locally for food and fodder. It has intermediate traits between wild and cultivated oats.	Aase and Powers, 1926

Hexaploid oats are inter-fertile and regarded as a single biological species due to their shared genome (AACCDD) (Ladizinsky and Zohary, 1971; Baum, 1977). However, with scientific advancements, hexaploid oats have since been classified into multiple taxonomic species (Ashenafi, 2018). *Avena sativa* is a self-pollinating hexaploid crop ($2n=6x=42$) with a base chromosome number of x=7 and a genomic structure of AACCDD (Rines et al., 2006). The cultivated oat (*A. sativa* L.) is believed to have evolved primarily from the hexaploid species *A. sterilis* (Trabut, 1914) rather than *A. fatua* (Thellung, 1912; Zade, 1918). The two primary cultivated oats species—*A. sativa* L. and *A. byzantina* C.—are grown for both fodder and grain. These all hexaploid, autogamous species likely arose from the natural combination of three ancestral diploid genomes: AA, CC, and DD (Rines et al., 2006). The A genome is thought to originate from *A. strigosa* species (Nishiyama, 1929), while the C genome was contributed by *A. ventricosa* (Rajhathy, 1966; Thomas, 1970). Although the exact origin of the D genome remains unclear, studies suggest it is closely related to the A genome (Linares et al., 1966; Leggett and Markhand, 1995; Linares et al., 1998). Since no extant D-genome diploid species have been identified, it is possible that an A-genome diploid species donated both the A and D genomes to hexaploid oats (Rajhathy and Thomas, 1974). Among cultivated oats, *A. sativa* L. and *A. byzantina* C. dominate global production, with common oat (*A. sativa* L.) being the most significant, accounting for over 80% of the world's oat acreage (Atman, 2017). Due to extensive human selection and breeding efforts, domesticated *A. sativa* exhibits far greater genetic diversity and a broader distribution compared to other oats species (Ladizinsky, 2012a; Esvelt et al., 2016).

3.2. Botany of oat

The cultivated oat (*Avena sativa*) is an annual, self-pollinating grass (Purseglove, 1972; Rines et al., 2006) with both seminal and adventitious root systems. The seminal roots develop during embryogenesis and include a primary root along with two or three lateral roots emerging from the first node. Adventitious roots, which form the plant's primary root system, arise from the nodes of the main stem and tillers, just below the soil surface. Oats exhibit an erect to prostrate juvenile growth habit and can grow to a height of 1.5–2.0 m by the full heading stage (Fekede, 2004). The stems feature solid nodes, while the elongated internodes of mature stems are hollow. However, during early vegetative growth, the internodes remain solid (Fekede, 2004).

The arrangement of leaves on the oats plant and the structure of its plant parts are typical of grasses. The leaves are solitary, alternate, two-ranked, and sessile (Fekede, 2004). A fully developed oats leaf consists of three main components: the terminal blade, the basal sheath, and a thin membranous ligule. The blade is elongated, flat, narrow, and linear, with an acute margin and pointed tip. The sheath forms an open cylinder that, in young plants, encloses the stem and younger leaves. At maturity, it surrounds the entire elongated internode above it. The ligule, a delicate membranous extension, connects the inner margin where the blade and sheath meet. It curves upward, clasping the stem. Lateral branches of the oats plant emerge from the axils of the foliage leaves. The leaves of tillers grow at a right angle to the parent axis. Before or during anthesis, the leaves exhibit a green to dark grayish-green hue (Fekede, 2004).

The inflorescence of cultivated oat is a many-branched, determinate panicle that can be either equilateral (spreading) or unilateral (one-sided). Unlike other temperate cereals, oat is characterized by its open, spreading panicles with large pendulous spikelets, which may or may not bear awns (Fekede, 2004). The oat panicle consists of a loose, open central rachis with five to seven nodes, from which branches emerge, each bearing spikelets (Coffman, 1977). The lateral branches typically end in a single apical spikelet, while additional spikelets develop on secondary or tertiary branches. A single panicle may carry 20 to 50 spikelets, each containing 2–3 florets. At maturity, the spikelets do not disarticulate, and the lemma is usually yellow, with awns that may be small, reduced, or entirely absent (Ashenafi, 2018). The flowers are perfect, zygomorphic, bracteates, and hypogynous, composed of a lemma and palea, two lodicules, three stamens, and a single pistil. The oat kernel—also called a caryopsis or groat—is obtained after removing the palea and lemma. It is typically covered in fine silky hairs and consists of the seed coat, starchy endosperm, and embryo.

4. Origin and domestication of oat

4.1. Origin of oat

The exact center of origin for oats remains uncertain, but evidence suggests it likely emerged in the western Mediterranean region (Ashenafi, 2018). The common cultivated oat (*A. sativa* L.) is thought to have originated in Asia (Gibson and Benson, 2002; Ladizinsky, 2012a; Ankita, 2019). However, other studies propose alternative origins: Vavilov (Vavilov,

1926) identified the Near East as its center of domestication, while Trabut (Trabut, 1914) and Malzew (Malzew, 1930) included the Mediterranean region, particularly for the cultivated red oat (*A. byzantina*). From the Fertile Crescent—a historical region spanning from Israel to western Iran—the cultivated oat (*A. sativa* L.) spread into Europe as a weed mixed with wheat and barley (Leggett and Thomas, 1995: Ladizinsky, 2012b).

4.2. Domestication of oat

Cultivated oat (*Avena sativa*) emerged in global agriculture around 4,000 years ago (Holland, 1997), undergoing domestication alongside wheat and barley (Ashenafi, 2018). Initially spreading as weeds within emmer wheat (*Triticum dicoccum*) crops, oats thrived in temperate regions due to their adaptability, eventually displacing emmer as a cultivated crop (Leggett and Thomas, 1995). During his 1916 explorations, Vavilov observed oat species intermixed with emmer wheat samples across western Asia (Jones, 1956). Some resembled cultivated oats, yet since oats were not actively grown in these areas, Vavilov hypothesized that they originated there but were domesticated further north. Oat domestication most likely occurred outside its diversity center, in northern Europe, where human populations migrated after the Neolithic Revolution (Murphy and Hoffman, 1992). As wheat and barley cultivation expanded into temperate zones, non-shattering oat grains were selectively favored from weedy oat contaminants introduced from the Middle East (Ashenafi, 2018). Today, wild oats species (*A. fatua* and *A. sterilis*) persist as problematic weeds in these regions. Overall, oats domestication is closely linked to mid- and northern Europe, driven by the northward expansion of other cereal crops like wheat and barley (Leggett and Thomas, 1995).

5. Importance of oat

5.1. Livestock feed

Oats are an important annual cereal crop, particularly suited to higher altitudes in the tropics and widely cultivated in cooler, wetter temperate regions. This dual-purpose crop serves both as forage and grain globally (Fekede, 2004; Suttie and Reynolds, 2004). The uses of oats are summarized in Table 2. A well-managed oats field can yield two cuttings—the first often used as feed, while the second is left for grain production (Fekede, 2004). Oats are valued worldwide for their adaptability, rapid regrowth after cutting, and high-quality herbage. They play a significant role as both fodder and grain, supporting human nutrition and livestock feed (Fekede, 2004; Suttie and Reynolds, 2004). Oats produce abundant, high-quality fodder during periods when other succulent forages are scarce. The crop can be fed fresh, or surplus yields can be preserved as hay or silage for later use. Oats herbage is rich in soluble carbohydrates, making it ideal for high-quality silage that is palatable to all livestock types. Feeding oats forage reduces reliance on concentrated feeds, offering a cost-effective way to maintain livestock health and productivity.

Oats serve as a valuable source of protein, sugar, fiber, and essential nutrients and minerals. Green oats fodder typically contains 10–12% protein and 30–35% dry matter (DM) (Ruwali and Deo, 2009). When harvested at the milk stage, oats have the following chemical composition (on a DM basis): 6.44% crude protein, 28.72% fiber, 53.20% nitrogen-free extract, 2.31% ether extract, 9.33% total ash, 0.47% calcium, 0.22% phosphorus, 0.22% magnesium, 0.52% sodium, and 2.84% potassium (Monika, 2017). Forage harvested at the soft dough stage contains, on average, 79.0 g/kg DM ash, 60.7 g/kg DM crude protein (CP), 634.7 g/kg DM neutral detergent fiber (NDF), 420.3 g/kg DM acid detergent fiber (ADF), 65.5 g/kg DM acid detergent lignin (ADL), and 529.8 g/kg DM in-vitro organic matter digestibility (IVOMD) (Fekede et al., 2008). Oats straw is a preferred livestock feed due to its softness, higher digestible organic matter, and greater metabolic energy compared to other cereal crop residues. It is considered superior to wheat and barley straw, making it an excellent choice for both feed and bedding material (Fekede, 2004), thanks to its absorbent properties.

Oats caryopsis has high nutritional value due to its richness in protein (particularly lysine) and oil. It serves as a quality fodder for livestock, providing high energy when used as animal feed (Ruwali et al., 2013). Additionally, oats grain acts as a well-balanced concentrate in rations for poultry, cattle, sheep, and other animals. Several studies support its use as livestock feed (Fekede, 2004; Getnet et al., 2004; Gezahagn et al., 2016; Nikoloudakis et al., 2016). While the hull constitutes about 25% of the grain weight and reduces energy density, ruminants tolerate it well. Oats are a highly nutritious cereal, abundant in fat, protein, fiber, vitamin B1, phosphorus, and iron, making them suitable for both human and animal consumption (Butt et al., 2008). Their nutritional value stems primarily from their protein, lipid, and fiber content. Further studies highlight oats as a valuable source of protein, fats, carbohydrates, fiber, vitamins, minerals, and antioxidants, all of which contribute to health benefits (Peterson et al., 2005).

5.2. Human food

While the majority of the world's oats production is used as livestock feed, only 17% of global grain output is dedicated to human consumption. Whole oats groats are highly nutritious, serving as an excellent source of unsaturated fatty acids, vitamins, dietary fiber, protein, antioxidants, and minerals, particularly β-glucan (Premkumar et al., 2017; Varma et al., 2017). Recognized as one of the most important cereal crops for human nutrition, oats provide essential nutrients worldwide (Boczkowska and Tarczyk, 2013). The health benefits of oats-based products have even been endorsed by the USFDA (USFDA, 1997). Oats are consumed in various forms, including porridge, oatcakes, and other foods, with oats bran being a particularly nutritious addition to diets. Compared to other cereals like barley, wheat, maize, and rice, oats offer superior nutritional value (Purseglove, 1972). Before consumption, the grain is typically dehulled, while the processed husk can be repurposed for industrial uses. Oats groats contain significant amounts of β-glucan, ranging from 2.3 to 8.5 g per 100 g (Welch et al., 2000). This β-glucan is primarily found in the endosperm cell walls, making up about 75% of their composition. Due to their lack of gluten, oats are unsuitable for traditional bread-making but are commonly consumed as porridge, flakes, or breakfast cereals. Oats flour and oatmeal are often incorporated into baked goods, such as composite bread made with wheat flour. Additionally, oats can serve as a thickening agent in soups, while oats bran can be sprinkled on salads, soups, and other dishes to boost fiber intake (Fekede, 2004).

Oats stand out among cereal crops due to their high content of beneficial lipids and proteins. Their nutritional profile, rich in antioxidants and soluble fiber, makes them a valuable dietary component (Marmouzi et al., 2016). Oats are an excellent source of soluble carbohydrates and fiber (Peterson et al., 2005), particularly β-glucan, a dietary soluble fiber found in concentrations of 5.0 g (oatmeal) to 7.2 g (oat bran) per 100 g (Glore et al., 1994). Research indicates that β-glucan helps reduce cholesterol buildup, supporting heart health (Whitehead et al., 2014). Additionally, oats positively influence plasma glucose and insulin levels, making them beneficial for diabetes management (Zhu et al., 2016). Oats bran, the outermost layer of the oat kernel, is produced by grinding groats or rolled oats and constitutes no more than 50% of the original material. It contains at least 5.5% β-glucan and 16.0% dietary fiber, with soluble fiber making up a third of the total (Anonymous, 1989). Like oatmeal, oats bran provides B vitamins, protein, healthy fats, minerals, and β-glucan. Its nutritional composition includes 17.1% protein, 67.9% carbohydrates, 8.6% fat, 15–22% dietary fiber, 10.4% β-glucan, and essential micronutrients such as niacin, magnesium, iron, copper, potassium, and a-tocopherol (Saunders, 1985; Marlett, 1993). Studies suggest that oats bran consumption may lower cholesterol and reduce the risk of heart disease (Anderson et al., 2009; Satija and Hu, 2012). Furthermore, its high phenolic content and anti-proliferative properties contribute to its health benefits (Butt et al., 2008).

Oats have long been recognized as a valuable source of protein for human nutrition. The protein concentration in oats is relatively high, and its amino acid profile is more balanced than that of most cereal grains (Klose and Arendt, 2012). Oats contain 15–20% protein in the groat, a higher proportion than many other grains, and their amino acid composition remains stable regardless of protein content variations (Robbins et al., 1971). Compared to barley, wheat, maize, rice, rye, sorghum, and millet, oats protein has a superior amino acid balance (Kellems and Church, 1998), primarily due to its main storage protein being a globulin—a legume-like protein.

Globulins contain higher levels of lysine and other essential amino acids than typical cereal storage proteins, though oats are still marginal in methionine, histidine, tryptophan, and lysine than legumes (Fekede, 2004). Starch is the primary component of oats grains, consisting of amylose and amylopectin. Its content varies depending on the oats variety and growing conditions. The amylose content in oats ranges from 16 to 29% (Mimoghtadaie et al., 2009), with no known waxy varieties. Oats starches exhibit typical gelatinization properties but are highly shear-sensitive and behave similarly to waxy starches. Upon cooling, they develop unusually high viscosity. Compared to other cereal starches, cooled oats starches are clearer, softer, more elastic, and more adhesive.

Oats grain has a soft kernel and a relatively high oil content (7%), which is distributed throughout the seed, making its milling process more challenging compared to wheat and maize (Kirk and Sawyer, 1999). While higher oil content is beneficial in animal feed due to its greater energy density compared to carbohydrates, oats millers typically prefer lower oil concentrations for food products. This is because high oil content increases susceptibility to rancidity, thereby reducing shelf life (Fekede, 2004). Oats oil is primarily composed of palmitic (16:0), oleic (18:1), linoleic (18:2), and linolenic (18:3) acids, with their relative proportions varying depending on genotype and growing conditions (Zwer, 2010). The high proportion of monounsaturated oleic acid makes oat oil nutritionally favorable for food applications. Additionally, oats oil contains tocols (vitamin E compounds), predominantly α-tocotrienol and α-tocopherol, along with minor amounts of other tocols (Marmouzi et al., 2016). These compounds act as antioxidants, protecting cells from free radical damage and reducing lipid peroxidation (Fardet et al., 2008). Beyond their antioxidant properties, tocols have been shown to lower serum cholesterol levels and inhibit the growth of certain cancer cells (Aggarwal et al., 2010). Unlike other grains, oats are particularly rich in α-tocotrienol, along with other antioxidants such as α-tocopherol and avenanthramides, as well as dietary fiber, including the soluble fiber β-glucan (Oliver et al., 2010). Although tocotrienols are more potent free radical scavengers than tocopherols, they are less readily absorbed. Tocols are unevenly distributed within the oats grain: α-tocotrienol is concentrated in the endosperm, while α-tocopherol is primarily found in the germ.

Oats dietary fiber, composed of cellulose, non-starch polysaccharides, non-cellulosic polysaccharides, and lignin, has demonstrated protective effects against colorectal cancer. Dietary fiber can be categorized into two types based on water solubility: soluble and insoluble, both of which contribute to health in distinct ways. Soluble fiber, primarily consisting of polysaccharides, gums, pectin, arabinoxylan, and β-glucan, is particularly abundant in oats, with β-glucan being its major component (Lazaridou and Biliaderis, 2007). Oatmeal and oats bran, rich in β-glucan, are highly effective in lowering blood cholesterol and stabilizing blood sugar levels (Wood et al., 1990; Wood et al., 1991; Kahlon and Chow, 1997). On the other hand, insoluble fiber—comprising lignin, cellulose, and hemicellulose—exhibits high water-holding capacity, promoting increased fecal bulk and aiding digestion. Oats grains contain approximately 1.8-7.9% mixed-linked β-glucan, primarily located in the endosperm cell walls (Saastamoinen et al., 2004). Notably, β-glucan helps moderate post-meal blood sugar spikes, making it beneficial for diabetes management. Additionally, it plays a crucial role in: preventing constipation, reducing colorectal cancer risk, lowering serum cholesterol, regulating blood glucose levels in diabetics, and enhancing immune function and disease resistance (Shen et al., 2016; Arena et al., 2017). Oats with high β-glucan content are valuable for functional foods and industrial processing, whereas low β-glucan varieties are preferred in poultry feed to improve digestibility. Concentrated in the bran, β-glucan is widely used in food products and has promising medical applications, including wound healing, immune system stimulation, and skin protection. Furthermore, dietary fiber may influence mineral balance (Idouraine et al., 1996; Haack et al., 1998).

The mineral composition of oats is similar to that of other cereals, with minerals primarily concentrated in the bran fraction. The major minerals found in oats include manganese, phosphorus, copper, iron, selenium, magnesium, and zinc (Garg et al., 2005). Among these, manganese is the most abundant, while copper is present in relatively lower amounts. Instant oats bran flakes contain the highest mineral concentrations, whereas extruded oats have the lowest (Skibniewska et al., 2002). In addition to minerals, oats contain small but notable amounts of vitamins such as thiamine, niacin, riboflavin, pyridoxine, folacin, biotin, and pantothenic acid. They also contain minor bioactive constituents, including tocols and avenanthramides, which exhibit antioxidant properties and may offer health benefits (Fardet et al., 2008). Avenanthramides are predominantly found in the oats groat and bran, with only trace amounts present in the hull (Liu et al., 2005). These compounds are believed to contribute to the anti-irritant effects of oats-based lotions and creams. The cosmetic and personal care industries utilize colloidal oat extract—a blend of phytochemicals such as avenanthramides, flavonoids, and saponins—for its skin-protective properties, particularly in soothing sunburned skin (Sur et al., 2008; Tiwari, 2009). While other antioxidant compounds like phenols, flavonoids, saponins, lignans, and sterols are present in oats; their concentrations in the soluble fraction are significantly lower compared to avenanthramides and tocols.

Table 2: Summary of oats uses and description

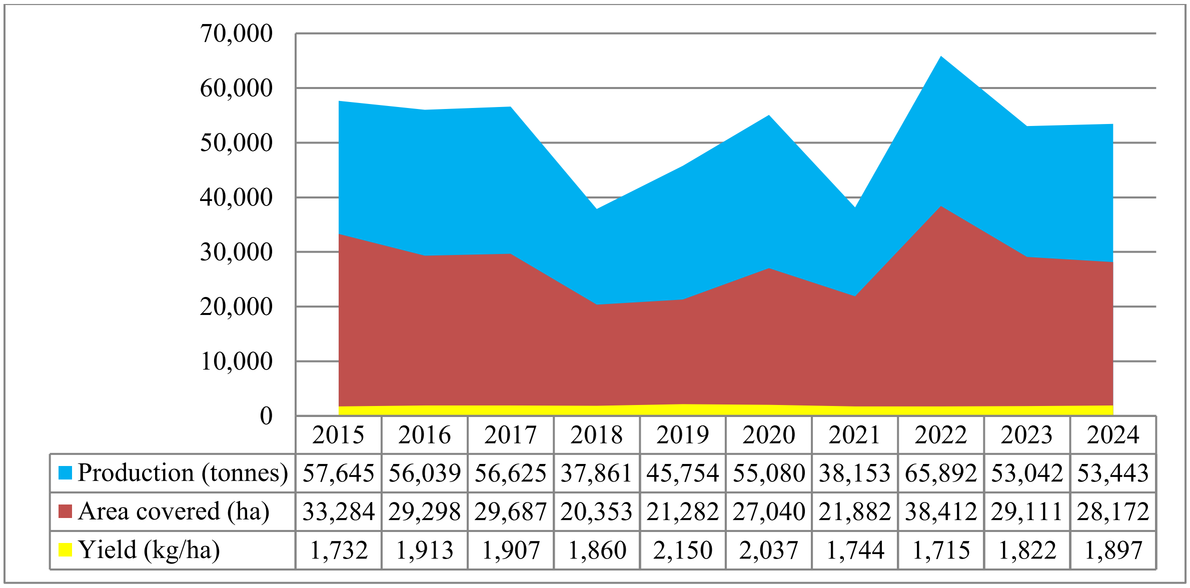
Uses of oats	Description	Reference
Food and nutrition	- Breakfast cereals (oatmeal, muesli, granola) - Baking (cookies, bread, muffins) - Thickening agent (soups, stews) - Plant-based milk (oat milk) - Infant foods	Rasane et al., 2015
Animal Feed	- High-nutrient feed for horses, cattle, and poultry - Improves milk yield in dairy cattle - Used in poultry diets for better growth	NRC, 2001
Health Benefits	- Lowers cholesterol (beta-glucan fiber) - Regulates blood sugar (low glycemic index) - Aids digestion (high fiber) - Supports weight management (satiety)	Slavin, 2005
Cosmetics and Skincare	- Used in lotions and creams (moisturizing properties) - Oatmeal baths for eczema and skin irritation - Exfoliating scrubs (colloidal oatmeal)	Cerio et al., 2010
Industrial Uses	- Biodegradable packaging material - Adhesives and binding agents - Biofuel production (oat hulls as biomass)	Reddy and Yang,2005
Agricultural Benefits	- Used as a cover crop to prevent soil erosion - Green manure for soil enrichment - Rotational crop for sustainable farming	Magdoff and Van, 2009

6. Global oat production

Oats thrive in cool, moist climates and are best suited to temperate regions due to their winter-hardy nature. They are also cultivated in subtropical areas and at higher altitudes worldwide. Global oats production is primarily concentrated between 35–65°N and 20–46°S latitudes. Among cereal grains, oats rank sixth in global production, following wheat, rice, maize, barley, and sorghum (FAO, 2012). However, they lead in fodder production (FAO, 2011). As one of the world's most important crops, oats covered 8.54 million hectares in the 2024 cropping season, yielding 22.43 million tonnes of grain with an average productivity of 2.63 tonnes per hectare (FAOSTAT, 2024). At the continental level, Europe is the largest oats producer, followed by the Americas, Oceania, Asia, Australia, and Africa (FAOSTAT, 2024). Europe dominates production with 54.4% of the global output, while the Americas contribute 27.9%, and Oceania accounts for 5.6%. Canada is the world's top oats producer, contributing 15% of global production (FAOSTAT, 2024). Oats are primarily a European and North American crop, as these regions provide the ideal cool, moist climate. Other leading producers include Russia (13.4%), Poland (7.2%), Australia (5.9%), and Finland (5.4%), which together with Canada account for 46.9% of global oats output (FAOSTAT, 2024). In Africa, the largest oats-producing countries in 2024 were Algeria (105,000 tonnes), Ethiopia (53,443 tonnes), South Africa (42,800 tonnes), Morocco (11,013 tonnes), and Kenya (3,668 tonnes). However, Africa's total contribution to global oats production was less than 1% (FAOSTAT, 2024).

7. Oat production in Ethiopia

Oat is one of the most widely cultivated forage crops in Ethiopia's highland farming system. It thrives in cool, moist climates and performs well at elevations between 1,750 and 3,000 meters (Fekede, 2004; Getnet et al., 2004). However, at lower altitudes, its suitability decreases due to limited tillering and poor canopy formation (Fekede, 2004). As shown in Figure 1, Ethiopia's oats production, area coverage, and productivity exhibited significant fluctuations over the past decade (2015–2024), with annual averages of 51,953 tonnes, 27,852 hectares, and 1.878 tonnes per hectare, respectively (FAOSTAT, 2015-2024). In 2024, Ethiopia ranked 38th globally in oats production and second in Africa (FAOSTAT, 2024). During that year's cropping season, oats production reached 53,443 tonnes, covering 28,172 hectares, with a yield of 1.897 tonnes per hectare (FAOSTAT, 2024).



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
🟦 Production (tonnes)	57,645	56,039	56,625	37,861	45,754	55,080	38,153	65,892	53,042	53,443
🟥 Area covered (ha)	33,284	29,298	29,687	20,353	21,282	27,040	21,882	38,412	29,111	28,172
🟨 Yield (kg/ha)	1,732	1,913	1,907	1,860	2,150	2,037	1,744	1,715	1,822	1,897

Figure 1: Oats production, area coverage, and productivity trend in Ethiopia. Source: (FAOSTAT, 2015-2024).

8. Oat research in Ethiopia

8.1. Germplasm introduction/collection and evaluation

Forage research as a national program in Ethiopia began formally in the mid-1960s with the establishment of the Institute of Agricultural Research (IAR) (Alemayehu and Getnet, 2012). Since then, the IAR (later renamed the Ethiopian Institute of Agricultural Research, EIAR) has collected and introduced various indigenous and exotic forage species from different parts of the country and abroad. Additionally, the International Livestock Research Institute (ILRI) has contributed significantly by introducing forage species and supporting the collection and evaluation of indigenous legumes (Fekede et al., 2015). The Arsi Rural Development Unit (ARDU), later known as the Chilalo Agricultural Development Unit (CADU), also played a key role after its establishment in 1967 in Asela. This project introduced several temperate and tropical forage species, including oats, and bolstered Ethiopia's national agricultural research system, particularly in forage and pasture development. Oats variety evaluations began in the late 1960s at Holetta and possibly other locations (Getnet et al., 2004). The initial introduction of oat germplasm included 19 genotypes from the USA in 1969 (IAR, 1970), followed by a larger collection of 9,054 genotypes from over 55 countries in the early 1970s, supported by the Food and Agriculture Organization (FAO) of the United Nations (IAR, 1973; Astatke, 1976; Lulseged and Alemu, 1985). Later, in the early 1980s, the International Maize and Wheat Improvement Center (CIMMYT) introduced 40 grain-type oats varieties—suitable for both food and feed—to the Holetta Agricultural Research Center (HARC) (IAR, 1982). These efforts aimed to expand the genetic diversity of oats for evaluation and to identify suitable varieties for Ethiopia's diverse agroecological conditions.

Over the past five to six decades, oats research has primarily focused on germplasm introduction and collection, evaluation, and the selection of promising varieties suited to different agro-ecologies. Key activities have included micro-seed multiplication, on-farm demonstrations, and promoting adoption among farmers. The introduced or collected oats varieties were assessed for various desirable traits, such as: adaptation to local climatic and soil conditions, ease of establishment, herbage and seed yield potential, resistance to pests and diseases, forage quality and dual-purpose utility (fodder and grain), suitability for multi-cut systems and intercropping (e.g., with vetch), role as a precursor crop (e.g., before chickpea cultivation), and compatibility with existing farming systems. However, oats production in highland areas faces several environmental constraints, including: low soil and air temperatures, delaying establishment and growth, excessive rainfall and waterlogging, particularly on vertisols, high soil acidity and low fertility, seasonal frost (October–January), disease pressure (especially rust), and severe weed competition. Additionally, high population density and limited arable land pose significant challenges to oats cultivation in Ethiopia's highlands. Despite these limitations, several high-yielding and adaptable oats varieties have been identified and recommended for mid- and high-altitude regions. Given these factors, evaluating oats varieties for high yield potential, environmental adaptability, and socio-economic suitability remains crucial for selecting the most promising options across Ethiopia's diverse agro-ecologies.

8.2. Variety selection, demonstration, and adoption

Through rigorous screening and evaluation in the mid-1970s, approximately six promising oat varieties—including CI-8237, Jasari, Lampton, Grey-Algiers, CI-8251, and CI-8235—were selected and recommended for forage production in the highlands of Ethiopia. It is believed that the oats currently cultivated by smallholder farmers may belong to one of these varieties (Gezahagn et al., 2016). While different oats varieties were tested, selected, and distributed based on desirable traits, survey reports from the central highlands revealed that farmers do not distinguish between them, instead referring to all varieties collectively as one (Getnet, 1999). Locally, oats are known by different names, such as Sinar, Shalo, and Shemame, depending on the region (Getnet et al., 2004). Although oats were initially introduced for forage production, they are now widely cultivated as a food grain. However, farmers appear largely unaware of the existence of distinct oats varieties with varying advantages, leading them to grow a single variety for multiple purposes (Getnet, 1999). Oats grain has become a staple food in certain parts of Ethiopia, particularly in Selale, Debre-Berhan, Sheno, Arsi, and Gojam (Lulseged, 1981; Getnet, 1999, Getnet et al., 2004). Research efforts have focused on developing grain-type oats varieties, resulting in the national release of one grain-type variety (MoA, 2017) and two dual-purpose varieties (MoA, 2015). The Ethiopian Institute of Agricultural Research (EIAR) and Regional Research Institutes, as key players in the National Agricultural Research System (NARS), have been actively engaged in oats evaluation and selection. Additionally, other governmental and non-governmental organizations, particularly ARDU/CADU and ILRI, have played significant roles in supporting oats selection and development initiatives.

Despite being a major constraint in the livestock sector, improved forage and oats technologies developed through research have seen limited promotion and dissemination. This is due to insufficient attention from the agricultural extension system, as well as minimal efforts by national agricultural research systems and the private sector. Consequently, awareness and adoption rates of these technologies remain low, even though multiple improved forage/oats options have been recommended for different regions of the country. However, some promising forage and oats technologies have been promoted through initiatives like the Fourth Livestock Development Project (FLDP), with varying levels of utilization across regions. Additionally, the national agricultural research system, higher education institutions, the Ethiopian Seed Enterprise, NGOs, and private sector actors such as Aden Field have contributed—directly or indirectly—to oats demonstration and adoption efforts. Unlike other food crops, oats lack a formal release mechanism; instead, it has been informally demonstrated and distributed to farmers for forage production (Getnet et al., 2004). In the 2014 production year, the overall adoption rate of forage crops in the Oromiya region was just 10%. Oat-vetch had the highest adoption rate (35%), followed by elephant/Napier grass (15%) and tree lucerne (7%) (Agajie et al., 2016). However, a more recent 2017 study in the same region showed a slight increase, with adoption reaching 12% due to expanded promotion and dissemination efforts by various stakeholders (Agajie et al., 2018).

As the size of farmland increases by one hectare, the likelihood of adopting improved forage technologies including oats increases by 1.6% and the likelihood of adoption of forage technologies including oats increases by 6 and 4% in households with exposure to earlier experience on forage production and training on improved feeding practices, respectively, as compared to those who did not have such an opportunity (Agajie et al., 2016). On the other hand, as a household gets access to credit services; the likelihood of adoption of improved forage technologies including oats declines by 5.6% and it was also noted that the likelihood of adopting forage technologies including oats declines by 6% for households with no exposure to extension services as compared to those who have exposure (Agajie et al., 2016). The adoption intensity of improved forage technologies including oats is positively influenced by the size of cultivated land, training, and experience on forage production. However, it is negatively correlated with access to credit services and household income. Farmers' intensity of using improved forage technologies tended to rise as their access to extension services increased. According to Mamaru (2021), households with more frequent interactions with development agents were more likely to adopt improved forages at higher levels than those with limited or no extension contact. Similarly, Alemayehu et al. (2018) found that the number of extension contacts had a positive and significant influence on farmers' decisions to intensively use improved forages.

The persistently low adoption of oats in Ethiopia is a multifaceted issue rooted in complex farmer decision-making processes, significant extension service shortcomings, and critical institutional gaps. Early research using decision models to understand farmer behaviour in the Ethiopian highlands revealed that adoption decisions are not straightforward, requiring extension efforts to be tailored to farmers' specific opinions, attitudes, and circumstances (Darnhofer et al., 1997). This complexity is compounded by practical constraints, as empirical evidence from North Shewa identifies severe land scarcity and a critical lack of access to improved seeds as primary barriers to adoption (Mamaru, 2023). These challenges are further exacerbated by systemic institutional and extension failures, including inadequate training for farmers, insufficient collaboration between research institutions and extension services to effectively promote the technology, and a notable gender disparity in adoption that suggests extension efforts may not be reaching all segments of the farming population equitably (Mamaru, 2023). Together, these factors create an environment where even demonstrated technologies like improved oats varieties struggle to achieve widespread uptake.

8.3. Varietal registration/ release

The primary goal of introducing, collecting, and evaluating forage germplasm is to develop and recommend superior varieties of different species for widespread use, primarily as livestock feed. However, unlike food crops, forage research historically lacked formal variety release mechanisms (Fekede et al., 2015; Getnet et al., 2004). Despite this, nine forage varieties—including one oat variety (CI-8237)—were informally promoted and adopted by farmers before being registered in the Ministry of Agriculture's crop variety register (Fekede et al., 2015). Formal variety release procedures and guidelines for forage crops were established in 2009 (Fekede et al., 2015). Since then, the National Agricultural Research System (NARS) has released 73 forage varieties under these guidelines (2009–2022). To date, 82 forage varieties—including 12 forage oat varieties—have been officially registered (EAA, 2022). Additionally, four food-type oat varieties have been released for acid-prone areas (EAA, 2022). The released forage oat varieties exhibit a dry matter (DM) yield potential ranging from 7.5 to 19.5 t/ha, with an average of 11.9 t/ha. Their seed yield varies between 1.5 and 4.1 t/ha, averaging 3.2 t/ha. Beyond productivity, these varieties offer superior nutritional value compared to crop residues and natural pasture, the dominant feed resources in the country. Table 3 summarizes the forage and seed productivity of the released oat varieties.

Table 3: Forage and seed productivity of officially released oat varieties

SN	Variety	Mean forage yield (t/ha)	Mean seed yield (t/ha)	Year of release	Breeder/ Maintainer
1	Legend-567	10.3	3.9	2022	HARC
2	FL-720	13.1	4.1	2022	HARC
3	Ezo ote (Acc# ILRI-5527)	12.6	3.6	2022	Arbaminch ARC
4	Enat (Ajay, NZ#: 3107; 2010AFRI core)	-	4.1	2022	Adet ARC
5	Hulegeb (Goslin)	-	3.9	2019	Adet ARC
6	Tena (Souris: ND961161)	-	3.5	2019	Adet ARC
7	Was (CI-1506)	19.5	2.5	2019	HARC
8	Walqaa (SRCPX80Ab2596)	7.5	1.5	2019	HARC
9	Bate (ILRI-5453)	8.6	3.3	2018	BARC
10	Sorataf (79Ab382(TX)80SA94)	10.7	3.2	2017	HARC
11	SRCPX80Ab2806	13.5	3.1	2015	HARC
12	SRCPX80Ab2291	13.8	4.1	2015	HARC
13	CI-8251	12.8	2.9	2013	HARC
14	Bona-bas (IAR-PI. 1660)	10.3	2.1	2011	SARC
15	Bonsa (IAR-PI. 79Ab384)	10.8	2.9	2011	SARC
16	CI-8237	11.5	3.1	1976	HARC
	Mean yield	11.9	3.2		

HARC= Holetta Agricultural Research Center; BARC= Bako Agricultural Research Center; SARC= Sinana Agricultural Research Center; ARC = Agricultural Research Center. Variety # 4, 5, 6, and 10 are food oat released for acid prone areas while variety # 11 and 12 are dual type oat but other released varieties are forage type oat. Source: (EAA, 2022).

8.4. Oat consumption in Ethiopia

Oats consumption in Ethiopia is characterized by a distinct dichotomy between traditional, localized food uses and an emerging modern market for packaged products. In specific regions like the Gozamin District in the northwest, oats are not merely a casual food but a traditional staple crop. Research indicates that in these areas, oats are cultivated by nearly all producers and rank first in household consumption compared to other cereals like tef, maize, and wheat (Getaneh et al., 2021). This deep-rooted culinary tradition involves processing the grain into a variety of local foods and beverages, including injera, “kitta and anebabiro”, Gruel (“Atmit”), porridge, and local brews like tella, demonstrating the grain's significant role in food security and cultural heritage in these pockets of the country (Getaneh et al., 2021). According to Fekadu et al. (2018), an injera prepared with a blending ratio of 75% tef and 25% oats achieved excellent overall acceptability. This blend produced quality parameters including texture, color, odour, taste, and eye distribution that were on par with traditional 100% tef injera. Furthermore, the study found that several other composite flours also yielded favourable results. Specifically, the blends of 50% tef with 50% oats, 60% tef with 40% oats, 40% tef with 40% oats and 20% wheat, as well as a mixture of 50% barley, 30% oats, and 20% wheat, demonstrated better overall acceptance and an appealing color (Fekadu et al., 2018). However, this traditional consumption is geographically concentrated, and on a national level, oats are less recognized as a food crop compared to its primary use as a livestock feed (Getaneh et al., 2021; Lensa, 2023).

9. Conclusion

Oat (*Avena sativa* L.) is a versatile and nutritionally rich cereal crop with significant contributions to global agriculture, livestock feed, and human health. Their taxonomic diversity, spanning diploid to hexaploid species, highlights their genetic adaptability, with *A. sativa* and *A. byzantina* dominating cultivation due to their high yield and nutritional value. Domestication of oats traces back to their emergence as weeds in wheat and barley fields, eventually becoming a staple in temperate regions. Today, oats are valued for their high protein, soluble fibre (β-glucan), and lipid content, offering numerous health benefits, including cholesterol reduction, blood sugar regulation, and antioxidant properties. Globally, oats production thrives in cool, moist climates, with Europe and North America leading in output. In Ethiopia, oats are primarily cultivated in highland areas, though adoption of improved varieties remains low due to insufficient extension services and limited farmer awareness. Despite these challenges, research efforts have introduced and released several high-yielding forage and grain-type oat varieties, enhancing livestock feed and food security. Further research on oats in Ethiopia is poised to significantly enhance both climate adaptation and environmental sustainability. A primary focus will be the development of climate-resilient oats varieties through advanced breeding programs, aiming to create cultivars with improved tolerance to drought, waterlogging, and frost, alongside resistance to prevalent diseases, thereby ensuring stable forage production under increasingly unpredictable weather patterns. Concurrently, investigations into the methane mitigation potential of oats are emerging as a critical research frontier, exploring how specific oats cultivars or forage management practices can reduce enteric methane emissions from livestock, a vital step towards sustainable intensification. Given their adaptability, nutritional benefits, and role in sustainable farming systems, oats hold great potential for addressing food and feed demands in Ethiopia and beyond. Therefore, future research should focus on enhancing yield, disease resistance, and climate resilience to ensure oats remain a cornerstone of agricultural and nutritional security.

Declaration of competing interest

The authors declare that they have no competing interests.

References

Aase, H.C., & Powers, R. (1926). Chromosome Numbers in Crop Plants. American Journal of Botany, 13, 367–372.

Adugna, T., Getnet, A., Diriba, G., Lemma, G., & Alemayehu, M. (2012). Major Feed Resources. In: Livestock Feed Resources in Ethiopia: Challenges, Opportunities and the Need for Transformation (pp. 5–35). Ethiopian Animal Feed Industry Association.

Aemiro, K. (2016). The Effect of Natural Feed Additives on Methane Emissions, Nutrient Intake, Digestibility and Rumen Fermentation Parameters [Doctoral dissertation]. Obihiro University of Agriculture and Veterinary Science.

Agajie, T., Tadele, M., Tesfaye, S., Yared, D., Wudineh, G., Tolesa, A., Diriba, H., Tamirat, F., & Seyoum, B. (2016). Adoption Analysis of Smallholder Dairy Production Technologies in Oromiya Region. Research Report 115. Ethiopian Institute of Agricultural Research.

Agajie, T., Tadele, M., Tolesa, A., Abera, G., Wudineh, G., & Takele, M. (2018). The Dynamics of the Central Ethiopian Farming Systems. Research Report No 120. Ethiopian Institute of Agricultural Research.

Aggarwal, B.B., Sundaram, C., Prasad, S., & Kannappan, R. (2010). Tocotrienols, the Vitamin

E of the 21st Century: It's Potential Against Cancer and Other Chronic Diseases. Biochemical Pharmacology, 80, 1613–1631.

Alemayehu A., Afework H., Habtamu A., & Mulisa F. (2018). Determinants of adoption of improved forages in selected districts of Benishangul-Gumuz, Western Ethiopia. (2018) Vol. 6(2):104–110. DOI: 10.17138/TGFT (6)104-110.

Alemayehu, M., & Getnet, A. (2012). The Evolution of Forage Seed Production in Ethiopia. In: G. Assefa et al. (Eds.), Forage Seed Research and Development in Ethiopia. Ethiopian Institute of Agricultural Research (EIAR).

Alemayehu, M., Getnet, A., Gezahagn, K., & Fekede, F. (2016). Review on the Evolution of Forage Seed Production in Ethiopia: Experiences, Constraints and Options. Academic Research Journal of Agricultural Science and Research, 4(6), 231–240.

Alemayehu, M., Gezahagn, K., Fekede, F., & Getnet, A. (2017). Review on Major Feed Resources in Ethiopia: Conditions, Challenges and Opportunities. Academic Research Journal of Agricultural Science and Research, 5(3), 176–185.

Anderson, J.W., Baird, P., Davis, R.H., Ferreri, S., Knudtson, M., Koraym, A., Waters, V., & Williams, C.L. (2009). Health Benefits of Dietary Fiber. Nutrition Reviews, 67(4), 188–205.

Ankita, S. (2019). Genetic Studies for Various Agro-Morphological Traits and Diversity Analysis Using In Situ Hybridization in Different Oat Species [Doctoral dissertation]. Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya.

Anonymous. (1989). AACC Committee Adopts Oat Bran Definition. Cereal Chemistry, 1–24.

Arena, M.P., Spano, G., & Fiocco, D. (2017). β-Glucans and Probiotics. American Journal of Immunology, 13, 34–44.

Ashenafi, A. (2018). Genetic Diversity, Relation Between Characters, and Aluminum Toxicity Tolerance of Avena Species from Ethiopia [Doctoral Dissertation]. Addis Ababa University.

Astatke, H. (1976). Results of Experiments in Forage Crops and Pasture Management in the Highlands of Ethiopia (1971 - 1976). Forage and Range Bulletin No. 1. Institute of Agricultural Research (IAR).

Atman, P. (2017). Evaluation of Oat (*Avena sativa* L.) Genotypes for Yield and Quality Characters [M.Sc. thesis]. CCS Haryana Agricultural University.

Baum, B.R. (1977). Oats: Wild and Cultivated, A Monograph of the Genus Avena L. (Poaceae). Minister of Supply and Services.

Boczkowska, M., & Tarczyk, E. (2013). Genetic Diversity Among Polish Landraces of Common Oat (Avena sativa L.). Genetic Resources and Crop Evolution, 60, 2157–2169.

Butt, M.S., Tahir-Nadeem, M., Khan, M.K.I., Shabir, R., & Butt, M.S. (2008). Oat: Unique Among the Cereals. European Journal of Nutrition, 47(2), 68–79.

Carson, M. (2009). Broad-spectrum Resistance to Crown Rust, Puccinia coronata f. sp. avenae, in Accessions of the Tetraploid Slender Oat, Avena barbata. Plant Disease, 93, 363‑366.

CSA (Central Statistical Agency). (2021). Agricultural sample survey 2020/21. Report on livestock and livestock characteristics. Volume II, Statistical bulletin 589, Addis Ababa, Ethiopia.

Cerio, R., Dohil, M., Jeanine, D., Magina, S., Mahe, E., & Stratigos, A.J. (2010). Mechanism of Action and Clinical Benefits of Colloidal Oatmeal for Dermatologic Use. Journal of Drugs in Dermatology, 9(9), 1116–1120.

Coffman, F.A. (1977). Oat History, Identification and Classification. Technical Bull N 1516, USDA-ARS.

Darnhofer, I., Gretzmacher, R., & Schneeberger, W. (1997). Modeling farmers' decisions: a comparison between HDM and CART for oats-vetch adoption in the Ethiopian Highlands, Die Bodenkultur, 48(4): 271–280.

Esvelt, K.K., Huang, Y.F., Bekele, W.A., Obert, D.E., Babiker, E., Beattie, A.D., Bjørnstad, Å., Bonman, J.M., Carson, M.L., & Chao, S. (2016). Population Genomics Related to Adaptation in Elite Oat Germplasm. The Plant Genome, 9(2), 1–12.

Ethiopian Agricultural Authority (EAA). (2022). Plant Variety Release, Protection and

Seed Quality Control Directorate, Crop Variety Register, Issue No. 25. Addis Ababa, Ethiopia.

Ethiopian Institute of Agricultural Research (EIAR). (2017). Livestock Research Strategies, Feeds and Nutrition, Rangelands and Animal Health (2016 – 2030), Feeds and Nutrition Research Strategy (2016 – 2030). Addis Ababa, Ethiopia.

FAOSTAT. (2015-2024). Food and Agriculture Organization of the United Nations Statistical Database.

FAOSTAT. (2024). Food and Agriculture Organization of the United Nations Statistical Database.

Fardet, A., Rock, E., & Remesy, C. (2008). Is the In Vitro Antioxidant Potential of Whole-Grain Cereals and Cereal Products Well Reflected In Vivo? Journal of Cereal Science, 48, 258–276.

Federal Democratic Republic of Ethiopia (FDRE). (2011). Ethiopia's Climate Resilient Green Economy: Green Economy Strategy. Addis Ababa, Ethiopia.

Fekadu, M., Biadge K., & Yadesa A. (2018). Potential of oats (Avena sativa) for food grain production with its special feature of soil acidity tolerance and nutritional quality in central highlands of Ethiopia. Advances in Crop Science and Technology, 6(4): 1–5. https://doi.org/10.4172/2329-8863.1000376.

Fekede, F. (2004). Evaluation of Potential Forage Production Qualities of Selected Oats (Avena sativa L.) Genotypes [M.Sc. Thesis]. Alemaya University of Agriculture.

Fekede, F., Adugna, T., & Solomon, M. (2008). Nutritive Value of Different Varieties and Morphological Fractions of Oats Harvested at the Soft Dough Stage. Tropical Science, 47(4), 188-196. https://doi.org/10.1002/ts.213.

Fekede, F., Getnet, A., Gezahagn, K., & Alemayehu, M. (2015). Cultivated Forage Crops Research and Development in Ethiopia. In: Y. Alemu, G. Assefa, & L. Gizachew (Eds.), Proceedings of Pasture and Rangeland Research and Development in Ethiopia. Ethiopian Society of Animal Production (ESAP).

Food and Agricultural Organization of the United Nations (FAO). (2019a). Ethiopia, Availability and Utilization of Agro-Industrial By-Products as Animal Feed 2018. Rome.

Food and Agricultural Organization of the United Nations (FAO). (2019b). The Future of Livestock in Ethiopia, Opportunities and Challenges in the Face of Uncertainty. Rome.

Food and Agricultural Organization of the United Nations (FAO). (2012). Production Statistics. Rome.

Food and Agricultural Organization of the United Nations (FAO). (2011). Grassland Index. A Searchable Catalogue of Grass and Forage Legumes, FAO Statistics, (2010/2011).

Fu, Y.B. (2018). Oat Evolution Revealed in the Maternal Lineages of 25 Avena Species. Scientific Reports, 8(1), 4252–4264.

Garg, M.R., Bhandari, B.M., & Sharma, R.L. (2005). Assessment of Adequacy of Macro and Micro Mineral Content of Feed Stuff for Dairy Animals in Semi-Arid Zone of Rajasthan. Animal Nutrition and Feed Technology, 5, 9–20.

Getahun, K. (2019). Sugarcane By-products as Feed Resources and Performance of Sheep Fed on Sugarcane Tops Based Diets [PhD Dissertation]. Addis Ababa University.

Getaneh, F.A. Forsido, S.F., Yetenayet, B.T., Addisu, A.A., Minbale, A.T., & Endale, A. 2021. Traditional food processing practices of oats (*Avena sativa*) and its contribution to food security in Gozamin district of northwest Ethiopia. African Journal of Food, Agriculture, Nutrition and Development, 21(5): 18083–18100. https://doi.org/10.18697/ajfand.100.19810.

Getnet, A. (1999). Feed Resource Assessment and Evaluation of Forage Yield, Quality and Intake of Oats and Vetches Grown in the Highlands of Ethiopia [MSc. Thesis]. Swedish University of Agricultural Sciences.

Getnet, A., & Gezahagn, K. (2012). Seed Research and Development of Perennial Forage Crops in the Central Highlands. In: G. Assefa, M. Dejene, J. Hanson, G. Anemut, S. Mengistu, & A. Mengistu (Eds.), Forage Seed Research and Development in Ethiopia. Ethiopian Institute of Agricultural Research (EIAR).

Getnet, A., Fekede, F., Abreham, G., & Muluneh, M. (2004). Characterization of Selected Oats Varieties for Their Important Production Traits in the Highlands of Ethiopia. In: Y. Asfaw & T. Degefa (Eds.), Farm Animal Biodiversity in

Ethiopia: Status and Prospects, Proceedings of the 11th Annual Conference of the Ethiopian Society of Animal Production (ESAP). ESAP.

Getnet, A., Gezahagn, K., & Fekede, F. (2012). Forage Seed Production and Quality in Ethiopia. In: D. Alemu, S. Kiyoshi, A. Kirub, & K. Assefa (Eds.), FRG II Project, Empowering Farmers' Innovation Series No. 3, Ensuring Seed Quality in Ethiopian Seed System, Status and Challenges. Ethiopian Institute of Agricultural Research (EIAR).

Getu, K. (2019). Assessment on the Production, Conservation and Utilization Practices of Brewery Spent Grain Across Selected Districts in Ethiopia, and Its Supplementary Value for Dairy Cows [PhD Dissertation]. Addis Ababa University.

Gezahagn, K., Fekede, F., Getnet, A., Alemayehu, M., Tadesse, T., & Muluneh, M. (2016). Study on Current Production and Utilization Status and Further Prospects of Oats (*Avena sativa*) in Mixed Farming Systems of the Central Highland Areas of Ethiopia. Academic Research Journal of Agricultural Science and Research, 4(5), 164–173.

Gibson, L., & Benson, G. (2002). Origin, History, and Uses of Oat (*Avena sativa*) and Wheat (*Triticum aestivum*). Iowa State University, Department of Agronomy.

Gill, B.S., Schank, S.C., & Wallace, A.T. (1964). Studies on the Morphology of Oat (*Avena byzantina* C. Koch) Chromosomes. Crop Science, 4(3), 271-273. https://doi.org/10.2135/cropsci1964.0011183X000400030010x.

Glore, S.R., Van Treeck, D., Knehans, A.W., & Guild, M. (1994). Soluble Fibre and Serum Lipids: A Literature Review. Journal of the American Dietetic Association, 94, 425–436.

Haack, V.S., Chesters, J.G., Vollendorf, N.W., Story, J.A., & Marlett, J.A. (1998). Increasing Amounts of Dietary Fibre Provided by Foods Normalizes Physiologic Response of the Large Bowel Without Altering Calcium Balance or Fecal Steroid Excretion. American Journal of Clinical Nutrition, 68, 615–622.

Harshita, N. (2018). Morphological Characterization, Evaluation and Seed Quality Assessment of Oat Germplasm [M.Sc. thesis]. G.B. Pant University of Agriculture & Technology.

Holland, J. (1997). Oat Improvement. In Crop Improvement for the 21st Century (pp. 57-98). Research Signpost.

Idouraine, A., Khan, M.J., & Weber, C.W. (1996). In Vitro Binding Capacity of Wheat Bran, Rice Bran, and Oat Fiber for Ca, Mg, Cu, and Zn Alone and in Different Combinations. Journal of Agriculture and Food Chemistry, 44, 2067–2072.

Institute of Agricultural Research (IAR). (1970). Holetta Research Center Progress Report for the Period April 1969 – March 1970. Addis Ababa, Ethiopia.

Institute of Agricultural Research (IAR). (1973). Holetta Research Center Progress Report for the Period April 1972 – March 1973. Addis Ababa, Ethiopia.

Institute of Agricultural Research (IAR). (1982). Holetta Research Center Progress Report for the Period April 1981 – March 1982. Addis Ababa, Ethiopia.

Jones, E.T. (1956). The Origin, Breeding and Selection of Oats. Agricultural Review, 2, 20–38.

Kahlon, T.S., & Chow, F.I. (1997). Hypocholesterolemic Effects of Oat, Rice, and Barley Dietary Fibres and Fractions. Cereal Foods World, 42, 86–92.

Kaur, R., & Kapoor, R. (2017). Accessing Genetic Diversity in Oats Based on Morpho-Agronomic Traits. Forage Research, 42, 271–273.

Kellems, R.O., & Church, D.C. (1998). Livestock Feeds and Feeding (4th ed.). Prentice Hall.

Kirk, R.S., & Sawyer, R. (1999). Pearson's Composition and Analysis of Foods (9th ed.). Addison-Wesley Longman.

Klose, C., & Arendt, E.K. (2012). Proteins in Oats; their Synthesis and Changes during Germination: A Review. Critical Reviews in Food Science and Nutrition, 52(7), 629–639. https://doi.org/10.1080/10408398.2010.504902.

Ladizinsky, G. (1975). Oats in Ethiopia. Economic Botany, 29(3), 238–241.

Ladizinsky, G. (2012a). Studies in Oat Evolution: Oat Morphology and Taxonomy. Springer.

Ladizinsky, G. (2012b). Studies in Oat Evolution: A Man's Life with Avena. Springer.

Ladizinsky, G., & Zohary, D. (1971). Notes on Species Delimitation, Species Relationships and Polyploidy in Avena sativa L. Euphytica, 20(3), 380–395.

Lazaridou, A., & Biliaderis, C.G. (2007). Molecular Aspects of Cereal β-Glucan Functionality: Physical Properties, Technological Applications and Physiological Effects. Journal of Cereal Science, 46, 101–118.

Leggett, J.M., & Markhand, S.M. (1995). The Genomic Identification of Some Monosomics of Avena sativa L. cv. Sun II Using GISH. Genome, 38, 747–751.

Leggett, J.M., & Thomas, H. (1995). Oat Evolution and Cytogenetics. In R.W. Welch (Ed.), The Oat Crop: Production and Utilization. Chapman & Hall.

Lensa, U. 2023. Trends of Oat Production Area, Productivity and Utilization Status in Ethiopia. American Journal of Bioscience and Bioinformatics, 2(1): 14-19. https://journals.e-palli.com/home/index.php/ajbb.

Linares, C., Ferre, E., & Fominaya, A. (1998). Discrimination of the Closely Related A and D Genomes of the Hexaploid Oat (*Avena sativa* L.). Proceedings of the National Academy of Sciences, USA, 95, 12450–12455.

Linares, C., Gonzalez, J., Ferrer, E., & Fominaya, A. (1996). The Use of Double In-Situ Hybridization to Physically Map the Positions of 5S rDNA Genes in Relation to the Chromosomal Location of 18S-5.8S-26S rDNA and a C Genome Specific DNA Sequence in the Genus Avena. Genome, 39, 535–542.

Linneaus, C. (1753). Species Plantarum (Vol. 1).

Liu, L., Zubik, L., Collins, F.W., Marko, M., & Meydani, M. (2005). The Antiatherogenic Potential of Oat Phenolic Compounds. Atherosclerosis, 175, 39–49.

Lulseged, G. (1981). Summary of Fodder Oats Research Undertaken by IAR. Pasture and Fodder Forage Bulletin No. 2. IAR.

Lulseged, G., & Alemu, T. (1985). Pasture Research and Development in Ethiopia. In: J.A. Kategile (Ed.), Pasture Improvement Research in Eastern and Southern Africa. IDRC.

Magdoff, F., & Van Es, H. (2009). Building Soils for Better Crops. Sustainable Agriculture Publications.

Malzew, A.I. (1930). Wild and Cultivated Oat (sectio Euavena Griseb). Bulletin of Applied Botanical Genetics and Plant Breeding, Supplement 38. (English translation).

Mamaru, T. (2021). Improved forage technologies adoption and its impact on smallholder dairy productivity: the case of Debrelibanose, woreda, oromia region, Ethiopia [M.Sc. thesis]. Addis Ababa University College of Developmental Studies Centre for Rural Development.

Mamaru, T. (2023). Assessment of the Status of Improved Forage Technologies and Factors Influencing Technology Adoption: Empirical Evidence from North Shewa, Oromia, Ethiopia. Journal of Biology, Agriculture and Healthcare, 13(7): 15–26.

Marlett, J.A. (1993). Comparisons of Dietary Fiber and Selected Nutrient Compositions of Oat and Other Grain Fractions. In P.J. Wood (Ed.), Oat Bran (pp. 49–82). American Association of Cereal Chemists.

Marmouzi, I., Saidi, N., Meddah, B., Bouksaim, M., Gharby, S., El-Karbane, M., Serragui, S., Cherrah, Y., & Faouzi, M.E.A. (2016). Nutritional Characteristics, Biochemical Composition and Antioxidant Activities of Moroccan Oat Varieties. Food Measurement, 10(1), 156–165.

Mimoghtadaie, L., Kadivar, M., & Shahedi, M. (2009). Effects of Crosslinking and Acetylation on Oat Starch Properties. Food Chemistry, 116, 709–713.

Ministry of Agriculture (MoA). (2015). Plant Variety Release, Protection and Seed Quality Control Directorate, Crop Variety Register, Issue No. 18. Addis Ababa, Ethiopia.

Ministry of Agriculture (MoA). (2017). Plant Variety Release, Protection and Seed Quality Control Directorate, Crop Variety Register, Issue No. 20. Addis Ababa, Ethiopia.

Monika, O.P. (2017). Effect of Cutting Management and Phosphorus Fertilization on Forage Yield, Quality and Seed Yield of Multicut Oat (*Avena sativa* L.) [M.Sc. Thesis]. Chaudhary Charan Singh Haryana Agricultural University.

Muluneh, M., Getnet, A., Fekede, F., Gezahagn, K., & Tadesse, T. (2012). Strengthening Forage Seed Supply through Farmers-Based Seed Production. In: G. Assefa, M. Dejene, J. Hanson,

G. Anemut, S. Mengistu, & A. Mengistu (Eds.), Forage Seed Research and Development in Ethiopia. Ethiopian Institute of Agricultural Research (EIAR).

Murphy, J.P., & Hoffman, L. (1992). The Origin, History, and Production of Oat. Oat Science and Technology, 1(5), 1–28.

National Research Council (NRC). (2001). Nutrient Requirements of Dairy Cattle. National Academies Press.

Nikoloudakis, N., Bladenopoulos, K., & Katsiotis, A. (2016). Structural Patterns and Genetic Diversity Among Oat (Avena sativa) Landraces Assessed by Microsatellite Markers and Morphological Analysis. Genetic Resources and Crop Evolution, 63, 801–811.

Nishiyama, I. (1929). The Genetic and Cytology of Certain Cereals, Morphological and Cytological Studies in Triploid, Pentaploid and Hexaploid Avena Hybrids. Japanese Journal of Genetics, 5, 1–48.

Oliver, R.E., Obert, D.E., Hu, G., Bonman, J.M., & Jackson, E.W. (2010). Development of Oat-Based Markers from Barley and Wheat Microsatellites. Genome, 6, 458–471.

Peterson, D.M., Wesenberg, D.M., Burrup, D.E., & Erickson, C.A. (2005). Relationships Among Agronomic Traits and Grain Composition in Oat Genotypes Grown in Different Environments. Crop Science, 45(4), 1249–1255.

Premkumar, R., Nirmalakumari, A., & Anandakumar, C.R. (2017). Germplasm Characterization for Biochemical Parameters in Oats (*Avena sativa* L.). International Journal of Pure and Applied Bioscience, 5, 68–72. https://doi.org/10.18782/2320-7051.2799.

Purseglove, J.W. (1972). Tropical Crops. Monocotyledons. Longman Group Limited.

Rajhathy, T. (1966). Evidence and Hypothesis for the Origin of C Genome of Hexaploid Avena. Canadian Journal of Genetics and Cytology, 8, 774–779.

Rajhathy, T., & Thomas, H. (1974). Cytogenetics of Oats. Miscellaneous Publication of the Genetic Society of Canada No. 2.

Rasane, P., Jha, A., Sabikhi, L., Kumar, A., & Unnikrishnan, V.S. (2015). Nutritional Advantages of Oats and Opportunities for Its Processing. Journal of Food Science and Technology, 52(2), 662–675. https://doi.org/10.1007/s13197-013-1072-1.

Reddy, N., & Yang, Y. (2005). Biofibers from Agricultural By-products for Industrial Applications. Trends in Biotechnology, 23(1), 22–27. https://doi.org/10.1016/j.tibtech.2004.11.002.

Restelatto, R., Pavinato, P.S., Sartor, L.R., & Paixão, S.J. (2014). Production and Nutritional Value of Sorghum and Black Oat Forages under Nitrogen Fertilization. Grass and Forage Science, 69(4), 693–704. https://doi.org/10.1111/gfs.12076.

Rines, H.W., Molnar, S.J., Tinker, N.A., & Phillips, R.L. (2006). Oats. In C. Kole (Ed.), Cereals and Millets: Genome Mapping and Molecular Breeding in Plants (pp. 211–242). Springer.

Robbins, G.S., Pomeranz, Y., & Briggle, L.W. (1971). Amino Acid Composition of Oat Groats. Journal of Agricultural and Food Chemistry, 19, 536–539.

Ruwali, Y., & Deo, I. (2009). Analysis of Combining Ability Estimates, Gene Action and Heterosis for Various Quantitative Characters in Oats. Forage Research, 35, 127–136.

Ruwali, Y., Singh, K., Kumar, S., & Kumar, L. (2013). Molecular Diversity Analysis in Selected Fodder and Dual-Purpose Oat (*Avena sativa* L.) Genotypes by Using Random Amplified Polymorphic DNA (RAPD). African Journal of Biotechnology, 12(22), 331–333.

Saastamoinen, M., Hietaniemi, V., Pihlava, J.M., Eurola, M., Kontturi, M., Tuuri, H., Niskanen, M., & Kangas, A. (2004). β-Glucan Contents of Groats of Different Oat Cultivars in Official Variety, in Organic Cultivation, and in Nitrogen Fertilization Trials in Finland. Agriculture and Food Sciences, 13, 68–79.

Sanjeet, S. (2018). Studies on Gene Action for Agro-Morphological Traits and Factors Affecting Haploid Production Efficiency Following Chromosomal Elimination Technique in Oat (*Avena sativa* L.) [Doctoral dissertation]. Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya.

Satija, A., & Hu, F.B. (2012). Cardiovascular Benefits of Dietary Fibre. Current Atherosclerosis Reports, 14(6), 505–514.

Saunders, R.M. (1985). Rice Bran: Composition and Potential Food Uses. Food Reviews International, 1, 465–495.

Shen, Y., Zhang, H., Miao, X., Zhang, H., Cheng, L., Qi, Y., Wang, L., Qian, H., Qi, X., Zhang, Y., & Zhang, H. (2016). Effects of Extraction Solvents on Antioxidants Activities and Total Phenolic Contents of Four Whole Grains. European Journal of Biomedical Research, 2, 1–6.

Skibniewska, K.A., Kozirok, W., Fornal, L., & Markiewicz, K. (2002). In Vitro Availability of Minerals from Oat Products. Journal of the Science of Food and Agriculture, 82, 1676–1681.

Slavin, J. (2005). Dietary Fibre and Body Weight. Nutrition, 21(3), 411–418. https://doi.org/10.1016/j.nut.2004.08.018.

Sur, R., Nigam, A., Grote, D., Liebel, F., & Southall, M.D. (2008). Avenanthramides, Polyphenols from Oats, Exhibit Anti-Inflammatory and Anti-Itch Activity. Archives of Dermatological Research, 300, 569‐575.

Suttie, J.M., & Reynolds, S.G. (2004). Fodder Oats: A World Overview. Plant Production and Protection Series No. 33. FAO.

Thellung, A. (1912). Uber die Abstammung, den systematischen Wert und die kulturgeschichte Saathafer- Arten (*Avenae sativae* cosson). Beitrage Zu einer naturlichen systematic von Avena sect, Euavena, Vrtjscher, Naturf, Gessell, Zurich, 56, 293–350.

Thomas, H. (1970). Chromosome Relationship Between Cultivated Oats Avena sativa (6x) and Avena ventricosa (2x). Canadian Journal of Genetics and Cytology, 12, 36–43.

Thurston, J.M. (1951). A Comparison of the Growths of Wild and of Cultivated Oats in Manganese-Deficient Soils. Annals of Applied Biology, 38(1), 289-302. https://doi.org/10.1111/j.1744-7348.1951.tb07804.x.

Thurston, J.M., & Phillipson, A. (1976). Distribution. In D.P. Jones (Ed.), Wild Oats in World Agriculture, an Interpretive Review of World Literature (pp. 19-64). Agricultural Research Council.

Tiwari, U., & Cummins, E. (2009). Simulation of the Factors Affecting β-Glucan Levels During the Cultivation of Oats. Journal of Cereal Science, 50(2), 175–183.

Trabut, L. (1914). Origin of Cultivated Oat (a translation). Journal of Heredity, 5, 56–85.

U.S. Food and Drug Administration (USFDA). (1997). Food Labeling: Health Claims; Oats and Coronary Heart Disease. Federal Register, 62(15), 3584–3601.

Valentine, J. (1995). Naked Oats. In R.W. Welch (Ed.), The Oat Crop: Production and Utilization (pp. 504–532). Chapman and Hall.

Varma, D., Meena, R.S., & Kumar, S. (2017). Response of Mungbean to Fertility and Lime Levels Under Soil Acidity in an Alley Cropping System in Vindhyan Region. International Journal of Chemistry Studies, 5(2), 384–389.

Vavilov, N.I. (1926). Studies on Origin of Cultivated Plants. Bulletin of Applied Botany and Plant Breeding, 17, 139–245.

Welch, R., Brown, J., & Leggett, J. (2000). Interspecific and Intraspecific Variation in Grain and Groat Characteristics of Wild Oat (Avena) Species: Very High Groat (1–3), (1–4)-b-D-glucan in an Avena atlantica Genotype. Journal of Cereal Science, 31, 273–279.

Whitehead, A., Beck, E.J., Tosh, S., & Wolever, T.M. (2014). Cholesterol-Lowering Effects of Oat β-Glucan: A Meta-Analysis of Randomized Controlled Trials. The American Journal of Clinical Nutrition, 100(6), 1413–1421.

Wood, P.J., Braaten, J.T., Scott, F.W., Riedel, D., & Poste, L.M.J. (1990). Comparisons of Viscous Properties of Oat and Guar Gum and the Effects of These and Oat Bran on Glycemic Index. Journal of Agricultural and Food Chemistry, 38, 753–757.

Wood, P.J., Weisz, J., & Fedec, P. (1991). Potential for β-Glucan Enrichment in Brans Derived from Oat (*Avena sativa* L.) Cultivars of Different (1,3), (1, 4)- β-D-glucan Concentrations. Cereal Chemistry, 68(1), 48–51.

Zade, A. (1918). Der Hafer, Eine Monographie auf Wissenschaftlicher und Praktischer Grundlage.

Zhu, F., Du, B., & Xu, B. (2016). A Critical Review on Production and Industrial Applications of Beta-Glucans. Food Hydrocolloids, 52, 275–288.

Zwer, P. (2010). Oats: Characteristics and Quality Requirements. In C. Wrigley & I. Batey (Eds.), Cereal Grains (pp. 20-34). Woodhead Publishing.