Linum usitatissimum L. is the most important crop in Russia for the production of high-quality oil with low cost (review)

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Abstract. Oil crops play an important role in providing society with food, livestock feed, industry and raw materials and are of great importance for economically stable agricultural production. The purpose of this review article was to show the importance of the agricultural crop of oil flax and its oil seeds for various types of industries, the possibility of expanding its cultivation areas in Russia, as well as a way to reduce the cost of production. The article provides overview information on studies conducted on oilseed flax (Linum usitatissimum L.), on the possibility of using its products in food, technical industry, medicine, for the production of biodiesel, in crop production and fodder production. High resistance to abiotic and biotic factors put oil flax in a number of crops that can be cultivated everywhere; however, its yield, oil content and cost in different regions of Russia and the world are very different. This question has not been sufficiently studied in the literature. This review focuses on modern research by both foreign and Russian scientists. The possibilities of cultivating Linum usitatissimum L. in Russia according to the modern no-till farming system (direct sowing technology, zero technology, technology without tillage) and the directions of its oil use are shown, which indicates their relevance and high demand in various fields of human activity. Oil flax is a unique natural and biological resource that has rational and environmental benefits in cultivation.

1. Introduction

Oil crops play an important role in providing society with food, livestock feed, industry and raw materials and are of great importance for economically stable agricultural production [1]. The traditionally dominant oilseed crop in Russia is sunflower, which share in the structure of sown areas has been decreasing in recent years, but remains very high anyway, which negatively affects the fertility of our soils, since it is a poor predecessor for winter wheat [2, 3]. Rapeseed and soybeans are grown in small areas, in contrast to the global agricultural production, this is due to adverse climatic conditions for these crops. Therefore, they cannot meet the growing needs of the vegetable oil market in Russia and the world [4–6]. Therefore, an important issue is the search for other oilseeds that can...
occupy this niche, which will have a wide adaptive potential, which will ensure cost-effective seed production throughout the Russian Federation, as well as in the world.

The purpose of this review article was to show the importance of oil flax and its oilseeds for various industries, the possibility of expanding its cultivation areas in Russia, as well as a way to reduce the cost of production.

One of such crops can be oilseed flax (Linum usitatissimum L.), which is one of the most valuable and recently quite common oilseeds in world agricultural production [2, 7]. It is cultivated on all continents and in the last five years has gained great popularity in Russia [8].

Flax seeds contain from 30 to 50% fatty quick-drying oil, which is of great economic importance [9]. Oil of oil flax contains unsaturated fatty acids, and therefore prevents the occurrence of vascular diseases. In addition, in combination with other drugs, flax oil is used to remove cholesterol from the body. Its seeds, following the popular practice and scientific medicine data, have medicinal properties. In addition to fat, it contains protein, carbohydrates, organic acids, vitamin A, and enzymes. Its broth is used to treat stomach ulcers, gastritis and diabetes, metabolic disorders in the body. From flax seeds, the linolen preparation is made which is used to treat skin burns [2]. Flaxseed oil is used in the diet of patients with atherosclerosis, coronary heart disease, brain, hypertension, cirrhosis, hepatitis [5, 6]. The mucus that is secreted by soaking flax seeds has a good effect on intestinal diseases [3]. Oilseed flax seeds also contain lignins, easily digestible proteins, dietary fiber, linamarin, phytosterols, squalene (about 8% of the total), lecithin and beta-carotene, vitamins B (B1, B2, B3, B4, B6, B9, B12) E, F, K, H, C, D and P, microelements (potassium, selenium, copper, iron and others). In terms of protein content, oilseed flax seeds surpass cereal crops 2.0–2.5 times [10]. Protein molecules are characterized by a significant amount of sulfur-containing amino acids, which has an antioxidant effect [11]. The bulk in linseed oil is glycerides containing linoleic (50-60%) and linolenic (24-40%) acids. Flaxseed oil also contains myristic, thearic and palmitic saturated fatty acids. It refers to desiccants, the iodine number is 170–180 [7], 175–195 [8]. Boiled oil (drying oil) is used for the manufacture of paints (including underwater work), enamels, varnishes and lubricants. There is also a great demand for linseed oil in the electrical, rubber, leather, soap, aviation, automotive, shipbuilding, foundry, metal and other industries, medicine and pharmaceutical business. It is used to produce oilcloth, linoleum, waterproof fabrics, high-quality artificial leather and various medicines [12]. Sometimes fresh linseed oil in its natural form is used directly for food [13].

The flaxseed cake remaining after oil extraction serves as a valuable concentrated feed for dairy cattle, while increasing milk yield [2, 12]. Waste from the oil production (press cake and oil cake) is a valuable feed that contains up to 1.2 feed units, 31–38% of digestible protein and approximately 9% fat. In terms of feed quality, they stand above other plants, as it is easily absorbed by animals. Addition of it to the cattle’s diet improves muscle mass gain [13].

The stems of oil flax contain 10-15% of fiber which is suitable for the manufacture of coarse fabrics. Plant residues, which contain up to 50% cellulose, serve as raw materials for the production of paper for cigarettes and cardboard. Also, the flax stalk is used for the manufacture of plates that are used in construction [2, 14]. Briquettes from plant residues are a good fuel for heating residential and industrial premises [3, 5, 13].

Oil fields in Russia and the world become depleted every year [2]. Prices for petroleum products are rising, requirements for environmental indicators of diesel engines are being tightened. One of the most promising raw material bases for the production of alternative fuels for diesel engines is vegetable oil [15], including linseed [2]. The fatty acid composition of flaxseed oil is slightly different from the similar composition of the most common in Russia sunflower oil. So, if sunflower oil is rich in linoleic acid, then linseed oil is rich in linolenic acid, which has three unsaturated bonds. In this regard, linseed oil is less stable in oxidative processes compared to sunflower oil [16, 17]. Low oxidative stability (high oxidizability) of linseed oil causes its limited storage time. If the shelf life of unrefined sunflower oil is 38 weeks, then linseed unrefined oil has life of only 26 weeks, but expired linseed oil can be used as motor fuel [18]. The use of linseed oil as an environmental additive (about 5%) to petroleum diesel fuel is an effective means of improving fuel economy and decreasing exhaust
gas toxicity. Oxygen contained in the molecules of linseed oil favorably affects the emissions of regulated toxic components from diesel exhaust gases [15].

In the Russian Federation, soil-climatic conditions are favorable for the cultivation of oil flax and is fully suitable for its biological and environmental characteristics [2, 5, 12]. In crop production, it belongs to the group of plants that are not very demanding on the thermal regime. Flax seeds germinate at a soil temperature of 3-4 °C, and seedlings appear at 4-6 °C. From the end of the herringbone phase, cold resistance increases markedly, and it can tolerate frosts up to 10 °C. Temperatures above 18–22 °C during budding and flowering inhibit flax. It requires the greatest heat in the ripening phase. The full development of oilseed flax and ripening requires the sum of average daily temperatures of 1600–1800 °C of heat with the number of frost-free days no less than 80–90 [13, 19]. Flax is not demanding on the presence of moisture in the soil. The transpiration coefficient is 420–690. It is demanding on soil moisture in the phases of budding and flowering. It grows best when soil moisture is 70% of the lowest moisture capacity. Abundant seedlings appear at the optimum content of available moisture in the soil (10–20 mm in a ten-centimeter layer). Flax does not tolerate excess moisture and the proximity of groundwater. Large precipitation during ripening is undesirable, it can cause diseases. Flax takes the greatest amount of moisture from the soil layer of 0–50 cm, in drought conditions it uses moisture from the layer of 50–100 cm [2, 11, 20]. In relation to light, ecotypes of oil flax grown in Russia belong to middle-day plants [9]. Flax is demanding on soil fertility. For the formation of a unit of dry matter, it uses twice as many nutrients than crops. One centner of oilseeds takes out the following amount of nutrients from the agrolandscape: 7.6 kg of nitrogen; 2.4 kg of phosphorus; 5.5 kg of potassium. Flax consumption of elements of mineral nutrition occurs unevenly. At first, they need a small amount of them, and after the “herringbone” phase, intensive growth occurs, and, accordingly, the elements of nutrition consumption increases by an order of magnitude. Nitrogen is most needed from the “herringbone” phase to budding, phosphorus during the growth period to the phase of 5-6 pairs of leaves, potassium in the first twenty days of life. Oilseed flax is very demanding on soils [2, 13, 21]. Considering its peculiarity of impeded assimilation of hard-to-reach nutrients, it should be planted on agrolandscapes with a high content of easily accessible nutrients. For instance, soils with a content of at least 2%, easily hydrolyzable nitrogen of 10 mg, potassium and phosphorus 10–15 mg / 100 g of soil are suitable, and the soil density should be no more than 1.3 g/cm$^3$ [7, 11]. The best for oil flax are weed-free fields on chernozems and chestnut soils. Sandy and sandy soils are not suitable for flax. Flooded soils and those that form a crust upon precipitation are not suitable. Solonetzes and acid peat soils are unsuitable for growing oil flax [11].

Variatel composition *Linum usitatissimum* L. suitable for cultivation in various regions of the Russian Federation is as follows. Varieties of Russian selection are: Sympatik, Turquoise, VNIIMK 630, Istok, Kinelsky 2000, LM 98, Raduga, Sanlin, Svetlyachok, Sokol, Fliz, Chibis, Slavny, Yantar. Varieties of Ukrainian selection are: Aisberg, Orfey, Yuzhnaya Noch, Rucheyok, VNIIMK 620, Vera, Kivika, Nadezhny, Slavny, Sine-oranzhevyi, Debut. Varieties of European selection are: Lirina, Bilstart [2].

A zero-tillage system, also known as a no-till or direct sowing system, is a modern farming system in which the soil is not cultivated and its surface is covered with specially ground plant residues—mulch [22, 23]. Consequently, fuel is saved and soil moisture is more economically consumed. Oil flax is one of the few crops that can be grown without reducing yield and product quality, with minimal and zero tillage, which reduces production costs and, therefore, is more competitive in domestic and foreign markets [24]. Consequently, Russian agricultural enterprises should cultivate this culture using these technologies as much as possible, which will allow them to increase their level of profitability.

The cultivation of oil flax by no-till technology includes the following elements. Oil wheat flax is preceded by winter wheat, which should be harvested at a cutting height of at least 25 cm (at least in the first 2–3 years), and crop residues should be crushed and evenly distributed along the field [25]. When seedlings of weeds and drops of winter wheat appear and their height is not more than 10 cm, the field should be treated with a continuous action herbicide from the glyphosate group [26]. If at the
end of summer weeds and drops reappeared, then glyphosate treatment should be repeated. It is important that in winter no vegetative weeds or drops of the previous culture remain on the field, which will become food for mouse-like rodents [25]. Sowing of flax should be carried out in early spring, so it is better to treat the field with glyphosate 2-3 days after sowing. If the field is clean of weeds, then sowing can be done without treating the field with glyphosate [26]. The optimal seeding rate for oil flax is 5.0–6.0 million pcs/ha of germinating seeds (30–50 kg/ha), the method of sowing is continuous, ordinary with 15-row spacing, the depth of seed placement is 3-4 cm [25, 24]. With a direct seeder, during sowing, we introduce 50–100 kg/ha of ammophos (depending on the cultivation zone), the aftereffect of which will be used by the following crop rotation crop [27, 28]. Care for oilseed flax crops consists of seedling treatment with one of the permitted herbicides fighting different types of fleas, which are very dangerous pests during emergence of this crop. Fleas eat significant areas of the parenchyma from cotyledons and true leaves, which weaken the plants and can lead to their death [25, 29]. To control weeds in the “herringbone” phase at a flax height of 10–15 cm, when the plants are less vulnerable, since the leaves are located at an angle to the stem and are covered with wax coating, the crops are treated with one of the permitted herbicides [30]. Oilseed flax cultivated in the agricultural system without tillage should be harvested using the crop stripping method, since the standing flax plants remaining after harvesting do not interfere with the sowing of winter barley following it in the crop rotation [26]. When flax is mowed (by direct combining), the plant residues remaining after harvesting clog the working bodies of the seeder, especially in wet weather, and they are not cut by the coolers (turbo discs) of the seeder [31], which reduces the quality of sowing and leads to numerous sifting [26].

The given, far from incomplete, research review shows the widespread use of oilseeds of oil flax, its relevance and high demand in various fields of human activity. The analysis of the relationship of *Linum usitatissimum* L. to soil and climatic conditions is given, which indicates the possibility of increasing its area with the help of zoned Russian, Ukrainian and European varieties in Russia. The possibility of growing it with the use of a modern no-till farming system is shown, which will allow obtaining products with low cost. In fact, oil flax is a unique natural-biological resource with positive rational and environmental benefits, and advances in agricultural systems will further unlock the potential of this crop.

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