DEVELOPMENT OF INNOVATIVE MACHINE TECHNOLOGY FOR FIBER FLAX GROWING IN CONDITIONS OF NORTH-WEST REGION

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Abstract. In the North-West region of Russia, the main branch of agriculture is animal husbandry, and as a result, fodder production takes the first place in the crop production in most farms. However, some areas of the region have a large soil-climatic potential for introduction of fiber flax into the production, thereby it is possible to increase the duration of the crop rotation. The cultivation of flax as a cover crop for meadow perennial grasses is of great importance for the region and is a relevant topic for scientific study. The main objective of the research was to study the effect of seeding of various types of perennial meadow grasses on the yield and quality of flax used for fiber. It has been established that the productivity of fiber flax is primarily dependent on the ripening period of the variety, and to a lesser extent depends on sowing of meadow perennial grasses. The Rosinka variety, which has the highest fiber yield at the level of 1.8 $t \cdot ha^{-1}$, which is by 3-27 % higher than the middle-ripening Alpha variety and 35-47 % from the early-ripening variety Zaryanka, is reliably the best in flax productivity. When seeding festulolium under flax varieties Zaryanka and Rosinka, the yield of fiber is reduced by 7-30 % and 15-21 %, respectively. In the Alpha variety, the decrease in yields of flax is due to the sowing of meadow bluegrass by 15-34 % and creep clover by 4-21 %. Based on the analysis of the characteristics of the cultivation of flax with seeding of perennial meadow grasses, the machine technology was developed, the use of which ensures the production of high quality products and maximum productivity when performing the most important technological operations, which is very important for the difficult climatic conditions of the region. Using of this technology will allow to obtain high-quality fiber from flax and to produce forage for farm animals.

Key words: fiber flax, machine technology, perennial grasses, complementary seeding, broken flax.

Introduction

At present, when generally the tendency is observed to enlargement and specialization of farms, their economic sustainability becomes a hostage to market conditions with imperfect mechanisms of its state regulation. It is known that a large number of agricultural enterprises in the North-West region specialize in milk production [1;2]. For increasing dairy enterprise economic sustainability, there is a need to improve the production efficiency due to production diversification and expanding the range of products.

One of the perspective directions of crop production in Russia is growing of fiber flax. This tendency is caused by the fact that there has been a steady downward trend in the supply of raw cotton from the republics of Central Asia and the Russian textile industry has been forced to reorient to the production of flax fiber fabrics. In connection with the need to provide textile enterprises with high quality raw materials, the Russian government adopted a program of state support for flax growers and flax processing enterprises, which is aimed at stimulating the production of this crop [3]. This means that flax growing is a perspective and highly profitable direction of the crop production industry in the North-West with a constantly growing consumption potential [4-6].

It should be noted that after flax growing two products are obtained: broken flax as raw material for fiber production and seeds that have high oil content. Therefore, the transition to flax growing carries additional economic weight due to the fact that the oil cake after processing of flax seeds will be fully used as a valuable additive in feeding animals, eliminating the need to purchase this component of the forage ration [7;8].

The simple copying of the flax cultivation technology used in specialized flax farms of the Russian Federation will not allow, in the conditions of the North-West of Russia, to ensure the required quality of the products obtained. Therefore, for the soil-climatic and economic conditions of the North-West region, it is required to develop a technology of flax growing, the introduction of which will ensure the production of high-quality products and a high level of profitability. In addition, practically all the machines used for flax production can be used on the farm for the cultivation of grain and perennial grasses.

To obtain high quality products at flax primary processing enterprises with a long fiber share of 60-70 % (the level of the world's leading flax producers), it is necessary to significantly improve the quality of broken flax. Flax is a good cover crop for many plants. It overshadows the soil a little, it is harvested pretty early and at the end of the growing season it slightly consumes moisture and nutrients from the soil, therefore flax weakly depresses the grass sown under it [9]. In addition, the contact of flax straw, when it is laid down directly on the soil, in which there is a significant number of soil biota microorganisms, leads to rotting of the stems, which leads to deterioration in the quality of the broken flax entering the further primary processing [10]. The creation of an artificial cover of the field surface by low height perennial grasses leads to increasing the fiber yield from the broken flax and improving of its quality. Growing of perennial grasses together with fiber flax helps improve the conditions of broken flax maturing, improve the microbial activity of the soil, preserve organic matter in the soil, and the number of fungal microflora decreases 1.4-1.7 times, which contributes to improvement of the soil sanitary condition [11].

To date, the planting of bottom grasses, such as pasture ryegrass, meadow fescue and meadow clover, suitable for pastures, has been well studied. In the scientific literature there is no information about seeding of such meadow grasses that can be used in the second and subsequent years for preparation of different kinds of forage [12].

In this regard, on a small experimental field of SPSAU, studies were conducted on the peculiarities of flax growing together with seeding of perennial grasses; based on the results of these studies the innovative technology of flax cultivation for the conditions of the North-West Region was developed.

Materials and methods

Experimental spring sowing of flax was carried out according to the scheme (PFE 3×7): factor A – variety (Zaryanka, Alpha and Rosinka); factor B – sowing of meadow grasses – without sowing (control); red fescue (Celiana variety), meadow bluegrass (Balin variety); festulolium (variety VIC 90); grazing ryegrass (variety VIC 66); creeping clover (Klondike variety); grass mix timothy grass (Vega variety) and meadow clover (VIC variety 7).

The experiment included 21 variants, the area of each experimental plot was 3 m^2. Field experience is placed by the method of organized reiterations, variants of reiterations are placed systematically, in 4-fold repetition.

Type of the soil of the experimental plots leached sod-carbonate, based on the eluvo-carbonate bedding breed, medium loamy. The experimental field has a flattened relief. Profile typical of carbonate soil. The humus content is 3.3 %, the soil is well saturated with bases (87 %), has a weakly acidic soil solution (pH_{KCl} – 5.2) and does not need liming, mobile forms of phosphorus are very high – 392 and exchangeable potassium is high – 213 mg per 1 kg of soil.

The prior crops were spring wheat and spring barley, which were grown for fodder. Due to the fact that flax demands fine tillage due to poor development of the root system and a small sowing depth (1-2 cm), in the fall plowing to a depth of 20 cm (MTZ-82 + PLN-3-35) was done, and in spring – double passes of the disc cultivator (MTZ-82 + BDN-160) with leveling by a tine harrow.

A necessary condition for joint growing of flax and perennial grasses is the later terms of sowing grasses, so that they do not have a great height by the time of harvesting flax to prevent them from being picked up by belts of harvesters. Therefore, when the experimental trials were fulfilled, the sowing of flax in 2011 was carried out on May 12, grass was seeded on May 17; in 2012, flax planting took place on May 12, grass was seeded on May 15, and in 2013, respectively, on May 10 and 13 [12].

Flax sowing method - narrow-row (10 cm inter-row spacing), with a seeding rate of 22 million pcs. ha^{-1}. The method of seeding perennial grasses - dispersed with a seeding rate: red fescue – 18 $kg \cdot ha^{-1}$, meadow bluegrass – 12 $kg \cdot ha^{-1}$, festulolium – 18 $kg \cdot ha^{-1}$, pasture ryegrass – 18 $kg \cdot ha^{-1}$, creeping clover – 10 $kg \cdot ha^{-1}$, clover meadow and timothy grass 6 and 8 $kg \cdot ha^{-1}$, respectively.

The pick up of flax straw and stripping of flax balls was made manually: in 2011 – from August 15 to August 20 (picking of the broken flax on September 10); in 2012 - from July 30 to August 6 (picking of the broken flax – August 31); and in 2013, from July 17 to 20 (picking of the broken flax – August 16). After picking of the broken flax top dressing of meadow grasses was done with complex fertilizers (Azofoska universal N16: P16: K16) at a dose of 200 $kg \cdot ha^{-1}$ of physical weight.

Analysis of the meteorological data showed that during the three vegetative periods of fiber flax the mean monthly air temperature was 1.5-5.8 ºC higher throughout the months, and the precipitation distribution was characterized by uneven inflow.

Results and discussion

The timing of the onset of the phenological phases of development and the duration of the interphase periods were determined mainly by the temperature level and soil wetness during the vegetation period, the genetic characteristics of the flax [13;14], and were not dependent on grass seeding. The same trend was noted in determining the field germination and vitality of flax to the moment of harvesting.

Field germination of flax seeds over the years of the experiment was at a high level and amounted to 80-85 for the varieties Zaryanka, 84-88 for Alpha and 90-92 % for Rosinka. In the second year of the research in the varieties the same trend was maintained at the same level, and in the third year the percentage of field germination was higher, respectively, by 4-10 %, 3-7 % and 3-5 %.

To eliminate damage of the flax sprouts, seeding of perennial grasses was carried out by their even distribution by a spreader, therefore, this operation did not affect the field germination of fiber flax [12]. For an average of three years of the research, the vitality according to the experience variants was at the level of 68 to 91 %, with the variety Zaryanka having higher rates of 1-18 % and 4-12 %, respectively, compared with the varieties Alpha and Rosinka, which was caused by the early ripening this variety.

The length and quality of fiber is closely related to the length of the flax stem. Factors that provide intensive and long-term growth of the stem lead to an increasing yield of the fiber as the main output of flax. On average over the years of the research, in most cases with perennial grasses seeding, the height of the flax plants was higher in Zaryanka and Alpha varieties than in the control and reached respectively 90.7 and 99.6 cm, and with grasses from 91.2 to 95.7 and from 102.8 to 103.7 cm.

The technical length of the flax stem depended on the varietal characteristics, i.e. the longer the growing season, the higher this index. Over the years of the experiment, the technical length of the Alpha and Rosinka varieties was on the same level and amounted to 74-79 cm, while that of the early ripe variety Zaryanka was 1.2-6.3 cm shorter. Flax plants, characterized by the technical length of the stem from 70.0 to 79.4 cm, can be attributed to the average-stem group.

In this experiment, the stem diameter in the middle part of the plant was medium: in the early ripening variety Zaryanka – 1.1-1.4 mm, in the mid-ripening variety Alpha and late ripening Rosinka this indicator was slightly higher and was therefore 1.3-1.6 mm and 1.2-1.6 mm.

The number of the formed seed balls on the flax plants at the time of harvesting was small, and according to the variants of the experiment, it varied from 2 to 3 pcs. per plant. The number of seeds varied in a wider range – from 9 to 23 pcs. per plant.

It has been established that the resources of temperature and soil wetness during the vegetation period in the North-West region, as well as the level of mineral nutrition of sod-calcareous soils, allowed us to get a high-level flax crop yield (Fig. 1).

On average, over the years of the experiment, the actual yield of flax products of the variety Zaryanka was at the level of 5.2 $t \cdot ha^{-1}$ of flax straw, 3.6 $t \cdot ha^{-1}$ of broken flax, 1.1 $t \cdot ha^{-1}$ of total fiber, 0.8 $t \cdot ha^{-1}$ of long fiber and 0.5 $t \cdot ha^{-1}$ seed. In the varieties Alpha and Rosinka, these indicators were 1.2-1.7 times higher. Regarding the difference of productivity between the Rosinka and Alpha varieties, a positive shift towards late ripening was also noted, but the variation was smaller from 4 to 13 %.

Mathematical processing of the obtained data showed that the genetic characteristics of the crop, the weather conditions during maturation of broken flax and to a lesser extent the sown perennial grasses influenced the overall fiber yield. When analyzing the fiber length, the opposite tendency is observed, i.e. without seeding all grasses, a decrease in the fiber length of 0.8-5.7 cm was observed.

Since one of the advantages of the developed technology is the possibility of obtaining forage from perennial grasses for the next year on the field after flax harvesting, one of the research tasks was to determine the yield of perennial grasses that were sown in the first year of use. Grasses were used for haying from festulolium, pasture ryegrass and timothy grass mixture with meadow clover.

The highest dry weight yield was obtained in 2012 at the level of 9-12 t/ha, which is 8-51 % more compared to 2013. It should be noted that the highest yields of green and dry weights are noted in the variants where were the early ripe grade of flax Zaryanka and mid-season Alpha. This can be explained by the fact that these varieties free the field more quickly after pick up of broken fax, thereby contributing to favorable development of perennial grasses.

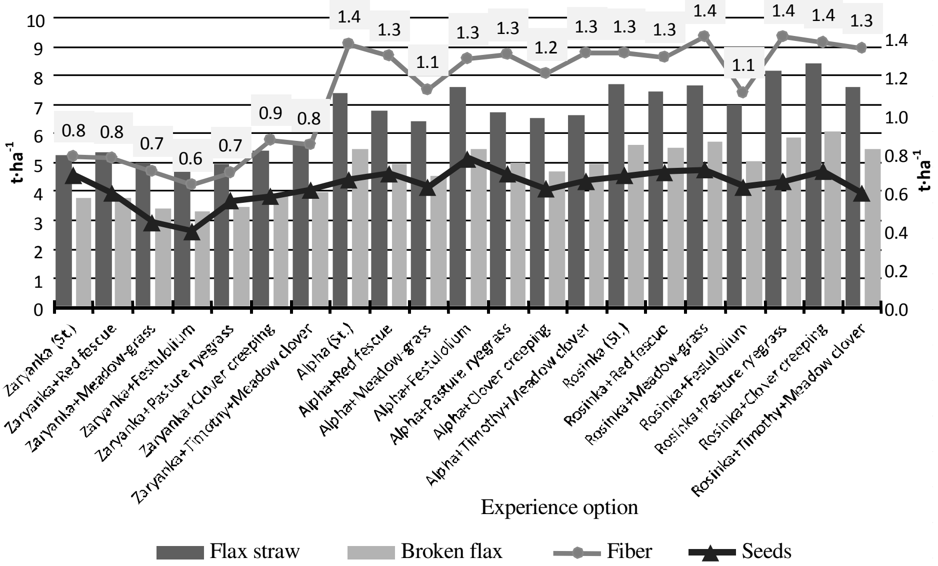

Fig. 1. **Yield of flax products, t·ha^{-1} (average for 2011-2013)**

During the process of conducting the field studies of flax growing together with seeding of perennial grasses, a search was made for rational methods of this technology with using modern machines, as a result of which it is possible to guarantee high quality flax fiber and as a foundation of a reliable forage base for dairy farms.

One of the key points of this technology is the correct choice methods of soil preparation. Selection of a rational tillage system is aimed at creating the most favorable conditions for the growth and development of crops, ensuring maximum productivity during the field work with minimal consumption of labor and material resources, as well as with reduction of the influence of adverse weather conditions [15;16].

For accurate placement of small seeds of flax and perennial grasses in the desired depth of sowing it is necessary to prepare structured and smooth soil surface without residues of the previous crops. It allows to provide high-quality seeding of flax at a depth of 1-2 cm and on the surface of the field there is not an open source of pathogenic microorganisms, contact with which would lead to deterioration in the quality of the broken flax during the period of its maturing. Therefore, stubble cultivation must be carried out by cultivators equipped with working bodies designed to full turnover of the treated layer with the aim of maximum burying of the previous crop residues. The key point of the proposed technology is the use of cultivators equipped with TriMix paws (Fig. 2), able to provide all necessary conditions for further obtaining of high quality broken flax. The use of stubble cultivators with such paws not only performs high-quality burying of plant residues (Fig. 3), when adjusted to a depth of 10-15 cm, but also provides good leveling of the soil surface, which allows fulfilling subsequent operations with the highest possible productivity [17].

Two or three weeks after stubble cultivation, deep tillage needs to be carried out in order to destroy sprouted weeds, as well as to create a deep loose layer that is permeable to the flax root system with its weak penetrating ability. Deep loosening also contributes to accumulation of significant reserves of autumn and winter water, which falls down with precipitation [18].

The proposed technology provides deep treatment to a depth of 30-35 cm by a combined cultivator (Fig. 4), that is equipped with paws with narrow point on high racks that are located in 3-4 rows, special tools (discs, leveling bar etc.) for leveling the soil surface after the paws pass, as well as rollers [19]. Rollers provide leveling of the field surface and consolidation of the top layer. The use of such tillage machine allows eliminate the compaction, created by arable aggregates and wheel systems of tractors and farm machinery, leveling the field surface to ensure maximum productivity of subsequent technological operations, and also protect the upper layer of soil from water and wind erosion [20].

Fig. 2. **TriMix paws on stubble cultivator for maximum residues burying**

Fig. 3. **Stubble cultivator with TriMix paws in work position**

To ensure the required plant nutrition regime, the proposed technology provides for the use of wide-spreading mounted or trailed spreaders of mineral fertilizers capable of ensuring a high uniformity of fertilizer distribution at the level of 93-95 %. An increase in the working width of fertilizer spreaders reduces the number of passes of heavy aggregates. On the trails after the tractor and spreader's wheel passes a decrease is observed in the yield and quality of flax due to its sensitivity to soil compaction.

In order to maximize the preservation of soil moisture and provide the most favorable conditions for germination of flax seeds and seeds of perennial grass, the proposed technology provides for sowing flax with a combined sowing aggregate (Fig. 5), combining soil preparation, consolidation of the treated layer and sowing [21;22].

Fig. 4. **Tillage cultivator for deep soil preparation**

Fig. 5. **Combined seeding aggregate for flax**

To create the most favorable conditions for germination of flax seeds [23] and the subsequent development of their root system, the tillage module of this combined aggregate must be equipped with a straight loosening point on the spring gamma-shaped tine (Fig. 6). Such shape of tines helps produce intensive tillage at a depth of 2-10 cm in early spring without extracting of wet soil elements from the lower layers to the soil surface. The spring tines provide a high crumbling intensity of the treated layer, and its narrow chisel point minimizes the soil compaction zone below the treatment depth.

Perennial grasses are sown in 5-7 days after sowing flax by mounted fertilizer spreaders capable of providing an insignificant seeding rate (10-25 $kg \cdot ha^{-1}$) with high uniformity of seed distribution over the field surface (at least 95 %).

Plant protection from weeds, pests and diseases is carried out by wide-range boom field sprayers, the width of which is equal to the width of the distribution of mineral fertilizers by spreaders. It helps minimize the soil compaction by the wheel systems.

Flax harvesting is carried out by special harvesters LK-4A, which pick up flax, strip and collect seeds and lay flax-straws in a row on the field surface covered by perennial grass. The presence of perennial grasses eliminates the contact of the stems with the soil, which minimizes the ingress of pathogenic microorganisms on them that can deteriorate the quality of the broken flax during its maturation. For even maturation of the broken flax, the proposed technology provides for one or two passes of a special belt turner.

After full maturing, the broken flax is collected by round balers [24;25], which form dense bales and wrap them with a net (Fig. 7). The use of a net for wrapping allows get maximum productivity of this technological operation, ensures safe storage of the broken flax in the bales in open air, and greatly facilitates the unwinding of bales at flax primary processing enterprises.

Fig. 6. **Straight chisel point on gamma-shaped spring tine**

Fig. 7. **Balers picking broken flax with netting**

After the bales are collected and removed from the field, the broadcast dressing of perennial grasses is done with mineral fertilizers by spreaders. Further technological operations for the care of perennial grasses and their harvesting are carried out according to the technologies of forage harvesting adopted for local farms.

Conclusions

1. For typical conditions of the North-West region of the Russian Federation a comprehensive scientific study was carried out and a biological rationale was given for accepting the technology of seeding perennial grasses under fiber flax. The resources of heat, moisture characteristic for most regions of the North-West region and the level of mineral nutrition of sod-calcareous soils made it possible to get a high level flax fiber and flax seed yield.
2. Based on the analysis of the demands for joint growing of these crops, an innovative machine technology was developed. Practical using of this technology ensures production of high-quality fiber as well as maximum productivity performing the most important technological operations, thus it is very important for the difficult climatic conditions of the North-West region.
3. Thus, for agricultural enterprises of the North-West region of Russia specializing in milk production, one of the ways to diversify production in order to increase economic sustainability has been proposed, for which an innovative machine technology for growing of fiber flax with seeding of perennial grasses has been developed. The use of this technology allows obtaining high quality fiber and flax seed as well as producing formation of the fodder base for dairy farms.

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