Assessment of fiber flax varieties according to the parameters of ecological plasticity in the conditions of the Ural region of the non-chernozem zone of Russia

E V Korepanova*, I Sh Fatykhov, V N Goreeva and Ch M Islamova

Izhevsk State Agricultural Academy, Izhevsk, Russia

* E-mail: k_evital@mail.ru

Abstract. Experimental data on the assessment of flax varieties and breeding numbers were obtained in field experiments at the experimental field of ERPC - Agrotechnopark FSBEI HE Izhevsk SAA on sod-medium podzolic medium loamy soil in the grain-grass crop rotation in 2015-2016, 2018, 2020. It was found that the change in the yield of whole and long fiber in the varieties and breeding numbers of fiber flax by 41.6...64.3% was caused by the influence of soil and meteorological conditions. Among the studied collection, the combination of good plasticity and stability to abiotic conditions is characteristic of the domestic variety TOST 2, according to the yield of long fiber – the breeding number from Lithuania – B-168 and the variety from France – Diane. It was found that the domestic varieties TOAST 1, Zaryanka, Antey and the breeding number K4196×1288/12 provided relatively high stability in the yield of the whole and long fiber in various abiotic medium conditions. This made it possible to use these varieties as a source material in breeding programs.

1. Introduction

The linen industry is considered the most complex among all branches of the agro-industrial complex with the longest technological chain - from flax straw, hemp straw and fibers as raw materials, to fabrics and a wide range of products of various properties for various industries, including logistics and trade. Being the most important technical crop, flax is of great economic importance for the national economy of Russia, as it is the only renewable source of natural fibers for the production of domestic fabrics [1; 2]. As a renewable raw material, flax is becoming increasingly important as the range of its use expands more and more. In addition to the traditional use in home textiles, clothing and sailing products, the demand for flax raw materials for technical purposes is growing rapidly, since flax fibers have high specific properties, become components of biodegradable composites, environmentally friendly insulation materials, in addition, flax offal is used in the production of environmentally friendly building materials [3; 4].

It has been repeatedly proven that the yield of almost any crop is 20-25% determined by the variety. The role of the variety is especially high where soil and climatic conditions are extreme for crops [5]. For most agricultural crops, the yield by 60-80% depends on unregulated environmental factors and, above all, on meteorological conditions, which are not always possible to predict accurately [https://apps.webofknowledge.com/OutboundService.do?SID=F1YG4UGjoiRhhobHNPe&mode=rrcAuthorRecordService&action=go&product=WOS&daisIds=13013916]. In the conditions of the Ural region of the Non-Chernozem zone on sod-podzolic soils, 73.2 and 86.4% change in the yield of fiber...
and seeds of fiber flax varieties, respectively, is caused by the influence of meteorological conditions [7; 8]. Optimization of the methods of cultivation of fiber flax modern varieties adapted to the conditions of the Udmurt Republic allows to obtain a fiber yield of at least 10.0 c/ha, seeds - at least 5.0 c/ha. The efficiency of the developed basic elements of the cultivation technology for fiber and seeds is confirmed by economic and energy estimates with a profitability level of at least 35% and energy costs for the main products - no more than 17.3 MJ/kg. When the yield of fiber is less than 8.0 c/ha, seeds - less than 3.0 c/ha, the quality of the offal - less than 1.50 of the number, the cultivation of fiber flax becomes economically inefficient [9].

The level of seed yield of oilseed flax varieties in similar soil and meteorological conditions varied significantly over the years and varied from 4.1 c/ha to 12.3 c/ha [10; 11; 12; 13; 14]. Varieties of Central Russian monoecious cannabis, as another equally important bast-fiber crop, on sod-podzolic soils of the Middle Urals formed a straw yield of 63-147 c/ha, seeds of 7.0-9.0 c/ha [15]. Experimental data on the study of the productivity of technical cannabis varieties Vera, Nadezhda and Surskaya were carried out under different abiotic conditions.

In recent years, new prospects have opened up for the use of flax seeds as renewable raw materials in the production of functional food products, feed additives, due to their amino acid and fatty acid composition of its oil [16; 17; 18]. Therefore, a comprehensive assessment of flax varieties to introduce the best of them for practical application is of urgent importance for science and production.

The purpose of the study is to identify the responsiveness of varieties and breeding numbers of flax of different ecological and geographical origin to the soil and meteorological conditions of the Ural region of the Non-Chernozem zone of Russia by the formation of flax yields.

Objectives:
1. to establish the shared participation of the variety and abiotic conditions for the impact on the productivity of different fiber flax varieties;
2. to evaluate the parameters of ecological plasticity by the yield of fiber flax varieties.

2. Materials and methods
The object of research is the varieties and breeding numbers of fiber flax from the world collection of VIR and the national collection of VNIIL. Experimental data were obtained in 2015-2016, 2018, 2020, laying field experiments on the experimental field of the ERPC - Agrotechnopark FSBEI HE Izhevsk SAA on sod-medium-podzolic medium loamy soil in the grain-grass crop rotation after winter crops in accordance with the experimental work methodology [19]. Generally accepted methods were used to determine the agrochemical parameters of the arable soil layer [20].

Data on the average daily air temperature and the amount of precipitation for the growing season are determined based on the daily indicators of the listed parameters of the Izhevsk weather station [21]. Significant differences in the experiment variants were established using analysis-of-variance methods [19]. Based on two-factor analysis of variance, the proportion of the influence of genotype, environmental factors and their mutual effect were determined [19]. The variability of yield from the average value of the experiment or the coefficient of variation (V) was calculated by B.A. Dospekhov [19]. Calculation of ecological plasticity (bi) and stability (S^2di) parameters - according to the methodological instructions of S. A. Eberhart and W.F. Russel [22], using the calculation method of V. A. Zykin [23]. The coefficient of plasticity (bi) shows the reaction of the variety to changes in cultivation conditions. The higher its value (bi > 1), the higher responsiveness this variety has. When bi = 1 indicates a direct dependence of yield on weather conditions. The stability coefficient (S^2di) is the deviation of the actual yield from the theoretically possible one when testing the variety. Stable varieties are those in which changes in environmental conditions do not affect the development of traits.

3. Research results
In the arable layer of the soil in different years of the study, there was a low, medium and increased content of humus (1.6-2.7%); from increased to high content of mobile phosphorus (148-240 mg/kg), from medium to very high - exchangeable potassium (114-276 mg/kg), exchange acidity of the soil from
medium acidic to close to neutral (5.0-6.3). Based on this, the doses of mineral fertilizers in the years of research were N\textsubscript{16-32} P\textsubscript{10-32} K\textsubscript{10-32}. Azofoska was introduced.

The years of research varied according to the hydrothermal regime. This made it possible to evaluate the parameters of ecological plasticity in terms of the yield of the studied varieties and breeding numbers of fiber flax in the conditions of the Ural region of the Non-Chernozem zone of Russia. Meteorological conditions in 2015 were characterized by a humid and cool growing season in the second half of the growing season (HTC - 1.7), in 2016 - hot and acutely arid (HTC - 0.64); in 2018 and 2020 - relatively warm and moderately humid (HTC - 1.00 and 1.18, respectively).

The reaction of varieties and breeding numbers to soil and meteorological conditions with the yield of the whole and long fiber was different (Table 1).

| Variety, breeding number | Yield of the whole fiber | Yield of the long fiber | Yield of seeds |
|-------------------------|-------------------------|------------------------|---------------|
| Tomskiy 18 - standard   | 101                     | 71                     | 93            |
| Sinichka                | 84                      | 54                     | 77            |
| Voskhod                 | 105                     | 68                     | 95            |
| K4196×1288/12           | 80                      | 54                     | 80            |
| 3938/15                 | 139                     | 99                     | 117           |
| B-192                   | 152                     | 104                    | 93            |
| Nord                    | 140                     | 98                     | 93            |
| AR-4                    | 144                     | 99                     | 84            |
| Tverskoy                | 148                     | 97                     | 95            |
| Zakaz                   | 149                     | 115                    | 108           |
| AR-5                    | 94                      | 68                     | 95            |
| Alpha                   | 107                     | 86                     | 111           |
| ER-138                  | 154                     | 122                    | 94            |
| Dobrynya                | 136                     | 104                    | 93            |
| Antey                   | 117                     | 77                     | 98            |
| B-168                   | 144                     | 103                    | 81            |
| Diane                   | 175                     | 125                    | 97            |
| Aurore                  | 150                     | 100                    | 93            |
| TOST 4                  | 134                     | 92                     | 73            |
| TOST 3                  | 147                     | 103                    | 85            |
| TOST 2                  | 125                     | 86                     | 87            |
| TOST 1                  | 105                     | 76                     | 78            |
| Crystall                | 60                      | 35                     | 121           |
| Tomskiy 16              | 98                      | 71                     | 88            |
| Zaryanka                | 91                      | 64                     | 115           |
| Jitka                   | 123                     | 91                     | 67            |
| LSD\textsubscript{05}   | 14                      | 12                     | 46            |

Fiber flax Tomskiy 18, taken as a standard, formed the yield of the whole fiber 101 g/m\textsuperscript{2}. A significant increase in the yield of the fiber by 16-74 g/m\textsuperscript{2} was provided by varieties and breeding numbers of domestic origin – Nord, AR-4, Tverskoy, ER-138, Dobrynya, Antey, TOST 4, TOST 3, and TOST 2, the variety from the Republic of Belarus – Zakaz, breeding number from Ukraine – 3938/15, breeding number from Lithuania – B-192, B-168, varieties from France – Diane and Aurore variety from the Czech Republic – Jitka at LSD\textsubscript{05} – 14 g/m\textsuperscript{2}.  

Table 1. Average yield of the whole and long fiber, seeds, g/m\textsuperscript{2}.
For long fiber yield a significant increase of 15-54 g/m² was provided by varieties and breeding numbers of domestic origin – Nord, AP-4, Tverskoy, Alpha, ER-138, Dobrynya, TOST 4, TOST 3, and TOST 2, the variety of the Republic of Belarus – Zakaz, breeding number from Ukraine – 3938/15, breeding number from Lithuania – B-192, B-168, varieties from France – Diane, Aurore and variety of the Czech Republic – Jitka with LSD_05 = 12 g/m², compared to the same period in standard variety Tomskiy 18. The variety from France, Diane, stood out in terms of yield of whole (175 g/m²) and long fiber (125 g/m²), forming an advantage in these parameters by 21-115 g/m² and 21-90 g/m², respectively, over other studied varieties and breeding numbers. According to the yield of long fiber, the exception was the varieties Zakaz and ER-138, in which this indicator was 115 and 122 g/m², respectively.

The increase in seed yield was not provided by any variety and breeding number, in comparison with the seed yield of the Tomskiy 18 variety (LSD_05 = 46 g/m²). The highest indicator (115-121 g/m²) was provided by: the domestic variety Zaryanka, the breeding number from Ukraine - 3938/15 and the variety from the USA - Crystall. The increase in the yield of these seeds was 48-54 g/m², relative to the yield of other varieties.

Over the years of scientific research, soil and meteorological conditions have influenced the yield of the whole and long fiber and the content of long fiber to a greater extent by 41.6–64.3% (Figure 1).

![Figure 1](image)

Figure 1. The share of the factor influence on the trait variability:
1 – yield of the whole fiber; 2 - yield of the long fiber;
3 - seed yield, 4 - whole fiber content; 5 - long fiber content
(Reliably at a 95% probability level.
The number of gradations of factor A (variety) – 26, B (year) - 4).

The genotype of the variety had the greatest influence (40.1%) on the change in the content of the whole fiber. The yield of seeds to a greater extent (by 41.0%) was due to the interaction of varietal characteristics and environmental factors. The genetic program and the potential of plant productivity
are realized through regulatory mechanisms and systems that, in interaction with technological techniques and weather factors, form a certain morpho-physiological type of plant, the level of productivity, the final yield and its quality. One of the adaptation ways is the breeding of new genotypes of plants that are more adapted to local environmental conditions, the level of agricultural technology and its resource provision [24].

To identify the responsiveness of varieties and breeding numbers of fiber flax to abiotic conditions by fiber yield, the parameters of ecological plasticity for the yield of whole and long fiber were calculated (Table 2).

Table 2. Parameters of ecological plasticity of varieties and breeding numbers in terms of yield of the whole and long fiber.

| Variety, breeding number | CV, % | whole fiber yield | stability coefficient (Sd^2) | Variability, breeding number | CV, % | Long fiber yield | stability coefficient (Sd^2) |
|--------------------------|-------|-------------------|-----------------------------|-----------------------------|-------|------------------|-----------------------------|
| Tomskiy 18 – standard    | 42.2  | 0.83              | 1388                        | Sinichka                    | 31.1  | 0.31             | 8                           |
| Sinichka                 | 31.1  | 0.31              | 8                           | K4196×1288/12               | 20.4  | 0.44             | 23                          |
| Voskhod                  | 24.6  | 0.92              | 822                         | 3938/15                     | 26.3  | 0.47             | 1527                        |
| K4196×1288/12            | 20.4  | 0.44              | 23                          | B-192                       | 30.9  | 1.26             | 75                          |
| 3938/15                  | 26.3  | 0.47              | 1527                        | Nord                        | 42.1  | 1.59             | 165                         |
| B-192                    | 30.9  | 1.26              | 75                          | AR-4                        | 44.7  | 1.65             | 689                         |
| Nord                     | 42.1  | 1.59              | 165                         | Tverskoy                    | 34.7  | 1.32             | 390                         |
| AR-4                     | 44.7  | 1.65              | 689                         | Zakaz                       | 28.6  | 1.03             | 484                         |
| Tverskoy                 | 34.7  | 1.32              | 390                         | AR-5                        | 47.8  | 1.56             | 710                         |
| Zakaz                    | 28.6  | 1.03              | 484                         | Alpha                       | 61.6  | 1.70             | 679                         |
| AR-5                     | 67.8  | 1.56              | 710                         | ER-138                      | 44.6  | 1.81             | 259                         |
| Alpha                    | 61.6  | 1.70              | 679                         | Dobrynya                    | 47.6  | 1.73             | 132                         |
| ER-138                   | 44.6  | 1.81              | 259                         | Antey                       | 41.0  | 1.28             | 80                          |
| Dobrynya                 | 47.6  | 1.73              | 132                         | B-168                       | 31.5  | 0.99             | 978                         |
| Antey                    | 41.0  | 1.28              | 80                          | Diane                       | 18.8  | 0.78             | 370                         |
| B-168                    | 31.5  | 0.99              | 978                         | Aurore                      | 21.2  | 0.52             | 1050                        |
| Diane                    | 18.8  | 0.78              | 370                         | TOST 4                      | 21.0  | 0.51             | 661                         |
| Aurore                   | 21.2  | 0.52              | 1050                        | TOST 3                      | 32.3  | 1.24             | 191                         |
| TOST 4                   | 21.0  | 0.51              | 661                         | TOST 2                      | 35.8  | 0.99             | 972                         |
| TOST 3                   | 32.3  | 1.24              | 191                         | TOST 1                      | 25.0  | 0.70             | 7                           |
| TOST 2                   | 35.8  | 0.99              | 972                         | Crystall                    | 29.3  | 0.43             | 72                           |
| TOST 1                   | 25.0  | 0.70              | 7                           | Tomskiy 16                  | 34.4  | 0.50             | 1320                        |
| Crystall                 | 29.3  | 0.43              | 72                           | Zaryanka                    | 28.1  | 0.68             | 2                           |
| Tomskiy 16               | 34.4  | 0.50              | 1320                        | Jitka                       | 37.3  | 0.76             | 1706                        |
| Zaryanka                 | 28.1  | 0.68              | 2                           | F_05=19.4                   | 0.67  | 0.78             | 50.8                         |
| Jitka                    | 37.3  | 0.76              | 1706                        | F_05=19.4                   | 220   | 19.4             | 50.8                         |

* - reliable at 95 % probability level

All tested varieties and breeding numbers of fiber flax had significant variability according to these indicators with a variation coefficient, respectively, V=20.4–67.8% and V=35.0–89.4%. The varieties of domestic origin - Nord, AR-4, AR-5, Alpha, ER-138 and Dobrynya with a plasticity coefficient of 1.56-1.81 – were characterized by the highest response to changes in soil and meteorological conditions.
with the yield of the whole fiber. Varieties with good responsiveness to changes in cultivation conditions include varieties of domestic origin TOST 2 and Voskhod and a variety from Lithuania - B-168 with a plasticity coefficient of 0.92–0.99.

The most stable in terms of the whole fiber yield were the varieties Sinichka, TOST 1 and Zaryanka with a stability coefficient of 8, 7 and 2, respectively. The lowest stability in the yield of the whole fiber (1527-1706) had foreign varieties and breeding numbers - 3938/15 and Jitka.

According to the yield of long fiber, varieties AR-4 (1.63), Dobrynya (1.57), Nord (1.52), B-192 (1.47), ER-138 (1.39) and Antey (1.41) reacted better to changes in abiotic conditions. The varieties TOST 1 (8) and Zaryanka (3) had high stability according to a similar parameter.

A significant change in seed yield was observed in all varieties of fiber flax distinguished by seed productivity (V=22.0-28.1%), except for the variety from the USA - Crystall with a variation coefficient V = 14.5% (Table 3).

### Table 3. Adaptability parameters of fiber flax varieties by seed yield.

| Variety     | CV, % | Plasticity coefficient (b1, *) | Stability Coefficient (Sd2 *) |
|-------------|------|--------------------------------|-------------------------------|
| Tomskiy 18  | 23.1 | 1.06                           | 414                           |
| 3938/15     | 22.0 | 1.84                           | 196                           |
| Crystall    | 14.5 | 1.21                           | 115                           |
| Zaryanka    | 28.1 | 1.81                           | 771                           |

* - reliable at 95 % probability level

Among the varieties of fiber flax that stood out in terms of seed yield, the most responsive to improving cultivation conditions were the breeding number 3938/15 and the Zaryanka variety with a plasticity coefficient of 1.84 and 1.81, respectively. Nevertheless, the Zaryanka variety had a high stability coefficient Sd2 - 771, which indicates its low stability in seed yield. The most stable yield with a coefficient Sd2 – 115 was provided by the variety Crystall.

### 4. Discussion

Numerous scientific studies conducted in various soil and climatic conditions emphasize the importance of adapting varieties to specific environmental conditions and their different behavior in different agro-climatic zones.

In most European countries and regions, in India (New Delhi), the main factor limiting the yield of flax products is weather conditions, namely - precipitation [25, 26]. Experiments conducted in Poland showed that dry conditions led to a decrease in fiber yield by 39.7-49.3% [27]. This is also relevant for flax growing in the Middle Cis-Urals [28]. In China, to reduce the negative impact of drought on flax productivity, alternating small and large ridges with full-layer mulching is recommended, which provides an innovative option for optimizing hydrothermal soil conditions, thereby increasing the productivity and profitability of flax crops in arid semi-desert conditions [29]. According to A. Dmitriev [30] unfavorable conditions, such as nutrient deficiency and suboptimal soil acidity, contribute to a decrease in the quantity and quality of flax yield. Growing stress-tolerant varieties will significantly reduce crop losses. Understanding the mechanisms of flax response to stress will ensure the identification of resistance gene candidates. In the conditions of Central and Northern Italy, variety genotype, cultivation zone and vegetation conditions had a significant impact on the yield of flax products [6].

The main product of fiber flax is fiber. Therefore, the scientific research of many scientists is aimed at determining and improving the quality of flax fibers of modern varieties. To resume flax production in Croatia, M. Andrassy [31] established the dependencies and the influence of agroecological conditions on plants of flax varieties and fiber yield. In the conditions of the Middle Cis-Urals, the
influence of meteorological conditions on the quality of fiber and the duration of the growing season of flax varieties has been established [28].

Scientific research on the development of technology for flax growing is primarily based on the selection of varieties for local environmental conditions [32]. At the same time, it is necessary to consider the needs of two categories of consumers – producers and processors of flax. This is important for reducing the economic, environmental, and social costs of agricultural production [32, 33].

Thus, according to scientists from Russia and other countries, the role of a variety that provides a stable yield at a high level is especially important in various soil-climatic and economic conditions of agricultural production. Modern varieties of fiber flax must have a full range of economically valuable characteristics, meet the requirements of agricultural producers, and be adapted to the soil and climatic conditions of specific cultivation zones.

5. Conclusions

Thus, the change in the yield of the whole and long fiber in the studied varieties and breeding numbers by 41.6...64.3% is caused by the influence of soil and meteorological conditions during the years of research. Among the studied collection, the combination of good plasticity and stability to abiotic conditions is characteristic of the variety TOST 2, according to the yield of long fiber – the breeding number from Lithuania – B-168 and the variety from France – Diane. It was found that the domestic varieties TOAST 1, Zaryanka, Antey and the breeding number K4196×1288/12 provided relatively high stability in the yield of the whole and long fiber in various abiotic medium conditions. These varieties had a significant advantage over other studied flax varieties and breeding numbers in terms of the yield stability of the whole and long fiber. This will allow the use of the listed varieties and the breeding number as a source material in breeding programs.

References

[1] Gusakov V et al. 2010 Flax complex: the causes of unprofitability and the mechanism of increasing efficiency Agrarian economics 5 35-39
[2] Ponazhev V P, Rozhmina T A, and Medvedev O V 2015 Innovations – the most important resource for improving the efficiency of flax production Achievements of science and technology of the agro-industrial complex 5 64-67
[3] Haag K, Padovani J, and Beauprard J 2017 Influence of flax fibre variety and year-to-year variability on composite properties Industrial crops and products 98 1-9 https://doi.org/10.1016/j.indcrop.2016.12.028
[4] Kukle S, Stramkale V, and Strazds G 2011 Comparative technological and commercial evaluation of flax varieties for the revival of flax growing in Latvia. Environment, technology, resources, proceedings of the 8th international scientific and practical conference II pp 225-230 https://www.webofscience.com/wos/woscc/full-record/WOS:000393725800031
[5] Zhuchenko A A 2008 Adaptive crop production (ecological and genetic basis) (Moscow: Publishing house Agrorus) 1
[6] Tavarini S, Angelini L G, Casadei N, Spugnoli P, and Lazzeri L 2016 Agronomical evaluation and chemical characterization of Linum usitatissimum L. as oilseed crop for bio-based products in two environments of Central and Northern Italy Italian journal of agronomy 11(2) 122–132 https://doi.org/10.4081/ija.2016.735
[7] Korepanova E V 2014 Adaptive technology of cultivation of flax for fiber and seeds in the Middle Cis-Urals: abstract of dissertation of Dr. Agricul. Sciences (Ufa) 40 p
[8] Korepanova E V, Fatykhov I Sh, Goreeva V N and Islamova Ch M 2020 Innovative technologies in agronomy The role of agronomic science in the optimization of crop cultivation technologies: Materials of the International Scientific and Practical Conference dedicated to the 65th anniversary of the work of the Department of Plant Growing of FSBEI HE Izhevsk SAA in Udmurtia (Izhevsk: Izhevsk State Agricultural Academy) pp 190-193
[9] Korepanova E V, Fatykhov I Sh, and Goreeva V N 2020 Improving the efficiency of flax cultivation by optimizing cultivation techniques Flax growing: realities and prospects: materials of the International Scientific and Practical Conference (Minsk: Belorussian Science) 9 pp 24-30
[10] Fatykhov I Sh, Goreeva V N, Koshkina K V, and Korepanova E V 2014 The structure of the yield of oilseed flax varieties in the conditions of the Middle Cis-Urals Innovations in science, technique and technology: materials of the All-Russian Scientific and Practical Conference, April 28-30, 2014: collection of articles (Izhevsk: Udmurt University) pp 107-110
[11] Korepanova K V 2016 The reaction of oilseed flax to abiotic conditions and sowing techniques in the Middle Urals abstract, diss. candidate of Agricultural Sciences (Ufa) 20 p
[12] Goreeva V N, Galiev R R, Korepanova E V, and Fatykhov I Sh 2019 Productivity of oilseed flax varieties VNIIMK 620 and Severny when using fertilizers and insecticides Bulletin of the Kursk State Agricultural Academy 2 25-32
[13] Korepanova E, Goreeva V, Galiev R, and Fatihov I 2019 Mineral fertilizers and insecticides in the formation of seed yield of the oil flax varieties Development Strategy: International Scientific and Practical Conference 167 262-267
[14] Goreeva V N, Korepanova E V, Fatykhov I Sh, and Islamova Ch M 2020 Response of oil flax varieties to abiotic conditions of the middle cis-ural region by formation of seed yield Notulae Botanicae Horti Agrobotanici Cluj-Napoca 48(2) 1005-1016 https://doi.org/10.15835/nbh a48211895
[15] Korepanova E V, Fatykhov I Sh, Goreeva V N, Galieva G R, Kapeev V A, and Borisov B B 2020 Comparative productivity of varieties of Central Russian monocious cannabis in abiotic conditions of the Middle Urals Varietal agrotechnics of field crops - into production: materials of the All-Russian scientific and practical conference dedicated to the 80th anniversary of the birth of Professor of the Department of Plant Growing Ivan Vasilyevich Osokin - FSBEI HE Perm SATU (CPI Prokrost) V pp 97-100
[16] Rozhmina T A, Fu Y B, Diederichsen A 2018 Research of Genetic Polymorphism Species Linum sitatissimum L. on a Basis a RAPD-Method Journal of natural fibers 15(2) pp 155-161
[17] Galiev R R, Goreeva V N, and Korepanova E V 2020 Chemical composition of seeds of oilseed flax varieties when using herbicide and different methods of winter tillage Integration interactions of young scientists in the development of agricultural science: materials of the National Scientific and Practical Conference of Young Scientists. In 3 volumes (Izhevsk: FSBEI HE Izhevsk SAA) pp 62-65
[18] Rybakova L V, Galiev R R, Korepanova E V, and Goreeva V N Fat content and oil harvesting with the harvest of oilseed flax seeds depending on mineral fertilizers and insecticides Integration interactions of young scientists in the development of agricultural science: materials of the National Scientific and Practical Conference of Young Scientists. In 3 volumes (Izhevsk: FSBEI HE Izhevsk SAA) pp 185–189
[19] Dospekhov B A 2012 The methodology of field experience (with the basics of statistical processing of research results) (Moscow: Book on demand)
[20] Kidin V V, et al. 2008 Workshop on agrochemistry (M.: KolosS) 591 p
[21] Weather in Izhevsk. Air temperature and precipitation 2020 Reference and information portal "Weather and climate". http://www.pogodaiklimat.ru/monitor.php
[22] Eberhart S A, and Russell W A 1966 Stability parameters for comparing varieties. Crop Science 6(1) 36-40 https://doi.org/10.2135/cropsci1966.0011183X000600010011x
[23] Zykin V A 2005 Methodology of calculating and evaluating the parameters of ecological flexibility of agricultural plants (Ufa: BashSAU) 100 p
[24] Dragavtsev V A et al. 2011 Some tasks of agrophysical support of breeding technologies for genetic increase of productivity and yield of plants Agrophysics 1 14-22
[25] Dash P K, Gupta P, Jailani A K et al. October 2018 Hydropenia induces expression of drought responsive genes (DRGs) erdl, hat, pID-delta, and zfa in Linum usitatissimum L. Indian journal of experimental biology 56(10) 743–749
[26] Heller K and M Byczynska 2015 The Impact of Environmental Factors and Applied Agronomy on Quantitative and Qualitative Traits of Flax Fiber Journal of natural fibers 12(1) 26–38

[27] Kulma A, Zuk M, Long S H, et al June 2015 Biotechnology of fibrous flax in Europe and China Industrial crops and products 68(Special № SI) 50–59

[28] Maslova M P, Korepanova E V, and Fatykhov I Sh 2018 Reaction of flax varieties to meteorological conditions of the Middle Cis-Urals Bulletin of the Izhevsk State Agricultural Academy 2 (55) 57-66

[29] Mo F, Li X-Y, Niu F-J, et al. April 15, 2018 Alternating small and large ridges with full film mulching increase linseed (Linum usitatissimum L.) productivity and economic benefit in a rainfed semiarid environment Field crops research 219 120–130

[30] Dmitrievv A A, Krasnov G S, Rozhmina T A, et al. 2018 Flax (Linum usitatissimum L.) response to non-optimal soil acid and zinc deficiency 11th International Multiconference on Bioinformatics of Genome Regulation and Structure/Systems Biology (BGRS/ SB) Location: Novosibirsk, RUSSIA publ.: AUG 20-25, 2018 https://doi.org/10.1186/s12870-019-1641-1

[31] Andrassy M, Surina R, and Butorac J 2010 Influence of agroecological conditions on the properties of flax fibres in croatia 5th International Textile, Clothing and Design Conference: 5th international textile, clothing & design conference, book of proceedings: magic world of textiles: pp 32-37 https://www.webofscience.com/wos/woscc/full-record/WOS:000393719100004

[32] Heller K, Baraniecki P, and Praczyk M 2012 Fibre flax cultivation in sustainable agriculture. Handbook of natural fibres Vol 1: types, properties and factors affecting breeding and cultivation (118), pp 508-531 https://www.webofscience.com/wos/woscc/full-record/WOS:000323930000015

[33] Porsev I, Sozinov A, and Salomatina K 2020 Promising varieties of fiber and oil flax plants for agricultural technologies of Trans-Urals 2nd International Scientific-Practical Conference on Agriculture and Food Security - Technology, Innovation, Markets, Human Resources (FIES) 27 https://doi.org/10.1051/bioconf/20202700096