Acta Biol. Univ. Daugavp. 22 (2) 2022
ISSN 1407 - 8953

ASSESSMENT OF FLAX POPULATION PRODUCTIVITY UNDER VARIABLE ECOLOGICAL FACTORS DURING ONTOGENESIS

Inga Morozova*, Dace Grauda, Veneranda Stramkale,
Ieva Kroiča, Aldis Stramkalis

Morozova I., Grauda D., Stramkale V., Kroiča I., Stramkalis A. 2022. Assessment of flax population productivity under variable ecological factors during ontogenesis. *Acta Biol. Univ. Daugavp., 22 (2): 157 – 165.*

Abstract

The limiting factor that affects flax development often is different abiotic and biotic stress. Most crucially ecological adaptation of plants is dependent on the genetically determined productivity of flax and variation in yields in the agroecosystems. The aim of this study was to analyze the flax population of the important agronomic trait productivity under variable agroecological conditions and the incidence of fungal diseases at different flax growth stages. Field investigations were carried out from 2014 to 2017 for agronomically important traits of flax and from 2015 to 2017 for the incidence of fungal diseases at the growth stages of flax. In the study was evaluated flax population with Latvian origin in 24 fibre flax genotypes and 'Vega 2' (ST) as the standard variety of Lithuanian origin under Latvian meteorological conditions. According to the results obtained from analysis of variance between flax population agronomically important yield traits and years the significant higher plants stem yield, total plant height, technical plant height, number of seed vessels per plant, and oil content were measured in the growing seasons with high humidity. However, the higher seed yield and 1000 seed weight were measured in the driest year. The lowest lodging rate of flax population was found in years with higher humid level and rapid rainfall. Statistically significant higher average diseases incidence was detected during early yellow ripening stage for all diseases, except flax wilt. The incidence of flax wilt was detected during vegetative stages, anthracnose, stem break, browning of flax and fusarium browning during all growth stages, but pasmo and powdery mildew were found during the reproductive stages of flax population.

Key words: flax, hydrothermal conditions, yield, fungal diseases, growth stages.

*Corresponding author: *Inga Morozova. Institute of Agricultural Resources and Economics, Zinatnes Str. 2, Priekuli, Cesu district, Latvia, E-mail: inga.morozova@arei.lv*

Veneranda Stramkale, Ieva Kroiča, Aldis Stramkalis. Institute of Agricultural Resources and Economics, Zinatnes Str. 2, Priekuli, Cesu district, Latvia

Dace Grauda. Institute of Biology, University of Latvia, Miera Str. 3, Salaspils, Latvia

INTRODUCTION

Flax (*Linum usitatissimum* L.) was known mainly as the most general fibre crop in temperate region. Flax is traditional and perspective crop in Latvia as well as in the farthest northern region in Europe. In Europe, the flax yield very often is limited by weather conditions (precipitation) (Heller & Byczyńska 2014). Water stress is considered one of the main harsh abiotic stresses that can inhibit the growth, yield and quality of flax (El-Borhamy et al. 2022). However, flax is characterized by wide ecological differentiation including significant polymorphism in response to moisture deficiency (Djakov 2006).

Fungal diseases are among the main biotic stresses that affect plant growth, development and yield. Fungal diseases infect all types of flax including linseed and the fibre flax (Kumar 2016). Along with rust, fusarium wilt has become an important factor in flax production worldwide (Galindo-González & Deyholos 2016). Flax wilt and anthracnose under favourable conditions can cause partial or complete destruction of flax. Pasmo, anthracnose reduces seed productivity, yield and quality of fibre raw materials (Loshakova et al. 2014). The incidence and severity, and the importance of flax diseases, vary from one region to another in the flax-growing areas of the world (Alister & Westcott 2003). Many plant–pathogen interactions and the expression of resistance depend on the developmental stage at which the plant is infected (Develey-Rivière & Galiana 2007).

Knowledge on the impact of genotypes and growing conditions on flax yield traits as well resistance of disease of flax are still incomplete under the impact of the environments. The previous study (Stafecka et al. 2019) already analysed flax genotype resistance to diseases under variable meteorological conditions. However, it is important to understand at which stages of the flax population during ontogenesis, the resistance to fungal diseases can be found. Therefore, the aim of this study was to analyze the flax population of the important agronomic trait productivity under the variable agroecological conditions and the incidence of fungal diseases at different flax growth stages.

MATERIALS AND METHODS

Study object

The research was conducted at the Institute of Agricultural Resources and Economics, Department of Plant Breeding and Agroecology at Vilani from 2014 to 2017 for agronomically important traits of flax population and from 2015 to 2017 for the incidence of fungal diseases at the growth stages of flax. Experimental material for the study of flax population consisted of 24 fiber flax genotypes of Latvian origin: ‘Altgauzen’, ‘Rota 1’, ‘Rota 2’, ‘Rezeknes’, ‘Ruda 1’, ‘S13/5-7/5-93’, ‘S32/4-8-93’, ‘S53/8-3-93’, ‘S64-17-93’, ‘T11-6/2-15-94’, ‘T11-13/3-1-94’, ‘T25/5-33/12-8-94’, ‘T29-36/10-5-94’, ‘T29-36/7-1-94’, ‘T31-40-94’, ‘T36-26/4-8-94’, ‘K47-17/11-1-95’, ‘K47-17/11-6-95’, ‘L2-14/6-97’, ‘L11-11/10-97’, ‘L11-11/11-97’, ‘L19-6/15-97’, ‘L23-26/3-97’, ‘L26-47/1-97’ and ‘Vega 2’ (ST) as the standard variety of Lithuanian origin.

Experimental design

Plants were grown in standard block in 1 m^2 plots with 10 cm distance between rows. In total 1700 flax seeds per m^2 were sown by hand with a sowing depth of 1.5–2 cm at the field trial. Before sowing, germination tests were performed for all used genotypes. Seeds were sown during the first 10 days of May. Flax was grown in humi-podzolic gley soil. The main agrochemical parameters of the arable soil layer were following: humus content – 6.5%, pH_{KCl} – 6.4–7.0, available P_2O_5 – 130–145 mg kg^{-1} and available K_2O – 118–124 mg kg^{-1} soil (by results of The Latvian State Plant Protection Service). Complex fertilizer NPK 16:16:16 – 300 kg ha^{-1} was applied after the first soil cultivation. For plant further development a surface fertilizer – ammonium nitrate 30 kg ha^{-1} N in fir-tree like phase was applied. Fungicides for flax diseases were not used. Plants were pulled manually at the stage of early yellow ripeness and then left on ground for air-drying for 5–8 days. The seed-vessels were removed by ‘Eddi’ device. Seeds were cleaned with ‘MLN’ sample cleaner. The total and technical plant heights, fibre content were determined using randomly selected most typical 20 plants in each parcel area before the harvest. The resistance of plants to lodging was evaluated (Nozkova et al. 2016).

Thirty marked flax plants from each genotype at the 1 m^2 in the field trails were assessed for plant disease symptoms visually every 7th day till flax pulling over the three vegetation periods under natural field conditions. Growth stages of flax were noted according to BBCH scale ("Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie") (Nozkova et al. 2016). The analyses of infected parts of the plants were done following the methodologies developed for phytopathological research (Loshakova et al. 2000, Narayanasamy 2011) at the laboratory of the Institute of Biology of the University of Latvia. For the determination of internal pathogen infection, the infected parts of the plants were disinfected with 50% ethyl alcohol, then rinsed in distilled water and dried on a sterile filter paper. The infected parts of the plants were placed in Petri dishes (diameter 9 cm) on the agar (Agar-Agar Roth Art.-No. 4508.1) media. After 6–9 days of incubation at a temperature of 24–26 ºC the Petri dishes were inspected for fungal contamination on the plants. The fungus was identified after the emergence of mycelium. The conidia shapes of the fungus were detected using a light microscope (Carl Zeiss Jena by 640 × magnification). The diseases were determined by morphological features using disease descriptors (Malone & Muskett 1997, Loshakova et al. 2000, Damm et al. 2014).

Percentage of the affected plants was noted with disease incidence (I). Incidence was calculated by applying formula:

$$I = n / N \times 100,$$

where I – incidence, %; n – number of diseased injured plants; N – total number of plants assessed.

Meteorological conditions

Agro-meteorological condition characteristics were used by Rezekne hydrometeorological station. Facility provides information directly to the nearby field trials. In this study hydrothermal coefficient (HTC) of each month was calculated during the growing season (Fig. 1.). The calculations were performed by applying the formula (Selyaninov 1928):

$$HTC = \Sigma x / \Sigma t \times 10,$$

where Σx and Σt – sum of precipitation and temperature in the period, when the temperature has not been lower than 10 °C.

Data analysis

Significant differences among the measured characteristics (stem yield, total plant height, technical plant height, number of seed-vessel per plant, oil content, seed yield 1000 seed weight) of flax were compared by Fisher's least significant difference (LSD) tests ($p \leq 0.05$). The Pearson correlation coefficient was used to analyse linear relationship between two sets of data the disease incidence (I) and BBCH stages.

RESULTS AND DISCUSSION

Meteorological condition analysis

The hydrothermal conditions during the growing stages of flax are variable (Fig.1.). In 2014 HTC was 1.8 and in 2016 was 1.9, which is characterized as relatively humid, in 2015 it was 1.2 which means relatively dry. In 2017, when HTC was 2.7, very humid weather was found (317% of humidity in Augusts, which was much higher than the long term average).

Meteorological condition effect on flax population agronomic traits

Analysis of variance revealed that the average yield and components of the flax population were ($p \leq 0.05$) significantly different between years (Tab. 1). Stem yields ranged from 249.6 to 860.68 g m^{-2} and seed yield ranged from 115.96 to 166.93 g m^{-2} between study years. Latvian weather events have shown to have a significant impact on the yield stability of flax. In this study, the growing seasons were characterised from relatively dry in 2015 to very humid in 2017. The stem yields, total plant height, technical plant height, number of seed-vessel per plant and oil content of flax population were significantly higher in humid years (2017 and 2016). However, seed yield and 1000 seed weight value highest of flax population in the driest year (2015). According to soil analysis, agrochemical indicators did not significantly differ between years, which suggested complex (genetic, environment) factors influencing the growth and development of flax. The analysis of variance confirmed that stem yield, total plant height, technical plant height, seed yield, 1000 seed weight, number of seed-vessel per plant and oil contents are more dependent on environmental conditions. However, fibre content and seed number per seed-vessel value were more stable in environmental conditions. Wang et al. (2018) have revealed that the low heritability in stem yield suggests a considerable environmental influence and fibre content is more heritable. However, Gordeyeva and Shestakova (2018) have revealed the range of variation not only within the flax genotype but also with regard to climatic conditions. Furthermore, yield productivity depends on the humidity level at the growing stages in 2014 year with rapid and sudden rainfall of the flax population the stem yield was observed significantly ($p \leq 0.05$) low. Chudinova (2007) revealed that receiving high quality flax fibre, the smooth, wet climate without sudden changes in temperature and humidity is required.

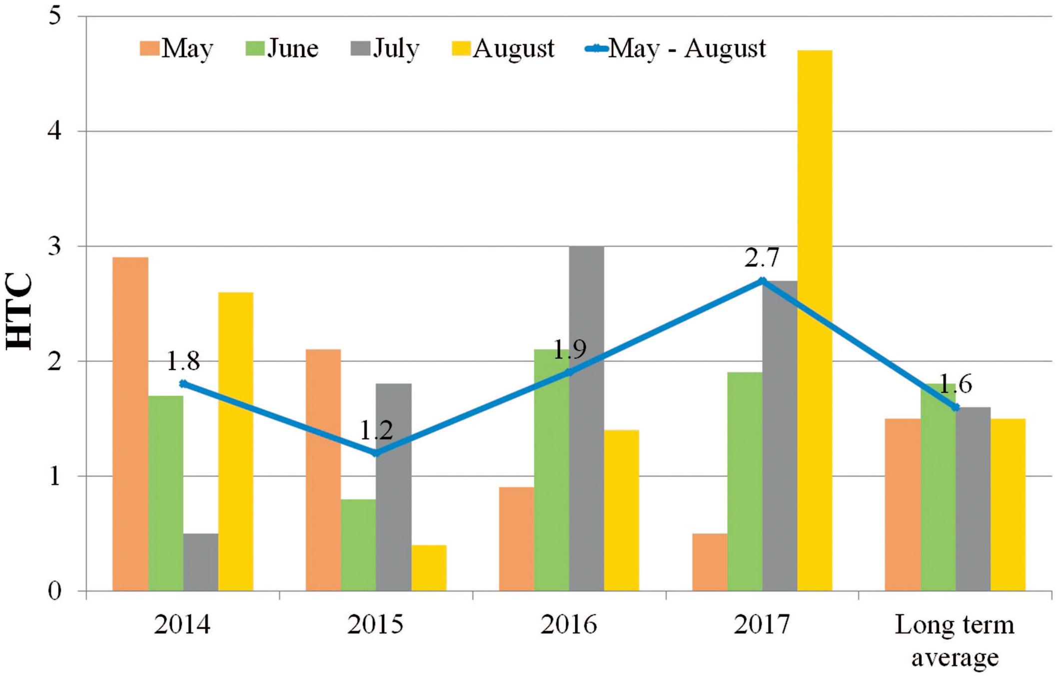

Figure 1. Hydrothermal coefficients (HTC) during the growth period of flax from 2014 to 2017 (y axis) and long term average (last 10 year data sets according WMO, 2017). Ranges of values (Skowera et al., 2014): HTC $\leq$ 0.4 extremely dry; 0.4 < HTC $\leq$ 0.7 very dry; 0.7 < HTC $\leq$ 1.0 dry; 1.0 < HTC $\leq$ 1.3 relatively dry; 1.3 < HTC $\leq$ 1.6 optimal; 1.6 < HTC $\leq$ 2.0 relatively humid; 2.0 < HTC $\leq$ 2.5 humid; 2.5 < HTC $\leq$ 3.0 very humid; HTC > 3.0 extremely humid.

Table 1. Agronomically important yield traits of flax. Explanations: STY – stem yield; ToPH – total plant height; TePH – technical plant height; FC – fibre content; SY – seed yield; NSVP – number of seed-vessel per plant; SNSV – seed number per seed-vessel; SW – 1000 seed weight; OC – oil contents, L – lodging value, ^{abcd} – followed by the same letters in each column are not statistically significant.

Year	STY, g m^{-2}	ToPH, cm	TePH, cm	FC, %	SY, g m^{-2}	NSVP	SNSV	SW, g	OC, %	L
2014	249.60c	71.30b	57.52b	25.97b	128.26b	9.5b	8.98a	4.74c	42.77ab	9
2015	592.00b	66.59b	55.94b	30.91a	166.93a	6.4c	8.86a	5.57a	42.47b	9
2016	807.20a	79.40a	64.44a	25.97b	151.74a	9.36b	8.42b	5.03b	42.76b	8.2
2017	860.68a	78.34a	59.05b	29.74a	115.96b	11.08a	8.76a	3.82d	43.21a	5.8
LSD$_{0.05}$	*102.39*	*4.97*	*4.76*	*1.96*	*17.33*	*0.94*	*0.29*	*0.25*	*0.45*	

According to Li et al. (2011), the lodging resistance of flax indirectly affected yield through various physiological mechanisms, allowing crop phenology and plant architecture to be adapted to regional growing conditions, thus avoiding yield and quality losses. The flax resistance to abiotic factors as lodging of the tested accessions ranged from 5.8 to 9 (Tab. 1). In 2017 the lowest rate of lodging reached 5.8 that characterized by often and rapid rainfall during the reproduction period. Xinwen (1997) revealed that excess moisture, especially when sowing densities and nitrogen content in the soil are high, can result in lodging.

Flax diseases on the flax population during ontogenesis analysis

In the present study on the genotypes of flax the incidence of six harmful fungal diseases were found: flax wilt, anthracnose, fusarium browning, browning and stem break of flax, pasmo, powdery mildew during the study period of three years. Three-year study showed statistically ($p \leq 0.05$) significantly different occurrences of six fungal diseases in the flax population at different growth stages (Tab. 2). Disease incidence showed significant differences between vegetative and reproductive stages of flax development.

Table 2. Incidence (I, %) of flax diseases on the flax population during 2015 to 2017. abcd – followed by the same letters in each column are not statistically significant, * – correlation significant at $p < 0.01$.

BBCH	Flax wilt	Anthracnose	Fusarium browning	Stem break, browning	Powdery mildew	Pasmo
10	0.2a	0.1a	–	–	–	–
19	4.7bc	2.7ab	0.3a	0.5a	–	–
31	6.5c	5.0abc	1.7a	1.8a	–	–
35	5.2c	4.7abc	3.3ab	1.3a	–	–
51	2.3ab	4.8abc	1.9a	0.5a	–	–
61	–	5.3bc	4.2ab	0.6a	–	–
65	–	5.7bc	6.8b	4.3ab	–	0.3a
71	–	7.9c	14.2c	11.8bc	1.4a	4.6ab
79	–	15.2d	18.9cd	14.9c	8.3b	7.6bc
81	–	18.7d	21.7d	17.5c	9.3b	12.4cd
83	–	16.4d	20.2d	16.1c	8.4b	16.0d
LSD$_{0.05}$	*2.43*	*5.09*	*4.04*	*8.67*	*4.64*	*6.49*
$r_{I/BBCH}$	0.26	0.85*	0.88*	0.87*	0.95*	0.95*

Flax wilt is the most widely studied, because it significantly affects plant development in certain years under favourable conditions. According to the results, flax wilt incidence was lowest between all diseases in three vegetation periods. However, causal agent of flax wilt is soil-borne and it can infect the flax at any growth stage. The first symptoms of flax wilt (Tab. 2) caused by *Fusarium oxysporum* f. sp. *lini*, were observed during flax emergence (BBCH10) (I = 0.2%) and the fungal occurrence on the plants continued until the bud stage (BBCH51) (I = 2.3%) after which it sharply decreased. The relationship between I and BBCH (r = 0.26) was weak and infection did not progress throughout the vegetation period. Kumar (2016) has revealed that plants are infected by wilt at any stage in flax development. In the present study, the disease did not show a high distribution rate on the genotypes, which indicates genotype resistance to fungus or unfavourable conditions for their spread. The study by Kroes et al. (1999) show ed that while the generation of fusarium-resistant cultivars worldwide has reduced the impact of the pathogen, there is a wide range of susceptibility among varieties, dependent in part on the specific fungal isolates/races involved in infection. However, Saharan et al. (2005) observations showed that flax wilt has a pathogen that demonstrates diversity within a species with numerous biotypes and pathotypes.

The anthracnose, fusarium browning and stem break, browning of flax occurred in all growth period (Tab. 2). The anthracnose, caused by *Colletotrichum lini*, was observed during flax emergence (BBCH10) (I = 0.1%), and the fungal occurrence on the plants continued until the early ripening yellow stage (BBCH83) (I = 16.4%). The significantly ($p \leq 0.05$) highest incidence of anthracnose on the plants was indicated from BBCH79 to BBCH83. Significantly positive ($p \leq 0.01$, $r = 0.85$) relationships were found between I and BBCH of flax. The first symptoms of fusarium browning, caused by *Fusarium* spp., and stem break, browning of flax, caused by *Polyspora lini*, were observed during flax fir-tree like stage (BBCH19), and the occurrence of both fungi on the plants continued until early yellow ripening stage (BBCH83). The significantly ($p \leq 0.05$) highest incidence of fusarium browning on the plants was indicated from BBCH79 to BBCH83 and the incidence of stem break, browning – from BBCH71 to BBCH83. Positive and significant ($p \leq 0.01$) relationship between fusarium browning I (r = 0.88), stem break, browning I (r = 0.87) and BBCH of flax was found. In general, correlation confirmed the progress of both fungus diseases during the whole growing season and highest at the reproduction stages of growth. According to Bačelis & Gruzdevienė (2001), anthracnose has spread throughout the growing period and it was proved that reduced fibre quality and yield has been attributed to infection with diseases during early growth stages of the flax. Anthracnose is a seed-borne disease. However, Karpunin (2016) observed that *C. lini* is also able to survive as saprophyte in the soil, and then the flax is infected through the soil, which is an adapted mechanism that preserves pathogen viability and is non-race-specific, but retains the ability to be a race-specific on the flax. According to Loshakova et al. (2000), fusarium browning and stem break, browning of flax can occur on flax at any growth stage, but considering that both casual agents are non-specific to flax. Both diseases spreading on the flax are currently not well understood.

In the study pasmo and powdery mildew occurred only in the reproductive period (Tab. 2). The first time was identified pasmo on the flax population in Latvia. Pasmo is widespread throughout the World on the flax and has a significant impact on the development and yield. The pasmo, caused by *Septoria linicola*, was observed during full flowering stage of flax (BBCH65) (I = 0.3%), and the fungal occurrence on the plants continued until early yellow ripening stage (BBCH83) (I = 16.0%). A positive and significant relationship was determined between I and BBCH of flax ($p \leq 0.01$, $r = 0.95$). Similar results of pasmo have been reported also by Penaud et al. (2017) in the different regions while infection with pasmo also occurs towards the end of the growing season. The powdery mildew caused by *Oidium lini*, is specific to flax and affects yields in certain years. The first symptoms of powdery mildew were observed during the full flowering stage of flax

(BBCH71) (I = 1.4%), and the fungal occurrence on the plants continued until the early yellow ripening stage (BBCH83) (I = 16.0%). The significantly higher occurrence of powdery mildew was observed from BBCH79 to BBCH83. Significant and positive relationship was found ($p \leq 0.01$, $r = 0.95$) between I and BBCH of flax. The correlation confirmed the progress of pasmo and powdery mildew occurrence during the reproduction stages of growth only. Kumar (2016) reported that the powdery mildew yield losses were greater when the disease appears early growth stages.

The findings of the current study suggest that the susceptibility of the plants to diseases such as anthracnose, fusarium browning, browning and stem break of flax, pasmo, powdery mildew was enhanced when the plants became older.

CONCLUSIONS

In an agroecosystem, most of the agronomically important traits of flax productivity vary depending on the effect of different humid conditions during ontogenesis. The significantly ($p \leq 0.05$) highest stem yield, total plant height, technical plant height, number of seed vessels per plant and oil content in humid years as well as seed yield and 1000 seed weight in the driest year were observed. The lowest lodging rate was obtained under higher humid conditions.

In flax population, the significantly ($p \leq 0.05$) highest diseases average incidence has been fixed during the early yellow ripening stage for all diseases, except flax wilt during the three study years. The development of flax wilt was detected at the vegetative stages of flax. The results confirmed the spreading progress of anthracnose, stem break, browning of flax and fusarium browning during the all vegetation period as well as pasmo and powdery mildew during the reproductive stages of the flax population.

Knowledge about the humidity impact on yield development and different disease spreading allows the development of effective management systems for flax breeding under Latvian agroecological conditions.

ACKNOWLEDGEMENTS

The study was funded by the project “Preservation gene pool of flax” of the Latvian Ministry of Agriculture according to Cabinet of Ministers Regulation No. 1524 of December 17th, 2013 “Regulations on State Support for Agriculture”.

REFERENCES

Alister D., Westcott M.N.D. 2003. Flax: The genus *Linum*. CRC Press, London. 90 pp.

Bačelis K., Gruzdevienė E. 2001. Resistance of fibre flax varieties to *Colletotrichum lini* Manns et Bolley. *Biologija* 3: 4 – 9.

Chudinova J.B. 2007. Flax breeding of biological basis (Biologicjeskie osnovi selekcii ljna). *Herald RAAS Vestnjik Rosisjskoi selshozaistvennoi nauki* 6: 38 – 40. (In Russian; abstract in English).

Djakova A.B. 2006. Fiziologija I ekologija ljna (Physiology and ecology of flax). Krasnodar. 214 pp. (In Russian; abstract in English).

Damm U., O’Connell R.J., Groenewald J.Z., Crous P.W. 2014. The *Colletotrichum* destructivum species complex – hemibiotrophic pathogens of forage and field crops. *Studies in Mycology* 79: 49 – 84. https://doi.org/10.1016/j.simyco.2014.09.003.

Develey-Rivière M.P., Galiana E. 2007. Resistance to pathogens and host developmental stage: a multifaceted relationship within the plant kingdom. *New Phytologist* 175: 405 – 416. https://doi.org/10.1111/j.1469-8137.2007.02130.x

El-Borhamy A., Khedr R.A., El-Mansoury M. 2022. Physiological, Biochemical and Agronomic Response of Some Flax Cultivars to

Water Deficit under Clay Soil Conditions in North Delta. *Journal of the Advances in Agricultural Researches* 27(2): 351 – 365. https://doi.org/10.21608/JALEXU.2022.139346.1065

Galindo-González L., Deyholos M.K. 2016. RNA-seq Transcriptome Response of Flax (*Linum usitatissimum* L.) to the Pathogenic Fungus *Fusarium oxysporum* f. sp. *lini*. *Frontiers in Plant Science* (7): 1766. https://doi.org/10.3389/fpls.2016.01766

Gordeyeva Y., Shestakova N. 2018. The Influence of agroclimatic factors on the formation of oil content in flax seeds in the North of Kazakhstan. *Journal of Ecological Engineering* 19(3): 102 – 105. https://doi.org/10.12911/22998993/85740

Heller K., Byczyńska M. 2014. The Impact of Environmental Factors and Applied Agronomy on Quantitative and Qualitative Traits of Flax Fiber. *Journal of Natural Fibers* 12(1): 26 – 38. https://doi.org/10.1080/15440478.2013.879088

Karpunin B.F. 2016. Antraknoz ljna. Selekcija na uztoichivosti (The anthracnose of flax. Selection of stability). Lambert Academic Publishing, London. 116 pp. (In Russian).

Kroes G. M.L.W., Loffler H.J.M., Parlevliet J.E., Keizer L.C.P., Lange W. 1999. Interactions of *Fusarium oxysporum* f. sp. *lini*, the flax wilt pathogen, with flax and linseed. *Plant Pathology* 48: 491 – 498.

Kumar S. 2016. Diseases of linseeds and their management. Crop diseases and their management. Apple Academic Press, Pp. 127 – 142.

Li X., Yan W., Agrama H., Jia L., Shen X., Jackson A., Moldenhauer K., Yeater K., McClung A., Wu D. 2011. Mapping QTLs for improving grain yield using the USDA rice minicore collection. *Planta* 234: 347 – 361. https://doi.org/10.1007/s00425-011-1405-0

Loshakova N.I., Krilova Ò.V., Kudravceva L.P. 2000. Metodjicheskie ukazanjia po fitopatalogicheskoi ecenke ustoichivoskji ljnabolgunca k boljeznjam (Methodes for the phytopathological resistance evaluation to diseases of flax). Moscow. 52 pp. (In Russian).

Loshakova N.I., Kudravceva L.P., Pavlova L.N., Pohzmina T.A. 2014. Rolj kollekcij fitopatogennih mikroorganizmov – vozbudjiteljei boljeznjei ljna (The role of collection of phytopathogenic casual agents – pathogens of flax diseases in the flax breeding programms for complex resistance to diseases). *Maslichnie kulturi. Nauchno tehniceskij bulletin Vserusiskovo nauchno issledovakjelskovo instituta maslichnih kultur* 2: 159 – 160. (In Russian).

Malone J.P., Muskett A.E. 1997. Seed-borne fungi. Description of 77 fungus species. 3rd edition, ISTA, Zürich, Switzerland. 191 pp. https://doi.org/10.1177/003072706500400609

Narayanasamy P. 2011. Microbial plant pathogens. Detection and disease diagnosis. Fungal pathogens. Volume 1. Springer 5 – 137. https://doi.org/10.1007/978-90-481-9735-4

Nozkova J., Pavelek M., Bjelková M., Brutch N., Tejklová E., Porokhovinova E., Brindz J. 2016. Descriptor list for flax *(Linums usitatissimum L.)*. Slovak University of Agriculture in Nitra. 102 pp.

Penaud A., Paumier D., Bamme B., Petiteau A., Héritier E., Suffert F., Valade R. 2017. Epidemiology of Pasmo and assessment of *Septoria linicola* resistance in French flax cultivars. In: *12th EFPP – 10th SFP Conference, 29 May – 2 June Malo-les-Bains*, France. https://www.researchgate.net/publication/317647361. [Accessed in 24.10.2022].

Saharan G., Mehta N., Sangwan M. 2005. Fungal Diseases of Linseed. Diseases of Oilseed Crops. Indus Publishing, Haryana. 176 – 201 pp.

Selyaninov G.L. 1928. About the agricultural evaluation of the climate. *Trudy GGO* 20: 177 – 185.

Skowera B., Jędrszczyk E., Kopcińska J., Ambroszczyk A.M., Kołton A. 2014. The effects of hydrothermal conditions during vegetation period on fruit quality of processing tomatoes. *Polish Journal of Environmental Studies* 23(1): 195 – 202.

Stafecka I., Grauda D., Stramkale V. 2019. The evaluation of disease resistance of flax genotypes in relation to environmental factors. *Zemdirbyste-Agriculture* 106(4): 367 – 376. https://10.13080/z-a.2019.106.047

Wang Y.F., Jankauskiene Z., Qiu C. S., Gruzdeviene E., Long S.H., Alexopoulou E., Guo Y., Szopa J., Hao D.M., Fernando A.L., Wang H. 2018. Fiber flax breeding in China and Europe. *Journal of Natural Fibers* 15(3): 309 – 324. https://doi.org/10.1080/15440478.2017.1325431

World Meteorological Organization (WMO) 2017. World meteorological organization guidelines on the calculation of climate normals. http://public.wmo.int/en/resources/meteoterm. [Accessed in 20.10.2022].

Xinwen L. 1997. Analysis of ecological adaptation of flax in dry and cool areas in China. *Proceedings of the flax and other bast plants symposium* 43 – 48.

Received: 29.10.2022.
Accepted 11.11.2022.