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EFFECT OF HUMIC-FULVIC COMPLEX ON FLAX FIBER AND SEED YIELD CHARACTERISTICS

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The aim of this research was to determine Humic-fulvic complex (HFC) efficacy in fiber flax cultivation of different fiber-type cultivars and to evaluate the quality of obtained products. The study of HS effect on fiber flax was carried out in the course of field experiments conducted in the Central Nonchernozem Zone of Russia (Moscow) in 2012–2014. The evaluated product (HFC) contained HS was used at $6{\cdot}10^{-2}$ g L^{-1} concentration, with 300 L $ha^{-1}$of spraying liquid in the BBCH 13 growth stage of flax and the second treatment was conducted two weeks later. Comparative analysis of the cellulose measurement in fiber, fat and protein content in different cultivars by near infrared spectroscopy, were conducted. The most beneficial effect of HFC was on fiber yield. The increase of fiber yield changed from 1.3 dt ha^{-1} (16.0%) to 2.7 dt ha^{-1} (28.1%). HFC application increased the protein content in the flax seeds by 9.8–12.9%, fat content in the seeds by 9,0–12.5%, cellulose content in fiber by 6.0%–7.6%, compared to control.

Key words: fiber flax, humic substances, cellulose, bio-stimulators, fiber, shive, near-infrared spectroscopy.

Fiber flax *(Linum Usitatissimum* L.) is the significant culture because of such unique properties as high hygienic and technical fiber internals, special chemical and medicinal oil internals. Flax raw materials are necessary for the defense complex, textile and chemical industries, the construction engineering sector and other sectors of the economy. Food and medical use of flax is rapidly developing trend in feedstock production technology as well as its processing [6, 23, 33, 43, 44].

Currently, the urgent problem is to increase the yield of flax and improve product quality. Fiber quality is determined by physical and chemical and mechanical properties: the yield of long and short fiber, shive content, flexibility, tensile strength, shrinkage after the heat treatment, air and vapor permeability, fiber content of cellulose, lignin, pectin, hemicellulose, nitrogenous compounds [2, 5, 38–41].

High quality flax fiber should contain more cellulose and less lignin, pectins. Flax fiber contains more than 30 chemical elements, which provide unique health and hygiene properties: high strength, ability to inhibit the harmful organisms, antimicrobial activity as well as high thermal conductivity, which is higher by 20–30% in comparison with cotton fiber, and high thermal resistance, so it is not hot or cold when wearing linen clothes. Linen yarn and fabrics are widely used in medicine [7, 12, 13, 19, 26].

Fiber flax cultivation areas in Russia are concentrated mainly in the Nonchernozem Zone and they are characterized by low soil fertility and unstable weather during growing season [42]. One of the ways of flax yield increasing and product quality improving is the use of highly effective plant growth regulators during the growing period. Nowadays environmentally friendly bio-stimulators isolated from natural raw materials are developed. These bio-products in combination with modern agricultural technologies can improve productivity and quality of the obtained products [1, 19, 30, 31, 36, 37].

Humic substances (HS), such as humic acid, fulvic acid, humin play an important role in soil fertility and plant nutrition. HS are obtained from a variety of materials such as compost, lignite, soil [16, 25]. Humic substances affect not only the plants, but also the soil, and processes occurring in it. HS accelerate the processes of nitrates formation, increase the mobility of soil phosphorus. Application of humates contributes to a significant increase in the total nitrogen and protein. Plants grown in soil containing sufficient amount of HS are less subjected to stresses, give higher yields, the quality of obtained products is considerably higher [4, 17, 28].

Numerous studies confirm the possibility of HS application as a bio-stimulants, plant protection under various abiotic stresses, which leads to increased productivity and quality of agricultural plants [11, 15, 35]. There are several ways to use humic substances: surface application directly to the soil, seed treatment before sowing, spraying of vegetating plants [17]. Meanwhile, a relatively small number of researches with HS have been conducted in Russia for fiber flax cultivation.

Material and methods

The goal of this research was to determine HS efficacy in fiber flax cultivation on different fiber-type cultivars and to evaluate the quality of obtained products.

HS for our research were isolated from humified plant raw materials (flax shive) using alkaline extraction method recommended by International Humic Substances Society (IHSS). To determine the composition of obtained extracts from humified shive (HFC) the FTIR, differential thermal and thermo-gravimetric analyses were carried out [7–10, 22]. The analysis of the HFC organic substance showed that concentration of humic acids was 5.3 g L^{-1} and fulvic acids – 0.7 g L^{-1}.

The study of HS effect on fiber flax cultivation was carried out in field experiments conducted in the Field Experimental Station of the Russian State Agrarian University in the Central Nonchernozem Zone of Russia (Moscow) in 2012–2014.

Previously a series of experiments in the laboratory of the Russian State Agrarian University were conducted in order to establish the optimal concentration of the HFC for plants [12, 13]. The Russian fiber flax cultivars Antey, TOST 5, Voskhod were used in our research. The soil of experimental plots belonged to sod-podzolic clay loam type, with humus content of 2.5–2.9 %, $pH_{Kcl.}$ – 5.6–5.8.

Crop management practices in flax cultivation included the following: tillage in the fall to 20–22 cm depth, spring harrowing, sowing cultivation. Sowing was performed each year by means of AMAZON D 9-30 drill, row spacing was 7.5 cm. Seeds were sowed approximately as deep as 2–3 cm at the rate of 24 million seeds per hectare. Sowing was carried out within the time periods recommended for the Central Nonchernozem Zone of Russia for the flax cultivation: 05.05.2012, 14.05.2013, 04.29.2014. Weeds were managed with post-emergent herbicide Kortes (a.i. chlorsulfuron, 5g ha^{-1}).

The evaluated product Humic-fulvic complex (HFC) contained HS and was used at $6 \cdot 10^{-2}$ g L^{-1} concentration, with 300 L ha^{-1} of spraying liquid in the BBCH 13 growth stage of flax and the second treatment was conducted two weeks later. The control plants were sprayed with clear water. Experimental plots were set in a manner of randomized block 20 m^2 with four replications. The area of harvested plots was 4 m^2.

Climatic conditions did not have a strong negative impact on the growth and development of flax during the growing seasons in 2012–2014. Hydrothermal index, which characterizes the degree of hydration of the growing season, was in 2012 – 1.4, 2013 – 1.1, 2014 – 1.05. Thus, 2012 refers to the sufficient moisture content, 2013 – slightly moistened, 2014 – moderately dry.

The plants were harvested at the BBCH 83 growth stage of flax (early yellow maturity). After harvesting determination of the yield structure was carried out. All data were analyzed with statistic program Statistica 6.1. LSD (0.05) were estimated for each treatment variant and used to prove significant mean difference.

The analysis of cellulose in flax fiber, protein and fat content in flax seed by Near Infrared Spectroscopy (NIS) were carried out as well. Model instrument SpectraStar XL 2500XL-R. Light source: halogen lamp pre-configured. The interval between the points of the spectrum – 1 nm. The number of points of the spectrum: 1820 Bandwidth: 10 +/– 0.3 nm. Photometric range: 3.0 Abs. Scan time: less than 0.8 seconds to scan. Analysis time: 10–60 seconds. Wavelength accuracy: less than 0.1 nm. Equipped with touch-screen operating system: Windows 7 software InfoStart to analyze the samples.

Nowadays the method is officially recognized by many countries for the analysis of grain, oil, feed, cotton, wool, synthetic fiber and other agricultural products. Special guidelines were developed for the use of infrared spectroscopy to determine the quality of agricultural products [3, 14, 20, 21, 24, 27].

Results and discussion

The application of HFC showed positive effect on the growth and development of fiber flax in the field experiments. The experiments were carried out in the Central Nonchernozem Zone of Russia (Moscow) in 2012–2014.

The highest flax yield was obtained using HFC at BBCH 13 growth stage on TOST 5 cultivar. The flax yield increased by 8.3 dt ha^{-1} (16.9%), fiber yield by 2.7 dt ha^{-1} (28.1%), seed yield by 0.9 dt ha^{-1} (15.3%), compared to the control treatment. The flax yield of the rest studied cultivars (Antey and Voskhod) grew by 14.5% and 14.0%, respectively, if compare with the control. The most beneficial effect of HFC revealed on fiber yield. The increase of fiber yield changed from 1.3 dt ha^{-1} (16.0%) to 1.9 dt ha^{-1} (20.7%) (Table 1).

Production quality is determined not only by the yield data, but also by the chemical composition. Currently there is a need to control the quality of the obtained products at various stages of manufacture. For this purpose method of near-infrared spectroscopy (NIR) was used in our research. It was established that the action of HFC changed the chemical composition of flax seeds, increased the protein content by 9.8–12.9%, fat by 9.0–12.5 %, compared to control (Table 2).

It was noted earlier that one reason of bio-stimulators positive effect on flax is their effect on the biosynthesis of cellulose, which results in the increasing cellulose concentration in fiber [34].

In our research HFC treatment led not only to an increase in the yield of fiber and seeds, but also to change the content of cellulose fiber. Cellulose content varied depending on the cultivar of fiber flax. Cultivar Toast 5 comprised the highest content of cellulose

T a b l e 1

Effects of HFC on fiber flax yield

Cultivar	Year	Treatment	Yield, dt ha^{-1}		
			Flax	Fiber	Seed
TOST 5	2012	control	48.5	9.5	5.9
		HFC	56.7	12.4	6.5
	2013	control	48.3	9.3	5.7
		HFC	55.4	11.8	6.6
	2014	control	50.3	10.0	6.2
		HFC	59.8	12.6	7.4
	average data	control	49.0	9.6	5.9
		HFC	57.3	12.3	6.8
Antey	2012	control	42.2	8.6	5.3
		HFC	48.1	9.6	6.1
	2013	control	39.6	7.0	4.6
		HFC	46.5	8.3	5.4
	2014	control	43.6	8.7	5.6
		HFC	50.2	10.2	6.9
	average data	control	42.2	8.1	5.2
		HFC	48.3	9.4	6.1
Voskhod	2012	control	45.9	9.2	5.9
		HFC	55.4	11.3	6.9
	2013	control	45.7	9.0	5.5
		HFC	49.5	10.5	6.5
	2014	control	49.7	9.3	6.0
		HFC	56.1	11.5	6.7
	average data	control	47.1	9.2	5.8
		HFC	53.7	11.1	6.7
LSD 0.05 A*			2.0	0.4	0.2
LSD 0.05 B**			1.9	0.3	0.2
LSD 0.05 C***			2.0	0.4	0.2
LSD 0.05 AB****			3.5	0.6	0.3
LSD 0.05 AC****			3.7	0.7	0.4
LSD 0.05 BC****			3.5	0.6	0.3

Note* LSD 0.05 A – Cultivar; LSD 0.05 B** – Year; C*** Treatment; LSD 0.05 AB, BC, AC**** – factor interaction (similarly in other tables).

T a b l e 2

Effect of HFC on chemical composition of flax seed

Cultivar	Year	Treatment	Fat	Protein
TOST 5	2012	control	34.2	16.5
		HFC	37.3	17.9
	2013	control	34.5	16.2
		HFC	37.5	18.0
	2014	control	34.8	16.4
		HFC	37.6	18.1
	average data	control	34.5	16.4
		HFC	37.6	18.0
Antey	2012	control	33.4	15.1
		HFC	37.5	17.0
	2013	control	33.6	15.1
		HFC	37.8	17.4
	2014	control	33.5	15.3
		HFC	37.7	17.3
	average data	control	33.5	15.3
		HFC	37.7	17.2
Voskhod	2012	control	34.1	16.2
		HFC	37.5	18.4
	2013	control	33.9	16.1
		HFC	37.8	18.5
	2014	control	34.2	16.5
		HFC	37.6	18.4
	average data	control	34.1	16.3
		HFC	37.6	18.4
LSD 0.05 A			1.5	0.6
LSD 0.05 B			1.5	0.7
LSD 0.05 C			1.6	0.7
LSD 0.05 AB			2.8	1.1
LSD 0.05 AC			3.1	1.2
LSD 0.05 BC			3.0	1.2

without treatments 74.7% and with the treatment it reached 80.1 %. Using HFC resulted in the increase of cellulose content by 6.0–7.6% (Table 3).

Table 3

Effect of HFC on cellulose content in flax fiber

Cultivar	Treatment	Year			Average data
		2012	2013	2014	
TOST 5	Control	74.3	74.5	75.2	74.7
	HFC	80.1	79.8	80.3	80.1
Antey	Control	72.1	72.6	73.5	72.7
	HFC	76.8	76.9	77.0	76.9
Voskhod	Control	77.1	72.5	74.2	74.6
	HFC	84.2	76.5	80.2	80.3
LSD 0.05 A		3.2	3.0	3.2	3.2
LSD 0.05 B		3.0	3.0	3.1	3.0
LSD 0.05 C		3.2	3.1	3.5	3.5
LSD 0.05 AB		5.9	5.8	5.9	5.9
LSD 0.05 AC		6.1	5.9	6.1	6.2
LSD 0.05 BC		6.0	6.0	6.1	6.1

The analysis of germination capacity of seeds obtained during the field experiments was carried out. It was found that the germination capacity of seeds without treatment were 95.1–96.6%, HFC treatment led to the growth of this value by 3.0–3.4%. The results of the analysis showed that seeds can be used for sowing in the field. Consequently, HFC has the positive effect not only on the yield of flax fiber, but also improves the quality of seeds (Table 4).

Thus, the HFC application evaluated in the experiments resulted in the significant yield increase of fiber and seeds. This increase is due to the positive effect of HFC application in the BBCH 13 growth stage of flax. Among the most investigated processes involving HS there are their ability to react with metal cations, and possibility to influence the root system of plants, which results in an increase of crop productivity [32, 45, 46]. According to Zandonadi et al. [48], HS act as auxin mimetics which stimulate root growth through the mechanism that stimulates activity of H^+-ATPase. Hormone-like activity of HS is associated with nitrogen-containing components exhibiting similar effect as auxin and polyamines [29, 47]. Hassanpanah [18] reports that spraying by HS under water deficit conditions increased tuber yield up to 11.01 ton ha^{-1}. Thereby, the action of HS is considered as antistress agent in water deficit regions. These data were confirmed by the results of our experiments performed in 2014 (moderately dry year), which had no negative impact on productivity and quality of flax yield.

Table 4

Effect of HFC on germination capacity of seeds

Cultivar	Treatment	Year			Average data
		2012	2013	2014	
TOST 5	Control	95.1	95.7	95.3	95.4
	HFC	98.3	98.5	98.6	98.5
Antey	Control	96.3	96.6	96.5	96.5
	HFC	98.9	99.2	99.0	99.0
Voskhod	Control	95.3	95.2	95.4	95.3
	HFC	98.8	98.7	98.7	98.7
LSD 0.05 A		4.5	4.3	4.5	4.6
LSD 0.05 B		4.6	4.5	4.6	4.6
LSD 0.05 C		4.6	4.5	4.5	4.7
LSD 0.05 AB		8.8	8.5	9.0	9.0
LSD 0.05 AC		9.0	8.2	8.7	9.0
LSD 0.05 BC		8.9	8.6	8.9	9.0

Ponazhev [34] reports that application of HS in herringbone phase provided an increase of productivity of flax fiber by 0.5–2.1 dt ha^{-1}, flax seeds – by 0.4–0.9 dt $ha^{-}1$. The difference in yields varied with cultivars. According to the results of our research the most responsive cultivar to HFC application was Toast 5. The flax yield increased by 8.3 dt ha^{-1} (16.9%), fiber yield – by 2.7 dt ha^{-1} (28.1%), seed yield – 0.9 dt ha^{-1} (15.3%), compared to control.

Currently, there are no data of HS effect on the composition of the flax fiber and seeds, but Kravets (2010) showed that HS treatment ("Gumostim" containing 1% of HS) of wheat resulted in the increase of wheat yield by 10%, protein content – by 1%, gluten content – by 3%. According to our data HFC application increased the protein content in the flax seeds by 9.8–12.9%, fat by 9.0–12.5 %, cellulose content in fiber by 6.0–7.6%, compared to control.

Conclusions

HFC are high-tech humic bioactive substances with the properties of a growth stimulant and an antistress agent. The application of this substance at the BBCH 13 flax growth stage provided considerable increase in the yield of fiber and seeds. Treatment of HFC increased the amount of cellulose in the fiber, fat and proteins in seeds, improved germination capacity. The HFC was produced by extraction from humified plant residues (flax shive). Thus, it is possible to develop low-waste technologies, based on the use of cellulose waste, generated and accumulated at the enterprises of agro-industrial complex.

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ВЛИЯНИЕ ГУМИНОВО-ФУЛЬВАТНОГО КОМПЛЕКСА НА УРОЖАЙНОСТЬ ЛЬНА-ДОЛГУНЦА И КАЧЕСТВО СЕМЯН

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Цель исследования заключалась в определение эффективности гуминово-фульватного комплекса (ГФК) при выращивании льна-долгунца разных сортов и оценке качества полученной продукции. Изучение влияния ГФК на растения льна-долгунца проводили в полевых экспериментах на Полевой опытной станции РГАУ-МСХА имени К.А. Тимирязева, расположенной в Центрально-черноземной зоне (Москва), в 2012–2014 гг. Препарат ГФК использовали в концентрации $6 \cdot 10^{-2}$ г/л с нормой расхода рабочей жидкости 300 л/га. Первую обработку проводили в фазу елочки (ВВСН 13), вторую спустя две недели. Сравнительный анализ определения целлюлозы в волокне, содержания жира и белка в семенах льна-долгунца различных сортов проводили с использованием метода ближней инфракрасной спектроскопии. Наибольшее влияние препарат ГФК оказал на урожайность волокна. Увеличение выхода *волокна изменялось от 1,3 ц/га (16,0%) до 2,7 ц/га (28,1%). Применение препарата ГФК способствовало повышению содержания белка в семенах льна на 9,8–12,9%, жира на 9,0–12,5%, целлюлозы в волокне на 6,0–7,6%, по сравнению с контролем.*

Ключевые слова: лен-долгунец, гуминовые вещества, целлюлоза, био-стимуляторы, костры, ближняя инфракрасная спектроскопия.

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