RESULTS OF RESEARCH ON FACTORS INTENSIFYING HEMP TRUST PREPARATION PROCESSES

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Abstract. The object of the research is technological processes, plant material (stems of industrial hemp), factors that intensify the processes of preparation of the trust. The influence of the stem mass, preliminary destruction of their outer shell by flattening or beating, periodic moistening of the stems every other day on the time of the pulp preparation and the quality of the fiber was systematically investigated. It has been established that the shortest time for preparing the trust is 35 days for flattened and moistened stems every other day at a stacking density of 1 kg·m^{-1}. The noted term is 20% less than with a stacking density of 2 and 3 kg·m^{-1}, 5.7% less than for stems laid out on a film with and without moistening every other day at a stacking density of 1 kg·m^{-1}, 31% less than for stems spread on the film at a density of 2 kg·m^{-1}, and 42.9% less for ones spread at a density of 3 kg·m^{-1}, by 31.4% less than for stems spread out on the rettery with a density of 1 kg·m^{-1}, and by 42.8% at densities of 2 and 3 kg·m^{-1}, respectively. The stem colour indicator, determined with the device during the laying period, changed from the initial value of 45.2 lux for a density of 1 kg·m^{-1}, density of 2 kg·m^{-1} – 45.4 lux, density of 3 kg·m^{-1} – 45.7 lux, to values of 21.2 lux, 21.6 and 21.8 lux at the time of raising the trust, respectively. It was established that the produced long fiber corresponded to the 2nd – 3rd grade according to the content of shive (1.2-1.6%), by the content of tow (1.8-2.5%) – 3rd – 4th grade, by the content of hurd (6.5-10.5%) 3rd – 4th grade, respectively. According to the index of breaking load (16.6-25.1 daN), the obtained long fiber corresponded to the 3rd-4th grade. The index of linear density of the produced long fiber in all options for the preparation of hemp trust exceeded the maximum permissible value of 50 Tex, which, along with the complex indicators, made it possible to classify the fiber as non-standard.

Keywords: technical hemp, harvesting technologies, trust, long fiber quality indicators.

Introduction

Among known hemp harvesting technologies, technologies with seed threshing by direct combining, separate harvesting technologies, and hemp harvesting technologies for the purpose of processing into the same type of fiber are better developed [1-3].

These technologies have certain advantages. However, none of them eliminates the movement of heavy harvesting and transport equipment in the field and the disadvantages caused by it. The energy intensity of harvesting and transportation costs, which make up the lion share of the costs of harvesting hemp, do not decrease.

It is well known that the unevenness of laying the trust in terms of the length and thickness of the tape is the main factor on which the output of the fiber depends in the process of preparing the trust. The unevenness of laying the trust is a function of the thickness of the spreading tape. Stretching of the stems, the terms of spreading and preparation of the trust have a significant influence on the quality of the fiber [1; 4].

Biological, chemical, and physico-chemical methods of preparing the trust are distinguished by the mechanisms of destruction of connections between fibers and tissues in stems [5].

Depending on the temperature of the water environment, cold-water (23-25 ºC) and warm-water (36 ± 2 ºC) irrigation are distinguished. The duration of soaking is from 2.5 to 14 days, depending on the temperature of the water environment [6; 7]. Disadvantages of this method of preparing trust include significant waste water consumption, the treatment of which requires additional capital investments, as well as high heat consumption for heating water.

Dew soaking is a variety of biological methods of preparing trust. According to this method, the collected stems are spread on hemp in a thin layer. In contrast to water irrigation, where the active substances are bacteria, with dew irrigation, the main pathogens are mold fungi. The duration of the dew wetting process, depending on the weather and climatic conditions, ranges from 25 to 40 days or more [8].

The chemical method of preparing trust includes the method of soaking the stems in an aqueous solution under the conditions of adding certain chemicals [7; 9]. Note that chemical reactions improve

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the quantitative and qualitative indicators of the fiber, increase the breaking load and flexibility of the fiber, which makes it possible to increase the percentage of the yield.

Disadvantages of the physico-chemical method include the nature of the acid-catalyzed hydrolysis reaction, the repeated use of washing liquid, which lead to the deterioration and loss of the technological and operational properties of the fiber [1; 6; 10; 12].

According to the results of many years of research and observations [1-4; 7], we note that the best technological and operational properties are the fibers obtained from the trust prepared by water soaking and steaming.

The research is aimed at increasing the efficiency of hemp cultivation by determining the influence of intensifying factors on the terms of preparation of hemp trust and changing the quality indicators of the obtained fiber.

To achieve the goal, the following tasks were solved:

- to determine the influence of the mass of the stem on the course of microbiological processes (the effect of a change in the mass of the stem per 1 m^2) – experiment 1;
- to determine the influence of the preliminary destruction of the outer shell of the stems (flattening) and the change in their mass per 1 m^2 on the duration of laying of the trust and fiber quality indicators – experiment 2;
- to determine the effect of the destruction of the stem by reflection and changes in the mass of the stem per 1 m^2 on the duration of laying and fiber quality indicators – experiment 3.

Materials and methods

The factors studied in experiments 1-3 were: the variable mass of stems per 1 m^2 of laying and the type of destruction of stems, i.e. the type of preparatory operation.

Experiments 1-3 provided for the following research program:

- spreading a strip of stems weighing 1 kg in one stem on the ground (control type of experiment);
- spreading 1 kg of hemp one stem thick with moistening after 1 day;
- spreading 2 kg of hemp in a strip two stems thick;
- spreading 3 kg of hemp in a strip three stems thick.

The research program of flattened and beaten stems is matched with the above.

Sampling and determination of stem characteristics was carried out simultaneously for all experiments.

The stems were spread over the polyethylene film 1.5 m wide (Fig. 1). Control spreading of raw materials was done on the ground.

Fig. 1. **Preparation of trust from hemp stalks spread on film**

The research program provided for determination of the following parameters: characteristics of the hemp crops; characteristics of hemp trust; qualitative indicators of the obtained fiber; duration of layover; colour change during the aging process.

The evaluation of the quality indicators of hemp trust was carried out according to GOST 27345-87 "Hemp trust".

Results and discussion

Analyzing the results of the research, we note that the average weight of a bundle of stems from 1 m^2 was 1201.7 g, with the largest value being 1480 g and the smallest being 1040 g. Therefore, the largest value of the sheaf mass exceeded the average value by 23%, and the smallest was 14.5% less. The average stem weight of a bundle weighing 1480 g was 44.85 g, for a bundle weighing 1040 g it was 54.74 g, for a bundle weighing 1085 g it was 72.33 g.

The deviation of the values from the average was: for the largest value – 32%, for the smallest – (-18%). Under such conditions, the average value of the seed weight from one sheaf was: for the first bundle – 7.27 g; the second bundle – 9.79 g; the third bundle – 14.67 g; the average value is 9.79 g.

The average value of the length of stems in the average bundle is 6% less than the largest, and 7.8% more than the smallest value. The average value of the stem diameter of 7.5 mm is 6.7% less than the largest and 4% more than the smallest.

Analyzing the results of the research, we note that the average weight of a bundle of stems per 1 m^2 was 1201.7 g, the largest value was 1480 g, the smallest was 1040 g. Therefore, the largest value of the mass of the bundle exceeded the average value by 23%, and the smallest value was 14.5% less. The average mass of the stem of a bundle weighing 1480 g was 44.85 g, a bundle weighing 1040 g – 54.74 g, a bundle weighing 1085 g – 72.33 g. The weight of the stem in the average bundle was 54.62 g.

We note that an increase in the number of stems per 1 m^2 led to a natural decrease in their average diameters, length, average weight of stems, average weight of seeds per stem.

After threshing the sheaves on the MLK-4.5 hemp thresher, the average value of the number of stalks in the sheaf was 82 for the mass of one stalk of 24.7 g. Comparing the characteristics of the stem of hemp before harvesting and before spreading after threshing the sheaves, the following was noted: – the average value of the weight of one stem for the period that passed after harvesting compared to the period immediately after threshing decreased by 2.2 times, the average value of the length of the stems increased by 3.4%, and the average diameter by 5.3%.

Spreading of the stems on the stem took place at the same time.

Analyzing the results of the control version of the research, it was noted that the shortest laying period was established in the version with a density of stems of 1 $kg{\cdot}m^{-1}$ (45 days), which is 8.7% less for 4 days than in the variants with a stacking density of 2 and 3 $kg{\cdot}m^{-1}$ (50 days) (Table 1).

The rising of the experimental trust with a stacking density of 1 $kg{\cdot}m^{-1}$ took place on the 37th day.

Table 1

Results of determining hemp trust preparation terms based on stem spreading method

No.	Spreading variant	Preparation time, days		
		Density 1 $kg{\cdot}m^{-1}$	Density 2 $kg{\cdot}m^{-1}$	Density 3 $kg{\cdot}m^{-1}$
1	Spreading on the rettery	46	50	50
2	Spreading on the film	37	46	50
2.1.1	Spreading on the film, moistening every other day	37	-	-
3	Spreading flattened stems on the film	35	42	42
3.1.1	Spreading on the film, moistening every other day	35	-	-
4	Spreading on the film, moistening after washing	35	42	42
4.1.1	Spreading on the film, moistening every other day	35	-	-

An almost complete coincidence of the results of studies with stacking on the ceiling of stems with a density of 1 $kg{\cdot}m^{-1}$ under natural moistening was noted with a similar experiment under the conditions of stacking on a film and moistening after a day.

Lifting of the trust in the experiment of stacking stems with a density of 2 $kg{\cdot}m^{-1}$ on the film took place in 46 days, with a stacking density of 3 $kg{\cdot}m^{-1}$ – 50 days.

Analyzing the research results, we note (Table 1):

- separation of fibers from the wood is present on most of the stems on the 35th day in the experiment with flattened stems spread on a film with a density of 1 $kg{\cdot}m^{-1}$ (the stem colour indicator according to the device was 20.0 lux);
- for the same period of trust preparation (35 days), according to the indicator of fiber separation from wood, the experiment with stems flattened and spread on a polyethylene film with a

density of 1 kg·m^{-1} was characterized by better indicators (separation was present on rather most than individual stems) than in the experiment, where the flattened stems were spread on the film;

- trust raising of the flattened stems spread on the film with a density of 1 kg·m^{-1} occurred on the 35th day of maturing, which is 7 days (by 20%) less than for the stacking density of 2 kg·m^{-1} and 3 kg·m^{-1}.

Comparing the results of trust preparation from stalks spread on a film with different densities after moistening, we noted the following:

- raising of the stem trust with a density of 1 kg·m^{-1} took place on the 35th day, which is 7 days less than with a density of 2 kg·m^{-1} and 3 kg·m^{-1};
- the stem colour indicator measured by the device changed during the maturing period from the initial value of 45.2 lux for a density of 1 kg·m^{-1}, 45.4 lux for a density of 2 kg·m^{-1}, 45.7 lux for a density of 3 kg·m^{-1}, to values of 21,2 lux, 21.6 and 21.8 lux at the time of raising the trust, respectively;
- separation of the fiber from the wood is established on most stems at stacking densities of 1 kg·m^{-1} and 2 kg·m^{-1} and at a density of 3 kg·m^{-1} - on a significant part of the stems.

In all variants of the experiments, the flip of the films was carried out on the 29th day of maturing under conditions of the upper layers darkening.

The color of the stems, determined organoleptically and by the instrument according to the intensity of the reflected light flux from the examined surface (lux), as well as the separation of the fiber from the wood by the organoleptic assessment, was adopted as the criterion for determining the maturity of the hemp plant in all variants of the conducted research.

The fiber output from the combed stalks was relatively uniform. The highest value of 21% is set at a stacking density of 1 kg·m^{-1} (Fig. 2).

Based on the results of the research, regression equations were established that describe the relationship between the density of stacking of stems and the index of fiber yield from the trust, obtained under the conditions of spreading stems:

- on the ceiling (control experiment)

$$y = 15.5 \cdot 10^{-4} x + 22.07, \quad (1)$$

- on a polyethylene film

$$y = -10.5 \cdot 10^{-4} x + 26.33, \quad (2)$$

- spreading flattened stems on a polyethylene film

$$y = 8.5 \cdot 10^{-4} x + 21.68, \quad (3)$$

- spreading stems after passing them on a polyethylene film

$$y = -3.5 \cdot 10^{-4} x + 21.36. \quad (4)$$

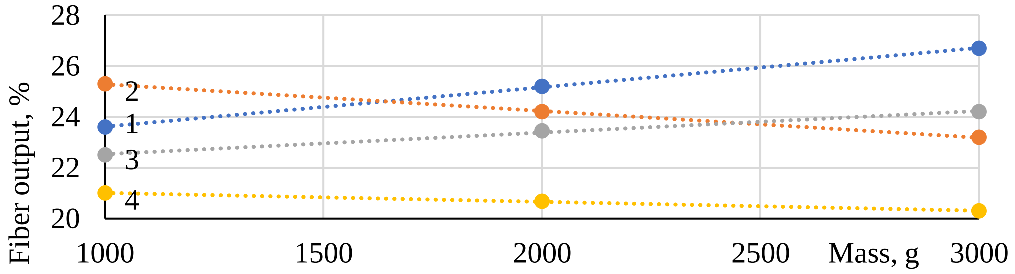

Fig. 2. **Dependence of percentage of the fiber yield on the density of spreading stems:**
1 – spreading stems on the rettery (control experiment); 2 – spreading stems on a polyethylene film; 3 – spreading flattened stems on a polyethylene film; 4 – spreading stems after passing them on a polyethylene film

The results of mathematical processing of the experimental data are shown in Table 2.

Table 2

Results of mathematical processing of experimental data

Number	R^2	Significance F	P-value (Intercept)	P-value (X)
1	0.99965326	0.011855165	0.001799099	0.011855
2	0.99924471	0.017498097	0.001507600	0.017498
3	0.99540758	0.043175166	0.003661778	0.043175
4	0.99755700	0.043175166	0.001115174	0.031479

In the control experiment, the highest fiber output at the level of 26.8% was established under the conditions of spreading stems with a density of 3 kg·m^{-1}. This indicator almost coincided with the values of the fiber output of the experiment with spreading stems with a density of 2 kg·m^{-1}, however, it was 13.5% higher than the fiber output of stems with a stacking density of 1 kg·m^{-1}.

In the experiment with spreading on the film, the highest fiber output was determined when stacking stems with a density of 1 kg·m^{-1}, which is 11% more than with a stacking density of 2 kg·m^{-1} and by 10.9% at a density of 3 kg·m^{-1}.

The highest fiber yield at the level of 26.8% of flattened stems was established at a stacking density of 2 kg·m^{-1}, which is 11.9% more than at a density of 1 kg·m^{-1} and by 11% at a density of 3 kg·m^{-1}.

The fiber output from the combed stalks was relatively uniform. The highest value of 21% is set at a stacking density of 1 kg·m^{-1}.

In the experiment with irrigation through a chisel, the highest fiber output at the level of 24.5% was found for stems spread on the film, which is 7% more than flattened and 14% more than beaten stalks.

It should be noted that flattening and combing the stems did not lead to an increase in the fiber output.

Analyzing the indicators of the quality of long hemp fiber, we note that according to the index of breaking load, the broken stems had the best indicators of 16.6 daN with a density of 3 kg·m^{-1}, and the highest value of 23.9 daN was noted in flattened stems with hydration every other day. According to the indicator of linear fiber density, all experiments were classified as non-standard.

The article presents the research results on trust preparation from stems grown at a seed sowing rate of about 15 kg·ha^{-1}. Note that fiber quality indicators are largely determined by crop cultivation technologies. The norms of hemp sowing have a special influence. At the seed sowing rate of about 15 kg·ha^{-1}, the seed vector of production is clearly visible, that is, the farmer's efforts to obtain high-quality seeds. Under the conditions of the indicated production directions, hemp crops are characterized by stems of a large diameter. Harvesting of the seed part of the specified stems is carried out by grain harvesters. The stem part is processed into trust in the autumn or spring. However, the short fiber from such a trust is coarse (linear density is more than 50 Tex), which makes it non-standard. To obtain a thin fiber, the linear density of which is less than 50 Tex, sowing rates are applied at the level of 50-70 kg·ha^{-1}, with the possibility of harvesting the green phase of hemp for fiber.

That is why the substantiation of the factors intensifying the processes of hemp trust preparation is an urgent scientific and practical problem, the solution of which will make it possible to significantly increase the efficiency of hemp farming.

Conclusions

1. In the development of the harvesting technological systems of monoecious drug-free forms of industrial hemp by tape storage, the influence of factors intensifying the processes of trust preparation was systematically investigated. The noted factors include: the stem mass, preliminary destruction of their outer shell by flattening or breaking, and periodic moistening of the stems every other day.
2. The shortest period of trust preparation is set for 35 days of maturing flattened and moistened stems every other day at a density of 1 kg·m^{-1}. The observed term is 20% less than at stacking densities of 2 and 3 kg·m^{-1}, 5.7% less than for stems spread on the film only and spread on the film with moistening every other day at a density of 1 kg·m^{-1}, 31% less than for stems spread on the film at a

density of 2 kg·m^{-1} and by 42.9% less at a density of 3 kg·m^{-1}, by 31.4% less for stems spread on the rettery with a density of 1 kg·m^{-1}, by 42.8% at densities of 2 and 3 kg·m^{-1}, respectively.

3. The stem colour indicator, determined by the device, during the maturing period changed from the initial value of 45.2 lux for a density of 1 kg·m^{-1}, 45.4 lux for a density of 2 kg·m^{-1}, 45.7 lux for a density of 3 kg·m^{-1}, to values of 21.2 lux, 21.6, and 21.8 lux at the time of raising the trust, respectively.
4. It was established that the produced long fiber corresponded to the 2nd - 3rd grade by the content of the shive (1.2-1.6%), the 3rd - 4th grade by the content of the tow (1.8-2.5%), and by hurd content (6.5-10.5%) it corresponded to the 3rd - 4th grade, respectively. According to the index of breaking load (16.6-25.1 daN), the obtained long fiber corresponded to the 3rd-4th grade.
5. The indicator of the linear density of the produced long fiber in all options for the preparation of hemp trust exceeded the maximum permissible value of 50 Tex, which, along with the complex indicators, made it possible to attribute the fiber to a non-standard category.

Conflict of interest

The authors declare that they have no conflict of interest in this research, including financial, personal, authorship, or any other nature that could affect the research and its results presented in this paper.

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Author contributions

Conceptualization, methodology – V. S., S. K., Y. S.; software – V. S., S. K., O. H., Y. S., D. S.; validation – V. S., O. H., Y. S., D. S.; formal analysis – V. S., O. H., Y. S., D. S.; investigation – V. S., O. H., Y. S., D. S.; data curation – V. S., S. K., O. H.; writing–original draft preparation – V. S., Y. S.; writing–review and editing – V. S., O. H., Y. S.; visualization – V. S., S. K., O. H., Y. S., D.S.; project administration – V. S., O. H. All authors have read and agreed to the published version of the manuscript.

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