INVESTIGATIONS INTO LOSSES OF BIOLOGICAL MASS AND QUALITY DURING HARVEST OF INDUSTRIAL HEMP

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Abstract. The interest in the possibilities of growing industrial hemp (Cannabis sativa L.) in Latvia is increasing from year to year. It is considered as one of the most promising renewable sources of biomass replacing the non-renewable natural resources used for the manufacturing of a wide range of industrial products. The aim of the work – to carry out an analysis of the potential shortage of the yield and the technological losses of the biological mass and quality of hemp during its harvesting, to determine the impact upon its individual factors and work out recommendations how to lessen them under the conditions of Latvia. The reason for the basic losses of the quality of retted stems of hemp is absence of or non-quality operations of raking and turning of the stalks in the swath during their biological retting, and delayed harvesting by pickup balers.

Keywords: industrial hemp, harvesting, technological variants, losses.

Introduction

Active expansion of the areas under industrial hemp is going on in the world during the last 20-25 years. In Latvia cultivation of this crop started in 2009. Now an association of the hemp producers has been founded, optimal technology of its growing and harvesting is being sought; new innovative technologies are being developed for the use of the raw materials extending the range of their application. By tradition the fibre of industrial hemp is used in textile industry but its seeds are a primary material for oils and medicines. One of the new perspective directions in the application of the biological mass of hemp may be the production of building and insulation slabs. In 2015 an EU regulation will come into force providing that in automobile industry at least 95 % of the renewable or recyclable raw materials must be attained. The Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing the Directives 2001/77/EC and 2003/30/EC) provides that the synthetic materials should be replaced by the natural or renewable ones [1; 2].

The harvesting technology of industrial hemp is selected considering a circumstance which will be the main product in the process of further recycling. After several technological variants of harvesting are tested, only one component of the biological mass is chosen and used for further recycling (i.e., either only stalks or only seeds), or various combinations of harvesting one component and partially the other. All biological mass is gathered either by specialised combine harvesters (when this variant is carried out, the seeds, as a rule, have reached the maturity not more than 40-50 %) or by silage harvesting combines (however, in this variant the seeds have not yet started to form even blossom clusters). Reduction of losses during the harvest season will allow raising the production efficiency of this crop [3].

The object and method

The aim of the work – to carry out an analysis of the potential shortage of the yield and the technological losses of the biological mass and quality of hemp during its harvesting, to determine the impact upon its individual factors and work out recommendations how to lessen them under the conditions of Latvia.

The operational-technological indicators were determined according to the existing as well as an original methodology for the determination of the losses and qualities in the experiments of flax and other fibrous crops [4]. Economic testing and field experiments took place on “Markos” farm in Piedruja municipality, Kraslava Region. The harvest of hemp proceeded in such times: most of the hemp areas – 90 % were cut on August 29. The seedy part was gathered in on October 12-14; gathering of the stalks took place in spring – on May 7 but in autumn – on November 1 and 2. The yield of the stalky part on industrial fields was within the range from 30 to 38 $t \cdot ha^{-1}$.

There are several technological variants of harvesting hemp. The schemes of two variants widely spread in Latvia are shown in Fig. 1 and 2.

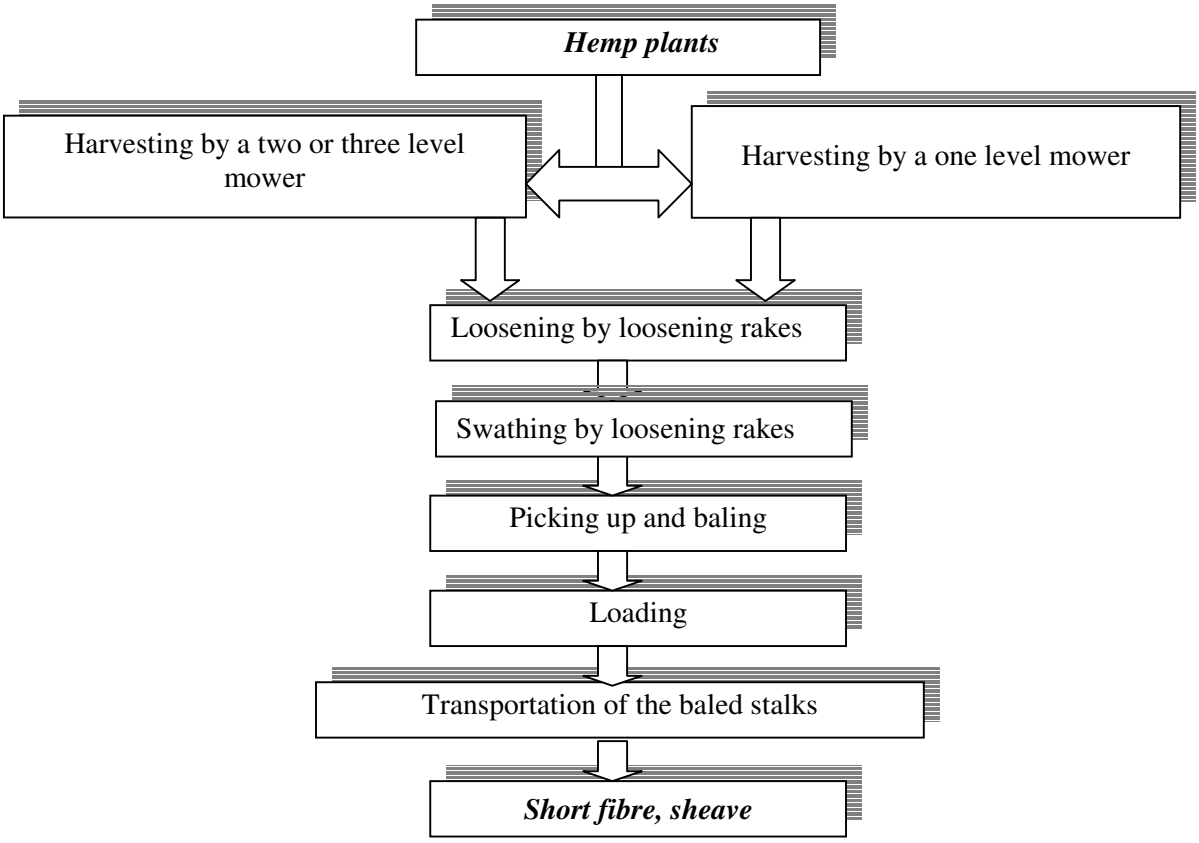

Fig. 1. **A1 variants of harvesting hemp without threshing of seeds**

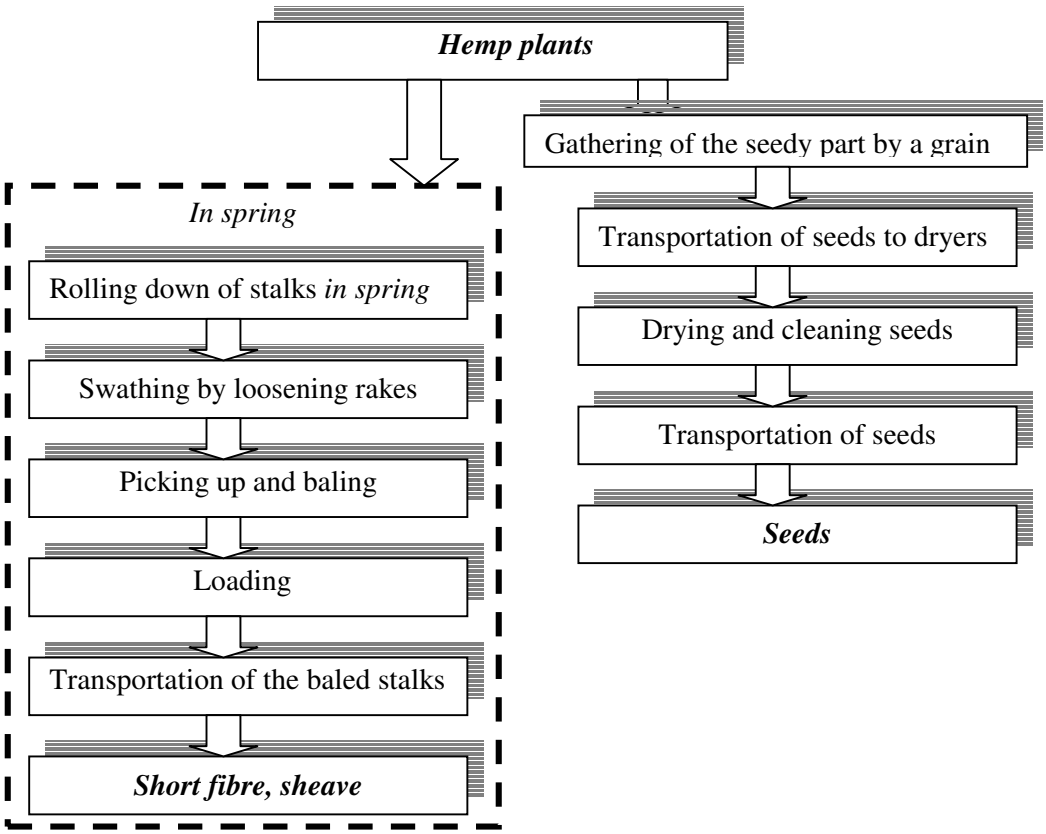

Fig. 2. **B1 variants of harvesting the seedy part in autumn and the stalky part in spring**

Results and discussion

As evident from the schemes, in some technological variants the final products are the stalky mass and seeds but in some other variants only one of the products, the other making losses. No doubt, there are losses of the biological mass or quality, to a certain extent, in all the variants and in all the technological operations. Therefore, we will try to distinguish the most essential losses and analyse the impact upon them from individual factors.

In some technological variants of hemp harvesting (for instance, variant A1, Fig. 1) the stalks are cut by movers, and then further operation is carried out in order to prepare them for realisation. In this case the seedy part is not gathered at all, or gathered according to the so-called two-stage partial (selective) technology of harvesting. In a two-stage harvesting technology the seeds of hemp become ripe in the cut swathe during one or two weeks, then they are threshed by the grain combine harvesters. During the cutting operation the losses of the stalky mass due to the stalks left in the stubble depend on the height of cutting. The height of cutting is determined by the design peculiarities of the mower, the preset parameters and the speed of work. In the investigations in order to find out the efficiency and ability to cut the stalks of hemp conducted in the year 2013 the trailed segment-finger mower TEBECO Beagle 3.2. (the operating width 3.2 m) and the mounted duplex mower KD-210 (the operation with 2.1 m) showed the best indicators of operation. The average cutting height of the mower TEBECO Beagle 3.2. was 18 cm and the cutting height of the mower KD-210 was 7 cm. At an average technical length of hemp 2.2 m this means a value of losses of the stalky mass accordingly 8.2 % and 3.2 %. In this case the height of the stubble and, hence, the corresponding values of losses depend on the design peculiarities of the header flotation units and the operating width of the mowers. Under real conditions, when working with a great operating width at a high speed on uneven microrelief, it is necessary to have greater cutting height of the stalks (to avoid striking the projections of the soil with the cutting apparatus).

In the springtime harvesting of the hemp stalks, using the technological variant of rolling down the standing stalks [3-5], the losses of the stalky mass in the form of stubble are practically zero, (because the stalks are broken at the contact place with the soil). However, in contrast to the autumn harvest, here will be considerable losses of quality, i.e., the fibre from the harvested retted stems in this variant is at least by 20-25 % less durable and, correspondingly, it has a lower selling price after its preliminary processing.

In Latvia a technological hemp harvesting variant (variant B1, Fig. 2) is sometimes applied in which the upper part of the stalks is cut by the combine harvester with its subsequent threshing. In this variant the lower part is left on the field to obtain retted stems afterwards but the upper part, after separation of the seeds, turns into waste. The losses of the upper part of the stalky mass during its cutting and threshing the seeds by means of the grain combine harvesters depend on the maximum height possible of the cutting apparatus of the header. This height on the common brands of the grain combine harvesters (without their updating) is 0.9-1.2 m [6]. At the technical length of hemp 2.2 m this means losses 59.1 % and 45.5 %. Increasing the cutting height by 0.3 m reduces the losses by 13.6 %, therefore, it is important to use combine harvesters with great cutting height. It is technically possible to improve the raising mechanism of the header of some grain combine harvesters ensuring the maximum cutting height of 1.5 m.

The losses of the stalky mass when a pickup baler is used may arise because the width of the swath is much wider than the operating with of the pickup baler. Considering the great length of the stalks and their chaotic position, in order to ensure that the allowed value of the losses is less than 1 %, the width of the swath may be up to 0.25-0.35 m greater than the operating width of the pickup baler. To reduce the moisture of the stalks, swathing of the stalks with obligatory transfer of the mass to a new place is necessary before baling. This ensures drying of the lower stalks which had been in contact with the soil before. If the stalks are swathed before baling and the rotary rakes work without a lateral limiting shield, the deviation from the average width of the swath (the variation coefficient) is 28 % but with a limiting shield it is considerably lower – 11 %.

The losses of the hemp wood when baling (due to shedding of the chaff while the dry stalks are turned into a round bale) are particularly great in the springtime harvesting when the fibre separates

very well from the dry wooden part (and, to a great extent, does not cling to the stalk at all). The losses of the hemp wood in the springtime baling constitute 12-23 %, in autumn – not more than 3 %.

The risk to lose the quality of the fibres, because there are no processing operations or they are not sufficient while processing the stalks during their maturing, is particularly high in rainy weather and at the mean daily temperature below 6-7 ºC, which is typical of Latvia in September and October. At the temperature 6-7 ºC the field-retting process of hemp continues for 45-50 days but at the temperature below 5 ºC – is stopped completely. If the yield of the mass is high, the lower stalks in the swath being in prolonged contact with the moist soil do not aerate and start rotting. Besides, the stalks inside the swath remain green, and the maturing processes in them continue much more slowly than in the upper layer. For this purpose the stalks during their maturing process must be turned. Complete turning of the swath of stalks (like flax) can be carried out only when the stalks are oriented in a transverse direction. Such a position of the stalks, after their cutting, is ensured only by combine harvesters (mowers) with a special spreading table used in a harvesting technology with an aim to obtain long fibres [6]. In Latvia such a technology is not for the time being applied. When harvesting with an aim to produce short fibres, a more efficient and simpler technology is used in which the maturing stalks in the swath are placed in a chaotic manner. Therefore, the only way how to treat such a swath is raking with partial turning. Depending on the weather conditions and temperature during the maturing process it is necessary to use from 1 to 3 such treatments. If the raking operation is not practised, then, depending on the weather conditions, the losses of the quality of the retted stems of hemp may be very great, reaching 40-60 %. In the experiments with the stalks left in the swath after cutting for 35 days without a treatment (raking) three different layers appear distinctly on the stalks. In the upper layer the stalks were in a normal condition (the fibre in the stalks separated well from the wooden part) and were ready for harvesting; in the medium layer 75-80 % of the stalks had a greenish shade and the fibre separated badly; and in the lower layer contacting with the soil 23-30 % of the stalks were affected by mould and had a corresponding typical colour. For this reason, to ensure complete aging of all the three layers of the retted stems, almost a twice as long time interval (49 days) was needed; besides the average tensile strength of the fibre was 1.58 times lower than in the variant with raking of the swath. In addition to this, the ripeness time of the stalks for baling had shifted to a season of extremely unfavourable weather conditions of late rainy autumn.

A risk to lose the quality of the fibres because of the low efficiency of the pickups is possible in short periods of dry sunny weather (the next favourable period sometimes sets in only after 10-15 and more days). In this case the loss of the optimal harvesting time means a loss of the quality of the retted stems. Emphasis exactly on the stalk pick up operation is made because the efficiency of the pickup baler working in the harvest of the hemp stalks is considerably lower than in the harvest of the forage grass, which can mainly be explained by comparatively lesser density of the mass in the swath. Due to the great volume of the swath one is forced to work at a low operating speed so that the pickup baler could manage to transfer the entire mass to the baling chamber. In case the operating speed is not lowered, a moment sets in when the mass accumulates in front of the pickup baler leading to a forced technological standstill. The results of the research how the height of the swath affects the efficiency of baling are shown in Fig.3. In the experiments the mass of a swath one meter long was the same, only its height and density were different. We have proposed a method how to increase the efficiency of the pickup baler at the expense of preliminary compaction of the swath of the hemp stalks. The average height of the swath in the conducted experiments in the ordinary variant was 64 cm but in the experimental variant with a special roll a 35 cm height of the swath was ensured [5]. Under practical conditions, in an experimental variant with the application of a special roll, the efficiency of baling increased by 65-76 % in contrast to the common variant, which was particularly valuable in late autumn with its short-term rainless periods.

When the seedy part of hemp is harvested according to scheme B1 (Fig. 2) a part of stalks which appear in a zone under the wheels of a combine harvester are pressed into the soil by the wheels and are lost. In this case the percentage of the losses can be characterised a percentage ratio of the width of the pass of the combine wheels and the width of the combine header. The rear wheels of the combine harvester follow the trail of the front wheels, therefore they with can be neglected. The losses of the hemp stalks caused by the wheels of the combine harvester depending on the width of the header are shown in Fig.4. The combine harvesters with wider headers have wider tires; therefore the dependency

of the percentage value of losses is not directly proportional. When the operating width of the combine header is increased, the losses diminish from 30 % to 22 %.

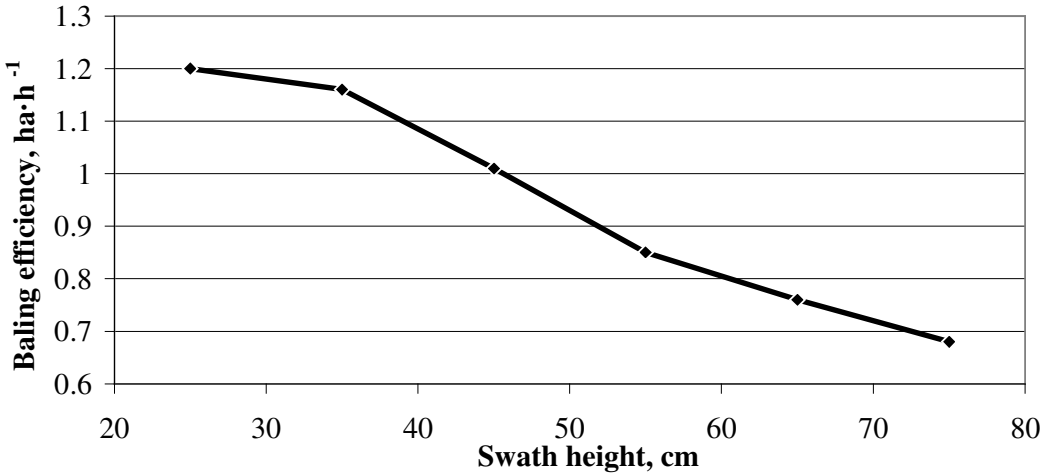

Fig.3. **Baling efficiency depending on the height of the shaft**

In such a way the total losses of the stalky mass harvested according to the technological variant reflected in Fig. 2 will constitute about 70 % (the upper part of the stalks passing through the threshing apparatus and the losses caused by the wheels). The extent of these losses depends mainly on the height at which the header is set, the technical length of the stalks and the width of the combine header.

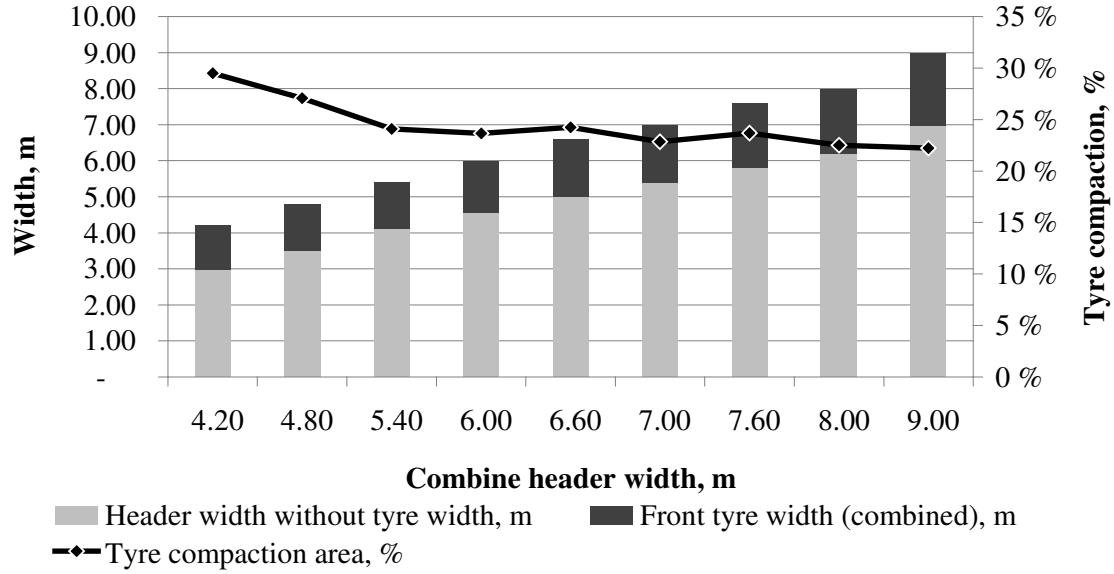

Fig.4. **Losses of the stalks of hemp depending on the width of the combine tires**

The losses of seeds when they fall down under the coercion of the header of the combine harvester and in delayed harvesting. The main reason of these losses is delayed harvesting. Under the weather conditions of Latvia the hemp seeds are ripe only in late autumn – the second half of September and in October. The male plants of hemp (fimble) and the female hemp plants become ripe in different times. The male plants of hemp reach maturity 40-45 days earlier than the female hemp plants. The average yield of hemp is 600-900 kg·ha^{-1} of seeds. It is known from literary sources and the research results that in Latvia the seedy part of hemp has to be gathered in before their 100 % maturity sets in. Otherwise under the coercion of the header of the combine harvester a great deal of the ripe seeds fall out; besides the hemp seeds is a favourite food for wild birds which seriously endanger the yield, particularly on small fields. In order to avoid great losses of the hemp seeds during the harvest by the grain combine harvesters, this operation has to be executed before 95 % of the seeds have reached the stage of complete maturity. In Latvia investigations witness that delayed harvest of the yield leads to considerable losses – up to 60-75 % of the seeds.

The losses of seeds when they are threshed by the threshing unit of the combine harvester (seed spillage, insufficient threshing, etc.) have rather a constant value, and, depending on the brand of the combine harvester, they constitute 2-4 % [6].

It is only natural that the economic evaluation of the losses will depend on the actual price of the product in the region. In 2013 the prices in Latvia, depending on the quality, were the following: the hemp seeds – 500-1200 EUR·t^{-1}, the stalks (retted stems) – 70-140 EUR·t^{-1}, the short fibre – 400-1000 EUR·t^{-1}, the sheave ("hurds", hemp wood) – 90-450 EUR·t^{-1}, the hemp tow up to 450 EUR·t^{-1}.

The direct products harvested from the field are hemp seeds and aged retted stems but the products of preliminary processing are the short fibre, sheave and the hemp tow. As it is evident, the prices depending on the quality of the retted stems may differ two times. However, even for the lower range the prices of retted stems should correspond to rather strict quality requirements (ability to separate retted stems and the tensile strength of the fibres). Considering the price of the product, it is possible to calculate the financial extent of losses of the biological mass or the quality of hemp [7].

Conclusions

1. The losses of the stalky mass in the form of stubble while cutting constitute 3-8 %.
2. When the variant B1 is used (harvesting of the seedy part by grain combine harvesters and subsequent retting of the remaining part of the stems in spring), the total losses of the stalky mass constitute approximately 70 %. The extent of these losses depends mainly on the height at which the combine header is set, the technical length of the stalks and the width of the combine header.
3. The reason for the basic losses of the quality of retted stems of hemp is absence of or non-quality operations of raking and turning of the stalks in the swath during their biological retting, and delayed harvesting by pickup balers.
4. The losses of the hemp wood while baling the retted stems in the summer season are 12-23 %, in autumn – not more than 3 %.
5. In order to avoid great losses of the hemp seeds during the harvest by the grain combine harvesters, this operation has to be executed before 95 % of the seeds have reached the stage of complete maturity.

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