MANAGEMENT PRACTICES IN INDUSTRIAL HEMP HARVESTING AND STORAGE
/
PRACTICI DE MANAGEMENT ÎN RECOLTAREA ŞI DEPOZITAREA CÂNEPEI INDUSTRIALE

Dragoș MANEA, Gheorghe STROESCU, Lucreţia POPA*), Alexandru IONESCU, Alexandru ZAICA
National Institute of Research-Development for Machines and Installations designed for Agriculture and Food Industry – INMA / Bucharest, Romania
Tel: 021/269.32.50; Fax: 021/269.32.73; E-mail: manea_dragos_05@yahoo.com
DOI : https://doi.org/10.35633/inmateh-69-49

Keywords: *stalks, harvest, equipment, quality indices.*

ABSTRACT
This paper presents the results obtained by INMA Bucharest, following a research project, in which a technology for harvesting and storing industrial hemp was developed. The equipment for harvesting green hemp stalks intended for this technology was tested in an experimental plot grown with Dacia - Secuieni hemp. Operating indices (actual torque at the power take-off, traction force at drawbar, total effective power to operate the equipment, working speed, effective working capacity) and working qualitative indices (stalk cutting height at lower knife and upper knife, degree of stalk cutting, stalk diameter, the average length of the stalk cut without inflorescence). As a result of the analysis of the values obtained for the operating indices and qualitative working indices, a series of pertinent conclusions and observations resulted, which will help guide harvesting and storage practices to ensure quality requirements for hemp fibre production are met.

REZUMAT
Această lucrare prezintă rezultatele obținute de INMA București, în urma derulării unui proiect de cercetare, în care s-a elaborat o tehnologie de recoltare și depozitare a cânepii industriale. Echipamentul pentru recoltarea tulpinilor de cânepă în verde destinat acestei tehnologii a fost testat într-un lot experimental cultivat cu varietatea de cânepă Dacia - Secuieni. Au fost determinați indicii de operare (momentul real la priza de putere, forța de tracțiune la bara de cuplare, puterea efectivă totală, viteza de lucru, capacitatea efectivă de lucru) și indicii calitativi de lucru (înălțimea de tăiere a tulpinilor la cuțitul inferior și la cuțitul superior, gradul de tăiere a tulpinilor, diametrul tulpinilor, lungimea medie de tăiere a tulpinilor fără inflorescență). În urma analizei valorilor obținute pentru indicii de operare și indicii calitativi de lucru au rezultat o serie de concluzii și observații pertinente, care vor ajuta la ghidarea practicilor de recoltare și depozitare, pentru a asigura satisfacerea cerințelor de calitate pentru producția de fibre de cânepă.

INTRODUCTION

Industrial hemp (*Cannabis sativa L.*) is a crop that provides raw material for the pharmaceutical industry, the industry of concentrates necessary for animal nutrition and last but not least it is used as biomass (obtaining fibres for the textile industry), under development in Romania. Hemp is among the few cultivated plants that can be fully utilized, being at the same time an ecological crop. After its harvest, the field remains clean of weeds, being an excellent precursor for most crops. In addition to these advantages, there is also the fact that the wood produced per hectare of hemp is equivalent to the amount of wood produced by the annual growth of a hectare of mature fir forest.

Currently there is a huge potential for growing hemp for fibre. Also, in recent years, there have been signs of a revival of hemp towards other production niches, such as the production of oil from hemp seeds. Hemp oil contains over 80% polyunsaturated fatty acids (PUFA) and is an exceptionally rich source of the two essential fatty acids (EFAs) linoleic acid (18:2 omega-6) and alpha-linolenic acid (18:3 omega -3) *(Carus et al., 2013)*.

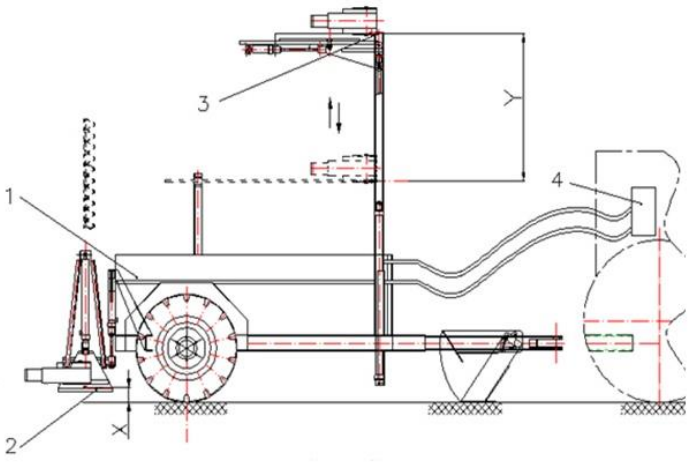
Stalks and seed productivity of diverse commercial cultivars were compared, with the aim of providing novel information to support dual-purpose cultivation of hemp in Europe (*Struik et al., 2016).* Hemp culture can represent circularity and zero waste for a future business model *(European Industrial Hemp Association, 2021).* The quality of the fibres used in the textile industry depends primarily on the efficiency of the hemp harvesting equipment.

Nedelcu et al., (2020), proposed an integrated method for hemp harvesting, which involved the manufacture of equipment to cut the stalks, sheaf-binding and leaving on the ground. *Huang et al, 2017* designed and test a self-propelled hemp harvester which could complete cutting, conveying and loading at a time. *Păun et al. (2020),* shows that when designing and manufacturing the equipment, several requirements imposed on the process of harvesting hemp for fibres must be taken into account (ex. stalk cutting height, damaged stalks etc.)

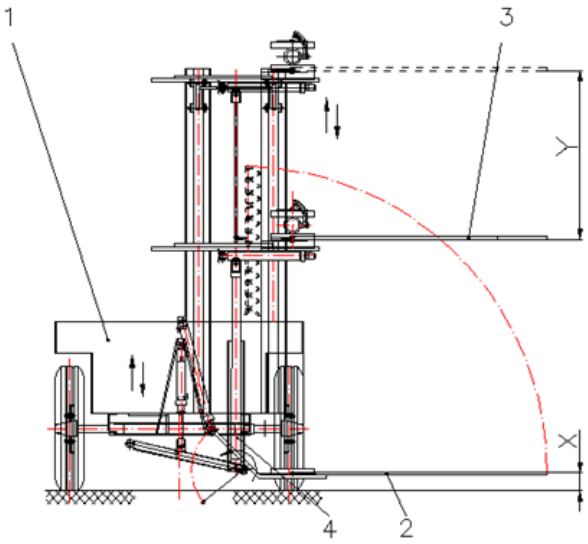
This paper will present the research results obtained by applying hemp harvesting technology with the equipment for harvesting green hemp stalks, designed, manufactured and tested at INMA Bucharest.

MATERIALS AND METHODS

The equipment for harvesting green hemp stalk was the subject of a patent application *(Păun et al., 2019)* and the concept design is presented in figure 1. The equipment was designed to be used in small and medium farms (*Păun et al., 2021).*



a) Side view



b) Rear view

Fig. 1 - Concept design of the harvesting equipment, lateral view (left) and back view (right)

1 - mobile platform; 2 - lower knife; 3 - upper knife 2; 4 - hydraulic system

The main subassemblies of the equipment for harvesting green hemp stalks are: *1*- mobile platform; *2* - lower knife; *3* - upper knife; *4* - hydraulic system. The mobile platform is a semi-mounted type construction, transferring part of the weight to the rear axle of the tractor. On the mobile platform, the following components are mounted: a mobile arm for fixing lower knife, a mobile arm for fixing upper knife and the hydraulic drive system. When moving, the platform rests on two wheels of the drivetrain, and when stationary, with the equipment decoupled from the tractor, a support leg mounted in the front part of the drawbar is used. The drawbar consists of a welded construction and a bolt that secures the coupling to the tractor.

The equipment for harvesting green hemp stalk was included in the harvesting technology, as it is shown in figure 2. The working process of the equipment involves cutting the inflorescences and green stalks and leaving them mixed on the ground.

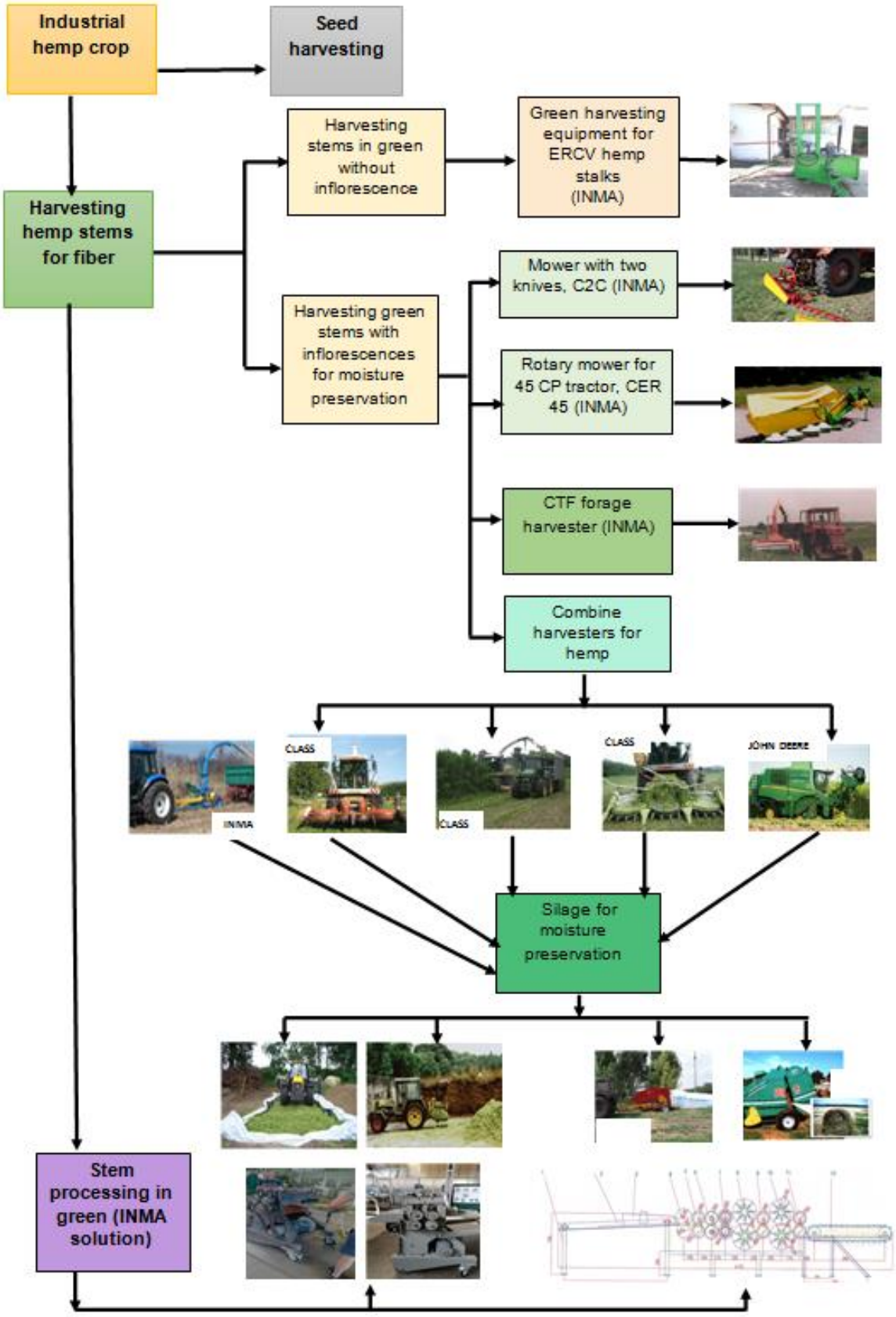


Fig. 2 - Green harvesting technology for hemp stalks

The equipment for harvesting green hemp stalks, was tested at INMA Bucharest. In order to ensure optimal testing conditions, an experimental hemp plot located at INMA Bucharest, with Dacia - Secuieni hemp variety, which is a specific variety for stalks and fibres, was established in the spring of 2021 (figure 3).

Fig. 3 - Experimental plot grown with hemp for fibre at INMA Bucharest location

During the hemp harvesting process, the most important components of the equipment are the lower knife and the upper knife. A T4A type transducer manufactured by HBM (Hottinger Baldwin Messtechnik), which is available at INMA Bucharest, was used to measure the torque at the tractor's PTO shaft.

The power transmitted through the power take-off, P_p, was calculated using formula (1):

$$P_p = M_p \cdot \omega_{p\cdot} \cdot 10^{-3} \text{ [kW]} \quad (1)$$

where:

M_p – is the torque measured at the tractor's PTO shaft, [N·m];

$\omega_p = \frac{\pi \cdot n_p}{30}$ - angular velocity of the PTO shaft, [rad/s];

n_p – the speed of the PTO shaft, [rpm].

The power required to trail the equipment during operation, P_t, was calculated using formula (2):

$$P_t = F_t \cdot V_l \cdot 10^{-3} \text{ [kW]} \quad (2)$$

where:

F_t – is the traction force measured at the drawbar, [N];

V_l – is the working (moving) speed of the aggregate, [m/s].

The total power, P_{tot} , required in the working process consists of the power transmitted through the power take-off and the power required to trail the equipment and was calculated using formula (3):

$$P_{tot} = P_p + P_t = \left(M_p \cdot \frac{\pi \cdot n}{30} + F_t \cdot V_l \right) \cdot 10^{-3} \quad (3)$$

RESULTS

The tests were carried out in August, when the hemp stalks were green, but also in October when they had a high degree of drying (figure 4).

a) b)

Fig. 4 - Aspects during the tests with the equipment for harvesting hemp stalks

a) harvesting green stalks in August; b) harvesting dry stalks in October

Tables 1, 2 and 3 present the results obtained during the tests with the equipment for harvesting hemp stalks, regarding the working conditions, operating indices and work quality indices.

Table 1

Working conditions

Den. no.	Specifications	UM	Values			
			Test I	Test II	Test III	Average
1	Harvested crop		Green hemp stalks of the Dacia - Secuieni variety			
2	Biomass production	t / ha	8.4	8.4	8.4	8.4
3	Vegetation year	-	2021			
4	Vegetation period	days	115-120	115-120	115-120	115-120
5	The appearance of the row	-	Not uniform with plants lying in small numbers			
6	The average height of the row	mm	1600-2300 (~2000)			
7	The average stalk thickness	mm				
	lower knife		10.2	9.9	11.0	10.4
	upper knife		4.2	3.6	5.1	5.3
8	Number of plants per m^2	pc	280-300			
9	Plant moisture at harvest	%	30.2	32.1	31.9	31.4

The working conditions presented in Table 1 provide a clear image of the parameters of the green hemp stalks in the experimental plot, at the time of the tests. The average plant moisture of 31.4% indicates that the time of harvesting was optimally chosen.

Table 2

Operating indices

Parameters	UM	Sample			
		Load drive			
		Test I	Test II	Test III	Average
Engine rotational speed, with power take-off at 540 rpm	rpm	2199	2198	2199	2198
PTO speed, n_p	rpm	540	540	540	540
Actual torque at the power take-off	daNm	42.1	42.1	42.1	42.1
Traction force at drawbar, F_t: - with the equipment trailed	daN	550	550	550	550
Pressure force on the tractor, F_{ap}	daN	355	354	356	355
Effective PTO power, $P_{p\,ef}$	kW [CP]	24.51 32.84	24.51 32.84	24.5 32.86	24.50 32.86
Total effective power to operate the equipment during operation, P_{tot}	kW [CP]	33.52 44.96	33.52 44.96	33.53 44.96	33.52 44.96
Working speed, V_l	km/h	6.1	6.5	5.5	6.03
Degree of pruning (stalks without inflorescence) G_{t2}	%	92.5	93.2	90.2	93.56
Effective working capacity (W_{ef})	t/h	7.5	7.9	7.2	7.6
Useful width (cutting)	mm	1300	1300	1300	1300

The data presented in Table 2 for the traction force at drawbar, the effective PTO power and the total effective power to operate the equipment indicates an optimal exploitation of the power resources of the energy source during operation. The degree of pruning average value of 93.56% was obtained in the conditions where the hemp from the experimental plot was not uniform, with plants lying in small numbers.

Table 3

Qualitative working indices

Den. no.	Specifications	UM	Values			
			Test I	Test II	Test III	Average
1	Cutting machine speed 1	rpm	1000	1000	1000	1000
2	Cutting machine speed 2	rpm	1000	1000	1000	1000
3	Working width	mm	1300	1300	1300	1300
4	Stalks cutting height	mm				
	lower knife		99.5	98.3	98.1	98.60
	upper knife		1550	2100	2400	2016.6
5	Degree of cutting (stalks cut - magnified)	%	92.5	93.2	90.2	91.96
6	Degree of pruning (stalks without inflorescence)	%	89.2	94.3	97.2	93.56
7	Stalks diameter	mm	10.2	9.9	11.0	10.4
	lower knife					
	upper knife		4.2	3.6	5.1	5.3
8	The average length of the stalk cut without inflorescence	m	1.38-1.65			

According to the data presented in Table 3, on the constant working width of 1300 mm, a good uniformity of the stalks cutting height was obtained for the lower knife (98.60 mm) and less good for the upper knife (2016.6 mm), due to the non-uniform development of the plants in height.

In figure 5 is presented the variation of the effective working capacity depending on the harvesting equipment working speed.

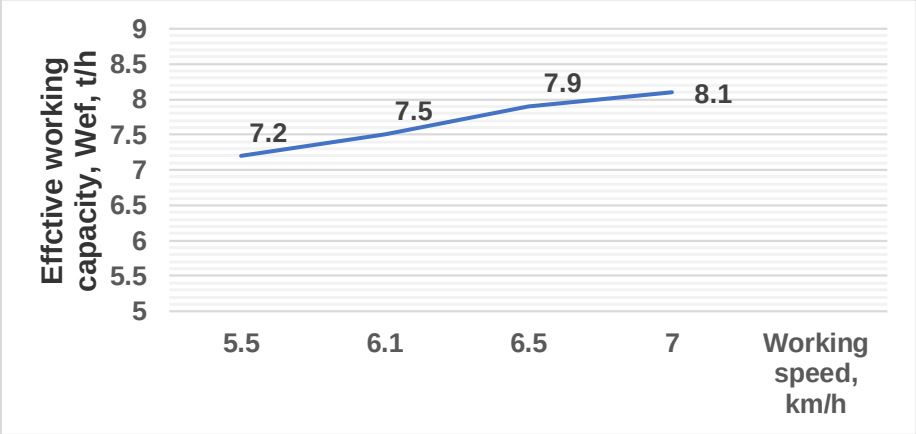


Fig. 5 - Variation of the harvesting equipment effective working capacity

The effective working capacity increases linearly with the increase of the working speed; for the working speed of 6.5 km/h the effective working capacity had the value of 7.9 t/h.

CONCLUSIONS

Following experimental research with the equipment for harvesting green hemp stalks, the results of which are presented in the tables 1, 2 and 3, main conclusions can be drawn:

- Stalks cutting height remained constant on the working width and had the following average values: lower knife - 98.60 mm; upper knife - 2016 mm;
- Stalks degree of cutting for 1 m^2 of cut plants for lower knife was 91.96% and for upper knife was 93.56%;
- During the tests, the hemp harvesting equipment moved with an average speed of 6.03 km/h;
- Actual torque at the power take-off had the value of 42.1 daNm;
- Traction force at the tractor drawbar was 550 daN with the equipment trailed;
- The average pressure force on the tractor had the value of 355 daN under load;

- The pressure force of the drawbar on the tractor (F_{ap}) had the value of 308 daN when empty and 355 daN under load, resulting in the coupling system of the harvesting equipment to the tractor working optimally;
- The average power take-off had the value of 24.5 kW;
- The working speed largely depends on the condition of the plot on which the hemp crop is located; the better the field is levelled and there are not many fallen plants, the faster the work speed increases.

In this paper, the results of the research obtained through the application of management practices in the harvesting and storage of industrial hemp were presented. By using green hemp stalk harvesting equipment in management practices, higher quality indices and quality material for hemp fibre production can be achieved.

ACKNOWLEDGEMENT

This research work was supported by:

- a grant of the Romanian Research, Innovation and Digitalization Ministry, PN 19 10 01 03-Substantion of the technology for harvesting and primary processing green hemp stalks, contract no. 5N/07.02.2019.

- PN 19 10 01 01 - Research on the realization of integrated systems for the field of Bioeconomy according to the concept of intelligent agriculture

REFERENCES

[1] Bogdanof G., Păun A., Brăcăcescu C., Stroescu Gh., (2019), Considerations on the hydraulic installation of the equipment for harvesting green hemp stalks, ISSN 1454 – 8003, *Proceedings of 2019 International Conference on Hydraulics and Pneumatics – HERVEX*;

[2] Carus M., Karst S., Kauffmann A. The European Hemp Industry, (2013), Cultivation, Processing and Applications for Fibres, Shives and Seeds. *Cologne: EIHA*, pp. 1–9;

[3] Huang J., Shen C., Li X., Tian K., Chen Q., Zhang B., (2017), Design and tests of hemp harvester, *International Agricultural Engineering Journal*, Vol. 26, No. 2.

[4] Nedelcu A., Popa L.-D., Zaica Al. Zaica A., Ştefan V., (2020), Considerations regarding technologies for hemp stem harvesting, *ISB-INMA TEH' 2020 International Symposium "Agricultural and Mechanical Engineering"* Jubilee Edition-Bucharest, October 30, 2020, pp. 609-614.

[5] Păun A., Stroescu Gh., Zaica Al., Olan M., Gheorghe G., Zaica A., Anghelache D., Ionescu Al., (2021), Technologies and technical equipment for hemp fibre crop, *Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series* (*Analele Universităţii din Craiova, seria Agricultură – Montanologie – Cadastru*), Vol. 51/2/2021, pp. 426-434;

[6] Păun A., Bogdanof G., Ganea-Christu I., Ciupercă R., Matache M., (2019), *Equipment for harvesting green hemp.* Patent application no. A-00426/04.07.2019 OSIM, Romania;

[7] Păun A., Stroescu Ghe., Bunduchi G., Olan M., Milea D., Epure M., Zaica A., (2021), The influence of morphological particularities of hemp plants on technical equipment during the harvesting process, *Symposium ISB - INMA TEH' 2021, Agricultural and Mechanical Engineering, ISB-INMA TEH' 2021*, pp.652-661;

[8] Păun A., Stroescu Gh., Zaica A., Ciupercă R., Bogdanof C-tin., (2020), Analysis of the process of green hemp stalks sequential harvesting, *TE-RE-RD 2020, 9th International Conference on Thermal Equipment, Renewable Energy and Rural Development*, E3S Web of Conferences 180, 03026, 7, https://doi.org/10.1051/e3sconf/202018003026;

[9] Struik P. C., Yin X., Thouminot C., Bjelková M., Stramkale V., et al. (2016), Comparing hemp (Cannabis sativa L.) cultivars for dual-purpose production under contrasting environments. *Ind. Crops Prod*. 87, pp 33–44;

[10] ***European Industrial Hemp Association, http://eiha.org