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ANALYSIS OF LINSEED PRODUCTION WITH USE OF FLAX PULLER AND COMBINE HARVESTER FOR ITS HARVEST

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Abstract

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The cultivation of linseed is an alternative to the production of flax stem, which is globally on the decline. The alternative method to the traditional harvest using the flax puller is increasing use of combine harvester. By this method the harvest efficiency will be increased, which represents a significant step to an improvement of economy of cultivation. Depending on the variety, the value of specific energy consumption was determined from (0.43 MJ/kg) up to (0.63 MJ/kg) if we use flax puller and from (0.58 MJ/kg) up to (0.86 MJ/kg) if it is used a combine harvester. Levelized costs for seed production in case of soil cultivaton with tillage rangein wide interval (9,714 CZK/t–17,308 CZK/t) depending on yield of a variety and used machinery.

Keywords: agricultural, engineering, levelized costs, consumed energy, linseed production

INTRODUCTION

In cultivation area of flax in the Czech Republic there have been recorded in the recent years very important changes. The sown area has been significantly decreased and all the production is concentrated on oil varieties of flax at the expense of fibre varieties. To this fact there is in relation the change in harvest technology. In cases, when the flax stem won't be used to fibre purposes, the traditional methods with use of flax pullers are mostly replaced by harvest using the combine harvesters.

The main importance of flax growing is in production of seed for food industry and technical purposes and fibre for textile industry. Other technical use of flax is about Leburn *et al.* (2013) possible in the field of paper production

Alternative method using flax stem and post-harvest residuesis represented by their use as raw material for energy production. In accordance with Blažej *et al.* (2012) it is possible to produce from disintegrated bullen or stem heating pellets and briquettes. Chauhan, M. P., *et al.* (2009) states, that owing to the mechanical properties and low production of emissions it is suitable. About Blažej *et al.* (2013) to produce the mixtured pellets and briquettes consisted of crushed flax stem and wood sawdust or wood shavings.

The flax had also considerable significance as a part of crop rotation in traditional agriculture as well as in organicfarming. The professional publications Fromet (1993) mention its importance in the sphere of soil microbiology. Other sources Paulsen (2008) mention the advantages of coproduction with spring cereales. From the cultivation point of view, the flax hasn't any special requirements for agricultural machinery. Soil preparation, establishment of crop stand and other operations can be carried out by means of standard machinery. According to several authors Pražan *et al.* (2015) and Nilsson, D., *et al.* (2005) it is necessary to put an emphasis on uniform application of fertilizers and plant protection preparations, especially desiccation of crop stand before harvest with use of combine harvester.

From the harvest machinery point of view, it is possible to use for harvest flax pullers, in case of linseed also combine harvester.The aim of research was to analyse and compare both of harvest methods and assess their impact on energy and economic parameters of production at five selected linseed varieties.

MATERIALS AND METHODS

Within the research there were measured the parameters of all technological operations related to soil preparation, establishment and treatment of crop stand, fertilization and harvest of seed and stem. Determination of all the values was carried out by measurements in operational conditions in sites of Lukavec, Morkovice, Šumperk, Loštice, Bludov, Bohutín and Nicov. The yield parameters of individual varieties were determined by means of five years lasting pilot plant experiments in the site of Lukavec. The studied varieties were: Recital, Oural, Amon, Flanders and Baikal.

The movement of machinery during the working operations was continuously monitored by means of record of GPS coordinates. On the basis of this record there were created and evaluated the time records in digital version.

Other measured parameter in the course of individual operations was fuel consumption (diesel fuel). Its values were determined by means of flow meter, possibly there were obtained from the record of on-board computer of a machine.

At each carried out measurements there were determined from measured values the following data:

Working width was determined from the record of passages by means of the GPS coordinates.

The quantity of harvested feedstock is determined by calculation from the results of analyses in laboratory.

$$m_s = \frac{m_{si}}{S_{si}}.S_s \text{ kg}$$

where

m_{si}........weight of dry matter of withdrawed sample (kg)

S_{si}.........area, from which the sample was withdrawed (m^2)

S_s.........harvested area (m^2)

In the text it is mentioned as weight of dry matter.

Cheking measurement was carried out by determination of feedstock weight on weighbridge with subsequent determination of dry matter content by gravimetric method according to the standard ČSN 44 1377.

Area efficiency was determined by calculation according to the following formula:

$$q_{ha} = \frac{0,36.B_p.l}{t} \text{ (ha/h)}$$

where

l............distance covered during the measurement (m)

t...........time of measurement (s)

B_p........working width (ordistance between harvested rows) (m)

Consumed energy in total was determined as:

$$W_{sp} = m_{pal}.Q^t_{i\,pal} \text{ (MJ)}$$

where

m_{pal}........ weight of consumed fuel (kg)

$Q^t_{i\,pal}$ .... calorific value of consumed fuel (MJ/kg)

Specific consumed energy was determined as:

$$W_e = \frac{W_{sp}}{m_s} \text{ (MJ/kg)}$$

where

m_s.........weight of processed feedstock (kg)

Real length of harvested stem was determined from the basic sample with drawed from 1 $m^2$of crop stand. In the course of each measurement there was with drawed minimally five basic samples. Each basic sample was divided into two parts. The first part was used to the determination of dry matter content and second part to the analysis of stem length. From the mixtured basic samples there were prepared 3 samples. These samples were divided according to the length of particles l_i in to intervals of 10 mm. There was determined the weight of particles m_i in each interval. The real length of stem l_s at one sample was calculated according to the following formula:

$$l_{si} = \frac{\sum_{i=1}^{n} m_i.l_i}{\sum_{i=1}^{n} m_i} \text{ (mm)}$$

where

m_i.........weight of stem in i-interval (g)

l_i...........average length of stem in i-interval (mm)

Real length of stem was determined as arithmetic average of measurement from three samples.

In order to calculate the unit costs for harvest there was used database programme AGROTEKIS (freely accessible on the website www.vuzt.cz) destined for model calculations of operational costs of machines, sets and for economic evaluation of crops and production purposes.

Obtained data were evaluated by ANOVA, using the PC software Statistica CZ v12.

I: *Time of duration and specific consumption of diesel fuel during the technological operations*

operation	area efficiency (ha/h)	specific consumption of diesel fuel (l/ha)
tillage up to the depth of 20 cm	0.65	19
soil preparation – combinator	0.30	18
sowing	0.60	20.7
treatment of crop stand	3.00	1.9
harvest by combineharvester	3.00	16.9
harvest by flax puller	0.50	7.4
tedding of flax stem	0.33	2.9
raking of flax stem	0.37	3.6
pressing of flax stem – roto-baler	0.64	7.01

RESULTS

Individual operations carried out during the cultivation and harvest of monitored flax varietiesfrom energy and exploitative parameters point of view. Overview of monitored operations and determined parameters is shown in the Tab. I. Pre-sowing preparation of soil was carried out by traditional technology withtillage up to the depth of 20 cm and pre-sowing preparation of soil with use of land leveller and harrows (working width of 3 m).

The values mentioned in the Tab. I include all the operations carried out in relation to the establishment, protection, harvest of crop stand and transport of products in a storage site. For the harvest of flax stem there was selected the alternative of pressing into round bales. It was taken into account the transport distance of 2.5 km. Exploitative parameters of operations there were determined by means of Global Positioning System (GPS). Consumption of diesel fuel was determinated by means of flow meter in-built in energy means, possibly by the method of full tank.

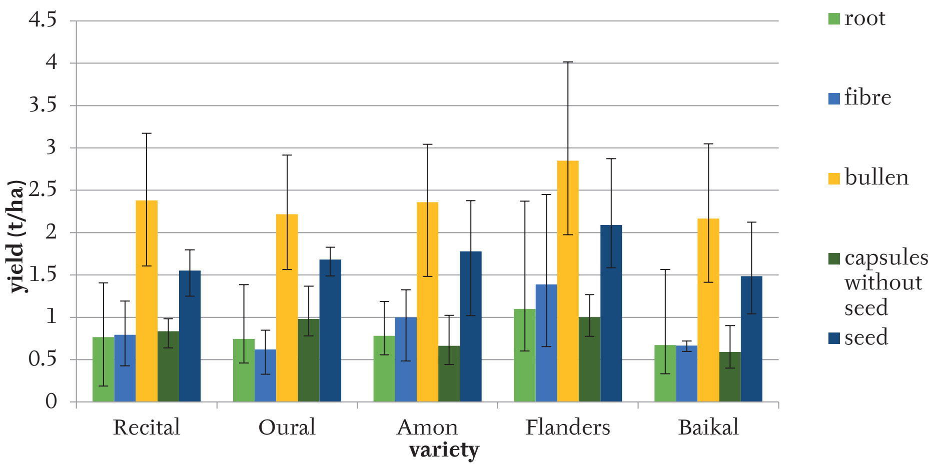
From the above mentioned values it is obvious, that the highest specific consumption of diesel fuel from monitored operations was recorded in case of tillage, harvest by combine harvester and sowing. The most time consuming operations are stem pressing,tillage andharvest with use offlax puller. Specific consumption of diesel fuel for production of linseed was in case of harvest with use of flax puller from 0.58 MJ/kg up to 0.86 MJ/kg and in case of harvest by combine harvester from 0.43 MJ/kg up to 0.63 MJ/kg.

Parameters of harvested flax stands were determined by sampling from random selected sample areas of 1 x 1 m. Within the yield monitoring the with drawed plant samples were divided into individual parts. There was recorded yield of seed, residue of capsules, fibre, bullen androots. Average yields of individual plants parts of monitored varieties are graphically shown on the Fig. 1.

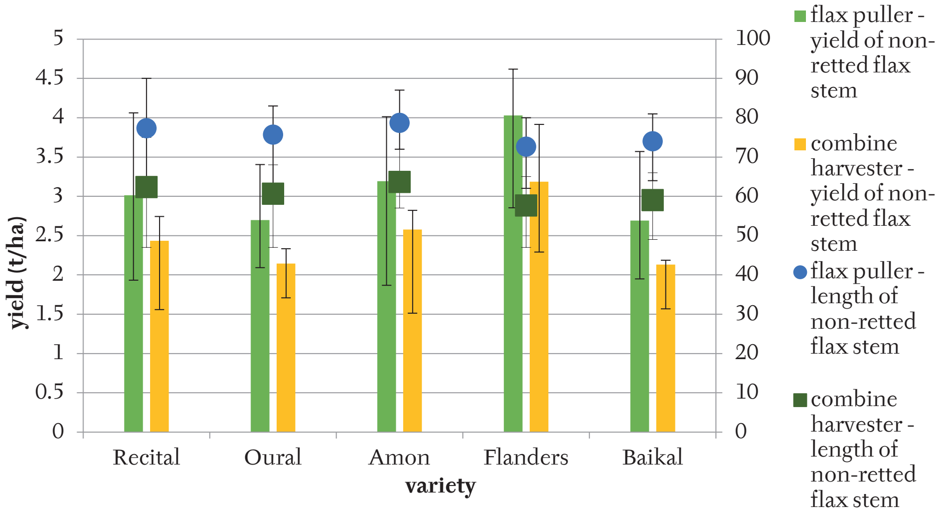
From the results on the Fig. 1 it is obvious, that the highest yield of seed and also other parts of plant was achieved in case of variety Flanders (2.02 t/ha of seed). The lowest yield was reached at the variety Baikal (1.48 t/ha of seed).

For the purpose of evaluation and comparison the flax stands were harvested both by combine harvester and by flax puller. In case of harvest by puller it was harvested more mass. The losses ranged around 5 %.

In case of harvest by means of combine harvester the yield of seed was the same, but the yield of



1: *Yield of individual parts of linseed selected varieties (site of Lukavec, average from the period 2009–2013, converted to dry matter)*



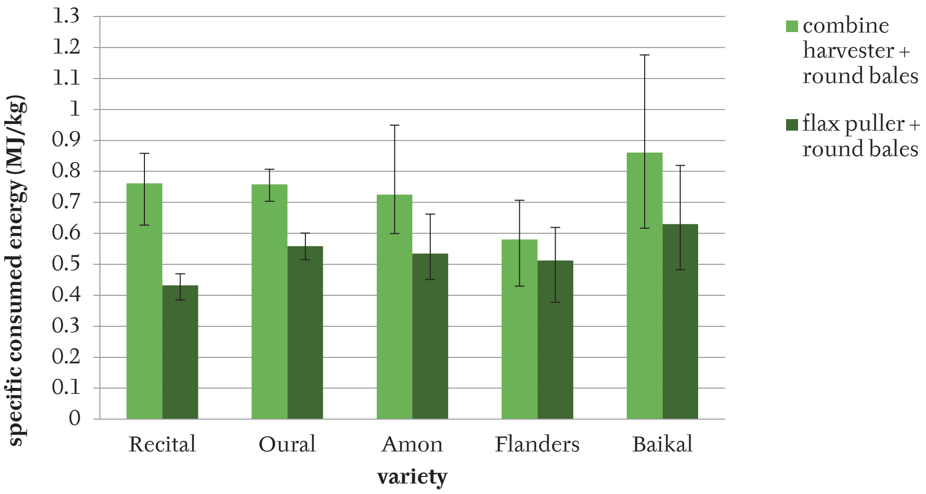
2: *Yield of non-retted stem of tested linseed varieties during the harvest by combine harvester and flax puller (converted to dry matter)*

other plant parts decreased. It was caused by non-harvested roots and part of stem forming the stubble (about 15 cm) and also by higher losses owing to a drift during the separation of seed. Quantity and length of harvested and non-retted flax stem is graphically illustrated on the Fig. 2. The highest yield of non-retted flax stem (fibre + bullen) was recorded at the Flanders variety 4.24 t/ha. The lowest yield was reached in case of the Baikal variety 2.83 t/ha.

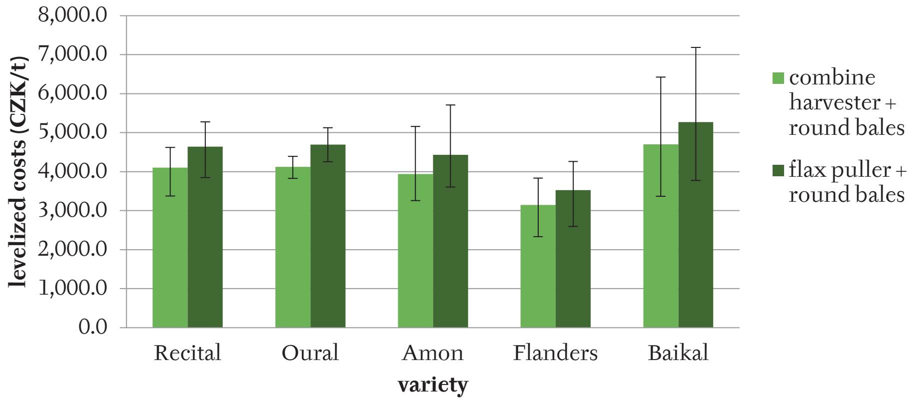
By conversion of direct consumed energy in form of diesel fuel into the yields of selected varieties it is possible to express specific energy consumed for 1 tonne of produced mass. In order to make the comparison more clear the values were related to 1 tonne of total harvested mass (in dry matter), without differentiation of individual plant parts. The values converted into 1 kilogram of dry matter of raw material are graphically shown on the Fig. 3.

In order to evaluate impartially the assessed technologies it is important to take into account the economic point of view. As the main indicator there were calculated for both alternatives of technological process at individual varieties the levelized costs related to 1 tonne of produced dry matter of harvested material. The levelized costs were calculated from real costs expended for machinery operation, machinery depreciations, wage costs and material costs (seeds, fertilizers, crop protection and desiccation).

On the Fig. 4 there are graphically shown the values of levelized costs for production of 1 tonne dry matter of harvested mass. In these values there are included all the costs originated in relation to soil preparation, establishment and cultivation of crop stand, plant protection, harvest and transport to the storage site (it was taken into account the distance of 2.5 km). The levelized



3: *Specific consumed energy for production of linseed selected varieties with use of different harvest alternatives*



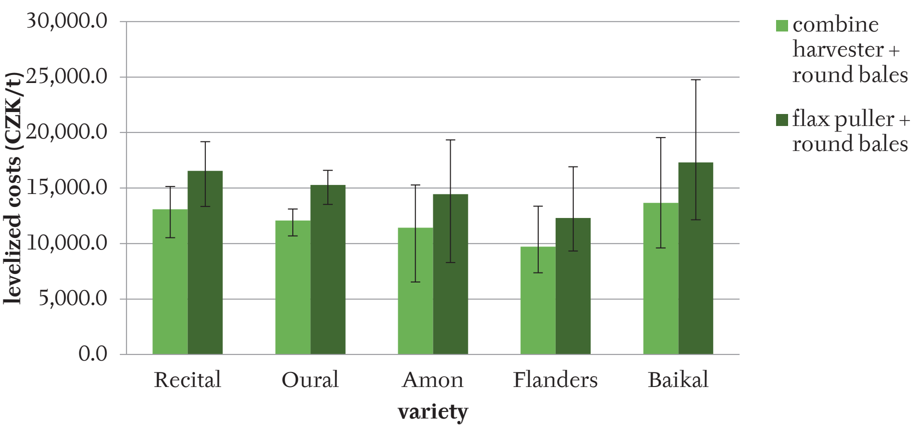
4: *Levelized costs for production of linseed selected varieties (related to the dry matter of harvested mass)*

costs shown on the Fig. 4 (from 3.149 CZK/t up to 5.271 CZK/t) indicates their real amount only in case, that the flax stem in sold for mentioned price at least. In case, that the stem isn't sold, it is necessary to relate the levelized costs to the seed production a these levelized costs are reflected in economy of flax growing in amount shown in graph on Fig. 5.

From the graph on the Fig. 5 it is obvious, that the levelized costs for1 tonne of seed will be considerably higher. They reach the amount from 9,714 CZK/t up to 16,560 CZK/t of seed dry metter.

DISCUSSION

Determination of parameters concerning the monitored operations carried out during the linseed production was realized in operating conditions with five varieties: Recital, Oural, Amon, Flanders and Baikal. These varieties achieved different yield parameters. The highest yield all the crop parts was recorded in case of Flanders variety (2.09 t/ha of seed, 4.24 t/ha of stem), the lowest yield was reached at the Baikal variety (1.48 t/ha of seed, 2.83 t/ha of stem). The amount of yield influenced significantly the specific consumed energy and alsolevelized costs for production. The lowest specific consumed energy was recorded in case of Recital harvested by flax puller 0.43 MJ/kg, Flanders variety (0.58 MJ/kg harvested by combine harvester, 0.51 MJ/kg harvested by flax) and Amon variety (0.73 MJ/kg combine harvester, 0.53 MJ/kg flax puller). Higher values of specific consumed energy were determined in case of varieties Recital and Oural (0.76 MJ/kg combine harvester). The highest values of specific consumed energy was recorded in case of Baikal variety (0.86 MJ/kg in case of combine harvester). In comparison with mentioned values the share of embodied direct energy is 2–4 percent of energy



5: *Levelized costs for production of linseed selected varieties (related to the mass of seed dry matter)* contained in harvested mass. Depending on ratio of individual parts of monitored varieties it ranges on level of 78–104 GJ/ha. The values are comparable to the work of Bjelková et al (2012).

From the obtained results it is obvious, that efficiency of harvest can significantly influence the whole economy of linseed growing. Apart from the timeliness of harvest by Nilsson (2005) with previous quality desiccation by Fromet (1993) and Pražan *et al.* (2015) it is also important right choice of variety suitable for climatic conditions of certain locality and used harvest machinery.

Levelized costs related to 1 tonne of harvested mass (seed + non-retted stem) werein relatively wide range. Lower costs were in case of harvest by combine harvester. They range from 3,148 CZK/t (Flanders variety) up to 4,700 CZK/t (Baikal variety). In case of harvest by flax puller it was longer technical length of stem (from 726.7 mm up to 786.7 mm) and therefore also its yield (from 2.69 t/ha up to 4.03 t/ha). Yield of non-retted stem in case of harvest by means of combine harvester was lower. It was in range (from 2.13 t/ha up to 3.19 t/ha). Thus, it was influenced the amount of levelized costs.

Under current system of agricultural production it is very important, apart from economic and qualitative parameters, as well as the efficiency of logistics, it means also the quickness of carried out operations about Syrový (1983). It is important above all in case of unfavourable conditions. From this point of view the combine harvester has indisputable advantages. In comparison with flax puller (0.5 ha/h) the area efficiency of combine harvester during the harvest of linseed is six times higher (3.0 ha/h).

In case, when the stem cannot be utilized, it is necessary to express the levelized costs only for seed production. In this case the levelized costs for production of seed dry matter during the harvest by flax puller range (from 12,299 CZK/t up to 17,308 CZK/t) and in case of harvest by combine harvester (from 9,714 CZK/t up to 13,670 CZK/t).

CONCLUSION

Cultivation of linseed in the Czech Republic is an alternative to the cultivation of fibre flax varieties and primary feedstock is flax seed used above all for food and technical purposes. From the results obtained within the research it is obvious , that the economy of linseed cultivation is significantly influenced by selection of suitable variety and chosen method of harvest. Generally, it is possible to state, that in spite of lower overall yield of mass, the alternatives with harvest by means of combine harvester have lower levelized costs in comparison with alternatives using flax puller.

It corresponds also to the current trend in agricultural practice. In relation to the possible energy utilization of production, the flax puller is less advantageous also owing to an increased share of anorganic particles (ash) in the final product. The use of flax puller is suitable in cases of technical use of flax stem, when it is desirable to achieve the necessary length of fibre.

As for the comparison of monitored varieties the lowest levelized costs were determined at the Flanders variety with use of combine harvester and pressing into round bales (3,149 CZK/t of dry matter). The highest levelized costs were reached by the Baikal varietyin alternative with harvest by flax puller bales (5,271 CZK/t of dry matter).

In practice the linseed growers are very often forced to produce the flax stem from field also in case, that they haven't any use for it. The reason can be for example a difficult way of its incorporation into the soil, unsuitability of its presence in soil for the subsequent cropsor elimination of excessive occurrence of pests. In these cases it is necessary to express the levelized costs as the total costs for production of seed and stem expressed only for quantity of harvested seed. Also in this case the lowest costs were determined at variant with pressing into round bales. These costs range from 9,714 up to 13,671 CZK/t in case combine harvester using and from 12,299 up to 17,308 CZK/t in case hasvesting by flax puller.

In terms of energy, the linseed cultivation reached a positive balance.The share of energy input in form of diesel fuel is 2.1 up to 3.8 % of the energy contained in harvested mass.

Method of flax harvest using the flax puller is utilized in the Czech Republic less and less. The disadvantage of flax puller is, that it is a single-purposed machine. On the contrary, the advantage of this machine is, that in case of subsequent use of stem, enables to achieve greater technical length of stem. In other cases, it is preferable to use a combine harvester.

Beside the technological process of harvest, the economy of linseed production depends also on selection of right variety. In the monitoring period the highest yield was recorded in case of Amon and Flanders varieties. The lowest yield was recorded in case of Baikal variety. However, the choice of variety must be always adapted to the conditions of locality.

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