Agronomy Research **14**(2), 450–459, 2016

New design of roller separation line and its effect on the separation of hop matter

M. Krupička* and A. Rybka

Czech University of Life Sciences Prague, Faculty of Engineering, Department of Agricultural Machines, Kamýcká 129, CZ165 21 Praha 9 - Suchdol, Czech Republic
*Correspondence: krupicka@tf.czu.cz

Abstract. This article deals with the roller conveyor which constitutes a part of a machine line to separate the hops harvested from low trellises. Various parameters affecting the right operation of this roller conveyor are examined. In the last season a model of roller conveyor designed and constructed for this purpose was subject to experimental verification with the objective of integrating it in the actual line. Dependency of hop matter falling through on the gap size between rollers was examined. They were standard, commonly used rollers.
In 2015 rollers with a different diameter and different profile of metal welded collars were designed and produced. The new construction allows for reducing the gap between rollers up to 20 mm. As compared to the former solution including rollers of 60 mm in diameter, this one constitutes a difference of 28 mm.
The measurements in the season of 2015 were conducted using these new rollers and there were two parameters to examine. They were the gap size between rollers and rotation frequency of the rollers. The measurements were carried out using a hop matter sample taken from low trellises. The dependency of the hop matter falling through was being examined for 3 gaps (28, 24 and 20 mm) between rollers and for three rotation frequencies of the rollers. The measurements revealed that with a setting resulting in the smallest possible gap between rollers (20 mm) by up to 15% more leaves can be separated, compared to the rollers of 80 mm in diameter, and by approx. 60% more leaves compared to the former solution including the rollers of 60 mm in diameter. Furthermore it was found that a change in rotation frequency of the gaps does not affect the separation of leaves in any significant way.

Key words: hops, separating machine, roller conveyor.

INTRODUCTION

Hops are currently used mainly as one of the basic ingredients in beer production. Ninety-eight percent of world hop production is grown for this purpose (Carter et al., 2007). Other purposes of use are not recorded in world statistics. However, their importance is well-known in pharmaceutics (Vrzalová & Fric, 1994). For instance, flavonoids contained in hop cones appear promising as antioxidants and antivirals, especially against the HIV virus (Wang et al., 2004).

Extraordinary climatic and soil conditions contribute to the exceptional aroma characteristic of Czech hop varieties. Saaz semi-early red-bine hop is still the worldwide most recognised aroma hops (EAGRI, 2014).

One of the key problems in Czech hop production is the problematic labour hiring for the most demanding operations which include e.g. hanging and sticking of hop wires and vine training. On these grounds, some growers tend to switch for hop growing on low trellises which do not require these operations. In the new growing system the hop bines spontaneously climb (wind) up a special plastic net, an essential part of a low hop-field structure (Štranc et al., 2010; Štranc et al., 2012).

Most of traditional hop varieties cannot be grown on low trellises, as these reach only 40 to 60% of the yield achieved on classic constructions (Seigner et al., 2008). New 'dwarf' varieties bred for low trellises should, according to breeders and economic experts, achieve at least 80% of the yield from the varieties grown on classic trellises (Darby, 1999).

In the Czech Republic, low trellis hop production is at the experimental stage and the current low-trellis hop-fields cover less than 50 ha (EAGRI, 2014).

This cultivation technology requires different machinery. Low trellis hops are harvested by a mobile harvester, pulled by tractor. The hop matter brought by the mobile harvester is then subject to separation in the machine separating line which is specifically adjusted contrary to the classical machine picking line. The separation is aimed at ensuring that hop cones are separated from stems and leaves (Jech et al., 2011).

This article deals with the part of a hop sorting line that is located after the secondary picker, namely with a roller conveyor with infinitely adjustable pitch of its individual rollers. This feature is important in terms of separating hop cones from stems and leaves. This roller conveyor serves as a roller screen. The main function of a roller conveyor is to separate hop matter into small-sized fraction formed by hop cones, leaves and fragments of size smaller than the size of the gap between separate rollers, and into coarse fraction composed of stems, clumps, large leaves that do not fall in between rollers (Neubauer et al., 1989).

A proper operation of a roller conveyor is affected by several parameters. They are the profile of the rollers and the gap between separate rollers. To be able to determine the precise significance of these parameters, in 2014 a model of roller conveyor was constructed, which is a scale copy of a real roller conveyor (Krupička & Rybka, 2014).

In the 2014 harvest season a set of measurements were conducted in the laboratory of the Department of Agricultural Machines, FE, CULS in Prague that addressed the dependency of the hop matter falling through on the gap size between rollers. Original rollers of 60 mm in diameter were used for the purpose of these measurements.

The objective of this research was to design and implement a new construction of the rollers which would allow for achieving better separation of leaves and small-sized impurities. Previous measurements conducted in the 2014 harvest season proved that the smaller the gap between rollers is, the more leaves get separated (Krupička & Rybka, 2015).

An original constructional solution of a roller conveyor with rollers of 60 mm in diameter enabled to set the smallest possible gap of 48 mm. When the rollers diameter was enlarged by means of pipes made of mirelon, the gap size decreased to 28 mm. Thanks to the newly designed rollers this gap became even smaller.

MATERIALS AND METHODS

Roller conveyor model

The model (Fig. 1) is a scale copy of the roller conveyor used in the sorting line to separate hops grown on low trellises. The model has a total of 9 rollers of a standard 60 mm diameter. The rollers are 600 mm long. The first roller is fixed to the frame, while the remaining 8 rollers allow for changing their pitch, thus modifying the gap between them. The space under the rollers was divided by means of KAPA boards, to be able to determine the amount of the hop matter fallen in between the separate rollers. Hop feeding was provided by a belt conveyor 600 mm wide and 1,000 mm long.

Figure 1. Model of a roller conveyor.

The throughput of the model is 450 kg h^{-1} of hop matter and is derived from the throughput of a real 2 m wide roller conveyor. This throughput corresponds to the peripheral speed of the conveyor belt of 0.27 m s^{-1} and the rotation frequency of the conveyor rollers of 0.67 s^{-1}. These values were set by means of frequency converters. Also the vertical distance of the belt conveyor from the roller conveyor corresponds to the real one.

Figure 2. Laboratory roller conveyor with rollers fitted with welded collars with toothed profile.

For the purposes of the measurement new rollers were used, of 89 mm in diameter and with toothed profile of the metal welded collars (Fig. 2). On the tube is 14 metal welded collars. They are spaced apart 39 mm. A metal welded collar has 30 teeth and the outer diameter is 125 mm. Due to the enlarged tube diameter and the height of collar 17.5 mm it is possible to set the gap between rollers to 20 mm. This profile of metal welded collars more effectively catches leaves and small-sized twigs and shifts them further on.

Measurement methodology

The 2015 harvest season measurements used again the hop variety Sládek, harvested from low trellises. To prevent the hops from changing their characteristics during the separation, the fresh hop matter was brought from the hop grower every single measurement day.

The hop matter sample was selected so that the percentage representation of individual components (hop cones, leaves) remained unchanged. A sample weighing 450 g (Fig. 3) corresponds to the throughput of the model roller conveyor, which is 450 kg h^{-1}. The sample contained 16 g of cones and 282 g of leaves. The average hop cone size was determined out of a sample comprising 100 pieces. The average value of the hop cone length was 28 mm the average value of the cone diameter was 16 mm.

Figure 3. A hop matter sample evenly spread over the conveyor belt.

The measurement was conducted in such a way that the hop matter sample was mingled and evenly spread over the conveyor belt. The sample layer was approx. 40 mm high. Then the roller drive was switched on, followed by the belt conveyor drive. The hop matter was being continuously separated on the roller conveyor and thanks to KAPA boards, installed under each roller, was falling through into 7 containers. The individual components of the hop matter that fell in between rollers were weight accurate to 1 g.

For the season of 2015 several measurements were prepared. This article deals with a measurement conducted with the rollers of 89 mm in diameter. With these rollers three gaps were possible to measure. Namely, they were gaps of 28, 24 and 20 mm.

With all the gap sizes between rollers the dependency of hop matter falling through on the rotation frequency of the rollers was also examined. The basic rotation frequency of the rollers was 0.67 s^{-1}, then 0.8 $s^{-1}$and 0.94 s^{-1}.

RESULTS AND DISCUSSION

Comparison of three different gaps between rollers of equal diameter and basic rotation frequency

The graph in Fig. 4 depicts the measured data with rollers of 89 mm in diameter and toothed profile of their metal welded collars. With the rollers measurements were carried out for a total of three gap sizes between rollers, namely 20, 24 and 28 mm. The graph clearly shows the dependency of the hop matter falling through for each gap (20, 24 and 28 mm). When the gap is set to 20 mm, only 17% of all the matter falls through the first gap, which is by approx. 13% less compared to the gap of 28 mm.

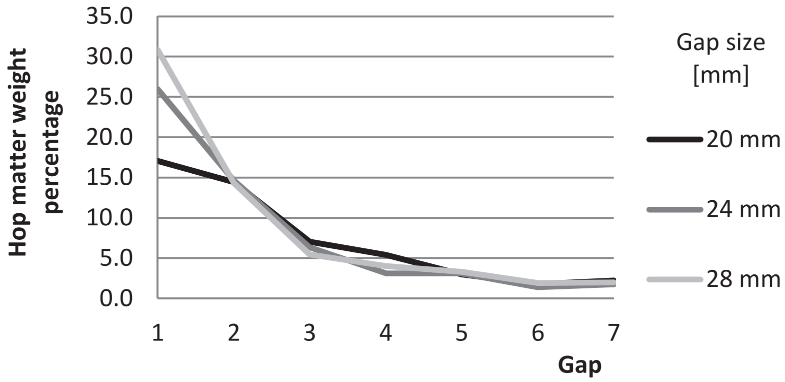

Figure 4. Weight percentage of the hop matter fallen through the separate gaps for rollers of 89 mm in diameter and rotation frequency of 0.67 s^{-1}.

A detailed view of the amount of the cones and leaves fallen through the individual gaps is illustrated in the following two graphs (Fig. 5 and 6).

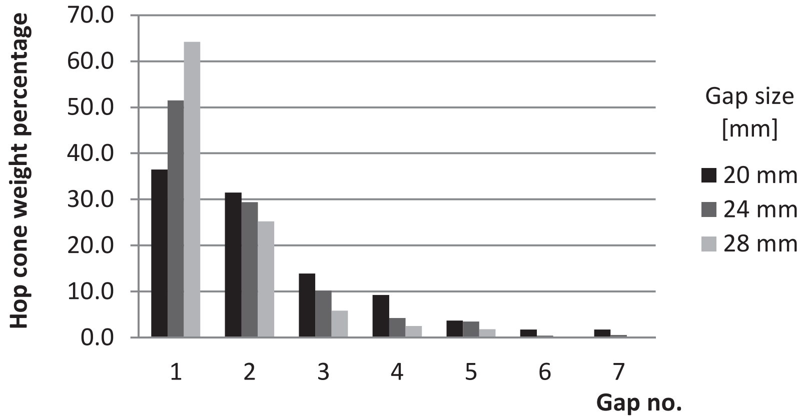

Figure 5. Weight percentage of the hop cones fallen through the separate gaps for rollers of 89 mm in diameter and rotation frequency of 0.67 s^{-1}.

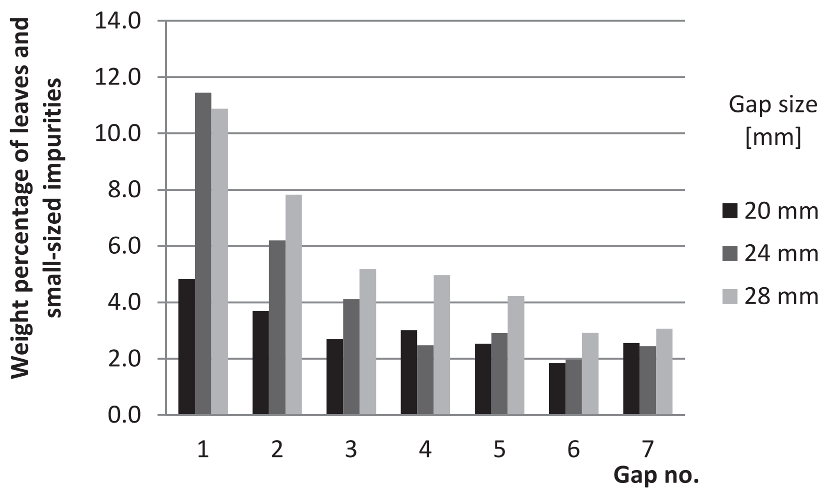

Figure 6. Weight percentage of the leaves and small-sized impurities fallen through the separate gaps for rollers of 89 mm in diameter and rotation frequency of 0.67 s^{-1}.

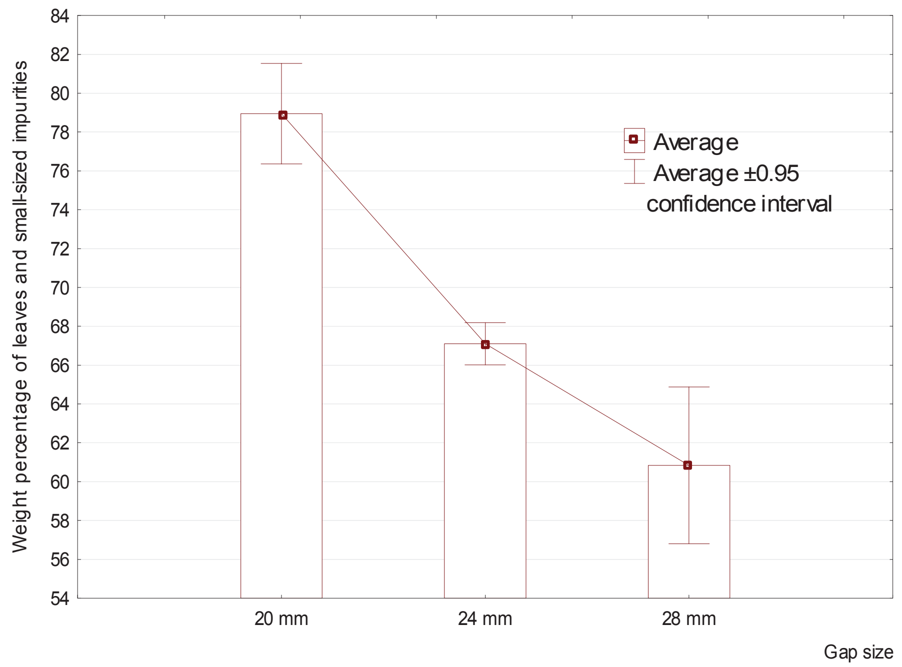

Figure 7. Weight percentage of leaves and small-sized impurities in the waste with the rollers of 89 mm in diameter and rotation frequency of 0.67 s^{-1}.

As regards the leaves and cones in the waste, the best results in terms of leaf separation were measured with the gap of 20 mm (Fig. 7). Less than 79% of all leaves were carried into the waste. With the gap set to 20 mm, by 18% more leaves were separated in comparison to the gap set to 28 mm. Another graph illustrates how many hop cones were carried into the waste. With the gap set to 20 mm the amount was 1.6% of cones, whereas with the other two gaps almost no cones ended up in the waste (Fig. 8).

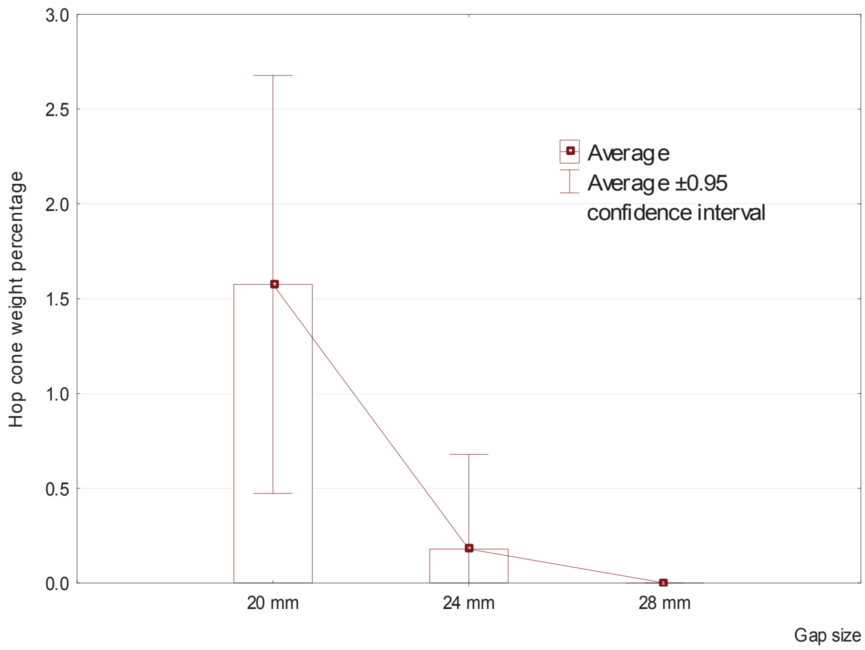

Figure 8. Weight percentage of hop cones in the waste with the rollers of 89 mm in diameter and rotation frequency of 0.67 s^{-1}.

Dependency of hop matter falling through on the gap size and rotation frequency of the rollers

The processed measured data revealed that the rotation frequency of rollers proved to have no significant effect on separation of leaves. Our assumption that increasing rotation frequency of the rollers would cause a higher percentage of leaves and small-sized impurities to leave for the waste, was not confirmed. The following graphs in pictures 9, 10 and 11 illustrate the weight percentage of leaves and small-sized impurities in the waste for individual gaps and three rotation frequencies of rollers. Apparently, no dependency can be derived from the measured data. A slight difference can be observed between the individual rotation frequencies with the gap between rollers of 28 mm and 24 mm. With the gap of 20 mm there is almost no difference.

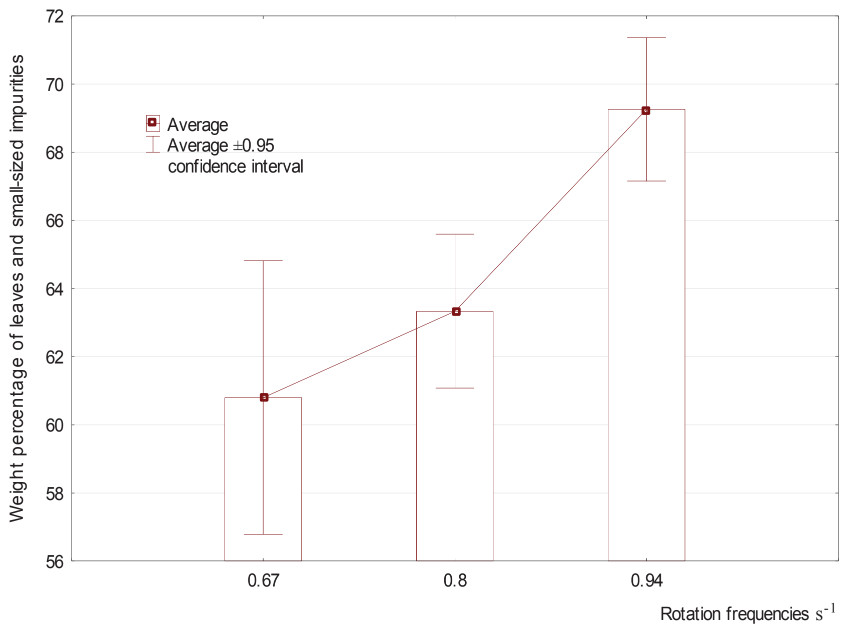

Figure 9. Weight percentage of leaves and small-sized impurities in the waste with the rollers of 89 mm in diameter, gap of 28 mm and three rotation frequencies.

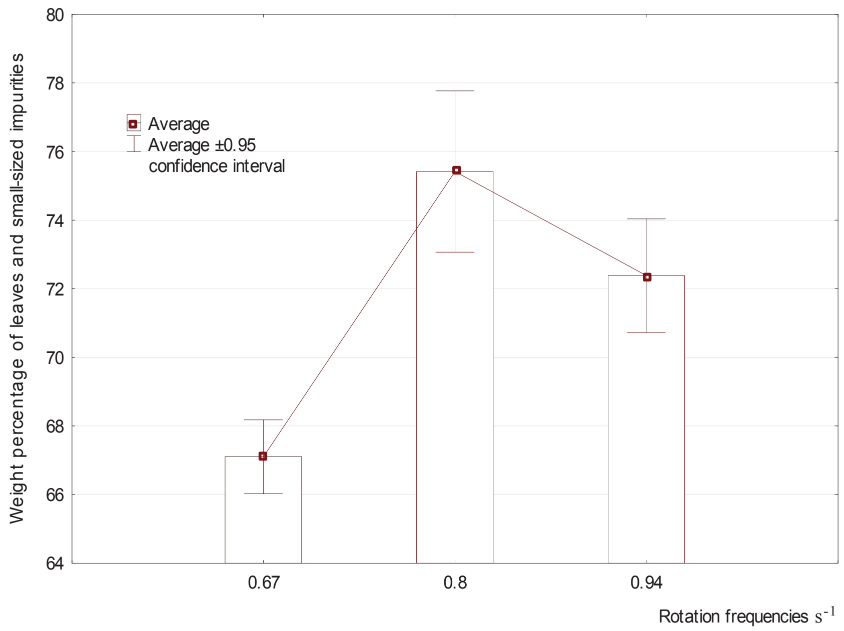

Figure 10. Weight percentage of leaves and small-sized impurities in the waste with the rollers of 89 mm in diameter, gap of 24 mm and three rotation frequencies.

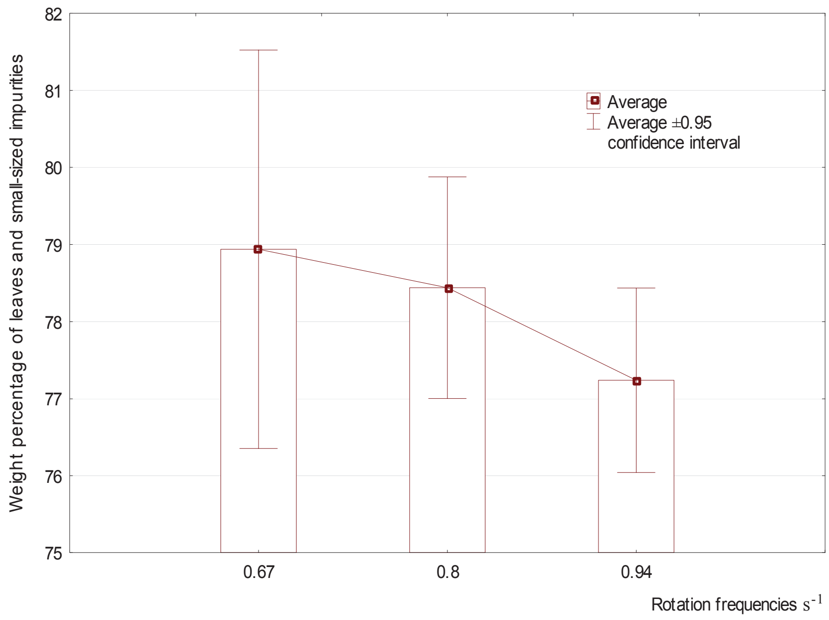

Figure 11. Weight percentage of leaves and small-sized impurities in the waste with the rollers of 89 mm in diameter, gap of 20 mm and three rotation frequencies.

CONCLUSION

In the course of the 2014 harvest season measurements it was found that neither the roller diameter nor the gap size between them have any effect on the separation of medium-length and long stems, which were separated perfectly in all cases. For this reason the measurements in 2015 were conducted using a hop matter sample which comprised only hop cones and leaves. The amount of these components had been precisely defined.

The measurements confirmed that decreasing gap between rollers results in separation of more leaves and small-sized impurities. At the same time, however, it increases the proportion of hop cones in the waste. In terms of the separation of leaves the best variant proved to be the variant with a gap of 20 mm, which was the smallest possible gap between rollers. With this gap setting, less than 79% of all leaves were carried into the waste. At the same time, however, 1.6% of hop cones was found in the waste.

When comparing these new rollers with a gap set to 20 mm with former rollers of 60 mm in diameter and the smallest possible gap of 48 mm, the difference in separated leaves makes approx. 60%.

No statistically significant differences were found when comparing different rotation frequencies of the rollers. For this reason any following measurements will be carried out with the basic rotation frequency of 0.67 s^{-1}.

ACKNOWLEDGMENTS. This article was written with the support of IGA TF CULS in Prague project number 2015:31160/1312/3112.

REFERENCES

Carter, P., Oelke, E., Kaminski, A., Hanson, C., Combs, S., Doll, J., Worf, G. & Oplinger. E. 2007. *Alternative field crops manual—hop*. [online] Last revision 1.8.2011). [cit. 12.1.2016]. Available from <http://corn.agronomy.wisc.edu/Crops/Hop.aspx>

Darby, P. 1999. *Economic yield potential of dwarf hop varieties. In: New Procedures in Hop Growing, Proceedings of International Symposium*, Hull, Bavaria, Federal Ministry of Food, Agriculture and Forestry, Germany

EAGRI. 2014 *Situation and Outlook Report of Hops* [online]. Last revision december 2015 [cit. 12.1.2016]. Available from: http://eagri.cz/public/web/file/433497/SVZ_Chmel_2014.PDF (in Czech)

Jech, J., Artim, J., Angelovičová, M., Angelovič, M., Bernášek, K., Honzík, I., Kvíz, Z., Mareček, J., Krnáčová, E., Polák, P., Poničan, J., Rybka, A., Ružbarský, J., Sloboda, A., Sosnowski, S., Sypula, M. & Žitňák, M., 2011. *Machines for crop production 3: machinery and equipment for post-harvest treatment of plant material,* Prague, Profi Press s.r.o., 368 p. ISBN 978-80-86726-41-0 (in Slovak).

Krupička, M. & Rybka, A. 2014. *Parameters affecting the separation small fraction of the roller track machine lines for the separation of hops*, XVI. International Conference of Young 2014, 9–10.9 2014, Czech university of life sciences Prague, Faculty of Engineering, 91–96 pp. ISBN 978-80-213-2476-3 (in Czech).

Krupička, M. & Rybka, A., 2015. Dependency of hop material fall through on the size of gaps between rollers of the roller conveyor in separating machine. *Agronomy Research* **13**(1), 101–108.

Neubauer, K., Friedman, M., Jech, J., Páltik, J. & Ptáček, F. 1989. *Machines for crop production.* SZN Praha, 716 s. ISBN 80-209-0075-6 (in Czech).

Seigner, E. & Lutz, A., Oberhollenzer, K., Seidenbergr, R., Seefelder, S., Felsenstein, F. 2008. *Breeding of hop varieties for the future*. Second International Humulus Symposium, Ghent, Belgium. ISHS *Acta Horticulturae* **848**, 49–58.

Štranc, P., Štranc, J., Holý, K., Štranc, D. & Sklenička, P., 2012. *Growing conventional varieties of hops in low trellis*, Praha: FAPPZ, ČZU v Praze a Zemědělská společnost při ČZU v Praze, ISBN 978-80-87111-33-8 (in Czech).

Štranc, P., Štranc, J., Štranc, D., Holopírek, F., Podsedník, J., Zídek, J., Alt, A. & Vent, L. 2010. *The benefits of the technology of low trellis* [online]. The last revision in 19.3.2010 [cit. 25.1.2015]. Available from: http://zemedelec.cz/prinos-technologie-nizkych-konstrukci/ (in Czech).

Vrzalová, J. & Fric, V., 1994. *Crop production – IV.* Prague: CULS Prague, FAPPZ, 80 p. ISBN 80-213-0155-4 (in Czech).

Wang, Q., Ding, Z.-H., Liu, J.-K. & Zheng, Y.-T. 2004. Xanthohumol, a novel anti-HIV-1 agent purified from hops Humulus lupulus. *Antiviral Res*. **64**, 189–194.