TRAINING MATERIALS USED IN A HOP PRODUCTION IN THE CZECH REPUBLIC

Pavel DONNER[16], Josef JEŽEK[17], Jaroslav POKORNÝ[18]

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Abstract
A development of the new materials usable as a support for growing hop in the Czech Republic (CR) stagnates. Despite the fact that we have materials (coir, paper, hemp etc.), that meet stringent ecological and environmental requirements such as biodegradability and ecological production, and at the same time meet the conditions necessary for use in hop growing, their use in practice is not accepted due to the high price of the material. Nowadays, annealed steel wire is the most used material in a hop production in the CR. Polypropylene twine (under commercial name Humulian) is used in lower extent (1.6 % of hop gardens in the CR). In case of steel wire, polypropylene twine is used for attachment of wires to the wirework at the ceiling, while Humulian is fixed directly by a knot. Environmentally friendly materials (hemp, jute, paper, sisal) are also tested as materials for attaching wires, but despite the promising results, the price of these materials is too high.
Keywords: hop / *Humulus lupulus* / wires / strings / twines

VODILA V PRIDELAVI HMELJA NA ČEŠKEM

Izvleček
Razvoj na področju novih materialov, ki bi bili primerni kot vodila v pridelavi hmelja, na Češkem stagnira. Kljub dejstvu, da obstajajo materiali (kokosova vrvica, papir, konopljena vrvica …), ki izpolnjujejo ekološke in okoljske zahteve, kot so biorazgradljivost in ekološka proizvodnja, in imajo obenem ustrezne lastnosti za uporabo kot vodila za hmelj, se v praksi ne uveljavijo zaradi visoke cene. V pridelavi hmelja na Češkem se uporablja žica. Polipropilenska vrvica (s komercialnim imenom Humulian) se uporablja le v manjšem obsegu (1,6 % hmeljišč na Češkem). Žica se na konstrukcijo žičnice zgoraj priveže s polipropilensko vrvico, medtem ko se Humulian nanjo naveže neposredno z vozlom. Okoljsko prijazni materiali (konoplja, juta, papir, sisal), s katerimi bi se z navezalo žico na žičnico namesto polipropilenske, so v fazi testiranja, a kljub obetajočim rezultatom je cena teh materialov previsoka.
Ključne besede: hmelj / *Humulus lupulus* / žice / vodila / vrvice

1 INTRODUCTION

Hop plants must be grown on a string or a pole (or other kind of support), on which they climb up. This way plants create a favorable microclimate and are able to use solar energy and space for biomass production effectively. This principle of growing hop is known for almost a

[16] Hop Research Institute, Co., Ltd., Kadaňská 2525, Žatec, 43846, Czech Republic, e-mail: donner@chizatec.cz and Czech University of Life Sciences, Kamýcká 129, Prague, Czech Republic, 16521, e-mail: donner@af.czu.cz
[17] Hop Research Institute, Co., Ltd., Žatec, Kadaňská 2525, Žatec, 43846, e-mail: jezek@chizatec.cz
[18] Hop Research Institute, Co., Ltd., Žatec, Kadaňská 2525, Žatec, 43846, e-mail: pokorny@chizatec.cz

thousand years. In such a long history material for training hop plants has undergone significant development, which continues even today. In hop producing countries, but also in regions within those countries, different kinds of support are being used. This is because of the historical development, tradition, experiences of hop growers, availability of materials, as well as ecological requirements.

Growing hop as a crop extended in the 12th century, when hop plants were already grown on wooden poles in hop gardens. The length of poles ranged from 5 to 8 (or even more) meters according to variety. Steel wires were used for the first time in 1850 in the Czech Republic. After World War I hemp twines were used for training. They were tossed over the wirework by means of different paperweights and were then fixed with a tie. In the 1930s these wines were replaced by cheaper annealed steel wire of approximately 1 mm diameter.

At the beginning, this wire was fixed by means of a special device but later by a simple bar to a hanging hook. Annealed steel wire is still used in the Czech Republic, but the technology of tying up has changed (Rybáček et al., 1980). Other materials are used now for training, particularly plastics, but also paper and coir are used and tested in the Czech Republic (Křivánek, 2010a). Hemp and jute twines are tested in Slovenia (Rijavec and Čeh, 2013).

2 MATERIALS USED FOR TRAINING HOP PLANTS IN THE CR

2.1 Steel wire

Steel wire of 1.06 - 1.25 mm in diameter is the most frequently used material to support hop bines in the Czech Republic. Wires (that are already cut to 8 m lenght) are delivered to hop growers in bunches of approximately 300 wires. Polypropylene twine is tied up to each wire, so the wire could be easily attached to the wirework at the ceiling of hop garden (Figure 1). Wire is fixed at the ceiling, it does not move in the wirework and is easily pulled down during a harvest. It's also easier for a staff to tie it up, which increases the labour productivity. Since relatively thin wire is used, polypropylene twine also prevents breaking the wire and falling hop plants during vegetation, because of decrease of friction between wires and corrosion. Most hop growers prepare wires themselves during the winter period (Figure 2). Some of them buy them from subcontractors. The price per one bunch ranges from 450 to 600 CZK (17 - 22 €). Preparing of wires helps to utilize employees during less-occupied period (Křivánek, 2010a).

The most common method of suspension of wires used in the Czech Republic, applied in hop-growing regions all over the world, involves a tractor-drawn platform (Figure 3). Wires are manually fixed to the wirework and slowly pulled out of bunches placed in plastic tubes as the platform moves forward (Rybáček et al., 1980). The average productivity is 230 – 280 tied wires/person/hour. The most common spacing used in Czech hop gardens is 300 x 100 cm. Some older hop gardens were made for 260 x 100 cm or 280 x 100 cm spacing. After suspension, a bottom part of wire is manually rolled up into so-called „bow" and stuck in the ground near a hop crown. The part of wire stuck in the ground decays in 2 – 3 years due to corrosion (Rybáček et al., 1980; Křivánek, 2010a).

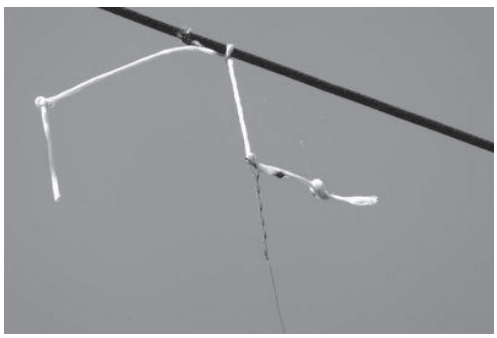

***Figure 1**: Tying of polypropilene twine on steel wire*
***Slika 1**: Način navezave polipropilenske vrvice na žico*

***Figure 2**: Winter preparation of bunches*
***Slika 2**: Povezovanje žice in polipropilenske vrvice – zimsko opravilo*

Benefits of using steel wire consist of proven production technology, higher effectiveness of the staff, quite low material costs as well as the possibility to occupy own employees during winter periods. Wire can be tightened also additionally, which prevent the bines to be slacked before harvest time (Křivánek, 2010a).

On the other hand, there are disadvantages in wire production. High weight that makes manipulation difficult, as well as impossibility to feed livestock with after-harvest biomass. Moreover, wire decays due to corrosion during the vegetation period by rain, pesticide and fertilizer sprays and irrigation water, which causes its reduction in the diameter by 17 - 20 %. That increases danger of breaking and falling bines. Wires also causes breakdowns of the picking machines, because they stuck in the rotating parts of harvester (Křivánek, 2010a).

***Figure 3**: Tractor-drawn platform for tying*
***Slika 3**: Traktorski stolp za napeljavo vodil*

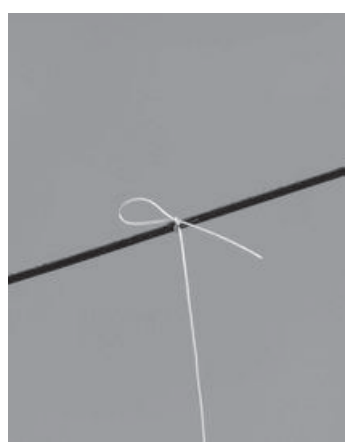

***Figure 4**: Humulian knot*
***Slika 4**: Vozel s polipropilensko vrvico, imenovno Humulian*

In 1985 the price was 3.63 CZK (0.13 €) per kg of wire. In subsequent years, the price steadily increased to a maximum of 22 CZK (0.81 €) per kg. Currently, in 2015, the price fell to 18.86 CZK (0.7 €) per kg. The total costs of buying wire rose from 1,500 CZK (55.5 €) per hectare in 1985 to 8,800 CZK (326 €) per hectar in 2008. The current average price for the wire is 7,543 CZK (280 €) per hectare.

2.2 Plastic string

Another support used in hop growing in the Czech Republic is „Humulian". It is a commercial name for polypropylene strings used in lower extent in a hop region Úštěk (1.6 %, i.e. 70 ha of hop gardens in the CR).

The Humulian is delivered in bunches prepared for stringing as a product. The diameter is 1.4 mm. Its surface is coarsened to increase climbing ability of hop bines. Polypropylene strings are uniform not only in their length (8 m) but in the number in a bunch (1000 pcs.) as well. It is necessary to keep them away from sun radiation in storage, because sunlight causes their decay and decreases their carrying capacity. Their durability is dimensioned to sustain till a harvest while degradation process (by the effect of sunlight and chemical compounds) is in progress. The part of string placed in the ground doesn't decay. During the fixation to hop crowns it is recommended to tie a small metal hook on the end of the string, which helps to fix it (Křivánek, 2010a). Polypropylene strings were originally made of white color, but hop growers wanted it to be green, because of attaching fallen bines - white string was hard to see on a background of blue sky.

Using polypropylene strings have some pros and cons. Winter preparation of wire bunches drops off, it is not necessary to modify their length and to use any kind of twine for fixing it at the ceiling. Polypropylene strings are fastened directly by a knot (Figure 4). Easy manipulation with the bunches is another advantage of plastic strings (Křivánek, 2010a).

The need to tie a hook on the end of the string is one of the reasons, which impede expansion of using plastic string in practice, because of its time and economic demands. A great number of deflected bine tips is another disadvantage of these strings. It is more difficult to remove parts of strings tangled in rotating parts of a harvester, because of a thermal deformation. If hop plants are more robust, it is necessary to tie them up together in a row due to bigger slackness caused by elongation of the plastic strings (Křivánek, 2010a).

2.3 Coir twine

Coir twine was used only experimentally in a part of a commercial hop gardens at Stekník farm in 2008. Twines were 8 m long with 4 mm in diameter (Figure 5). The surface was very coarse. They were attached to the wirework directly by a knot. Due to their strength they could be fixed directly to the ground (Křivánek, 2010a).

Using of coir twine can be assessed very positively. Number of deflected bine tips in the experiment was much lower than in the case of plastic string. Hop plants were very well stuck to it because of its coarse surface. No plants fell down before harvest. It was not necessary to

tie up hop bines together due to slackness. Coir twine is also good from an ecological and environmental point of view, as it is biodegradable (Křivánek, 2010a).

On the other hand, this type of a twine made stringing more complicated. It was very difficult to disentangle twines from bunches. They tangled in the suspension platform and were difficult to fix to the ground in windy conditions, because they flitted. There were also many problems during the harvest. It was laborious to remove parts of bines left at the ceiling because of too high strength of the coir twine. Coir twines also caused many problems in active parts of hop picking machines. This material is also too heavy, it is nearly the same weight as steel wire. Bigger utilization in the CR depends on the development of an appropriate and effective technology. These disadvantages impede expansion despite its very good ecological and environmental characteristics (Křivánek, 2010a).

***Figure 5**: Coir twine*
***Slika 5**: Kokosovo vodilo*

***Figure 6**: Paper strings*
***Slika 6**: Vodilo iz papirja*

2.4 Paper string

Paper strings of three different diameters (4.2, 5.0 and 6.0 mm) were tested at a Stekník farm in 2009. It is known under the commercial name BioCord (Figure 6). Its surface is smooth and it is delivered in reels. The producer is able to adopt individual needs of each client. Paper strings were attached to the wirework directly by a knot. Lower parts were fixed to the ground also with the help of a knot. Winding of hop bines on these strings was similar as on coir strings with the minimum of deflected bine tips (Křivánek and Ježek, 2010b).

No fallen plants were found during the vegetation. Nevertheless, there were found some rotten parts of paper strings, which were in contact with soil after hilling. Although the plants were high enough at that time, the rotten strings caused slackness of hop plants, that made treatments against pests and diseases difficult during the vegetation. It was necessary to tie up

the bines together. The producer recommends using metal wires for fixing the end of paper string to the ground. It should prevent rotting. Unfortunately, this operation is very difficult to realize in practice because of its high labor demands (Křivánek and Ježek, 2010b).

There were no problems pulling down the bines during the harvest. Only parts of 6.0 mm strings and bines left at the ceiling after a harvest were difficult to pull down. No problems occured in a hop picking machine. Practical utilization of paper string is possible of the same reason as the coir string, i.e. ecological and environmental impact. Nevertheless, missing suitable and effective technology of suspension to the wirework as well as fixing to the ground is a great disadvantage. It is also too heavy for a manipulation (Křivánek, 2010a).

2.5 Alternative attachment of wires

Recently, the research focuses on material change for fixing steel wires to the wirework at the ceiling. Polypropylene (PP) twine gets into the harvested product as the dopant and reduces its quality. The problem is also its presence in the soil. Alternative materials, such as hemp, jute, paper or sisal (cantala), are tested in the CR. The current results show perspective in using jute or hemp twines. During a harvest, hemp twine with a diameter of 1.8 mm obtained 100 % of rupture in a twine in the first case and 95 % in the second case, with spontaneous bine-fall rate of 0.68 %, respectively 0.34 % during a vegetation. Jute twine reached very good results too. The rupture in twine during a harvest occurred in 72 % of cases with only 0.06 % spontaneously fallen bines during a vegetation. Rybka et al. (2011) and Heřmánek et al. (2012) reached similar results in their experiments. However, the price of the material is crucial. It is 4.3-times higher in the case of hemp twine and 5.56-times higher in the case of jute twine, compared to PP twine. It might be possible to achieve a price reduction with a market research and by purchasing materials in large quantities (Vent et al., 2015).

3 HARVEST

The use of all above mentioned kinds of strings and twines allowed the same technique of harvest, so it was possible to compare the impact of various materials on this agrotechnological arrangement.

A tractor with a harvester and a single-axle transport trailer (with hydraulically operated side panels and a hydraulic motor driven rotating grate) passes row, while pulls down plants on the trailer (Figures 7 and 8). The harvester is equipped with a cutting device, which cuts each bine and then carries it with a chain conveyor (speed synchronized with the travel speed of the tractor) to the pulling drum, where the lower part of the plant is gripped, so it can be pulled down during the forward movement of the tractor and landed directly on transport trailer. Harvested bines are then transported to hop-picking machine, where the load is unloaded with rotating grate of the trailer. Each bine is then manually put in the chain conveyor of a hop-picking machine and drifted into the rotating plucking (picking) walls. After plucking the bare bine in conveyed to the cutter and branches, cones and leaves continue to hop-picker, where leaves and cones are separated from branches, and then to multiple mechanical and air cleaning. After cleaning, cones are either transported directly to the dryer or to the air-conditioned transport trailer, which transports clean cones to the dryer (if the dryer is not attached directly to the picking machine).

***Figure 7**: Tractor with a harvester*
***Slika 7**: Traktor z trgalnikom*

***Figure 8**: Transport to the hop-picking machine*
***Slika 8**: Trasport k obiralnemu stroju*

4 CONCLUSIONS

Although there are some perspective training materials, annealed steel wire is still going to be the most used material for training hop in the CR in the next decade. A proven technology, price of a material, relatively fast decay in soil, its strenght and ability to support hop plants are properties that cannot be substituted with any other of the tested materials. Plastic string (Humulian) is easier to use, because winter preparation drops off, but there are problems like great number of deflected bine tips, difficult removing of wound strings tangled in rotating parts of a harvester and need to tie bines up together due to bigger slackness. Polypropylene string is also not environmentally friendly. Coir twines and paper strings are environmentally friendly, but there are disadvantages like complicated stringing, rotting of parts that are stuck in the soil during vegetation and, of course, price of a material. Unfortunately, Czech hop growers will not be opened to new, more ecological materials, until the (crucial factor) price reduces.

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