Analysis of strength ratio of different hop strings

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Abstract

Heřmánek P., Rybka A., Honzík I., Vent L., Jošt B., Mašek J., 2012. **Analysis of strength ratio of different hop strings**. Res. Agr. Eng., *58*: 148–154.

In plant-growing, minimization of impurities in the final product plays a more and more important role. One of the risky places that can influence the final purity of granules in hop growing is the way of hop strings hanging on the trellis supporting wire. The ideal state is when hop-field supporting wires stay clean and without any attachments after the hop vines had been pulled down. The article deals with different variants of hop strings hanging, a description of the measuring equipment, and a measurement of the pulling force itself at a field test, and a realization of break tests in laboratory conditions with both new and used wires and twines. Two-year results of field tests proved advantageousness of the hop string hanging variant in combination of a black annealed wire of 1.06 mm in diameter with a polypropylene twine of strength labelled as 12,500 in the form of a simple attachment, as well as variants combining the same wire and a jute twine labelled 2,200 × 2 in the form of a double attachment. Other variants using attachments made of jute or sisal are unsuitable due to a large number of fallen hopvines in vegetation period. Paper attachments will be put to further tests.

Keywords: pulling down; hops; wire; twine

In the period of hops overproduction its purity is one of the priority indicators of hop processing quality ensured by grower. Nowadays, when hop strings – wires are hung on the supporting trellis by means of attachments made of polypropylene twine, it is possible to search for other hanging solutions which would substitute the polypropylene twine. Such a step would contribute to reduction of contamination of hops intended for further processing.

MATERIAL AND METHODS

The research dealing with different variants of hop string hanging was carried out for second year in a row in a hop field situated between the villages of Oploty and Neprobylice near the town of Žatec, Czech Republic. The hop field was founded in 1979. Field measurements in 2010 and 2011 used a part of the total hop field acreage. In 2011 we tested combinations of various strengths and versions of attachments made of polypropylene twine (simple and double attachments). In 2011 we adopted the 2011 attachment version only with the most suitable strength combination (Rybka et al. 2011). The experiment was further extended by another combination variants of wires with different strength and twines of different material. Besides hop-string hanging by means of twines, some other hanging variants were tested without using twines (Heřmánek et al. 2011).

Supported by the Ministry of Agriculture of the Czech Republic, Project No. QI101B071.

The field experiment monitored strength relations between a guide wire (hop string) and its attachment, or – with the variant of a direct attaching of a hop string to the supporting wire of the hop field trellis – the relation between a guide wire and the supporting wire. In the course of the experiment, during the hopvine harvest the measurement of the strength of the wires and twines was carried out. The field experiment included twenty-eight combinations of hop-string attachments to the hop field supporting wire.

Measured material:

– black annealed wire with diameter of 0.90, 1.06, 1.20, 1.30, 1.40 mm (ŽDB Drátovna corp., Bohumín, Czech Republic)
– polypropylene twine (JUTA Ltd., Dvůr Králové nad Labem, Czech Republic) 11,000, 12,500, 17,000 (strength labelling by producer)
– jute twine (JUTA Ltd., Dvůr Králové nad Labem, Czech Republic) 1,700 × 2, 1,700 × 3, 2,200 × 2 (strength labelling by producer)
– sisal twine (JUTA Ltd., Dvůr Králové nad Labem, Czech Republic) 2,000, 3,300 (strength labelling by producer)
– hemp twine (JUTA Ltd., Dvůr Králové nad Labem, Czech Republic) of strength labelled by producer 323 N,
– paper twine (producer Textilose, Les Echelles, France) of 4.20 mm in diameter.

With the twine attachments two versions were tested – the so called simple and double attachment (Fig. 1).

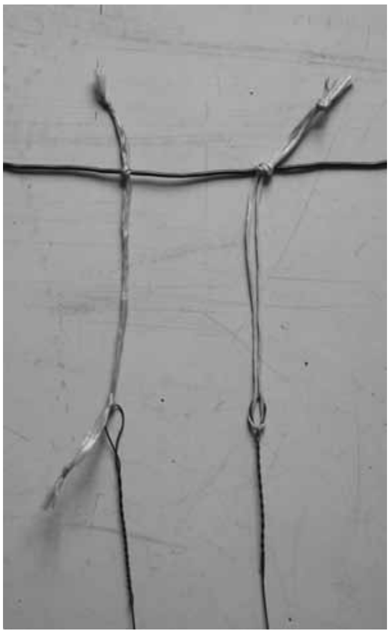

Fig. 1. Demonstration of a simple and double hop string attachment

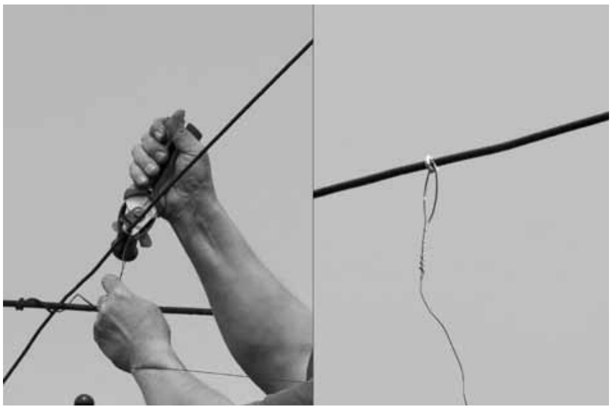

Fig. 2. Usage of stapling pliers and a stapled hop string

Steel galvanized staples of VR22 ZN type (Isaberg Rapid AB, Hestra, Sweden) were also used to attach the hop strings. The stapling was done by stapling pliers type FP 222 (Isaberg Rapid AB, Hestra, Sweden). To attach a hop string onto the hop field supporting wire by means of a staple, at the end of the hop string had to be created a loop through which it can be "stapled" to the hop-field wire (Fig. 2).

Stapling was fully convenient for the technological procedure of hop strings hanging when a hop string must be attached in such a way that it is spontaneously drawn up from the bundle of wires when the platform for hanging gets in motion and at the same time that it does not move along the hop field supporting wire.

Another specially tested variant was hanging a hop string on an attachment made of steel wire and attached beforehand. Such an attachment may be fixed to the supporting wire of a hop field already at its foundation and can stay there for the rest of its life. The attachment loop is designed in a way so that the hop string could be easily hung and could

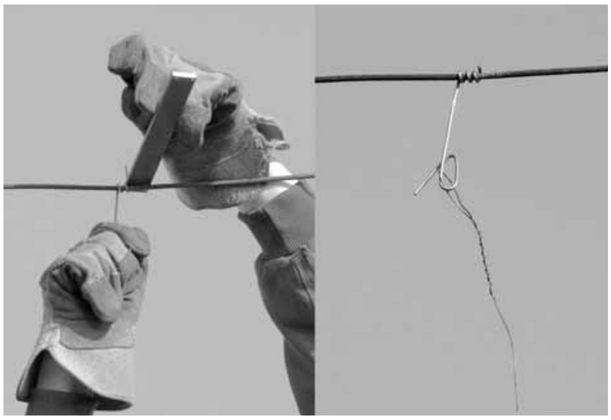

Fig. 3. Winding of an attachment around the hop-field supporting wire, and an attachment with a hung hop string

not slip out when the field trellis trembles due to wind gust or during the harvest pulling down. The shape of the attachment had been prepared beforehand to be further easily attached onto the supporting wire via winding by means of a lever (Fig. 3).

The field experiment focused on:

(1.) Detection of any hopvines fallen spontaneously down during the vegetation period before pulling down.

(2.) Measuring the breaking force of a hop string (or perhaps an attachment) at pulling down the hopvines.

(3.) Detection of the breaking point at pulling down the vines (with wire or twine).

(4.) Taking samples of a hop string and its attachment for purposes of laboratory measurements.

Owing to the construction of the vine puller that is used nowadays to harvest hops, it was impossible to place force sensors directly on the puller. Therefore an equipment was created in which pulling down is done under the same conditions as with pullers, yet it is possible to measure each single hop vine one by one in a row.

Measuring of force in field conditions. To measure the breaking force of a hop string or an attachment, equipment depicted in Fig. 4 was assembled. It consists of a tractor with a trailer which was supplemented with a frame for swing anchorage of the tensile sensor. The other side of the sensor was prolonged by the trailer to catch hopvines when pulled down. The equipment dimension had been designed in a way to enable the same conditions for pulling down as with harvest pullers.

This means that both the spot of vine attachment at pulling down and the vine angle at pulling down were kept. The swing placement of both ends of the tensile force sensors ensured that at pulling down only the axial force in the hop string was measured.

To measure the force itself we used a tensile force sensor supplied by HBM Brno company, Brno, Czech Republic with type designation of U9B (HBM, Darmstadt, Germany) and measuring range 0–1 kN.

The sensor output signal was further processed by means of MGC plus, a mobile central measuring station also supplied by HBM company and connected to a laptop. The central measuring station, sensor, and the measured data storage were secured by the Catman Easy program (producer, town, state??), which is provided with the station. After the whole measuring system had been installed, a control of the sensor calibration was done by means of a hanger (producer, town, state??) with weight of 30 kg (Vent et al. 2011).

Methods of measurement:

(1) Measuring in the course of an uninterrupted pulling of hopvines down in one row of the experimental hop field.

(2) Cutting vines off at the height of app. 0.8 m above the ground.

(3) Passing vines through the loop on the sensor arm.

(4) Stretching vines at an angle of 45° by tractor travelling with trailer (Fig. 4).

(5) Breaking a hop string or an attachment by a continuous pull.

(6) Placing the vines on the trailer after being cut down.

(7) Recording the tensile force at a time frequency of 50 Hz in the course of pulling one whole row of vines down.

(8) Recording with each pulled vine if the hop string or attachment had broken.

Measuring force in laboratory conditions. Measurements of breaking force with both new as well as used wire and twine was done on Amsler-200

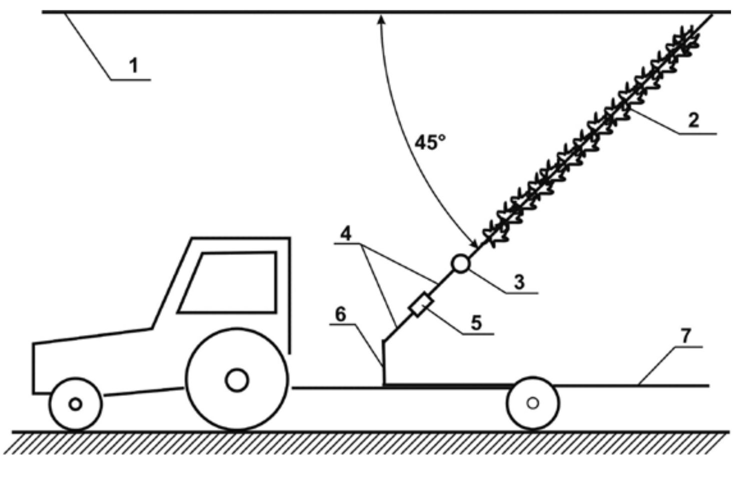

Fig. 4. Schematic description of equipment measuring the force at hop vines pulling down 1 – supporting wire of hop-field trellis, 2 – hopvine on hop string, 3 – loop to attach hopvine to tensile force sensor, 4 – swing arms of the sensor, 5 – tensile force sensor, 6 – frame to attach sensor arm, 7 – semi-trailer

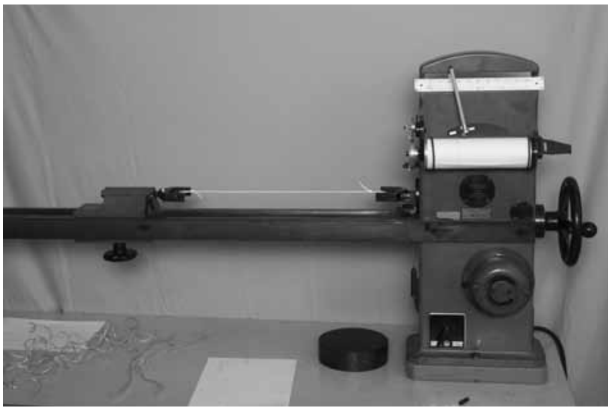

Fig. 5. Amsler-200 Break testing machine

break testing machine (producer, town, state??) (Fig. 5) with breaking mechanism shift speed of 100 mm/mm. During the breaking test the breaking force and elongation of the measured wire and twine were recorded (block diagram).

Taken samples of new wires and twines:
- 10 samples of each type of wire and twine were available for repeated measuring.

Samples of wires and twines taken after the harvest:
- from each type of hop string wire 5 pieces were taken, from which 1 m was cut off the upper, middle, and lower part of the string. Altogether 75 sample pieces were taken, 5 pieces × 3 samples (upper, middle, lower) for each of the 5 wire types
- from each type of twine 5 samples were taken in such a way that from the platform a vine with the wire was cut off closely under the twine attachment, and then the twine was cut from the hop field trellis. Thus when the sample was being taken, the twine was not strained by any tensile force. Altogether 50 pieces of twine samples were taken (10 types of twine × 5 pieces)

Theoretic analysis of tensile strength. Material that is subject of measuring the tensile strength is permanently deformed. A material of length l (mm) is at its one end secured in a fixed jaw and at the other end in a movable jaw where acts force F (N) in a horizontal (axial) pull. Due to the effect of this force the material breaks. From the difference in length of material after the break and length at the beginning of the tear test, elongation Δl (mm) is determined. The quotient of elongation Δl and original length l is elongation ε:

$$\varepsilon = \frac{\Delta l}{l} \qquad (1)$$

where:

ε – non-dimensional number

The quotient of force F (N) which takes an effect in the direction of the normal to material cross-section S (mm^2) is normal stress σ (N/mm^2):

$$\sigma = \frac{F}{S} \qquad (2)$$

Strength of a wire or twine is the stress at maximum loading force. The measuring device was set to required parameters and recorded the measurement number, measured sample diameter d (mm), breaking force acting horizontally (axially) F (N), and a corresponding elongation length of the guide wire – Δl (mm). For all the other repetitions the calculation determined elongation ε, normal stress σ (N/mm^2), and there average values [$\bar{\varepsilon}$, $\bar{\sigma}$].

The repetition variability was assessed by standard deviation and coefficient of variation (Puchmajer 1999).

RESULTS AND DISCUSSION

The field measurement was carried out on August 23, 2011 in an experimental hop field. For purposes of the measurement all of the variants of a hop string or attachment were chosen, and from the remaining rows that were not harvested, samples of hop strings and attachments were taken for following laboratory measuring. The resulting values are to be found in Table 1.

The laboratory measurement was carried out in the laboratory of the Department of Agricultural Machines, Faculty of Engineering, CULS Prague at an air temperature of 25°C and air humidity of 35%. The resulting values are shown in Table 2.

A substantial fraying occurred with every single twine sample, due to which it was not possible to measure the twine length after the break. For this reason the twine elongation measurement was abandoned.

After all the measurements had been processed, their analysis was performed, which compared the laboratory measurements of both strength and elongation of a new wire and a twine with the output values from the field measuring and the following laboratory measuring of samples taken in the hop field.

Table 2 shows a comparison of the breaking force and the elongation of a new wire and a wire exposed to the hop field environment and taken at the field measurement. Furthermore, it compares the breaking force of new twines and twines exposed to the hop field environment, taken at the field measurement.

Table 1 Field measurement results

No.	Description	Wire (mm)	Attachment type	Fallen vines (pcs)	Average *F* (N)	SD (N)	VC (%)	BP hop string wire (%)	BP attachment (%)
1	staple	1.06	staple		329	41.6	12.6	100	0
2	staple	0.90	staple		271	29.6	10.9	100	0
3	check	1.06	PP 12,500 D		record mistake of central measuring station				
4	check	1.06	PP 12,500 J		329	78.8	23.9	0	100
5	wire + twine	0.90	paper 4.20 J		measured value – same variant as ad/ 6				
6	wire+twine	0.90	paper 4.20 J		302	55.5	18.4	100	0
7	wire on wire	1.20			455	47.3	10.4	100	0
8	wire + twine	0.90	PP 12,500 J		245	46.7	19.1	7	93
9	wire + twine	0.90	PP 12,500 J		measured value – same variant as ad/ 8				
10	wire on wire	1.30			641	30.4	4.7	100	0
11	wire + twine	0.90	PP 12,500 D		measured value – same variant as ad/ 12				
12	wire + twine	0.90	PP 12,500 D		303	48.8	16.1	100	0
13	wire on wire	1.40			636	40.1	6.3	100	0
14	wire + twine	0.90	hemp 323 J		240	31.2	13.0	26	74
15	wire + twine	0.90	hemp 323 D		307	55.8	18.2	100	0
16	wire + attach. steel wire	1.06			389	61.6	15.9	100	0
17	wire + twine	0.90	jute 1,700×2 J	20	measured value – big share of fallen vines				
18	wire + twine	0.90	jute 1,700×2 D	2	record mistake of central meas. station				
19	wire + twine	1.06	jute 1,700×3 J	9	184	26.8	14.6	0	100
20	wire + twine	0.90	jute 1,700×3 D		327	70.0	21.4	93	7
21	wire + twine	0.90	jute 2,200×2 J	5	120	44.5	36.9	0	100
22	wire + twine	1.06	jute 2,200×2 D		333	72.1	21.6	7	93
23	wire + twine	0.90	sisal 2,000 J	27	measured value – all vines fallen				
24	wire + twine	0.90	sisal 2,000 D	13	measured value – big share of fallen vines				
25	wire + twine	1.06	sisal 3,300 J	14	measured – big share of fallen vines				
26	wire + twine	0.90	sisal 3,300 D	2	245	14.8	6.1	36	64
27	wire + twine	0.90	PP 11,000 D	2	265	33.1	12.5	79	21
28	wire + twine	1.06	PP 17,000 D		362	49.4	13.7	100	0

J – simple attachment, D – double attachment, PP – polypropylene, No. – treatment number, SD – standard deviation, VC – variation coefficient, BP – breaking point, F – breaking force

The results of the black annealed wire break test prove that the difference in breaking force between the new wire diameters of 0.90 and 1.06 mm is insignificant. Therefore it is recommended, regarding the material saving and related lowering of costs of hop strings, to use a wire of 0.90 mm in diameter.

According to the measured results it is possible to state that with the used wire the average elongation was lowered. This lowering is probably influenced by the hop field environment during the vegetation period (when growing vines weight, weather conditions, and chemical application increase).

When a used wire was break tested it was found out that its strength was not influenced by the sampling place on a hop string. Contrary to the measurements from two years ago, this time a dependency of the elongation on the place of wire sampling on a hop string was not affirmed.

To break a new wire of 1.20, 1.30, and 1.40 mm in diameter it is necessary to produce a relatively big

Table 2 Comparison of a new wire and twine with a sample taken at the field measurement

Material	Average F (N)	Average ε (%)	Average F (N)	Average ε (%)
Black annealed wire d (mm)	new		used	
0.90	244	28	252	13.4
1.06	247	24	354	14.3
1.20	456	24	457	12.3
1.30	602	32	620	10.9
1.40	496	24	608	23.3
Twine	new		used	
Polypropylene 11,000	471		445	
Polypropylene 12,500	520		364	
Polypropylene 17,000	682		526	
Sisal 2,000	222		77	
Sisal 3,300	360		106	
Jute 2,200 × 2	473		299	
Jute 1,700 × 3	434		240	
Jute 1,700 × 2	319		198	
Hemp 323 N	307		282	
Paper 4.20	1,384		636	

The average force values apply to simple attachment; d – diameter, F – breaking force, ε – enlogation

force which has 456 to 602 N on average, thus imposing an unnecessary strain on the pulling equipment as well as to the supporting hop field trellis at pulling down. These wire diameters were used only for the purpose of checking the so-called wire-on-wire hop string hanging, when the hop field supporting wire is directly winded by the hop string wire at hanging. With this type of hanging there is no elastic element between a hop string and supporting wire. Among hop growers there is an opinion saying that during the vegetation period of hop plants, hop strings hung in this way tend to break due to the wind.

The breaking force of twines reaches in most cases a higher value than with the most frequently used wire of 1.06 mm in diameter. They are values measured with new twines though.

Comparing the force at break of new and used twines proves its substantial decrease. Weather conditions and probably also application of plant protection chemicals cause a substantial damage to the twine material.

CONCLUSION

From the field measurements results it is apparent that in 2011, similar to 2010, as an effective variant of hop string hanging proved to be the combination of a black annealed wire 1.06 mm and a polypropylene twine of strength designation 12,500 in the form of simple attachment. The given variant showed 100% successful break in the place of a twine at pulling down (Table 1, var. 4).

Even better results showed the variant which combined a black annealed wire 1.06 mm and a jute twine of designation 2,200 × 2 in the version of double attachment (Table 1, var. 22). In this case from the total amount of vines in 93% occurred the break in a twine, and only in 7% occurred the break in the supporting wire. The break in twine includes 57% breaks right in the place of the attachment to the hop field supporting wire, which constitutes an ideal solution of a complete twine removal in hop fields.

The other variants using jute (except for var. 22) or sisal attachments are unsuitable due to fallen vines during the period of vegetation. Only the twine made of sisal with the highest strength and only with double attachment ensures that hopvines remained on the trellis. However, during the vegetation period also here two hop strings spontaneously fell down. The paper attachments will be subject to further testing.

The opinion saying that the hop string hung by method «wire on wire» results in hop string fall was not proven. Yet, here is necessary to emphasise that for the purpose of the experiments, bigger wire diameters were chosen.

With the hop strings hung by means of galvanized staples a problem occurred. At pulling down the vines the staple starts opening and then moves along the supporting wire. Taken into consideration the simplicity and speed of hanging, it would be helpful to find a solution that would prevent the opening staple from moving along. Also the staple strength can be lesser, as in every case the wire break occurred (of both diameters 0.90 and 1.06 mm).

With the steel wire attachment (Fig. 3) some vines also moved along the supporting wire at the harvest. It is obvious that it will be necessary to assess and compare also the economy of hanging in the current way and in the newly suggested ways.

Variants 23, 24, 25 were attached by means of sisal twine which proved to be incapable of resisting the weather conditions during the whole hop plant vegetation period.

In the following research we suppose to work up the field test with various types of hop strings and their attachments. We will examine the difference in characteristics of the same hop strings by various producers, and the testing will repeat the combinations of hop strings and attachments which have so far brought the best results. For further variants we will prefer natural materials for attachments. Within the bounds of the measurement we will compare harvesting using tensile equipment with harvesting by means of a common vine puller. For a better accuracy of the research we suppose using tensile force sensors, placed on hop strings and monitoring its rise during the vegetation period.

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Received for publication June 5, 2012

Accepted after corrections September 11, 2012

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