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Testing of quality of sowing by pneumatic sowing machines

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ABSTRACT

Purpose: The purpose of the paper is to presents two sowing machines for interval sowing, differing in the mode of operation. We were interested in adequacy of sowing at different working speeds of the pneumatic vacuum sowing machine OLT and the pneumatic pressure sowing machine Aeromat - Becker for sowing sugar beet. The goal of the paper is to find out the optimum working speed for the individual sowing machine.
Design/methodology/approach: : In completely identical conditions at different speeds of sowing two sowing machines which are most widely used in Slovenia were tested.
Findings: We measured and calculated the parameters such as working efficiency, depth of sowing, inter - row distance and distance between seeds in the sowing row.
Research limitations/implications: For successful sowing it is necessary to know adequacy of the soil for sowing, technical properties of the sowing machine and biotechnical characteristics of the seed. Cultivation of sugar beet depends primarily on expert and technically correct sowing. For growth and normal development of plants the distance between seeds in the sowing row is the most important parameter.
Practical implications: Expertly performed sowing and sowing machines are of great importance for cultivation of sugar beet. The tests were aimed at defining the most suitable sowing speed for both sowing machines on the basis of measured data. The principal aim of the paper is to establish whether the higher working speed influences the quality of sowing. It is very important for the producers to be well familiarized with all agro - technical measures because cultivation of sugar beet requires much money invested and work performed per unit of area.
Originality/value: : The optimum sowing speed of the pneumatic vacuum machine OLT is 8 km/h and the optimum sowing speed of the pneumatic pressure sowing machine Aeromat - Becker is 10 km/h.
Keywords: Technological devices and equipment; Sowing machines; Working speed; Inter - row distance

1. Introduction

Suitable sowing machines and expertly performed sowing is of great importance in cultivation of sugar beet and optimum lot of plants and their arrangement per ha can be reached [1]. The sugar beet is cultivated for its root rich in sugar. The most important product of the sugar beet is sugar (disaccharide saccharose), which is a rich source of energy and food easy to digest. By products are important for the food in animal production and in processing industry [2].

The sugar beet is of great importance for crop - rotation and is a crop with the greatest energy and ecological potential. Omitting of cultivation of sugar beet in the EU on a long term basis may have serious consequences [3].

Sowing must be performed fastest possible because the optimum time of sowing of sugar beet is short. The time of sowing is restricted also by bad spring weather. The sugar beet producers have doubts as to the quality of the increasing speed of sowing. The problem appeared when the producers were faced with a too bad sprouting of sugar beet on their lots. Thus, higher

costs of cultivation of sugar beet occurred due to smaller produce or repeated sowing. Due to doubts about the efficiency of fast sowing we decided to make a test of sowing at different speeds.

The sugar beet is sown on the final lot. The most important agro - technical measures is the sowing which is to be carried out on a well prepared land area to be sown [4]. The quality of working of the sowing machine and the driver's precision are of key importance so sowing must be accurate. The driver must follow up the trace of the coulter, he must drive as straightly as possible at constant speed and pay attention to operation of the sowing machine, quantity of the seed in the discharge container and possible clogging of sowing shares.

There are a lot of different sowing machines available on the market for sowing of sugar beet [5]. Comparison and analysis of sowing by the pneumatic pressure sowing machine Aeromat - Becker and the pneumatic vacuum sowing machine OLT were compared.

2. Material and work methods

2.1. Pneumatic pressure sowing machine Aeromat – Becker

This sowing machine ensures interval sowing of sugar beet and other crops which do not spread out. Calibrated or non - calibrated seed can be sown, since different sowing plates are available. During sowing the sowing plate rotates and is filled with seed. Onto it the air flow is directed, which blows off surplus seeds. The sowing machine was equipped with six sowing apparatuses which were connected in the form of a parallelogram to the supporting frame (Figure 1).

The coulters were of disk form and were controlled hydraulically. The sowing machine was driven by a fan driven by the tractor connecting shaft. The sowing apparatuses were connected to the fan by a plastic tube. The sowing machine is placed onto two guiding and, simultaneously, driving wheels driving the transmission shaft which drives the sowing plates. The sowing machine is provided also with an air pressure meter indicating the current working pressure and possible changes in functioning of the sowing machine. The sowing shares were of slide block form followed by the burying device and single - part pressing disk having a rubber ring round the circumference [6].

Fig. 1. Sowing machine Aeromat, model 6K-T [7]

2.2. Pneumatic vacuum sowing machine OLT

The pneumatic vacuum sowing machine ensures interval sowing of various crops including sugar beet (Figure 2). It works according to the principle of the vacuum so that the seeds adhere to the sowing plate. It, too, ensures sowing of calibrated and non - calibrated seeds. The tested sowing machine had six sowing apparatuses having available different sowing plates. The sowing apparatuses are provided with a forced spring enabling the sowing machine to adapt to unevennesses of the soil. The two disk coulters are interconnected by tightening chains and are controlled mechanically. The vacuum pump is driven by the tractor connecting shaft. The sowing apparatuses are connected to the vacuum pump by plastic tubes. The sowing apparatuses are provided with a safety clamp which is activated when the sowing paths are clogged. The sowing shares are of slide block form and are connected to the two - part pressing disk [8].

Fig. 2. Sowing machine OLT, model PSK [9]

2.3. Tractor as driving power on sowing machine

During testing, always an identical tractor was used. That was the tractor Eicher with four - cylinder engine of 37 kW output. The transmission with the highest speed of the connecting shaft 540 rpm with 2150 rpm of the tractor engine shaft was used. That was a quite sufficient power to reach sufficient pressure and/or vacuum already in case of 950 rpm of the tractor engine shaft. Both types of sowing machines are connected to the tractor by means of a three - point frame so that the tractor gravity center is moved backwards. Steering of the tractor posed no problems, since it has longer wheel - track centers and sowing was effected on the level ground. It had only the rear - wheel drive.

The tractor was equipped with narrow wheels of 11 inches or 28 cm size. This is very important, since the inter - row distance of sugar beet is only 45 cm, therefore, wider tyres might stamp the rows. Of greater importance, still, is the width of the wheel track which, in our case, was 1.35 m, which is ideal. Thus, the tractor is ideally prepared also for later activities, such as sprinkling, earthing etc.

2.4. Purpose of paper

To reach optimum hectare produce of the sugar beet it is necessary to perform expertly also the following agro - technical activities such as: basic cultivation of soil, fertilizing, pre - sowing cultivation of soil, sowing and care of the growing crop [10, 11].

One of the most important agro - technical activities in production of sugar beet is sowing. The purpose of the paper was to compare two pneumatic sowing machines, most widely used in this region for sowing sugar beet. We wanted to establish how different working speeds influenced the quality of sowing and to determine the optimum sowing speed of the individual sowing machine [12, 13].

The quality of sowing implied the following parameters:

- inter - row distance - 45 cm,
- distance between seeds in sowing row - 21 cm,
- depth of sowing - 2.5 cm.

The working speeds were as follows: 4.5 km/h, 6 km/h, 8 km/h, 10 km/h and 12 km/h. Of course, the increase of speed supposes the increase of productivity and cost - effectiveness of sowing [14]. Also the working efficiency of both sowing machines was measured.

2.5. Measurement of travelling speed

Measurement of travelling speed during sowing was performed by means of the measuring wheel. We decided on the measuring wheel because the existing tractometers are rather inaccurate. This applies particularly for tractors of older type, such as used by us. The measuring wheel was mounted on the tractor by means of a special beam, so that it ran in parallel with the rear right - hand wheel of the tractor. By an adjusting screw it was so adjusted that it pressed upon the soil sufficiently. Thus, undesirable slipping of the measuring wheel was avoided. Next, a display for indication of the travel speed close to the steering wheel was installed. Then the whole unit was connected to the tractor electric current. The speed could be read within 0.5 km/h accuracy. By means of the measuring wheel and display of the current travel speed the travel at the desired speed was always possible. It is only necessary to select the proper gear ratio of the change - speed gear and to dose softly the gas.

2.6. Technical setting of pneumatic pressure sowing machine Aeromat - Becker and sowing test

Before sowing, each sowing machine was inspected, lubricated, set to desired values and, finally, tested. For setting we used the maker's setting tables which must not be missing on any sowing machine. First, the sowing apparatuses were accurately set to the inter - row distance of 45 cm. This was achieved by moving the sowing apparatuses on the sowing machine frame.

Then the follow - up coulter was set to 90 cm length by means of the theoretic calculation. This is the distance between the outer sowing unit and the coulter tip. The sowing machine is provided with hydraulic coulter lifting and lowering facility. The coulter setting must be also practically tested. This was performed on the edge of the field, where we covered a length of 30 m, then we turned and measured the inter - row distance between the individual rows. In addition to proper setting, the tractor driver must pay high attention to drive with the tractor front wheel precisely along the trace made by the follow - up coulter. All distances were equal to 45 cm. On the field we also set the sowing depth. All sowing apparatuses were positioned in horizontal with the supporting frame.

Then, depth of sowing was set to 2.5 cm by means of the pressing disk. Setting of the fan pressure to 0.05 bar followed. The pressure must be adjusted depending on the size and weight of seeds of different crops.

We had only to adjust still the distance between seeds in the sowing row: this was performed by means of the gear ratios of the change - speed gear and setting tables. The distance between seeds in the sowing row was set to 21.3 cm.

For the sowing test the sowing machine was connected to the tractor, the hydraulic system lifted and the fan activated. A small plastic bag collecting the seeds falling out was placed onto each sowing apparatus.

The seed was filled into the discharge containers and the driving wheel was rotated 30 times. The circumference of the driving wheel was 155 cm. During the test rotation the wheel covered a distance of 4650 cm and 218.3 seeds would have to be ejected. On an average all sowing apparatuses ejected 218 seeds, which coincides with the desired distance between seeds of 21.3 cm.

2.7. Technical setting of the pneumatic vacuum sowing machine OLT and sowing test

The sowing machine OLT was prepared for sowing in the same order of activities as the Becker sowing machine. For setting the setting table was used. The sowing apparatuses on the sowing machine framework beam were moved to the desired inter - row distance of 45 cm. The follow - up coulter length was the same as on the preceding sowing machine (90 cm).

The desired sowing depth of 2.5 cm was set by relieving and lifting the pressure wheels by means of the adjusting spindle located close above pressure wheels. The distance between seeds in the sowing row of 21 cm was set by means of change - speed transmission 3 C and sowing plate with 22 openings.

Next, testing of density of deposition of seeds, which was the same as on the preceding sowing machine, followed. In this case, the wheel circumference was 189 cm, the wheel was rotated 30 times and the path covered was 5670 cm. Thus, each sowing apparatus should eject 270 seeds. On the average, all sowing apparatuses ejected 274 seeds.

2.8. Sowing

On 15. 3. 2005 sowing of sugar beet on a field in the level area was effected. The field had been ploughed in autumn. Towards the end of February the furrow was closed and the field well levelled. The preparation of soil for sowing was performed by a soil preparation machine. For sowing the sugar beet of Dorotea species was selected. Sowing was performed in slightly cloudy weather, but the soil was suitably dry and there were no problems the moisture could pose. With each sowing machine sowing was performed at five different speeds (4.5 km/h, 6 km/h, 8 km/h, 10 km/h and 12 km/h). During each test an area of 0.1728 ha was sown.

The length of the individual test lot was 160 m and 24 rows were sown. Sowing was performed by one tractor, first with the pneumatic vacuum sowing machine OLT and then still with the pneumatic sowing machine Aeromat – Becker.

Sowing was performed as accurately as possible and took place without unforeseen difficulties.

2.9. Measurements

We were interested in the efficiency of the individual sowing machine. In order to determine the efficiency factor of the individual sowing machine the following information was needed:

- effective time of sowing by the individual sowing machine at certain working speed,
- time of turning at the end of the field.

In order to gain that information two workers had to take part in sowing. One of them sowed and the other measured the two said times by means of a (stop) watch.

Measuring of the sowing depth requires much patience and accuracy. It was effected one day after sowing. The depth was measured for each sowing machine separately and for each sowing speed, with fifteen repetitions, in total. The sown strip of about 10 cm width was levelled longitudinally by means of 2.5 m long board. Then a layer of earth was carefully removed; attention had to be paid not to displace the seed. Then, a spirit level was placed over sowing furrow and the sowing depth was measured rectangularly to the position of the spirit level.

On the field, also the measurements of the inter - row distance and distance between plants in the sowing row were performed. That was carried out on 13. 4. 2005. The measurement was performed for both sowing machines and for all sowing speeds. During measurements only the outer rows of the sowing machine, i.e. the first and the sixth rows were not considered. The inter - row distances of those rows largely depend on the tractor driver's precision. Although the field was well prepared everywhere, measurements started at 30 m in the interior of the rows, particularly due to the speed. The measurement of the inter - row distances was repeated fifteen times for each working speed. For measuring the distances between plants in the row a length of 3.2 m was selected at the places, where no plants were missing due to bad sprouting.

2.10. Processing of measured data

The measurements of the effective time of sowing by the individual sowing machine, the time needed for turning the sowing machine and the tractor and settings of the coulter ensured the calculation of the efficiency factor. Then, the working efficiency of the compared sowing machines was calculated according to the formula:

$$W = Br \cdot v \cdot \eta \cdot 0{,}36 \quad (1)$$

W – working efficiency of sowing machine (ha/h)
Br – working width (m)
v – speed of working unit during sowing (m/s)
η – efficiency factor

The measured data were also statistically processed.
M – arithmetic mean or the average is the sum of all values of units divided by the number of units
N – number of measurements
x_i – measurement result (distance)

$$M = \frac{1}{N} \cdot \sum_{i=1}^{N} x_i \quad (2)$$

σ^2 - variance is the sum of squares and deviations from the average divided by the number of units

$$\sigma^2 = \frac{1}{N} \cdot \sum_{i=1}^{N} (x_i - M)^2 \quad (3)$$

σ - standard deviation is the square from the variance indicating for how much the units deviate on the average from the arithmetic mean

$$\sigma = \sqrt{\sigma^2} \quad (4)$$

KV – variability coefficient is calculated as the fraction between the standard deviation and the arithmetic mean and is given in percentage

$$KV = [\%] = \frac{\sigma}{M} \cdot 100 \quad (5)$$

Min – lower limit value in certain class
Max – upper limit value in certain class

3. Results with discussion

3.1. Working speed

The lowest working efficiency was reached with 4.5 km/h speed and the highest one with 12 km/h speed. Whereas the efficiency factor decreases, it may be claimed that the working efficiency increases with the speed. Table 1 shows the working efficiency increasing with the working speed.

Table 1.
Working efficiency of the pneumatic vacuum sowing machine OLT

Area sown (ha)	Sowing (min)	Stoppages (min)	η (%)	η	Speed (km/h)	W (ha/h)
0.1728	10.26	4.6	69.04	0.690	4.5	0.839
0.1728	8.05	4.6	63.64	0.636	6.0	1.031
0.1728	6.50	4.6	58.56	0.586	8.0	1.265
0.1728	5.48	4.6	54.37	0.544	10.0	1.468
0.1728	4.81	4.6	51.12	0.511	12.0	1.656

The lowest working efficiency was reached with 4.5 km/h speed and the highest one with 12 km/h speed. Whereas the efficiency factor decreases, it may be claimed that the working efficiency increases with the speed. Table 2 shows the working efficiency increasing with the working speed.

Table 2.
Working efficiency of the pneumatic pressure sowing machine Aeromat – Becker

Area sown (ha)	Sowing (min)	Stoppages (min)	η (%)	η	Speed (km/h)	W (ha/h)
0.1728	10.26	3.9	72.46	0.725	4.5	0.880
0.1728	8.05	3.9	67.36	0.674	6.0	1.091
0.1728	6.50	3.9	62.50	0.625	8.0	1.350
0.1728	5.48	3.9	58.42	0.584	10.0	1.577
0.1728	4.81	3.9	55.22	0.552	12.0	1.789

Working efficiency is on the pneumatic vacuum sowing machine OLT lower. This is due to longer time of turning of the sowing machine and stoppage at the end of the field which was equal to 4.6 minutes [15]. Figure 3 shows that the working efficiency on both sowing machines increases with the speed of sowing.

3.2. Depth of sowing

Table 3 shows the influence of sowing speed on the depth. The best results of average depth are reached with the sowing speed of 4.5 km/h and 6 km/h. Then the deviation from the average depth is less than 0.5 mm. The results show that the sowing speed decreases with the increase in speed. The smallest sowing depth occurs in case of 1.93 cm and 12 km/h.

Table 4 shows the influence of the speed of sowing on the depth. The desired depth of 2.5 cm was most approached with 4.5 km/h speed, when the average depth of sowing was equal to 2.44 cm. Acceptable depths of 2.4 cm and 2.36 cm also occur in case of sowing speed 6

km/h and 8 km/h. With 10km/h sowing speed the depth was reduced already for almost 0.5 cm. A very bad result of the average depth of sowing occurs with 12 km/h speed and is equal to 1.78 cm.

Table 3.
Sowing depth with pneumatic vacuum sowing machine OLT

Speed (km/h)	Max (cm)	Min (cm)	M (cm)	σ (cm)	KV (%)
4.5	2.7	2.2	2.460	0.12	4.88
6	2.8	2.1	2.453	0.17	7.12
8	2.6	1.8	2.267	0.23	10.27
10	2.6	1.7	2.093	0.26	12.63
12	2.4	1.6	1.933	0.23	11.74

Table 4.
Depth of sowing with pneumatic pressure sowing machine Aeromat - Becker

Speed (km/h)	Max (cm)	Min (cm)	M (cm)	σ (cm)	KV (%)
4.5	2.8	2.2	2.447	0.15	6.31
6	2.8	2.0	2.407	0.22	9.04
8	3.3	1.8	2.360	0.34	14.33
10	2.6	1.6	2.033	0.29	14.44
12	2.3	1.2	1.787	0.29	16.33

Figure 4 shows that on both sowing machines compared the sowing depth decreases with the increase in working speed. With 12 km/h it reaches the lowest value

3.3. Inter - row distance

Table 5 shows how the inter - row distances change with different working speeds. The best results of measurements of the inter - row distances were reached with the lowest speed of 4.5 km/h. With 12 km/h sowing speed the deviation is already more than 1.5 cm.

Table 5.
Inter - row distances of sugar beet seeds with pneumatic vacuum sowing machine OLT

Speed (km/h)	Max (cm)	Min (cm)	M (cm)	σ (cm)	KV (%)
4.5	45.1	43.0	44.553	0.624	1.400
6	45.2	43.2	44.413	0.577	1.300
8	46.0	43.0	44.200	0.773	1.749
10	45.6	42.4	44.047	0.863	1.960
12	45.9	42.3	43.480	0.879	2.021

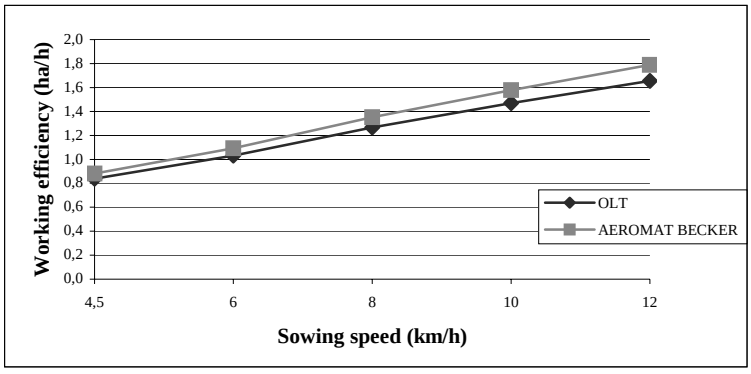

Fig. 3. Working efficiency of compared sowing machines

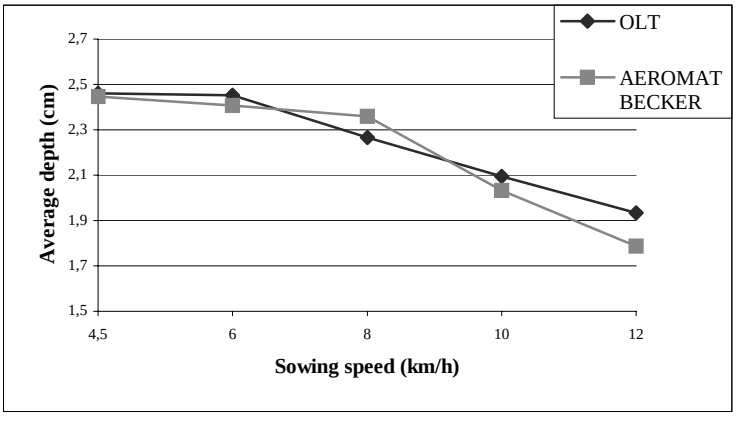

Fig. 4. Comparison of sowing depth of compared sowing machines

Table 6 shows how the inter - row distances change with different working speeds of sowing. The best result equal to 44.71 cm is reached with 4.5 km/h speed. Also with higher speed the inter - row distances remain within acceptable limits. The greatest deviation was measured with 8 km/h speed and was equal to 0.8 cm. It is interesting that with 10 km/h and 12 km/h the result is better than with 8 km/h.

Table 6.
Inter - row distances of sugar beet seeds with pneumatic pressure sowing machine Aeromat - Becker

Speed (km/h)	Max (cm)	Min (cm)	M (cm)	σ (cm)	KV (%)
4.5	45.4	43.7	44.713	0.50	1.13
6	45.5	42.9	44.547	0.63	1.42
8	46.2	42.9	44.213	0.83	1.87
10	46.2	42.9	44.407	0.77	1.73
12	45.8	42.7	44.300	0.69	1.55

Figure 5 shows the change of inter - row distance with different speeds of sowing with the two compared sowing machines. It is characteristic of the OLT sowing machine that the tolerance of the inter - row distance increases with the increase in the sowing speed. The like applies to the sowing machine Aeromat - Becker, except that it has the worst measurement result with 8 km/h sowing speed.

3.4. Distance between seeds in sowing row

Table 7 shows the distances between seeds in the sowing row with different sowing speeds. The distance between seeds in the sowing row increases with the increase in sowing speed. The smallest deviation from the desired distance was measured with 4.5 km/h sowing speed. With 12 km/h sowing speed the distance between seeds in the sowing row increased to 23.5 cm.

The influence of the speed on the maximum, minimum and average values of distances between the seeds in the sowing row are shown in figure 6. The distances were greatest with 12 km/h speed. The increase in working speed results in unequal distances between the seeds in the sowing row.

Table 7.
Distance between seeds in sowing row with pneumatic vacuum sowing machine OLT

Speed (km/h)	Max (cm)	Min (cm)	M (cm)	σ (cm)	KV (%)
4.5	24.1	19,7	21,200	1,05	4,93
6	23.3	19,8	21,360	1,02	4,80
8	24.8	18,2	21,513	2,01	9,35
10	25.5	17,8	22,053	2,23	10,10
12	25.9	17,2	23,500	2,03	8,62

Table 8 shows the distances between the seeds in the sowing row with different sowing speeds. The distance between the seeds in the sowing row increases with the increase of speed. With 12 km/h the distance is the greatest and is equal to 21.88 cm.

Table 8.
Distance between seeds in sowing row with pneumatic pressure sowing machine Aeromat - Becker

Speed (km/h)	Max (cm)	Min (cm)	M (cm)	σ (cm)	KV (%)
4.5	23.9	19.8	21.173	0.98	4.61
6	24.2	19.3	21.213	1.08	5.09
8	24.4	18.8	21.227	1.19	5.59
10	24.9	17.9	21.760	2.03	9.31
12	25.7	17.7	21.887	2.08	9.49

The influence of the speed on the maximum, minimum and average values of distances between seeds in the sowing row are shown in figure 7. The distances between seeds are the greatest with 12 km/h speed and increase in the sowing row with the speed.

The standard deviation with different sowing speeds are shown in figure 8. The value of the standard deviation on the pneumatic vacuum sowing machine OLT strongly increases with 8 km/h speed and on the pneumatic pressure sowing machine Aeromat - Becker with 10 km/h sowing speed.

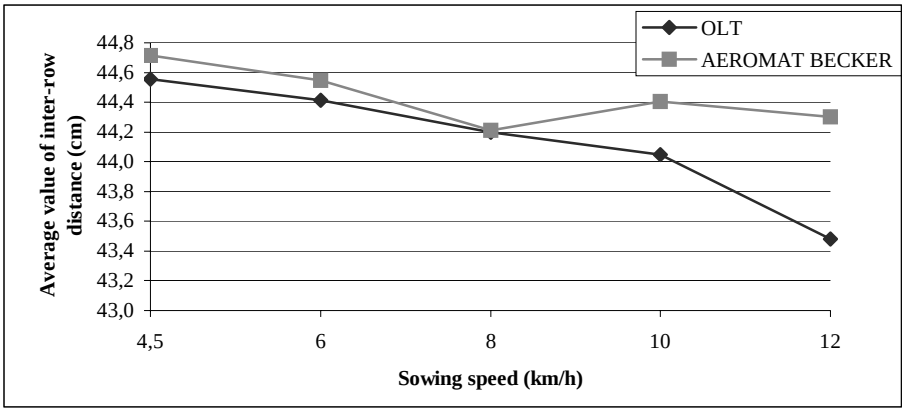

Fig. 5. Comparison of inter - row distance of compared sowing machines

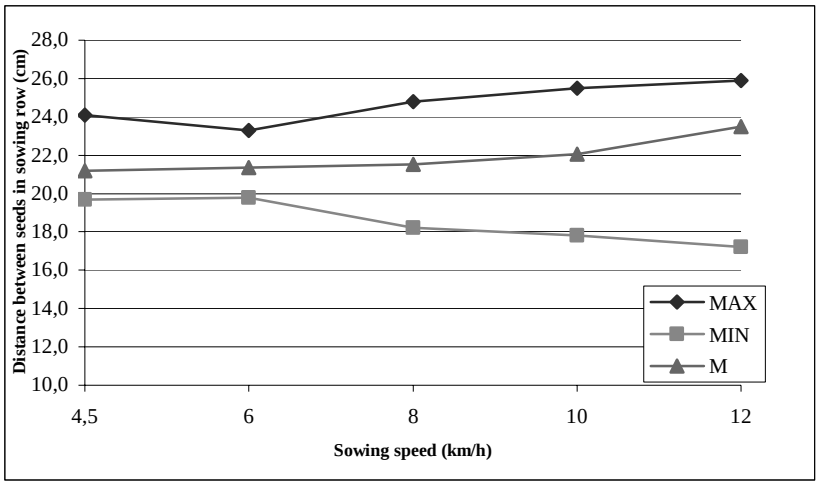

Fig. 6. Maximum, minimum and average values of distances between seeds in sowing row with pneumatic vacuum sowing machine OLT

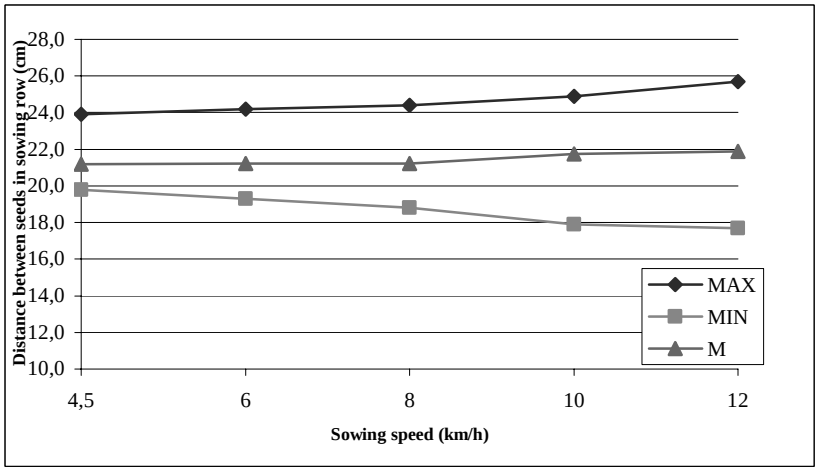

Fig. 7. Maximum, minimum and average values of distances between seeds in sowing row with pneumatic pressure sowing machine Aeromat – Becker

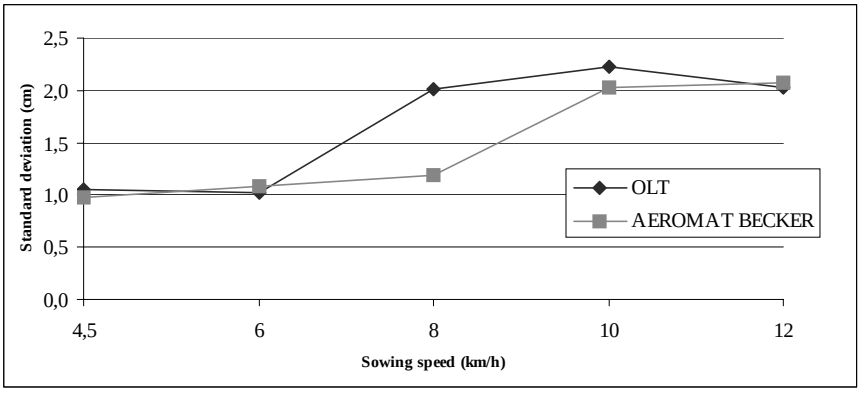

Fig. 8. Comparison of standard deviations of distances of seeds in sowing row on compared sowing machines

4. Conclusions

The paper presents two sowing machines for interval sowing, differing in the mode of operation. Cultivation of sugar beet depends primarily on expert and technically correct sowing. Sowing machines and expertly performed sowing are of great importance for cultivation of sugar beet. The sowing is influenced by technical perfection of the sowing machine, accurately performed sowing test and tractor driver's accurate steering of the sowing machine. For accurate sown the driver must have an assistant when no electronically controlled device, signalling possible defects, is located on the sowing machine. From the close proximity the assistant can find out the defects in operation of the sowing machine, the quantity of the seed in the discharge container, possible clogging of sowing shares etc.

The average deviation is the greatest on the pneumatic pressure sowing machine Aeromat - Becker, where it is equal to 0.7 cm with 12 km/h. The depth of sowing decreases with the increase of the speed. The sowing speed increases with the working efficiency, while in the meantime the efficiency factor decreases. The working efficiency of the pneumatic vacuum sowing machine OLT is lower due to stoppage at the end of the field, where the coulters have to be turned mechanically.

On the pneumatic vacuum sowing machine OLT the optimum distance between seeds in the sowing row is reached with 4.5 - 8 km/h speed and on the pneumatic pressure sowing machine Aeromat - Becker with 4.5 - 10 km/h. The comparison of distances between seeds in the sowing row on the compared sowing machines shows that the sowing speed influences the uniformity of the layout of seeds and the final unit of area. With the greatest speed measured, i.e. 12 km/h the deviation on the sowing machine OLT is as much as 2.5 cm and on the sowing machine Aeromat - Becker it is 0.9 cm which is still acceptable.

The comparison of inter-row distances with different speeds shows that the tolerance of the inter-row distance increases. The deviation is less than 1 cm and has no major influence only once it exceeded the permissible deviation of +/- 1 cm. The measurement results show that the quality of sowing depends on its speed. With both sowing machines sprouting was good even with 12 km/h speed. It is possible to contest the sugar beet producers' argument that only higher working speed of the sowing machine caused bad sprouting of sugar beet. The distance between seeds in the sowing row is excessive and that the seed has been sown too little deep. Therefore, the tractor drivers sowing with the two sowing machines should consider the said optimum speeds.

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