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DOCTORAL (Ph.D) THESIS

THEORETICAL AND PRACTICAL RELATIONS OF INCREASING THE WORKING WIDTH OF CENTRIFUGAL FERTILIZER SPREADERS

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1. INTRODUCTION

Hungary is basically an agricultural country, which is due to its natural facilities. Agriculture has always plaid a determinative role in the economy of the country. Nowadays, within agriculture, crop production has a greater role. A significant element of high-level crop production is the scientifically based, harmonic nutrient supply.

The nutrient content of the soil determines the quantity and the quality of the yield. In Hungary, artificial fertilizers are dominant in nutrient supply, as the organic manure producing capacity of the country can only cover one fifth (0.5 animal /ha) of total nutrient demand.

Besides the quantity and proportion of the agents, determined by the demand of the plant, the high quality of application is getting more and more important.

Today a significant part of solid fertilizers are spread by spinning disc fertilizer spreaders all over the world, and it is general in Hungary as well. Their popularity is due to their multiple usage, simple construction, low maintenance demand, easy operation and low price.

The field performance of spinning disc fertilizer spreaders basically depends on two factors: the forward speed and the working width. As there are some technical, operational and energetic limits of increasing the forward speed, my set objective in this study is to make further developments related to these machines' working width.

Rising the working width one can lower the damage of the soil, the costs of operation, and at the same time the area of overlapping falling on unit area, and so the unevenness of spreading.

Uneven fertilizer distribution will result in yield loss.

The main objectives of the examinations presented hereinafter were to explore the relationships between the parameters considered important from the above mentioned point of view.

In the course of examinations would not have been practical to use only one type of fertilizers, as every fertilizer type has equal importance.

The most significant factors affecting the working width of centrifugal fertilizer distributors and the evenness of their spreading are:

- the physical properties of applied fertilizers;
- the volume of fertilizer flow;

- the location of feeding on the surface of the spinning disc ;
- the number of blades;
- the length of blades;
- the shape of blades;
- the pitch angle of blades with the direction of the radius;
- the discs height position
- the axial distance of the discs;
- the number of rotation of the discs;
- the diameter and the shape of the discs;

From the above listed factors I studied the physical properties of fertilizers, the location of dosage on the surface of the spinning disc, the number, the length, the pitch angle of blades in the function of working width and spreading evenness. All the other factors were constant.

I did not examined the design of the feeder device, but the evenness and the symmetry of dosage was regularly checked

I performed my examinations on transversal spreading unevenness in the measuring track of the Department of Machinery, Faculty of Agricultural Sciences, Debrecen University.
The measuring track capable to perform out-door measurements, and so during the examinations we tried to eliminate the effects of external influences (irregularities in field surface, together with inclination of terrain, the wind, etc.)

2. MATERIALS AND METHOD OF RESEARCH

2.1. The method of measurements

I performed my examinations on transversal spreading unevenness on the measuring track of the Department of Machinery, Faculty of Agricultural Sciences, Debrecen University.

The measuring track consists of a concrete track and a row of collecting trays, set up perpendicularly to the track. The area of the measuring trays is 500x500 mm square and they are equipped with a grid to prevent particles from escaping. The line of the trays is raised above the ground to 800 mm. Under the measuring trays there are numbered collecting boxes. After repeating the test three times the boxes are collected and the quantity of theirs is measured with an accuracy of 0.1 g. The values are fed into a computer and with the help of target software the computer determines the main qualitative characteristics of the spreading device.

The software was made by Nagyné dr. Polyák Ilona.

Depending on the spreading width, determined by the parameters of the applied spreading device, I used the measuring track from 25 to 40 meters. To characterize the transversal unevenness of spreading, in compliance with international standards, I used the coefficient of variation (CV):

$$CV = \frac{100}{\bar{x}_i} \frac{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x}_i)^2}}{n-1} \ \%,$$

where:

x_i is the average of fertilizer quantities from three replications on one measuring site;

$\bar{x}_i$ is the average of grain volume from three replications on all the measuring sites;

n is the number of measuring sites.

Permissible value of CV is 15% (MSZ-05-10. 0283).

After each measurement three diagrams are given:

- The transversal spreading pattern (**Fig. 1**), in which the mass of the fertiliser in each measuring box is plotted, in grams. The number of the measuring boxes is determined by the spreading width, expected in the given adjustment with the given fertilizer type.

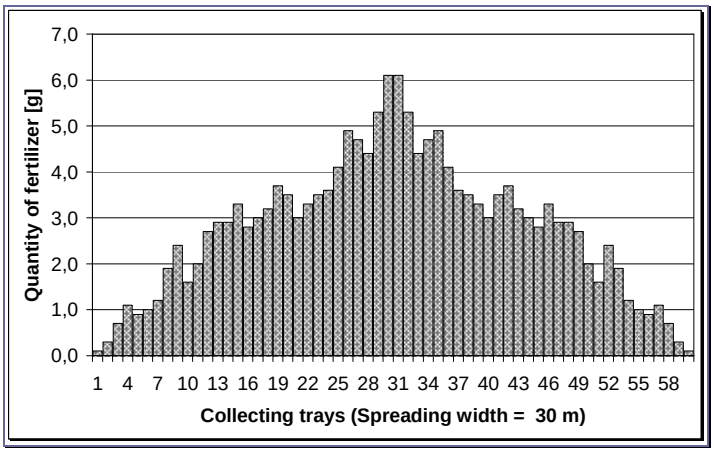

Figure 1. Transversal spreading pattern

- With centrifugal spreaders, the spreading width is larger than the working width. There is an overlapping of contiguous passages of the spreader in the covering zone. The spreading curve (**Fig. 2**) shows the unevenness of spreading in the function of the working width. According to the diagram, without overlapping, the spreading width is equal to the working width. In this case the unevenness is the largest. Increasing the overlapping per meter the working width and the unevenness will decrease. As a result, on the basis of the diagram we can determine the largest working width, at which the unevenness remains under 15%.

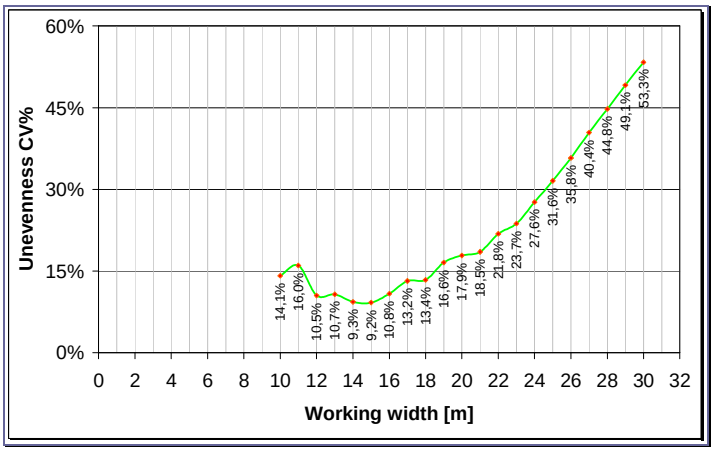

Figure 2. The spreading curve

- The third diagram (**Fig. 3**) shows the transversal spreading pattern with the maximal working width, determined by the spreading curve.
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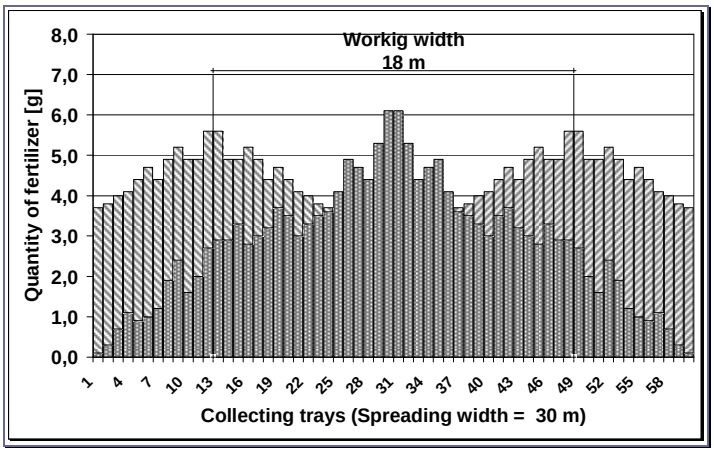


Figure 3. Transversal spreading pattern with overlapping

2.2. The experimental spinning disc fertiliser distributor

The experimental machine was manufactured by Tornádó International Ltd. Its main technical and operational data are given in **Table 1**.

Table 1. Technical and operational data of the experimental machine

Volume of the hopper:	400 dm^3
Number of spinning discs:	2
Diameter of spinning discs:	400 mm
Rpm of the spinning discs:	840 1/min
Axial distance of the spinning discs:	900 mm
Number of spreading blades:	2 or 3
Length of spreading blades:	400/300 mm or 400/350/300 mm
Height of spreading blades:	50 mm
Angle of spreading blades included with the radius, i.e. pitch angle:	Adjustable, according to **Fig**. **4.**
Travelling speed applied during measurements:	8 km/h

The two-disc spreader of the experimental machine can be equipped with two and three-bladed spinning discs. The blades are of different length. The pitch angle of the blades is adjustable in three stages, according to **Fig. 4**.

The angle of the spreading blade included with the radius in **A** position is 40^{o}, in **B** position 35^{o} and in **C** position 30^{o} backward to the direction of rotating. In the case of two blades the longer blade is indicated first, and the shorter afterwards, e.g. A/A. In the case of three blades the long blade is indicated first, than the medium, and than the short one, e.g. A/B/C.

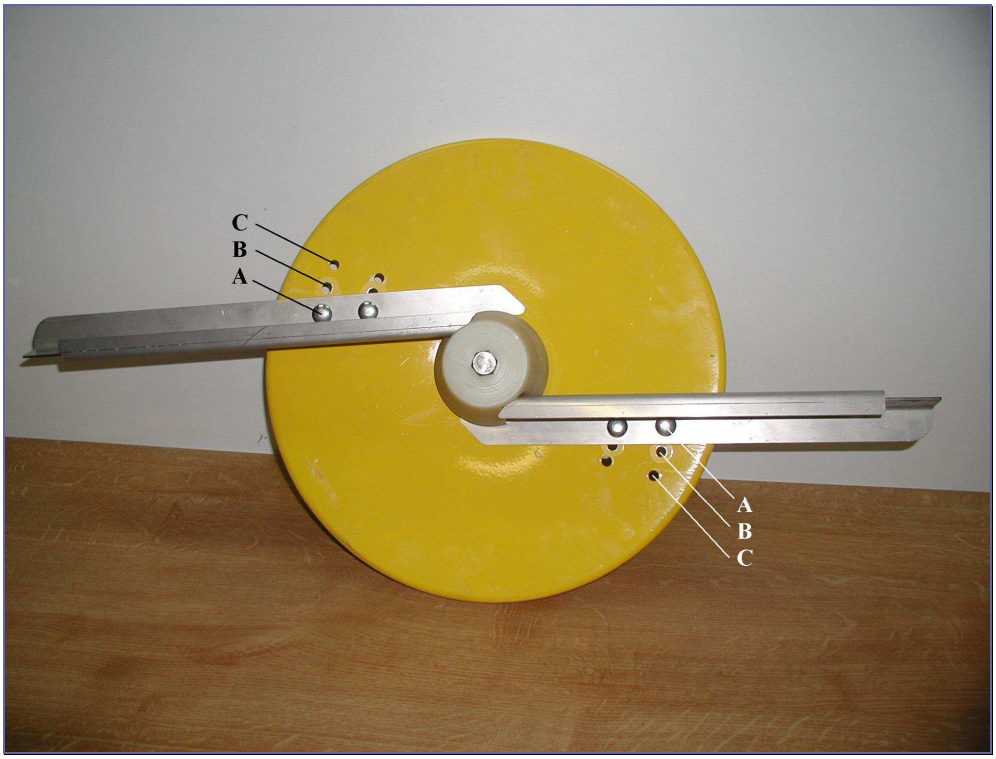


Figure 4. Possibilities of adjusting the pitch angle of blades

2.3. Possibilities of adjusting the location of feeding

There is a device on the experimental machine which is to adjust the location of feeding on the surface of the spinning discs in several directions. The adjustable feeding locations can be seen in **Figure 5**. Later these are indicated as e.g. A9, B8.

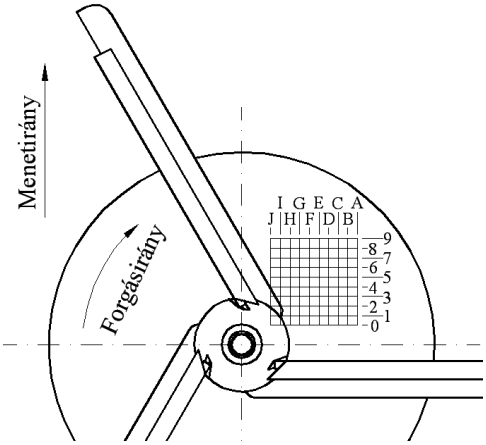


Figure 1. Locations of feeding related to the surface of the spinning disc *(Menetirány: Direction of travelling; Forgásirány: direction of rotation of the spinning disc)*

A feeding location can also be given with its coordinates, r_o; ψ_o, as it is shown in **Figure 6**.

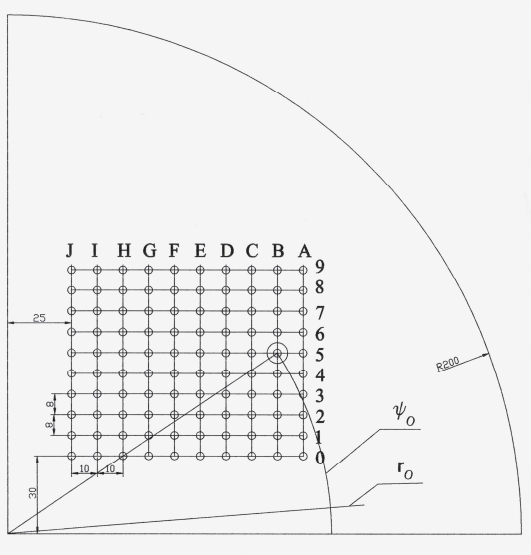


Figure 6. Coordinates of the feeding locations

2.4. The physical properties of fertilizers applied

The most often used fertilizer types were used to the experiments. Their physical properties were determined, since it is normal that these properties can be different even in the case of the same type.

Particle size and particle size distribution were determined with the aid of test sieves used under prescribed conditions, i.e. shaking intensity, amount of fertilizer and duration of shaking. The smallest and the largest particles are given with the proportion of the particles <1 mm and >4 mm in the sample ($d_{<1}$%, $d_{>4}$%).

The mass median diameter (d_{50} [mm]), the size distribution (σ) and the coefficient of variation of the particle size (CV %) was calculated with the following formulas.

$$d_{50} = \frac{\sum m_i \cdot d_i}{\sum m_i} \qquad \sigma = \frac{\sqrt{\sum m_i (d_i - d_{50})^2}}{\sum m_i} \qquad CV = \frac{\sigma}{d_{50}} \cdot 100\%$$

where: d_{50}: The mass median diameter [mm], d_i: the median diameter of each fraction [mm], m_i: the mass of each fraction [g], σ: size distribution.

Table 2. Size characteristics of the fertilizers

Size characteristic	Ammonium nitrate	NPK	Potassium salt	Urea
$d_{<1}$%	0,90	2,57	0,93	2,12
$d_{>4}$%	2,27	2,46	2,10	0,00
d_{50}[mm]	2,38	3,14	3,02	1,62
CV%	32,60	21,00	21,00	27,90

A measuring tube of 1000 cm^3 capacity was used to determine the bulk density of each fertilizer. The mass was measured with an accuracy of 0.1 g.

The moisture content of each fertilizer type was measured according to the international standard, with three repetitions: the mass of the sample was 25 g, the temperature inside the drying apparatus was 103 $\pm$ 1^{o}C, the duration of drying was 72 hours. The mass of each sample was measured with an accuracy of 0.1 g. The results are given in **Table 3.**

2.5. Endurance test of different types of spreading blade material

In the series of material test methods, wear tests are among of the least clear phenomena. The reason for this is that wear is influenced by so many factors that it is very difficult to determine an absolute wear index for a given material. Generally is true, that the harder is the surface of the material, the slower is its wear, under equal conditions. However, there are some exceptions to the rule. An endurance test is always only a comparative examination, and the more similar the conditions are to real conditions, the more reliable the examination results will be.

Accordingly, there are several types of wear test-machines.

The wear index shows the mass of the worn off material in a unit of time.

Table 3. Physical properties of fertilizers used

Type	**Appearance**	**Mass median diameter d_{50} [mm]**	**Bulk density [kg/dm^3]**	**Moisture content [%]**
Ammonium nitrate 34%		2,38	0,95	0,31
Potassium salt 60%		3,02	1,13	0,07
Urea 46%		1,62	0,74	0,32
NPK 8-24-24%		3,14	0,97	1,42

2.5.1. The wear test machine

The wear test machine consists of a one-disc spinning disc fertilizer distributor and an elevator. From the hopper of the fertilizer distributor, through an adjustable slot, wearing material is flowing to the spreading devise. The spinning disc is driven by an electric motor. The rpm is adjustable according to the real conditions.

Four spreading blades, made of different material, can be used simultaneously. Their shape and size are the same.

The spreading device is covered by a canvas, and below there is a funnel to take the wearing material to the elevator, and then to the hopper of the machine **(Table 4.)**.

Table 4. Technical and operational data of the wear test machine

Frame sizes of the machine [m]	5 x 2,4 x 2,0
Volume of he hopper [l]	500
Number of discs	1
Number of spreading blades	4
Rpm of the disc [1/min]	790

2.5.2. The wearing material

The material used to the wearing test was granular material. Its median particle size was similar to the median particle size of a common fertilizer type, but contrasted with fertilizers it can keep its original physical properties for a long time.

The name of the wearing material: Quartz stand NC 1,6-3.

The figures in the nomination indicate the size of the smallest and largest particles.

The bulk density of the material is 1,6 kg/dm^3

Place of origin: Kvarchomok Bányászati és Feldolgozó Kft. Sóskút.

2.5.3. Types of blade material

Table 5. Materials of the spreading blades

Indication	Blade 1	Blade 2	Blade 3	Blade 4
Standard name	X120Mn13 MSZ 520	X5CrNi1810 MSZEN 10088-1	St02F MSZ 23	X5CrNiTi1810 MSZEN 10088-1
Description	Wear –resistant steel	Corrosion resistant steel, 2 mm thick	Cold-pressed steel plate	Corrosion resistant steel, 4 mm thick
Brinell hardness	208	153	118	171
Tensile strength [N/mm^2]	680	530	360	560

3. RESULTS

3.1. Theoretical relations between the location of feeding, the pitch angle of the blades and the spreading width

In the case of two-disc spreaders the location of feeding and the pitch angle of the blades together determine the

- Duration of staying of particles on the disc
- The degree of the turning away of the disc in this time
- The discharge velocity and the discharge angle of the particles,

from which the width and the evenness of the spreading depends.

For all these, it is practical to examine the effect of the two factors simultaneously.

The technological process of the operation of spinning discs can be divided into two faze:

a.) Particle motion on the distributor device

b.) Particle motion through the air.

The mass flow of the fertilizer along the blades was modelled with a mass point to accomplish the technical analysis.

Forces, acting on a particle of m mass, staying r distant off the centre of the disc of ω angular velocity, are **(Figure 7)**:

1. gravitational force: $m \cdot g$
2. centrifugal force: $m \cdot r \cdot \omega^2$
3. Coriolis force: $2 \cdot m \cdot v_r \ \omega$ where v_r is the particle velocity along the blade
4. friction forces:
   - between the disc and the particle: $\mu \cdot m \cdot g$
   - between the blade and the particle under the influence of the centrifugal force: $\mu \ m \ r \cdot \omega^2 \ sin\psi$
   - between the blade and the particle under the influence of the Coriolis force: $2 \ \mu \ m \cdot v_r \ \omega$

Based on equilibrium of forces acting on a particle we get an inhomogeneous quadratic differential equation. Solving the homogeneous and inhomogeneous parts of the equation we can determine the particle velocity along the blade.

After this, the relation between the constructional parameters and the working width can be evaluated.

Determining the particle velocity along the blade the discharge velocity of the particle can be calculated (**Fig.8**) in the case of backward (**Fig. 8*a***) and forward (**Fig**. **8*b***) pitched blades.

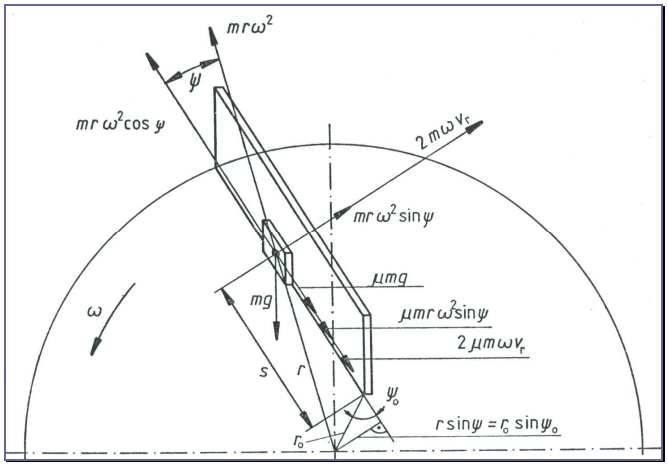


Figure 7. Forces, acting on a particle on the disc

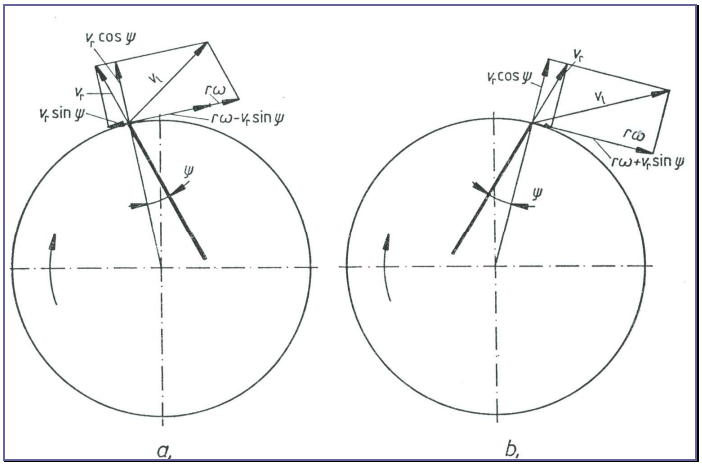


Figure 8. Discharge velocity of a particle in the case of backward and forward pitched blades

On the bases of the obtained equations, which are related to only one particle, the following conclusions can be drawn:

The width of spreading will increase, if the particle velocity along the blade increases.

The particle velocity along the blade depends on the following:

- The coordinates of the feeding location (r_o; ψ_o)
- The coefficient of friction between the particle and the blade (μ)
- The angular velocity of the disc (ω)

- The length of the blade (R)
- The pitch angle of the blade (ψ).

These last four factors influence also the discharge velocity of the particle.

The value of the discharge velocity is the biggest in the case of forward pitched blades, and the smallest in the case of backward pitched blades. In spite of this fact the backward pitched blades are studied afterwards, because by using forward pitched blades the unevenness of spreading is increasing considerably, and it is not possible to even up by overlapping.

From the above listed factors the effect of the coefficient of friction was not studied, it was supposed to be constant (0.22) in the case of corrosion resisted steel blade material. The rpm of the disc was also constant during the measurements (840 1/min).

3.2. The spreading width and the working width in the function of the feeding location

This series of measurements was carried out under the following conditions:

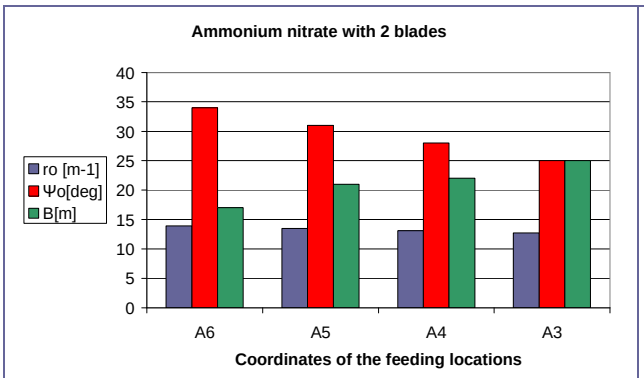
Type of fertilizer:	Ammonium nitrate
Mass flow of the fertilizer:	constant (47,44 kg/min)
Number of spreading blades:	2
Length of spreading blades:	constant (400/300 mm)
Pitch angle of the blades:	constant (A/A)
Feeding locations:	according to **Fig**. **9.**

The following values of working width were obtained on the feeding locations, marked in **Figure 9.**

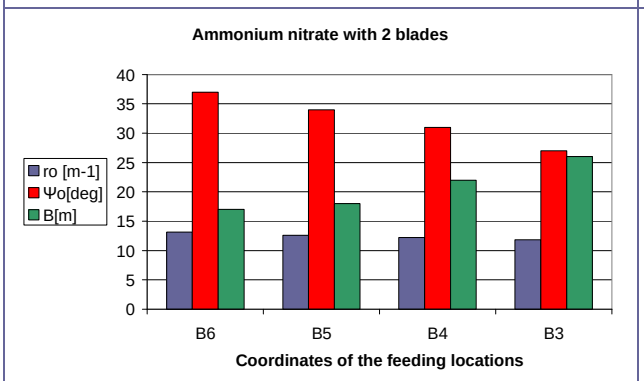
J	I	H	G	F	E	D	C	B	A	
										9
										8
										7
				15	**18**	**14**	**16**	**17**	**17**	**6**
			14	**14**	**20**	**17**	**18**	**18**	**21**	**5**
			17	**15**	**24**	**20**	**22**	**22**	**22**	**4**
				17	**24**	**21**	**25**	**26**	**25**	**3**
			13	**19**	**23**	**14**	**12**	**14**	**12**	**2**
					15					**1**

Figure 9. Working widths, obtained on the marked feeding locations

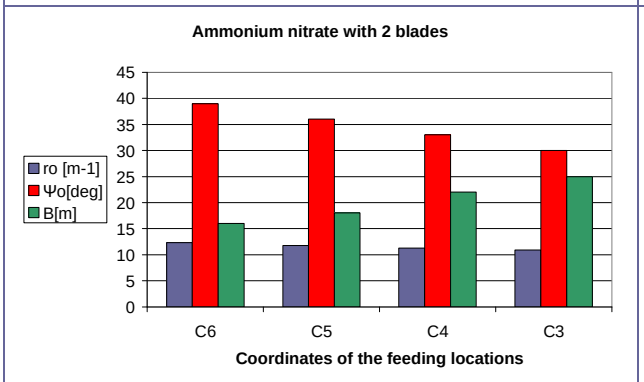
Relation was searched after this, between the position of feeding locations and the obtained values of working widths.



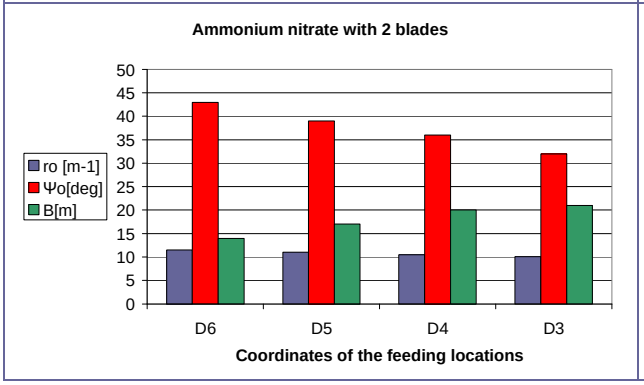
H	G	F	E	D	C	B	A	
								9
								8
								7
							x	6
							x	5
							x	4
							x	3
								2
								1
								0



H	G	F	E	D	C	B	A	
								9
								8
								7
						x		6
						x		5
						x		4
						x		3
								2
								1
								0



H	G	F	E	D	C	B	A	
								9
								8
								7
					x			6
					x			5
					x			4
					x			3
								2
								1
								0



H	G	F	E	D	C	B	A	
								9
								8
								7
				x				6
				x				5
				x				4
				x				3
								2
								1
								0

Figure 10. Relation between the coordinates of feeding locations and the obtained working width

The diagrams, shown in **Figure 10**., illustrate the relation between the coordinates of the feeding locations (r_o; ψ_o) and the obtained working width: it can be seen clearly, that there is a linear connection in the given direction. Decreasing the values of r_o and ψ_o in the marked direction, the working width will increase.

When other fertilizer types were used, and when three-bladed disc was examined, the same result was obtained.

3.3. The effect of the pitch angle of the blades on the working width

This series of measurements was carried out under the following conditions:

Type of fertilizer:	Ammonium nitrate
Mass flow of the fertilizer:	constant (47,44 kg/min)
Number of spreading blades:	2
Length of spreading blades:	constant (400/300 mm)
Pitch angle of the blades:	various
Feeding location:	constant (C2)

The objective of this series of measurements was to find out the effect of the alteration of the pitch angle of the spreading blades. When the blades were set in A/A position (**Fig. 4**.) the spreading curve had two minimal values, i.e. at the working width of 12 meters, and 25 meters (**Fig. 11**), but 25 metres can not be considered as working width, because the unevenness is higher than 15%.

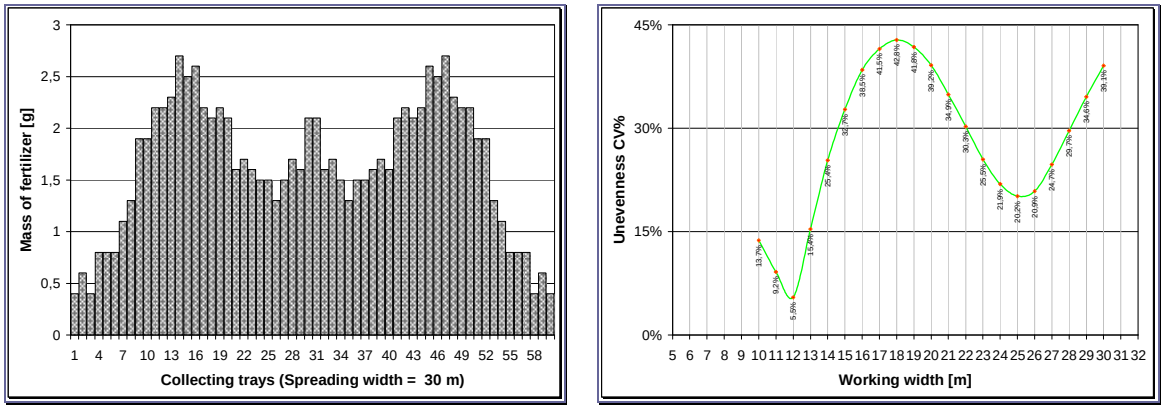


Figure 11. Transversal spreading pattern and spreading curve on C2 feeding location, in A/A blade position

The experiments were carried out with two- bladed discs, and the pitch angle of both blades was set in three positions.

According to the results, the alteration of the pitch angle of the longer blade has a greater effect on the transversal spreading pattern, and so on the working width.

Setting the blades in B/A position (the longer blade in B, the shorter one in A position), the working width increased from 12 meters to 28 meters (**Fig. 12**).

The character of the spreading pattern changed a lot, which can be seen in **Figure 13**. **Figure 14.** shows the transversal spreading pattern with overlaps, at 28 meters working width.

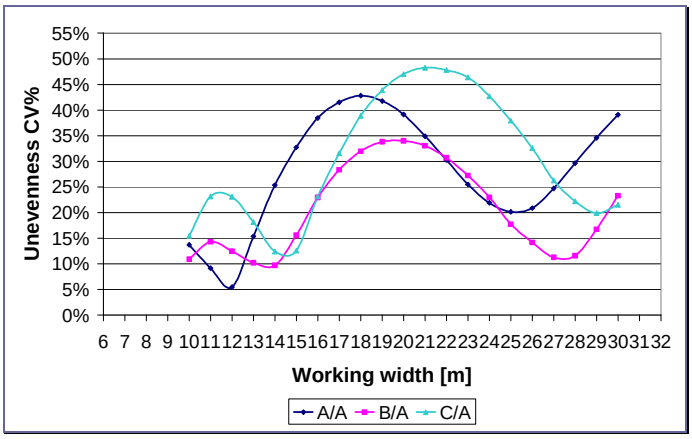


Figure 12. Working width with different blade positions

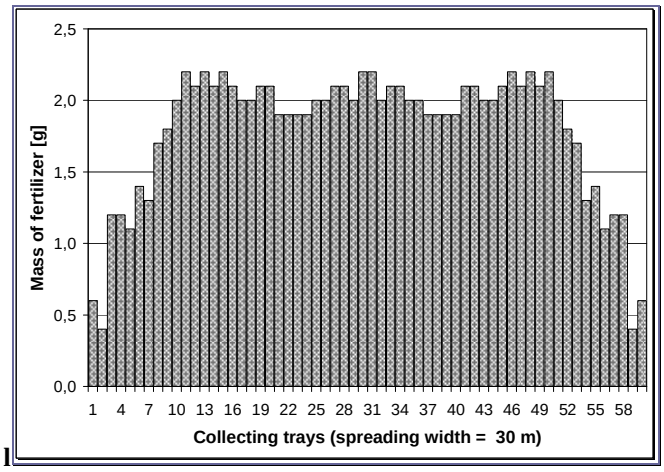


Figure 13. Filling in the centre of the transversal spreading pattern, adjusting the pitch angle of the longer blade

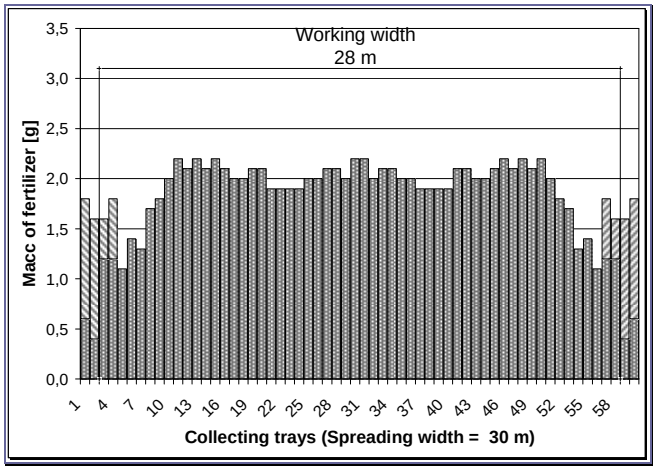


Figure 14. Transversal spreading pattern at 28 metres working width

3.4. Increasing the working width by altering the length of the spreading blades

According to the basic lows of physics, by increasing the length of the blades we can increase the cast distance of the fertilizer particles, and so the spreading width can increase. Increasing the length of the blades the discharge velocity of particles will increase. However, there are constructional limits of increasing the length of blades.

According to the experiments by using a blade of 400 mm length, a working width of 28 metres can be reached.

This series of measurements was carried out under the following conditions:

Type of fertilizer:	NPK
Mass flow of the fertilizer:	constant (35.56 kg/min)
Number of spreading blades:	3
Length of spreading blades:	various
Pitch angle of the blades:	constant (A/A/A)
Feeding location:	constant (A5)

Then length of the blades was altered as listed below:

- The length of the three blades was the same: 350/350/350 mm
- There was a long and two shorter blades: 350/300/300 mm
- The length of one blade was increased: 400/350/350 mm
- The length of two blades was decreased: 400/300/300 mm
- Three blades of different length were used: 400/350/300 mm.

According to **Figure 15**., considering the working width and the evenness of spreading, the 350/300/300 mm length combination was better than the 350/350/350 mm combination.

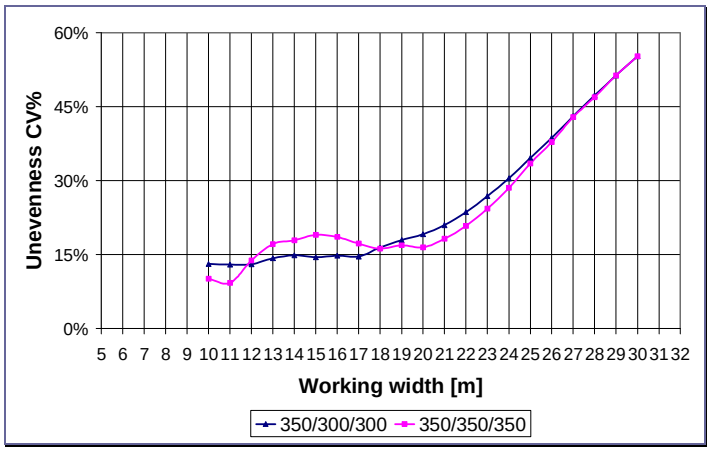


Figure 15. Spreading curves with blades of equal and different lengths

Further increasing the length of one blade the experiments were performed by using three combinations of blade lengths. The spreading curves obtained are shown in **Figure 16**.

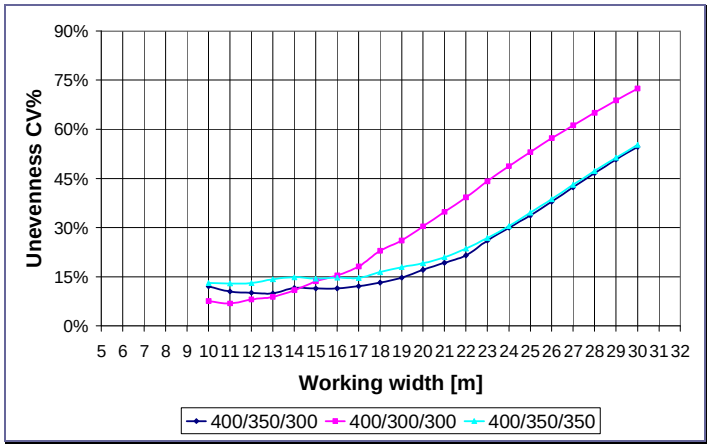


Figure 16. Spreading curves obtained by increasing the length of one blade

According to the experiment results the most advantageous is to use three blades of different length. By using the 400/350/300 mm blade length combination on an optimal feeding location we were able to reach a relatively large working width (e.g. on B4 feeding location, 26 metres working width).

3.5. The effect of the number of the blades on the value of the working width and the evenness of spreading

This series of measurements was carried out under the following conditions:

Type of fertilizer:	Ammonium nitrate
Mass flow of the fertilizer:	constant (47,44 kg/min)
Number of spreading blades:	2 or 3
Length of spreading blades:	400/300 mm or 400/350/300 mm
Pitch angle of the blades:	constant (A/A and A/A/A)
Feeding locations:	A6, A5, A4, A3, B6, B5, B4, B3, C6, C5, C4, C3.

Two conclusions were drawn according to the experiment results:

There is a linear relation between the coordinates of the feeding location (r_o; ψ_o) and the obtained values of working width, in both cases, using two or three blades.

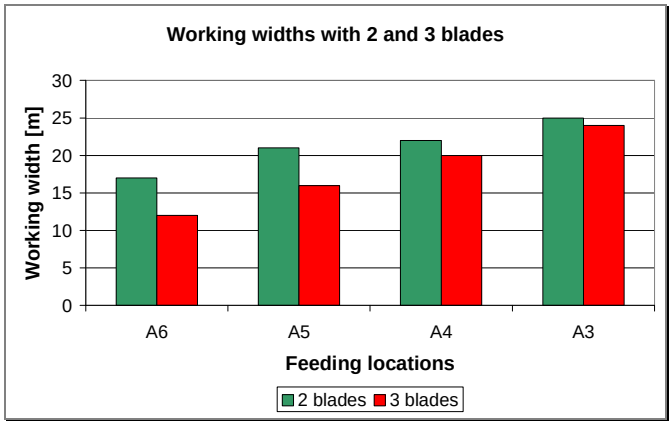
The obtained working width was always larger by using two blades (**Figure 17.**).

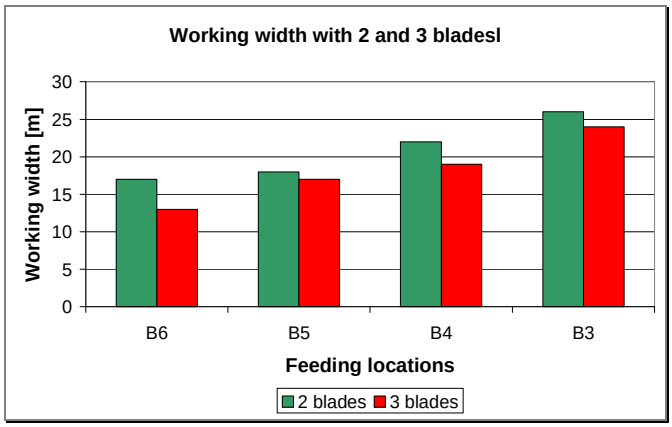
3.6. Determination of the optimal physical properties of fertilizers considering the working width and the evenness of spreading

The determination of the influence of the physical properties of fertilizers is not easy, because all these properties are present in process at the same time. It is not possible to separate them.

Basically three properties play a key role when we want to increase the working width. These are:

- the median particle size,
- the particle size distribution, and
- the bulk density.





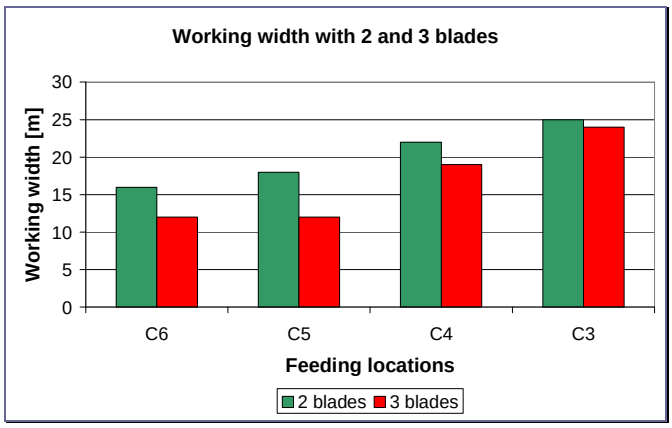


Figure 17. The obtained working widths by using two and three blades

The following series of measurements was performed with two types of fertilizers, the bulk density of which is almost the same, but their size characteristics are significantly different (**Table 6**.).

Table 6. Size characteristics and bulk density of fertilizers used

Characteristics	NPK	Ammonium nitrate
$d_{<1}$%	2,57	0,90
$d_{>4}$%	2,46	2,27
d_{50}[mm]	3,14	2,38
CV%	21,00	32,60
Bulk density [kg/dm^3]	0,97	0,95

This series of measurements was carried out under the following conditions:

Type of fertilizer:	NPK and ammonium nitrate
Mass flow of the fertilizer:	NPK: 35.56 kg/min; Ammonium nitrate: 47.44 kg/min
Number of spreading blades:	2
Length of spreading blades:	constant: 400/300 mm
Pitch angle of the blades:	constant (A/A)
Feeding locations:	A6, A5, B5, B4, C5, C4, D5, D4

One of the obtained transversal spreading patterns and spreading curves are shown in **Figure 18**. Studying these diagrams, the following conclusions can be drawn:

According to the laws of physics the working width obtained by using NPK will be larger, because of its larger median particle size.

However, comparing the two spreading patterns, it is apparent that the spreading pattern obtained with NPK shows more irregularities. Due to this the obtained working width is only one metre longer, and what is more the unevenness of spreading is much larger at every working width.

It was possible to find a feeding location with both fertilizer types where the 26 metres working width was reached. These were B4 (122 mm, 31^o) and B3 (118 mm, 27^o). Adjusting these feeding locations 24, 25, and 26 metres working width can be applied, but the unevenness of spreading with NPK will always be higher (**Figure 19.**).

The reason for this is the larger proportion of the particles smaller than 1 mm, in NPK.

To support this result an experiment was carried out, with two sorts of potassium salt.

There were significant differences between their size characteristics as it is set out in **Table 7**.

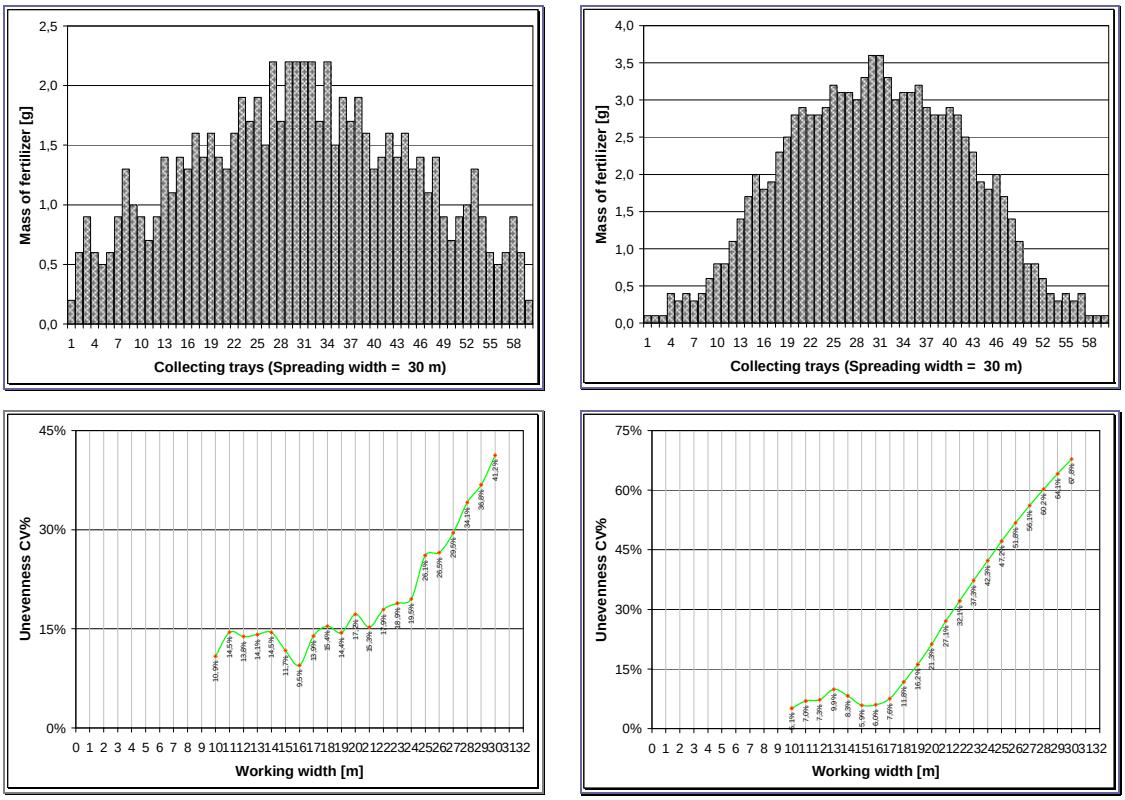


Figure 18. Transversal spreading patterns and spreading curves of NPK and ammonium nitrate on B5 feeding location

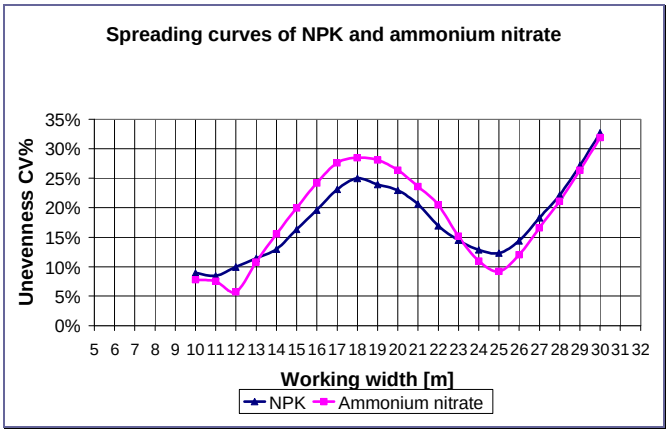


Figure 19. Spreading curves of NPK and ammonium nitrate at 26 metres working width

Table 7. Size characteristics and bulk density of the two sorts of potassium salt

Characteristic	Potash 1	Potash 2
$d_{<1}$%	10,68	0,93
$d_{>4}$%	1,58	2,1
d_{50}[mm]	2,54	2,98
CV%	39	21
Bulk density [kg/dm^3]	1,11	1,13

Considering the transversal spreading patterns obtained with the two sorts of potassium salt (**Figure 20 and 21**.) it is apparent that due to the larger proportion of particles, smaller than 1 mm (Potash 1), the working width is much smaller (Potash 1: 18 metres, Potash 2: 22 metres).

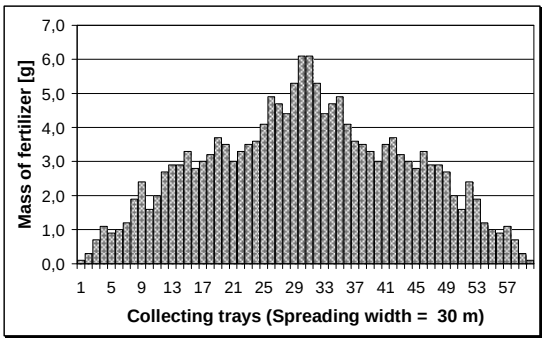


Figure 20. Transversal spreading pattern with Potash 1

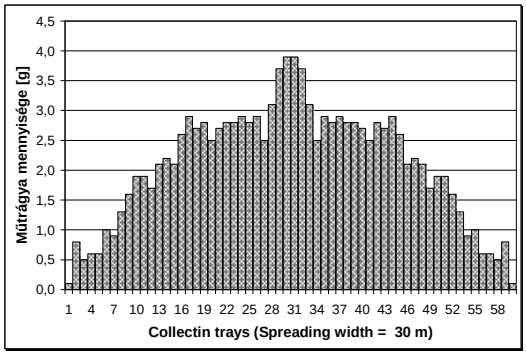


Figure 21. Transversal spreading pattern with Potash 2

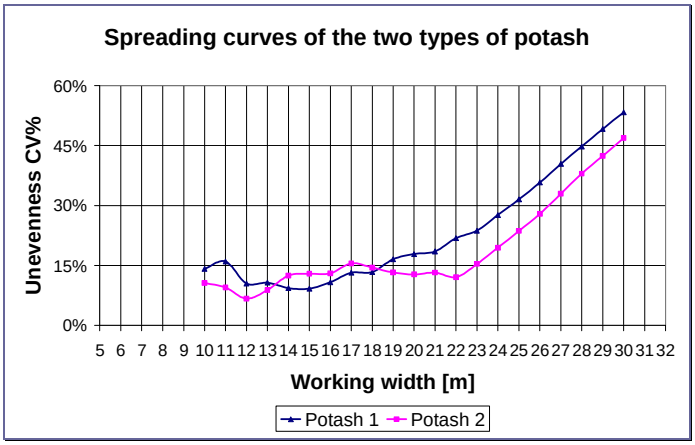


Figure 22. Spreading curves of the two sorts of potassium salt

3.7. Determination of the optimal spreading blade material

3.7.1. Falling off the quality of spreading by using worn out blades

The quality of spreading with spinning disc fertilizer distributors will fall off, if the parameters of the machine are different from the original parameters. The deformation of some machine parts and also the wear of the blades can occur. Using the blades for some time their surface will be wavy, and after this it will wear through (**Figure 23**.), which will result in the falling off the quality of spreading.

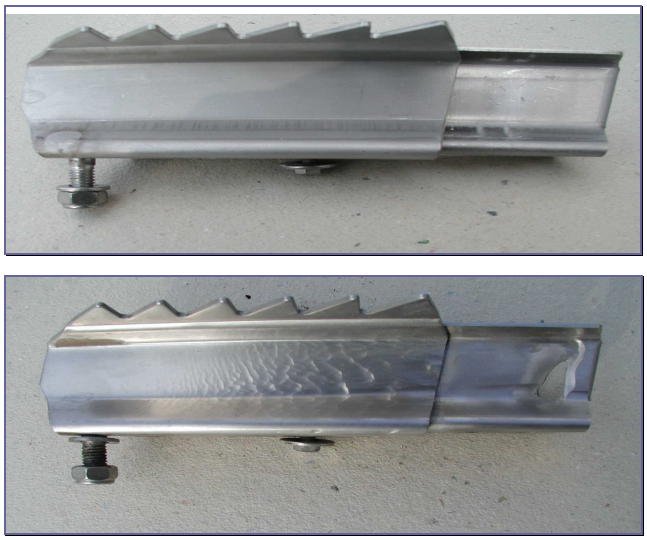


Figure 23. New and worn out spreading blades

The effect of the worn out blade surface was studied in an experiment. This proved clearly that the working width and the evenness of spreading increased when the worn out blades were changed to new ones. Applying exactly the same adjustment, at 20 metres working width the unevenness of spreading decreased from 22.23% to 9.43%.

These days the producers of fertilizer spreaders pay attention to the blade material. They try to find the most suitable blade material, which can preserve its original quality for the longest time, under the given bearing forces.

3.7.2. The results of the wear test of different types of blade material

Four different blade materials were tested under exactly the same conditions, at the same time. The wear test machine, the wearing material and the materials of the spreading blades were introduced in section “Materials and method”.

It took about two days to complete the test, and the clear wearing time was 11.5 hours.

At the beginning the blades were removed in every 0.5 hour, than in every 1or 2 hours. Their mass was measured with an accuracy of 0.1 g. The measurement results are in **Table 8**.

Table 8. Mass loss of the spreading blades during the wear test

Time [hours]	Blade							
	1		2		3		4	
	Mass [g]	Wear [g]	Mass [g]	Wear [g]	Mass [g]	Wear [g]	Mass [g]	Wear [g]
0,0	380,4	0,0	385,3	0,0	375,9	0,0	587,8	0,0
0,5	379,7	0,7	385,1	0,2	375,4	0,5	586,9	0,9
1,0	379,5	0,9	384,6	0,7	375,1	0,8	586,5	1,3
1,5	379,1	1,3	384,1	1,2	374,6	1,3	586,0	1,8
2,5	378,4	2,0	382,9	2,4	373,7	2,2	584,8	3,0
3,5	377,2	3,2	380,9	4,4	372,5	3,4	582,8	5,0
4,5	375,9	4,5	377,7	7,6	370,2	5,7	580,3	7,5
5,5	374,5	5,9	374,9	10,4	368,4	7,5	577,3	10,5
7,5	370,5	9,9	368,2	17,1	363,4	12,5	570	17,8
8,5	368,8	11,6	365,1	20,2	361,4	14,5	566,9	20,9
10,5	364,9	15,5	358,4	26,9	357,2	18,7	559,6	28,2
11,5	362,5	17,9	353,7	31,6	354,7	21,2	554,7	33,1

In the last hour of the wearing process two of the blades (Blade 2 and 4) wore through and the end of the other two blades grow sinner significantly.

These phenomena appeared on those parts of the blades where the particle velocity was the largest.

The wear test diagram, shown in **Figure 24.**, illustrates the relation between the mass of worn off material and the time.

On the basis of the test results the following conclusions can be drawn:

- In the case of all the four materials the mass loss was a function of the second order of the time.

- Under the given circumstances the most suitable material was the wear-resistant steel (Blade 1), as it was expectable.
- The wear of the blades made of corrosion resistant steel (Blade 2 and 4) was surprisingly fast and independent of their thickness.
- The wear of the blade made of cold-pressed steel plate (Blade 3) was not as fast as it was supposed, considering its small hardness.

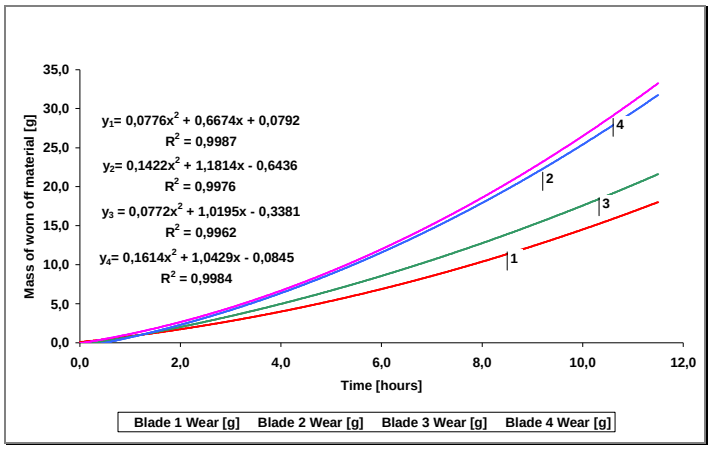


Figure 24. Wear curves, obtained as a result of the wear test

4. NEW SCIENTIFIC RESULTS

- I have found a linear relation between the coordinates of the feeding location (r_o; ψ_o) and the working width. I have proved that within certain limits, decreasing the distance from the centre of the disc and the angle from the line connecting the centres of the discs, the working width will increase.
- I have proved experimentally that by varying the pitch angle of the blades the working width will change. Applying two blades of different length, the pitch angle of the longer blade had a greater effect on the value of the working width.
- I have determined a correlation between the coordinates of the feeding location (r_o; ψ_o) and the working width applying two- and three-blade spreading systems. I have proved experimentally that by two-bladed spreading system larger working width can be reached than by three-blade system.
- I have proved experimentally that considering the working width and the evenness of spreading the length of the blades is significant. With blades of different length larger working width can be reached, than with blades of equal length.
- Two fertilizer types of approximately equal bulk density were used to prove the effect of size characteristics of particles on the working width.
- I have proved the influence of the quality of the blade surface on the working width and on the evenness of spreading.
- I have found a relation of the second order between the mass loss and the time performing the wear test of four blade materials.
- As a result of the wear test I proved that the most intensive wear occurred on those parts of the blades where the particle velocity was the largest.

5. PUBLICATIONS RELATED TO THE DISSERTATION

1. Z. CSIZMAZIA, – B. BALLÓ, – F. KASZA, – N. I. POLYÁK, – Z. HAGYMÁSSY, – K. Á. GINDERT, – **E**. **ANCZA,** 2001. Development of a friction measuring device. Mezőgazdasági Technika. 42. No. 7. 4-6. p.
2. Z. CSIZMAZIA, – Z. HAGYMÁSSY, – K. Á. GINDERT, – **E**. **ANCZA,** 2001. Examination of the friction of a compact fertilizer. Georgic Days, Keszthely.
3. **E. ANCZA** - Z. CSIZMAZIA - A. K. GINDERT - Z. HAGYMÁSSY, 2002. Friction between fertilizer particles and different types of surfaces. Hungarian Agricultural Engineering, 15. 41 – 43. p.
4. Z. CSIZMAZIA, - **E. ANCZA,** – K. Á. GINDERT, – Z. HAGYMÁSSY, 2002. Internal friction of fertilizers. AgEng International Conference on Agricultural Engineering, Budapest.
5. **E. ANCZA,** 2002. Test results of a spinning disc fertilizer distributor. EU conform agriculture and food-safety. Scientific Conference, Debrecen, 350-354. p.
6. **E. ANCZA,** – Z. CSIZMAZIA, – K. Á. GINDERT, – Z. HAGYMÁSSY, 2002. Friction of fertilizer particles on different surfaces. Workshop for Research and Development, Gödöllő.
7. Z. HAGYMÁSSY, - Z. CSIZMAZIA, – K. Á. GINDERT, – **E**. **ANCZA,** 2002. Internal friction of fertilizer particles. Workshop for Research and Development, Gödöllő.
8. K. Á GINDERT, – Z. CSIZMAZIA, – **E**. **ANCZA,** - Z. HAGYMÁSSY, 2002. Some physical properties of fertilizer particles. Workshop for Research and Development, Gödöllő.
9. K. Á. GINDERT, – Z. CSIZMAZIA, – **E**. **ANCZA,** – Z. HAGYMÁSSY, 2002. Comparative examination of physical properties of fertilizers. Wellmann Oszkár Scientific Workshop. Hódmezővásárhely.
10. K. Á. GINDERT, – Z. CSIZMAZIA, – **E. ANCZA,** – Z. HAGYMÁSSY, 2002. Examination of the aerodynamic properties of fertilizers. 5th International Conference on Food Science, Szeged.
11. **E**. **ANCZA,** – Z. CSIZMAZIA, – K. Á. GINDERT, – Z. HAGYMÁSSY, 2002. Test results of a fertilizer spreader. 5th International Conference on Food Science, Szeged.

12. Z. HAGYMÁSSY, – Z. CSIZMAZIA, – K. Á. GINDERT, – **E**. **ANCZA,** 2002. Examination of a modified plot fertilizer distributor. 5th International Conference on Food Science, Szeged.
13. **E. ANCZA,** – Z.CSIZMAZIA, 2002. The test results of Sulky DPX Expert fertilizer distributor. Gyakorlati Agrofórum. 10. 64-66. p.
14. **E. ANCZA.** 2003. The test results of Sulky DPX Expert fertilizer distributor. Natural Resources and Sustainable Development, International Scientific Session, Oradea.
15. **E. ANCZA,** 2003. Characteristics of spreading blades of spinning disc fertilizer spreaders and their influence. Workshop for Research and Development, Gödöllő.
16. **E**. **ANCZA,** – K. Á. GINDERT, – Z. HAGYMÁSSY, 2004. The influence of the characteristics of the blades on the quality of work with spinning disc fertilizer spreaders. Workshop for Research and Development, Gödöllő.
17. Z. CSIZMAZIA, **– E**. **ANCZA,** – A. KŐKUTI, 2004. Development of a high capacity fertilizer spreader. Workshop for Research and Development, Gödöllő.
18. Z. HAGYMÁSSY, – K. Á. GINDERT, – **E**. **ANCZA,** 2004. Examination of a plot fertilizer spreader. Workshop for Research and Development, Gödöllő.
19. K. Á. GINDERT, – Z. HAGYMÁSSY, – **E**. **ANCZA,** 2004. Prediction of the spreading pattern on the basis of the examinations of fertilizer particles. Workshop for Research and Development, Gödöllő.
20. **E. ANCZA** –A. KŐKUTI, 2005. Technical Conditions of Environment Protecting Fertilizer Application. Sustainable Agriculture across Borders in Europe. International Scientific Session, Debrecen –Oradea, 89-98 p.