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„PhD thesis”

TECHNICAL CONDITIONS OF EVEN FERTILIZER DISTRIBUTION ON EXPERIMENTAL PLOTS

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1. INTRODUCTION

In our country small plot experiments are made at several agricultural research institutes, species improvement stations, university research spots. By the expansion of plant improvement and agrotechnycal experiments more and more information is available for researchers. The increasing number of plots, the more and more precise labour quality demands require mechanization of experiments. Plot machines need to know more in every respect than appliances used in production. The more precise work, the rather high purchase price call our attention to tackle this matter with due consideration and in accordance with their rank.

In our country we can talk about mechanization of field small plot experiments from the 1970s *(Kunsági, 1988).* Afterwards an extremely dynamic development can be seen. While earlier the machines used in agricultural production were converted for plot cultivation, this development task follows a new direction nowadays. Production of plot machines became a separate field of agricultural mechanical engineering.

The importance of the plot mechanization is implied by the fact that an international organisation, the IAMFTE (The International Association on Mechanization of Field Experiments) was established in Norway in 1964. the aim of the organisation is to provide help in mechanization of field experiments *(OYJORD, 2000).*

To sum up, researchers declared in unison that the only solution and the most efficient way of making the experiments faster, more precise and safer is mechanization *(BETZWAR, 1996; OYJORD, 1998).*

The leading plot machine producing companies in Europe the Wintersteiger, the Hege, the Fiona, in the US the Almaco etc. usually cover the whole process of cultivation generally with plot machines of good technical quality. Unfortunately one of the most neglected fields of machine development by manufacturing companies is the research, design, production and examination of plot fertilizer distributors compared to the plot machines of the other cultivation technology elements.

Thus it is not surprising that few researchers deal with the improvement examination of plot fertilizer distributors and few publications can be found on this topic.

While manufacturers offer a lot of machines for harvesting and seeding tasks, there is little choice of plot machines for nutritive replacement tasks, e.g. FIONA Probeparcel/1.5 or HEGE 33, HEGE 34 which are usually continually distributing types. One of them, HEGE 33 distributes different amount in plots, however, it stands out with its high price. It cannot be found in Hungary yet.

Debrecen University has a FIONA/1.5 plot fertilizer distributor so I had opportunity to study the problems occuring during the use of the appliance.

Examinations made with the machine and the emerging deficiencies made me deal with the problem of plot fertilizer distributor mechanization and to respond with new technical solutions to requirements of plot fertilizer distributing.

Fertilizer of different amount and agent content must be dispensed to subsequent plots at experiments of plant number, chemicals and nutritive. At most places it is made manually with a measured fertilizer. Researchers executing small plot experiments believe that a handy new machine would be necessary for this hardly mechanized work.

The researchers drew up the following demands:

- It is important to develop an experimental plot fertilizer distributor that is able to dispense different amount of fertilizer on plots without stopping between the plots.
- The amount of fertilizer spread on plots should be as precise as possible.

- The machine should work with less unevenness of spreading than the continuous plot fertilizer distributors sold at present.
- The improved fertilizer distributors should be towable by riding- or plot-tractor.

Because of deficiencies in the choice of plot fertilizer distributors and the demand on behalf of researchers I aimed at designing and building a plot fertilizer distributor that dispenses different amount precisely on each plot.

I also consider it to be my task that the appliance should distribute equal amount in the whole length of the plot, achieve this amount at the shortest distance at the beginnning of the plot and at the end of the plot the decrease of amount should be limited to the shortest distance. This problem is not solved at the most up-to-date discontinuously dispensing plot fertilizer distributor either. My objective is to create an appliance with simple structure, can be used in flexible way and can be produced at moderate price.

I consider it to be my important task to set the design work on proper theoretical basis, therefore I aimed at making separate examinations with each main part before designing and building the fertilizer distributor.

Furthermore, my research targets included making work quality examinations with different fertilizers with the prepared experimental fertilizer distributor.

2. MATERIAL AND METHOD

2.1. Converting and examinations of FIONA Plot Fertilizer Drill/1.5 plot fertilizer distributor

As the first step my purpose was to convert the FIONA Plot Fertilizer Drill/1.5 plot fertilizer distributor that was available for row distribution and improve the unevenness of spreading. Converting the carcase of the appliance I got fertilizer near the ground from 12 feeding unit through flexible pipes **(Picture 1.).** The ends of the flexible pipes are located at an adjustable height from the ground surface with a division adjustable on a cross-bar. By this solution I made the machine suitable for row fertilizing with adjustable spacing. On spreading the whole surface a baffle plate at adjustable angle and height can be placed under the flexible pipes, by which transversal distributing of fertilizer can be made more even than formerly.

Picture 1. getting the fertilizer near the ground by the converted FIONA/1.5 Plot Fertilizer

I made the following examinations on the converted FIONA/1.5 Plot Fertilizer:

1. At the dosage device with fluted-feed roll the position of the tongue under the feeding device affects the dispensed amount and unevenness of

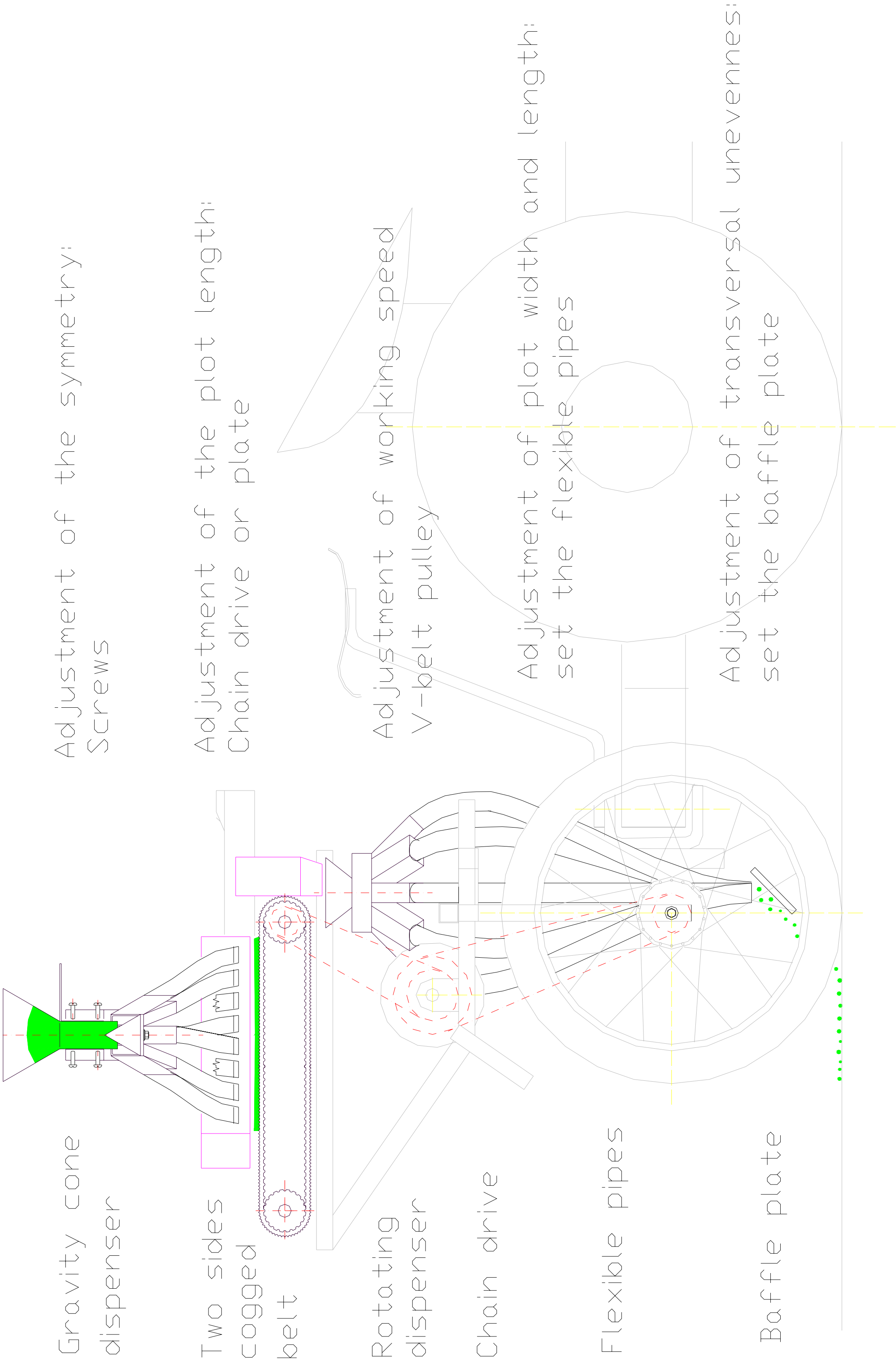
spreading. In order to study the phenomenon I made examinations on unevenness of dosage in the case of 1-5 tongue positions adjustable on fertilizer distributors, with three times repetition.

2. Next I examined the change of difference between the actually distributed amount of fertilizer at tongue position 3 which is optimal according to dosage unevenness measurements and theoretical amount that belongs to the fluted-feed roll settings adjustable on machines.
3. Afterwards I measured the transversal unevenness of spreading at different angles. I set the dispensing baffle plate between 0-90° at 5° steps.

According to my examinations the work quality features of the appliance improved after converting it, however, its basic problems remained. It was able to spread continuously, with small dosage it was not precise and could not be attached to a tractor.

2.2 The aspects of the designed plot fertilizer distributor

After the improvement of FIONA/1.5 Plot Fertilizer distributor I came to the conclusion by analysing its examination results that the basic problems of the appliance cannot be changed due to the structural design of the machine. In my opinion the demand can be met only with a completely new construction of the machine. Therefore I aimed at finding new technical solutions for distributing fertilizer. My principle was that the fertilizer distributor construction should spread precisely all the amount of fertilizer set during the experiment on one plot. A cone dispenser with a simple structure that spreads the grains on a cogged land-driven flat belt seemed to be a good construction for this job. The cogged land-driven flat belt empties the fertilizer grains without remainder from itself after the set length of plot. Transversal spreading of the fertilizer on the plot – in my notion – would be insured by the rotating dispenser which proved to be good at plot sowers **(Picture 2.)**.



Picture 2. The designed plot fertilizer distributor

As the next step of the design and development task – before starting the execution of the whole fertilizer distributor – I made examinations on the main units of the designed machine. On the one hand, these are individually developed units, on the other hand appliances purchased from plot machines manufacturers. The gravity cone dispenser and the cogged land-driven flat belt dispenser are individually developed units. The rotating dispenser is made by Wintersteiger. My construction principle was to make sure about the spreading features of the designed, theoretically working main units with measurements, model experiments in each case.

2.3. Examination of gravity cone dispenser

The cone dispenser is a simple, accurate device, but two setting inaccuracy can decrease the evenness of spreading.

1. If the symmetry axis of the feed roller and the cone dispenser does not coincide. On my experimental device it can be set by 3-3 screws that are in two alignments.
2. If the appliance is not horizontal. On this kind of appliances a level instrument is built both in longitudinal and transversal direction of the machine by which the cone must be brought to the level before spreading the plots.

These effects significantly influence the evenness of spreading, so I went on with my examinations in this direction. I prepared a test-bench for examining eccentricity between the gravity cone dispenser and the feed roller and for examining angular deviation.

2.4. Examination of rotating dispenser

The optimal working speed of the rotating dispenser in case of seeds was determined by *ZHIZHONG et al., 1994.* I wished to use the appliance for dispensing fertilizers, so I made examinations to determine the optimal working speed in case of the 4 selected fertilizers **(Picture 3.)**.

Picture 3. Examination of rotating dispenser

2.5. Preparation and examinations of an experimental model

The problematic point of cone type dispenser constructions – both the Oyjord-type cone dispenser and the Hege-type belted cone dispenser – is the deviated spreading at the beginning and end of the plot *(BETZWAR, 1987)*. I chose a solution that has not been used so far to be the dispenser construction of the experimental plot fertilizer distributor that I designed, by which – in my notion – I can eliminate the faults of the cone dispenser constructions. I prepared a flat rubber conveyer cogged on two sides to forward the grains. The flat belt cogged on two sides is a new type of dispenser, therefore I decided to prepare an experimental model with smaller measures before preparing and building it into the designed fertilizer distributor. I make examinations with the experimental model to determine how suitable is the construction for executing the job. I wished to make sure about the accuracy of my theory with model experimental measurements. To decide what the outer cogs of the flat belt should be like is an important factor from the optimal fertilizer distribution's point of view. In order to examine the problem I prepared flat belts with different cog-space. For the measurements I pushed the land-driven model mounted on a frame that can be moved by hand above a row of testing trays.

2.6. Work quality examination of an experimental plot fertilizer distributor

1. I examined unevenness of dosage on an experimental plot fertilizer distributor equipped with eight discharge pipes.
2. Next I tested the unevenness of spreading of the appliance by modelling of a 1.20 m wide piece of plot. **(Picture 4.)** I set the dispensing baffle plate that is under the eight fertilizer discharge pipes at 55° angle related to vertical.

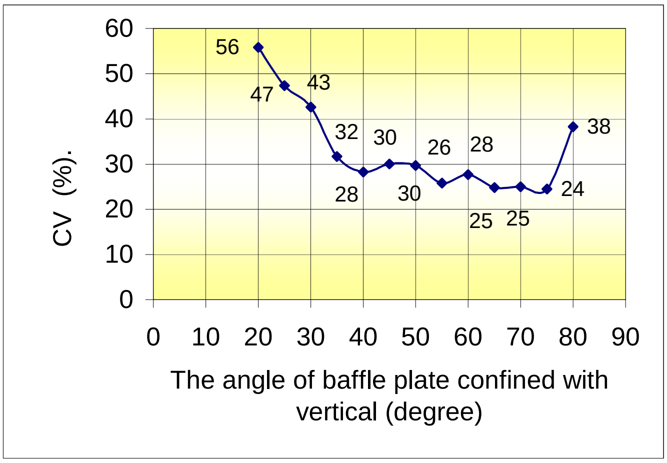
Picture 4. Examination of unevenness of spreading with testing trays placed on whole surface

3. I also tested the unevenness of spreading of the experimental plot fertilizer distributor in case of row distribution. I set the scale of the eight discharge pipes for 15 cm.
4. Finally I made examinations at the area of the beginning and end of the plot. The spreading of the cone type of dispenser appliances deviated for 50-60 cm length of path at average at the beginning and end of the plot *(BETZWAR, 1987)*. By using the cogged rubber-belt dispenser designed by me the spreading that is typical for the whole parcel is formed within shorter path in theory. To prove my assumption I made measurements. I assembled testing benches at the beginning and end of the plot, the trays were placed in 3 rows and eight columns.

3. **RESULTS AND CONCLUSIONS**

3.1. Results and conclusions reached by converting and examining FIONA/1.5 plot fertilizer distributor

1. At the dosage device with fluted-feed roll the position of the feeding tongue significantly affects the dispensed amount of fertilizer and transversal unevenness of spreading. The problem is that tongue 5 is ideal for dispensing the amount according to the setting table, however, the transversal unevenness of spreading is optimal at tongue position 3 or possibly 4.
2. We can declare that the fertilizer distributor performs the required u=5% standard unevenness of dosage in case of spreading at average 250 kg/ha amount of fertilizer, but in case of spreading 90 kg/ha the value of e=7.6% is not adequate.
3. I realised based on my measurements that at 30 various feed lever position the difference between the adjustable and actually dispensed amount of fertilizer is 14.7-46.3%. The extent of difference is not constant, the dispensed dosage cannot be calculated proportionally for another amount by setting the feed lever ta each type of fertilizer. The dosage required to be spread need to be checked by rotating test in each case. On dispensing small amount of fertilizer (dosage less than 100 kg/ha) the accuracy of the amount of fertilizer is still uncertain.
4. In case of whole surface spreading you can study the spreading features at different baffle plate positions in **Picture 5.** the mounted and accurately set dispensing baffle plate resulted in more than 100% improvement in transversal unevenness of spreading from CV=56% to CV=24-26%.



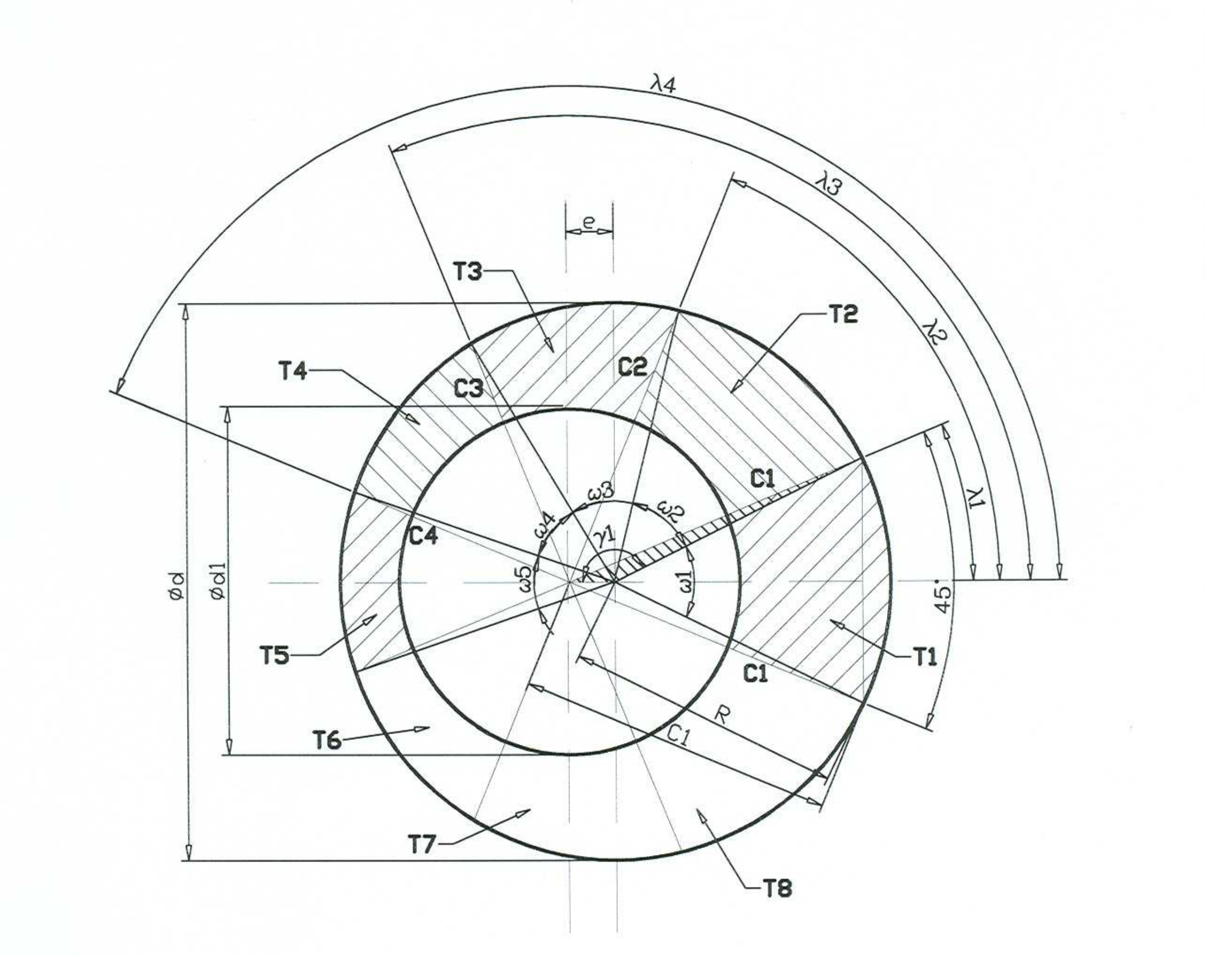
Picture 5. The transversal unevenness of spreading of the converted FIONA/1.5 plot fertilizer distributor at various baffle plate angles

3.2. Results of testing the cone dispenser

I realised while examining the units that the design task could be much faster and more reliable if a theoretical method would exist for analysing the two problems of the cone dispenser. Therefore my plans included to develop a theoretical method for examining the alignment of the cone dispenser and the feeding funnel and for testing the effects of level position of the cone dispenser. Both methods are computed mathematical programs by which – without building the cone dispenser – we can model the effect of the alignment or angle position fault on the dispensing unevenness of the cone.

3.2.1. Result of alignment model testing

It can be proved that the approximate theoretical method that models the unevenness of spreading due to the eccentricity of the cone dispenser and the feeding cylinder is able to depict the real conditions. The essence of the model – apart from the mathematical derivations – is that the grains leaving the feeding cylinder are in the same proportion to each other as the territories of the segments between the feeding cylinder and the cone dispenser (**Picture 6.**). It can be stated that the theory according to which the territory of the transfer hole's segments are in proportion to the amount of fertilizer leaving the discharge pipe is accurate based on my measurements.

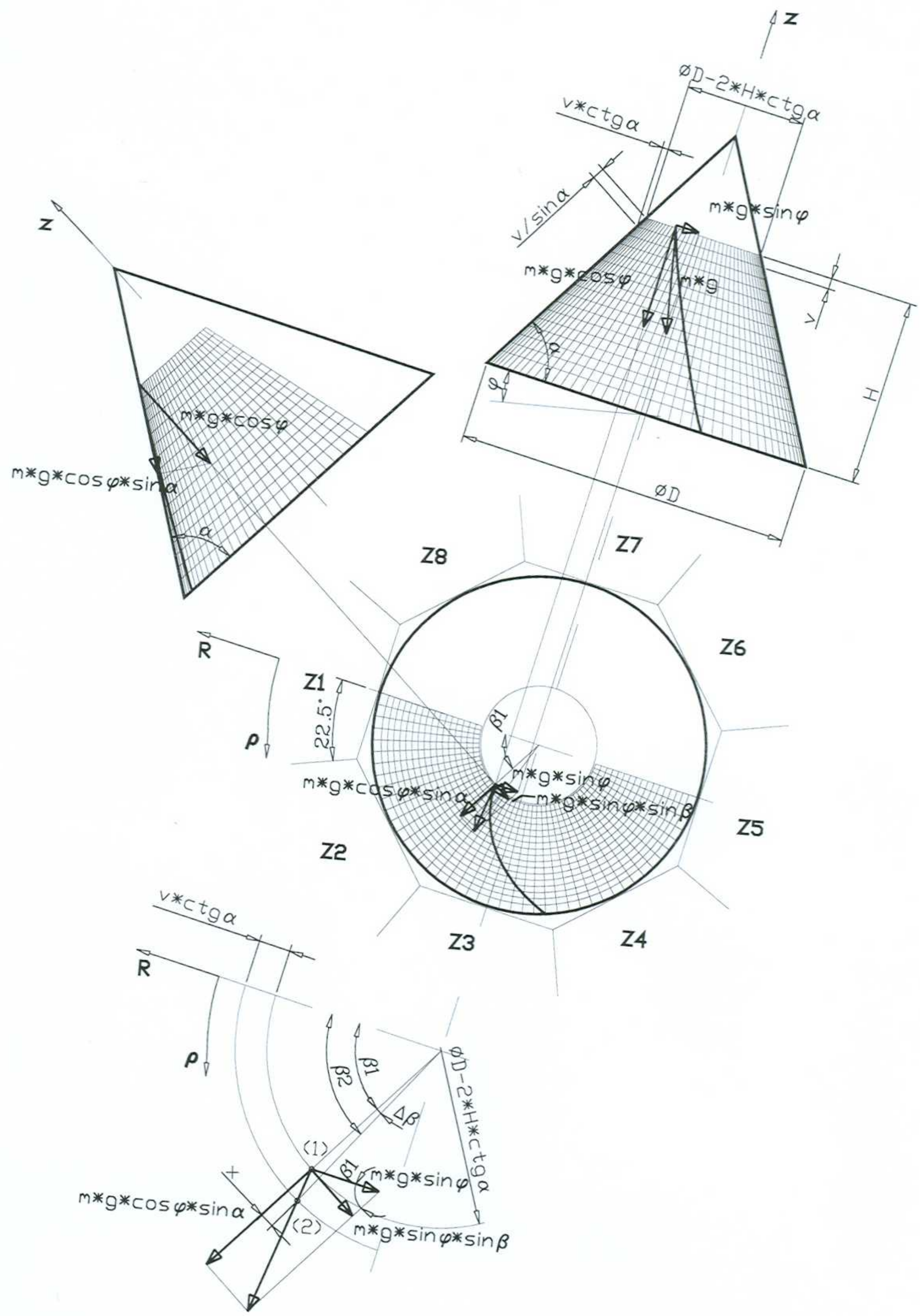


Picture 6. The territories of the segments (T1…T8) between the feeding cylinder (d) and the cone dispenser (d_1)

It can be stated that the unevenness of spreading caused by 0.25-0.5 mm eccentricity can be indicated by measurements and is in proportion to the theoretically determined variation factor.

3.2.2. Result of the angle position fault modelling program

The computer program modelling caused by the fault of cone dispenser angle can be regarded as approximate method. The essence of the model – apart from the mathematical derivations – is that I examine the path of the grain from leaving the feeding cylinder to the bottom of the cone dispenser. Due to the obliquity of the cone the path will be incurved. On the model I cover the cone piston with a net (**Picture 7.)** and at random scale between each scale interval I count the forces acting on the grain and the movement of the grain. If I set the scale of the net close enough, with good approximately I get the whole orbit.

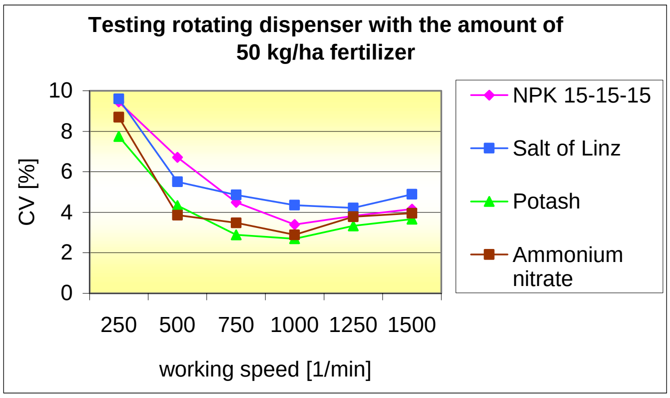


Picture 7. The movements of fertilizer on the not horizontal cone

The unevenness of dispensing can be calculated from the position of the grains getting to the bottom of the cone in case of different geometric data. My measurements imply that approximate method is able to model both the tendency and the value of the deviation caused by the fault of angle position. Both the theoretical model and the deviations prove that 2-3° deviation results in significant change in the unevenness of dispensing.

3.3. Results of testing rotating dispenser

1. We can declare that the accurately set rotating dispenser is a precise device for distributing fertilizer.



Picture 8. Results of testing rotating dispenser

2. Based on my experiences the 1000 l/min optimal working speed provided favourable dispensing in case of the examined fertilizers **(Picture 8.).** According to my observations the evenness of dispensing can be decreased if uneven dosage of grains get into the feed opening of the rotating dispenser or the arriving grain flood is lopsided.

3.4. Conclusions drawn from testing the experimental model

1. The rubber conveyor model cogged on two sides showed good results during the experiment. The fertilizer in the cogged rubber apron runs securely towards the discharge hole. The does not slip because of the

inner cogging, due to the outer cogging the grains do not move from their place with the heavy movement of the model either.

2. While examining the cog dimensions of the experimental model, I realised that the outer cog spacing of the conveyor significantly influence the longitudinal unevenness of spreading. The optimal value of the cog spacing is 3-4 mm.

3.5. Preparation of an experimental plot fertilizer distributor

I started to design and build the new plot fertilizer distributor based on the experience gained from the examination of the main units and the requirements raised concerning the appliance.

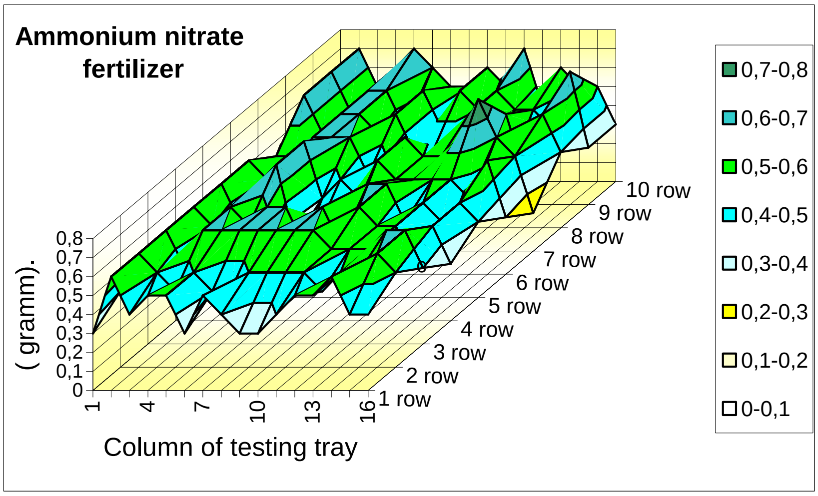
Picture 9. The designed and developed experimental plot fertilizer distributor

The small plot fertilizer distributor is towable by riding-tractor, at this time the operator sits on the seat fixed between the riding-tractor and the distributor **(Picture 9.)**. In this case the appliance can execute basic fertilizing jobs. The fertilizer distributor can be pushed by hand or attached to plot-tractor, this time it can be used for top dressing. Its working side can be continuously adjusted up to 1.5 m, the plot length can be regulated with scaling or continuously. The fertilizer distributor spreads the amount of fertilizer measured in the length of the plot, but without any remainder. In the numbered boxes of the machine's storing bins you can prepare the precisely measured amount and combination of fertilizer. Due to the working principle of the appliance the distributed amount of fertilizer – admeasured on scales – is much more accurate than other continuously dispensing constructions.

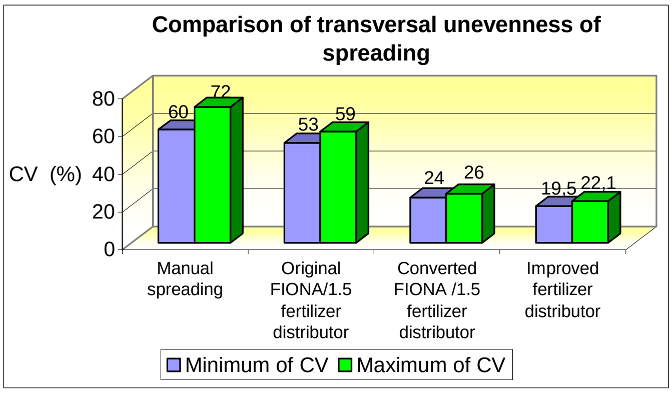
3.6. Results of work quality examinations

1. We can declare that the unevenness of dosage (u) with the experimental fertilizer distributor is much lower than the permitted standard value. In case of the experimental fertilizer distributor the (u) value is 0.26-0.56%, the permitted standard (u) value is 5%. The accuracy of the distributed amount of fertilizer results from the working principle of the fertilizer distributor. The fertilizer is measured in boxes for each plot. The fertilizer distributor spreads the amount of fertilizer filled into the machine at the beginning of the plot without any remains while going across the plot. It can be stated that the unevenness of dosage with the improved fertilizer distributor is much lower than the examined FIONA/1.5 continuous plot fertilizer distributor, therefore if the accuracy of the amount of fertilizer distributed on subsequent plots is important during the experiments, the use of a discontinuous plot fertilizer distributor is recommended.
2. The tests were executed on a whole piece of plot, thus the received results made me possible to use a new solution in data analysis. Using the finding of the 160 pieces of testing trays I drew the amount of fertilizer related to each area element as a map. The result is a demonstrating map of spreading on which the amount of fertilizer distributed on certain parts of the examined area can be followed. In **Picture 10.** I demonstrated the measured amounts of fertilizer in case of spreading ammonium nitrate on the whole surface in case of dispensing 300 kg/ha amount of fertilizer. My tests suggest that the transversal unevenness of spreading with the improved experimental plot fertilizer distributor (CV=19.5-22.1%) is also

much more favourable than that of the examined FIONA/1.5 (CV=24-26%) continuous plot fertilizer distributor **(Picture 11.)**.

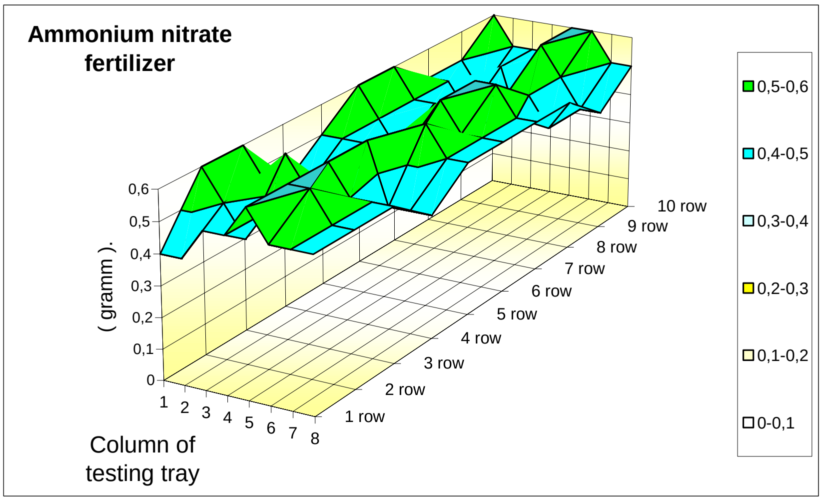


Picture 10. Map of spreading made in case of whole surface distribution. The dispensed amount of fertilizer: 300 kg/ha.



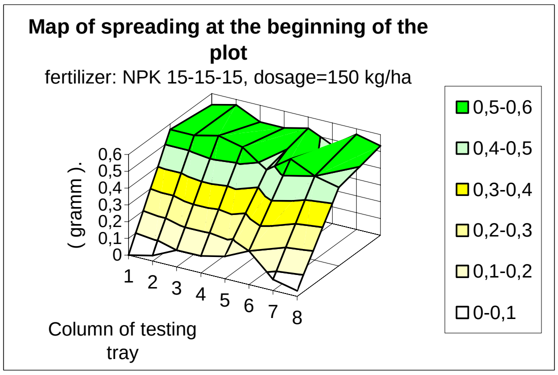
Picture 11. Comparison of transversal unevenness of spreading manually, with FIONA/1.5 fertilizer distributor and the improved experimental plot fertilizer distributor

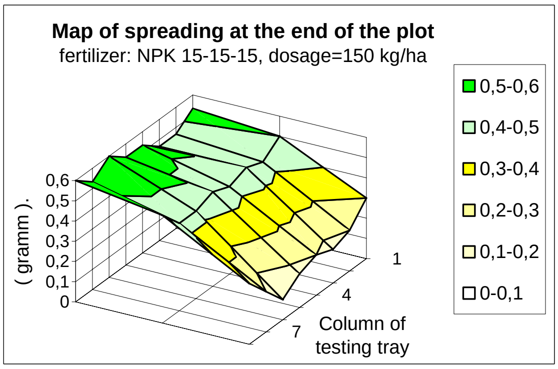
3. The unevenness of manual spreading (CV=60-72%) is far behind the features of machine spreading (CV=19-26%) according to my tests **(Picture 11.)**.
4. I proved by measurements that in case of row distribution (**Picture 12.)** the unevenness of spreading with the improved experimental plot fertilizer distributor is even smaller than in case of whole surface spreading (CV=8.6-11.6%).



Picture 12. Map of spreading made in case of row distribution. The dispensed amount of fertilizer: 150 kg/ha.

5. Based on my examinations it can be stated that at the beginning and end of the plot the improved fertilizer distributor has more favourable spreading features than the otherwise commonly used Oyjord-type cone dispenser and Hege-type belted cone dispenser (**Picture 13.).**





Picture 13. Map of spreading made at the beginning and at the end of the plot

4. NEW AND UP-DATED SCIENTIFIC FINDINGS

Based on converting and examining FIONA/1.5 plot fertilizer distributor

1. I revealed in which conditions and setting region is the fluted-feed roll suitable for fertilizing individual plots.
2. I determined the effect of the dispensing baffle plate angle on the unevenness of spreading and found the optimal setting (65-75°).

Results reached during examination and development of cone dispenser

1. I elaborated a theoretical method by which the effect of the alignment fault of the cone dispenser and the feeding funnel on evenness of spreading can be modelled.
2. I made a computed approximate model by which the effect of the cone dispenser angle fault on evenness of spreading can be simulated. Based on the findings gained by the two approximate models the optimal measures, settings of the cone dispenser can be determined.
3. I pointed out that even slight eccentricity (0.25-0.5 mm) and some degrees of angle deviation (2-3°) can also significantly increase the unevenness of spreading.

Results of testing rotating dispenser

1. I revealed the correlation between the rotating dispenser's working speed and unevenness of spreading in case of dispensing fertilizers. I determined its optimal setting ($n=1000\pm150$ l/min) (CV=2.6-4.3%).

Results of testing and development of the new type of fertilizer distributor

1. I proved that there is close correlation between the longitudinal distribution and the cog dimensions of the conveyor, and I determined its optimal setting (cog spacing=3-4 mm).

Results of testing and development of the experimental plot fertilizer distributor

1. I improved a new type plot fertilizer distributor.
2. I pointed out that the discontinuous working principle ensures more accurate and even distribution of fertilizer than the machine with continuous working principle or the manual spreading ($u_{discontinuous}$= 0.28-0.42%) ($u_{continuous}$=4.8-7.6%) ($CV_{discontinuous}$ =19.5-22.1%) ($CV_{manual\ spreading}$=60-72%) ($CV_{continuous}$=24-26%).
3. I proved that the deviation of spreading is limited to the shortest path at the beginning and end of the plot with the developed conveyor distributor compared to the cone dispenser type of plot machines.

5. FINDINGS THAT CAN BE USED IN PRACTICE

Suggestions for the use of the improved FIONA/1.5 plot fertilizer distributor

If we can make slight allowances in accuracy of the distributed amount of fertilizer and if we do not have to dispense different amount of fertilizer on subsequent plots, I can recommend its use with the following complements:

1. The adjusted dosage needs to be checked by rotating test in each case as the table of settings attached to the machine is not reliable in proportions either. On dispensing fertilizer dosage less than 100 kg/ha the accuracy of distribution is still uncertain.
2. The transversal evenness of spreading as a result of the mounted dispensing baffle plate is adequately accurate.
3. Row distribution with adjustable spacing can be realised with the appliance due to the mounted discharge pipes.
4. The appliance can only be pushed by hand, therefore I suggest it just for cultivating small number of plots. Its movement requires hard physical work. The unevenness of the plot path considerably influence the power demand of movement. Depending on it 2-3 workers are needed for doing the job evenly.

Suggestions for designing and building-in the cone dispenser

1. Before designing cone dispenser I recommend to run the computer programs modelling the fault of eccentricity and angle position in case of different cone dispenser geometric measures. The programs provide help in selecting the ideal diameters and cone angles.
2. Before using the cone dispenser I suggest adjusting the eccentricity of cone dispenser and feeding cylinder accurately because slight eccentricity (0.25-0.5 mm) can also decrease the evenness of spreading. This job need to be done once before using the machine.

3. Before starting distribution the level position of the cone dispenser also need to be checked taking the configuration of the terrain into consideration. This operation can be executed accurately with the level adjusting screw.

Suggestions for the adjustment of the rotating dispenser

The rotating dispenser with proper adjustment is an accurate device. I can recommend its use with the following complements:

1. I suggest setting the working speed of the rotating part near 1000 l/min for dispensing fertilizers.
2. It is advisable to lead the fertilizer into the rotating dispenser with a leading cone to ensure centric arrival of the grains into the rotating part.

Suggestions for building-in the cogged rubber conveyor

1. I recommend to select the setting for the cog spacing of the fertilizer conveyor for the 0.7…1.2 times of the grain size.
2. In my opinion, a trial spreading is advisable in order to check the setting of the plot length.

Suggestions for the use of the experimental plot fertilizer distributor

The prepared plot fertilizer distributor can be evaluated as experimental machine at present. Based on examinations executed on the fertilizer distributor, however, the following suggestions can be made.

1. The machine is suitable for basic fertilizing jobs, this time it is towable by riding- or plot- tractor. Certainly the amount of fertilizer for each plot is need to be prepared in boxes in each case.
2. For top dressing tasks I recommend towing by plot-tractor, or the manually pushed version in case of small number of plots.
3. The appliance is suggested both for spreading the whole surface of the plot and for spreading rows with optional spacing. The width of the plot need to be less than 1.5 m, the suggested plot length: 6-12 m.

6. LIST OF SCIENTIFIC PUBLICATIONS IN THE TOPIC OF THE THESIS

6.1. Consulted publications, journal articles:

1. ANCZA, E – CSIZMAZIA, Z. – GINDERT, A. K. – **HAGYMASSY, Z.** 2002. Friction between fertilizer particles and different types of surfaces. Hungarian Agricultural Engineering. 15. 41-43.
2. CSIZMAZIA, Z. – BALLÓ, B. - KASZA, F.- **HAGYMÁSSY, Z**. – GINDERT, K. Á. – ANCZA, B.E. 2001. Súrlódásmérő készülék fejlesztése. Mezőgazdasági Technika. 42. 7.sz. 4-6.
3. **HAGYMÁSSY, Z.** 2003. Parcella műtrágyaszóró gép fejlesztése és munkaminőségének vizsgálata. Agrártudományi Közlemények. 12. 35-38.
4. **HAGYMÁSSY, Z.** 2003. Parcella műtrágyaszóró gép fogazott lapos hevederes szóró szerkezete. Agrártudományi Közlemények. 12. 39-41.
5. CSIZMAZIA, Z. - ANCZA, B.E. – GINDERT, K.Á. – **HAGYMÁSSY, Z**. 2002. Internal friction of fertilizers. AgEng International Conference on Agricultural Engineering, Budapest. 170-171.
6. **HAGYMÁSSY, Z**. 2002. Parcella műtrágyaszóró gép fejlesztése. EU konform mezőgazdaság és élelmiszerbiztonság Tudományos Konferencia. Debrecen. 362-368.
7. **HAGYMÁSSY, Z.** 2003. A szántóföldi kisparcellás kísérletek gépesítése. EU konform mezőgazdaság és élelmiszerbiztonság Tudományos Konferencia. Gödöllő. 142-148.

6.2. Non-consulted publications, conference lectures:

1. CSIZMAZIA, Z. – **HAGYMÁSSY, Z**. – GINDERT, K. Á. – ANCZA, B.E. 2001. Összetett műtrágya súrlódási viszonyainak vizsgálata. Georgikon napok. Keszthely. 1136-1139.
2. **HAGYMÁSSY, Z. -** CSIZMAZIA, Z. – GINDERT, K. Á. – ANCZA, B.E. 2002. Műtrágyaszemcsék belső súrlódása. MTA Agrár-műszaki Bizottság XXVI. Kutatási és fejlesztési tanácskozás. Gödöllő. 160-164.
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