MEASUREMENT OF ELECTRICAL CONDUCTIVITY OF FERTILIZER LAD 27

J. Krupička[1], P. Šařec[2]

[1]*Department of Agricultural Machines, Faculty of Engineering, Czech University of Life Sciences Prague, Czech Republic*
[2]*Department of Machinery Utilization, Faculty of Engineering, Czech University of Life Sciences Prague Czech Republic*

Abstract
Paper deals with the measurement of electrical conductivity of significant size groups of mineral fertilizer LAD 27 divided in the air stream. Samples of these groups were dissolved in distilled water and the values of electrical conductivity recorded. Measurements will be used to monitor the electrical conductivity of other mineral fertilizers and to create a standard for qualitative assessment of fertilizer solutions.

Key words: electrical conductivity, air flow, fertilizer solution, concentration, LAD 27.

INTRODUCTION

Fertilisation is an important factor that affects crop yields (LOŽEK ET AL., 1997; KAJANOVIČOVÁ ET AL., 2011). Correct application of fertilisers has both positive economic and environmental effects (NOZDROVICKÝ ET AL., 2009; ŠIMA ET AL., 2012; ALARU ET AL., 2003; ŠIMA & DUBEŇOVÁ, 2013). One of the most important factors is the fertiliser particle-size distribution which depends upon the size of the fertiliser particles (MACÁK ET AL., 2011). The differences and variability in physical properties of fertilisers causes problems during the field application by the commonest spinning disc fertiliser spreaders. This process depends upon the particle's dimension, so that the dimension of particles is one of the main parameters that influence fertiliser effectiveness (KRUPIČKA & HANOUSEK, 2006). Therefore, granulometric studies of various fertilizers were carried out (KRUPIČKA & HANOUSEK, 2006; ŠIMA ET AL., 2013). In order to enable more accurate fertilizer application also in its liquid form, it is important to measure concentration of solution (KRUPIČKA&ŠAŘEC, 2013; KRUPIČKA ET AL., 2015). The concentration of fertilizers can be determined on the basis of the electrical conductivity (increasing the electrical conductivity). The value of the electrical conductivity can be used for precise application of fertilizers in liquid form. Monitoring the conductivity and knowing its value for target fertilizer concentrations enables to start the field application of fertilizers at an optimum moment. This would significantly increase the precision compared to the commonly used "mass percentage method" where the concentration accuracy attains only ±10 % according to fertilizer manufacturers. According to the electrical conductivity, the quality of the measured fluid can be assess accurately along with other data such as the level of pollution, the concentration of the various components of the solution, etc. (KABEŠ, 1999). In that way, electrical conductivity is the reciprocal of electrical resistance, is indicated with the letter G and its basic unit is the Siemens (S).

The effectiveness of mineral fertilizers in crop cultivation depends on the particle stability and speed of their transformation to solution state to be acceptable by plants. This process depends on the particles dimensions, so that the dimension of particles is one of the main parameters that influence the fertilizer effectiveness.

Application of solid commercial fertilizers play important role in precision farming technologies. The application quality is dependent on chemical composition and physical properties of fertilizer. Important from physical properties point of view is the grading of aggregate evaluation that is still performed by standard ČSN 01 50 30. The dimension of fertilizer particles only is characterized by this way.

In this paper, we continue in the previous research program, in which the granulometric examinations of mineral fertilizers were studied. In contrary to the similar study of other authors, sieve and airflow sorting were combined.

Experiments with particles can be designed differently. An elutriator was designed and constructed in which an airflow is supplied by a centrifugal fan (CSIZMAZIA, 2000). Methods for measuring the coefficient of friction, the coefficient of restitution, the aerodynamic resistance coefficient, and the breaking force (particle strength) of fertilizers (HOFSTEE, 1992) were taken into account. The breaking force feature was skipped. The problem of particle destruction was overcome by fertilizer selection. The control of fertilizer discharge was studied for different designs of distributors and an experimental accurate fertilizer distributor with a rotary vessel type feeder was developed (KUDOH, 1989) what shows that dissolution of fertilizer also makes some problems. Consequent logistical problems are difficult the same way both for pumping liquids, and for transportation of particles by the air.

The size of particles makes the fertilizer's shelf life and stability of particulars behavior in the airflow more stable in storage and better acceptable by the plant. Therefore, experiments studying motion of particles through the air were accompanied by grading of particles.

This paper contains results obtained for LAD 27 using the method developed previously.

MATERIALS AND METHODS

Electrical conductivity was measured using the device inoLab model WTW Cond 720. Instruments for the measurement of electrolytic conductivity, specifically electrical conductivity of liquids, consist of a measuring probe or conductivity sensor, transducer and evaluation unit. According to the manufacturer, accuracy of the device is 0.5% of value when measuring conductivity. Most of the apparatus is adapted for measuring the resistivity and weight concentrations of some components of the solution, which can be derived from the electrical conductivity. They are very sensitive and allow you to measure the content of various substances from small to very high concentrations and is often used to control a wide range of industrial processes (KABEŠ, 1999). Measurement was carried out for mineral fertilizer LAD 27 (alternative trade name LOVOFERT LAD 27; manufacturer LOVOCHEMIE, a.s. – the Czech Republic). The composition of LAD 27 is the following: nitrogen fertilizer containing 27 % of nitrogen and 4 % of MgO. It is a mixture of ammonium nitrate with finely ground dolomite in the form of whitish to light brown granules sized 2 mm to 5 mm. Fertilizer is an all-purpose fertilizer suitable for basic fertilization as well as fertilization during vegetation of winter crops and spring crops. Distribution of the air stream was carried out in the laboratory of the Department of Agricultural Machinery using the laboratory air sorting machine K - 293 (see Fig. 1).

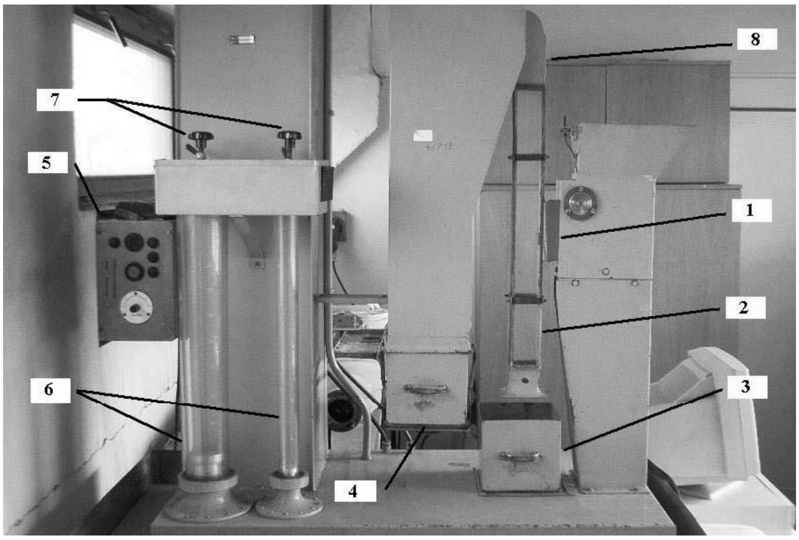

Fig. 1. – Laboratory Air sorter K - 293

Labels: 1 - adjustable damper hoppers, 2 - vertical (aspiration) channel, 3.4 - tanks, 5 - control panel with buttons, 6 - small and large graduated cylinder, 7 - cylinder adjusting screws, 8 – fan

The measurement procedure was as follows. First the laboratory sorting machine K-293 determined ranges of required amount of air, i.e. the minimum amount of air in which the particles are carried, and in the opposite a maximum amount of air in which the sample is completely sorted. With the help of graduated cylinders, interval of gradually increasing speed of the air flow is selected so that the number of classes was 7 to 10. It is necessary to ensure the right plane for the weights to ensure accuracy. Scales are calibrated and set to zero. Fertilizer is mixed because of the measurement accuracy and a sample of fertilizer weighing 500 g removed. An appropriate, predetermined, air speed is set for the laboratory device using graduated cylinders and adjusting screws. A sample of fertilizer is poured into the tank (1) with pre-set for the damper. With the help of a vibrator, fertilizer gets into the air flow in a vertical channel (see Fig. 2). Here comes the separation. Granules with larger than the critical speed set fall through the channel into the container (3). Granules with lower critical speeds are vertically entrained in air stream and in the extended portion of the channel are falling into the tray (4). The amount of fertilizer separated using air flow into the tank (4) is then placed in a pre-labeled bowl for later use. Emptied tank (4) is placed back into the machine and the speed of the air flow is checked. Then the fertilizer from the tank (3) is filled back to the tank (1) and the graduated cylinder is set to the next value of air stream speed. In this way, the experiment continues until the entire sample of fertilizer gradually falls into the tank (4).

The whole process is repeated with eight different samples of fertilizers to maintain the accuracy and reliability of statistical data measurements. Measurement in an air stream was carried out at a temperature of 22 °C and humidity of 22 %.

Subsequently, the material sorted by the air stream was further divided by laboratory sieves Haver EML 200. Three samples weighing 5 grams were taken from the portions with significant share.

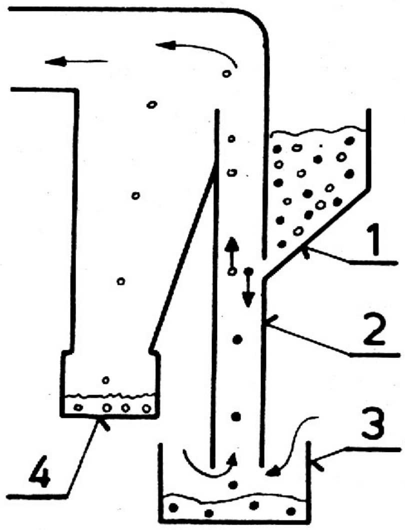

Fig. 2. – Thevertical channel (detailed view)
Labels: 1 - tray, 2 - vertical (aspiration) channel, 3 - stack, 4 - tray (particles of lower critical speed are carried into this tank)

Their electrical conductivity was measured on the machine Conductivity meter WTW inoLab model Cond 720. The measurements were carried out over nine hours in one-hour intervals. Before each conductivity measurement took place, the sample had been mixed to ensure its homogeneity.

RESULTS AND DISCUSSION

From the material divided by the air stream and the sieves, three samples weighing 5 grams were taken of each of significant proportions that were gained by the air stream of 105, 115, 125 $m^3.h^{-1}$ and by the sieves of size 1, 2, 3.15 and 4 mm (Tab. 1). The fertiliser meets the requirements of the national standards and is in conformity with the demanded range given by the manufacturer. ŠIMA ET AL. (2013) came with the same conclusion in the case of DASA 26/13 and ENSIN fertilizers.

Subsequently, the samples were collected and mixed and then dissolved in distilled water of the volume of 50 ml and of the room temperature of 17 °C.

Tab. 1. – Relative representation of groups of LAD 27 after sorting by air stream and sieves (significant proportions highlighted by italics)

Air stream $[m^3.h^{-1}]$	Sieves [mm] 1.00	2.00	3.15	4.00	Total
105	0.01 %	***8.09 %***	***11.79 %***	0.40 %	**20.31 %**
115	0.01 %	***3.13 %***	***38.84 %***	2.82 %	**44.80 %**
125	0.00 %	0.76 %	***24.38 %***	***9.76 %***	**34.90 %**

Tab. 2 to 4 show the measured values of electrical conductivity. Conductivity measurements were performed in one-hour steps and started half an hour after solution had begun.

Tab.2. – Measured values of electrical conductivity of LAD 27 fertilizer for the air stream of 105 $m^3.h^{-1}$

Time	Electrical conductivity[$m^{-2}.kg^{-1}s^3.A^2$]						Average
[h]	Sieve 2.00 mm			Sieve 3.15 mm			
0.5	55.40	53.00	51.20	51.20	45.60	46.70	50.52
1.5	81.60	78.90	79.80	73.50	68.20	71.50	75.58
2.5	92.40	86.20	84.50	81.50	79.70	82.40	84.45
3.5	97.40	94.50	95.50	92.10	89.80	85.40	92.45
4.5	99.80	96.30	98.10	98.60	96.40	97.10	97.72
5.5	102.20	97.40	99.50	99.40	97.50	98.60	99.10
6.5	103.10	98.10	99.70	100.20	98.90	99.80	99.97
7.5	103.80	98.60	100.40	101.30	100.40	101.50	101.00
8.5	104.30	99.40	101.70	102.40	101.10	102.60	101.92
9.5	105.10	100.90	102.10	103.00	101.90	103.10	102.68

Tab. 3. – Measured values of electrical conductivity of LAD 27 fertilizer for the air stream of 115 $m^3.h^{-1}$

Time	Electrical conductivity[$m^{-2}.kg^{-1}s^3.A^2$]						Average
[h]	Sieve 2.00 mm			Sieve 3.15 mm			
0.5	46.80	47.80	45.40	46.80	47.80	45.40	46.67
1.5	74.10	76.20	78.70	74.10	76.20	78.70	76.33
2.5	85.70	84.50	86.40	85.70	84.50	86.40	85.53
3.5	88.60	89.80	91.50	88.60	89.80	91.50	89.97
4.5	94.40	95.00	95.70	94.40	95.00	95.70	95.03
5.5	95.70	95.30	96.70	95.70	95.30	96.70	95.90
6.5	96.40	96.10	97.80	96.40	96.10	97.80	96.77
7.5	99.40	99.70	99.80	99.40	99.70	99.80	99.63
8.5	99.80	100.50	100.20	99.80	100.50	100.20	100.17
9.5	101.30	102.20	102.10	101.30	102.20	102.10	101.87

Tab. 4. – Measured values of electrical conductivity of LAD 27 fertilizer for the air stream of 125 $m^3.h^{-1}$

Time	Electrical conductivity[$m^{-2}.kg^{-1}s^3.A^2$]						Average
[h]	Sieve 3.15 mm			Sieve 4.00 mm			
0.5	51.20	49.30	52.40	56.70	55.90	58.90	54.07
1.5	78.60	72.50	81.20	79.70	84.80	86.90	80.62
2.5	86.50	81.20	92.40	85.20	92.30	97.80	89.23
3.5	94.50	88.70	97.80	97.30	96.10	103.60	96.33
4.5	98.70	94.60	101.20	99.10	95.70	107.00	99.38
5.5	101.60	95.80	104.30	101.70	96.80	107.80	101.33
6.5	103.70	96.80	105.20	102.90	97.80	108.50	102.48
7.5	104.50	98.20	106.10	104.50	99.80	109.90	103.83
8.5	105.90	99.10	106.80	105.60	101.20	111.60	105.03
9.5	106.50	100.40	108.50	107.70	103.20	113.60	106.65

Fig. 3 demonstrates the logarithmical increase of electrical conductivity of air flow classes 105, 115, and 125 $m^3.h^{-1}$. The differences among classes were minor only. KRUPIČKA & ŠAŘEC (2013) and KRUPIČKA ET AL. (2015) concluded the same for Lovogreen, resp. DAP fertilizers. After five hours, electrical conductivity values of LAD 27 got stabilised and showed only slight increase. Similar study concerning DAP fertilizer showed on the other hand linear increase of the conductivity even after ten hours (KRUPIČKA ET AL., 2015). Concerning Lovogreen fertilizer (KRUPIČKA & ŠAŘEC, 2013), the conductivity decreased with time, but still did not get stabilised after ten hours. Hence, the results could not be generalized for different fertilizers.

Undissolved residues were detected by using filter paper - the solution was filtered and the solids were weighed and dried in a dryer at a constant temperature of 105 ° C to constant weight. These weights are not given here, because the amount of undissolved fertilizer cannot be determined, i.e. it would require nutrient analysis to decide whether undiluted sample contains nutrients, or it is carrier roughage only.

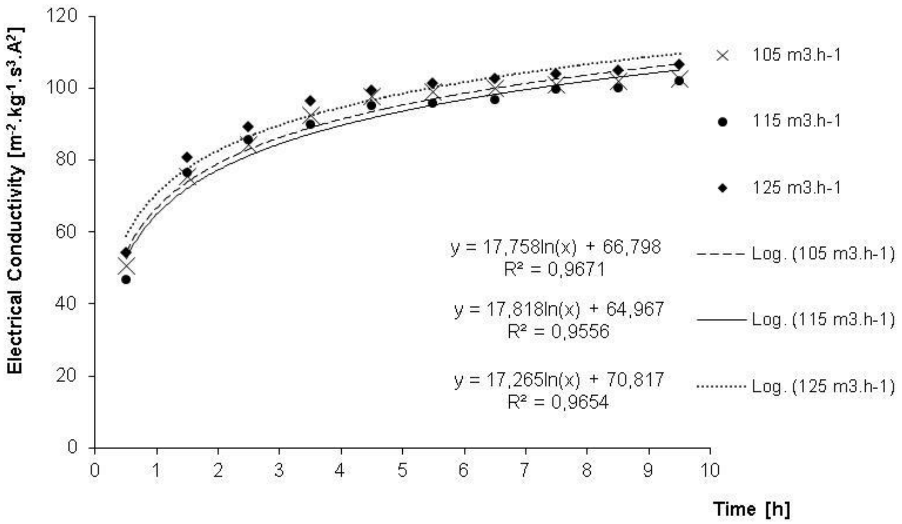

Fig. 3. – Graph of time dependence of electrical conductivity on the air stream of 105, 115 and 125 $m^3.h^{-1}$ respectively

CONCLUSIONS

On the basis of the electrical conductivity, the concentration of dissolved mineral fertilizer can be determined. Fig. 3 indicates that the values for the significant proportions are analogous. These values are crucial for the production of concentrated solutions of mineral fertilizers that LAD 27 fertilizer is well soluble, and thus five hours are a sufficient time period for dissolving it. Electrical conductivity values are noticeably high which means that the ions can be absorbed easily by plant roots. The LAD 27 is therefore suitable for application into soil.

Measurements are taken as the guidance for the methodology verification that will be used to measure other samples of similar fertilizers. These results will be used for the precise application of fertilizers and can be used as a reference for qualitative assessment fertilizer solutions. The research is about to continue with simultaneous measurement of concentrations in order to determine the relationship between concentration and electrical conductivity. Unfortunately, current measurement devices available to authors do not allow such approach.

ACKNOWLEDGEMENTS

This work was supported by Research Project of the Ministry of Education of the CR no. MSM 6046070905.

REFERENCES

1. ALARU, M., LAUR, Ü., JAAMA, E.: Influence of nitrogen and weather conditions on the grain quality of winter triticale. Agronomy Research, 1, 2003: 3–10.
2. CSIZMAZIA, Z.: Some physical properties of fertiliser particles. In: Aspects-of-Applied-Biology, Department of Agricultural Engineering, Faculty of Agricultural Sciences, Debrecen University, Hungary. 2000: 219-226.
3. HOFSTEE, J.W.: Handling and spreading of fertilizers: part 2, physical properties of fertilizer, measuring methods and data. Journal of Agricultural Engineering Research, 53, 1992: 141-162.
4. KABEŠ, K.: Instruments for conductivity measuring. Automatization, 42(11), 1999: 826–832. (in Czech).
5. KADLEC, K.: Sensors for electrolytic conductivity of liquids. Automatization, 42 (3), 1999: 823–825. (in Czech).
6. KAJANOVIČOVÁ, I., LOŽEK, O., SLAMKA, P., VÁRADY, T. 2011: Bilancia dusíka v integrovanom a ekologickom systéme hospodárenia na pôde. Agrochémia, 51, 2011:7–11 (in Slovak).
7. KRUPIČKA, J., HANOUSEK, B.: Granulometric study of Synferta N-22 and Synferta N-17. Res. Agr. Eng., 52, 2006: 152–155.
8. KRUPIČKA, J., ŠAŘEC, P.: Measurement of electrical conductivity of lovogreen fertilizer. In 5th International Conference Trends in Agricultural Engineering 2013, Prague: Czech University of Life Sciences Prague, 2013: 368-371.
9. KRUPIČKA, J., ŠAŘEC, P., NOVÁK, P.: Measurement of electrical conductivity of DAP fertilizer. Agronomy Research, 13(1), 2015: 109-114.
10. KUDOH, M.: Flowability of fertilizers and development of an accurate fertilizer DISTRIBUTOR. JOURNAL OF HOKKAIDO COLLEGE, 22, 1989: 1-87.
11. LOŽEK, O., BIZÍK, J., FECENKO, J., KOVÁČIK, P., VNUK, Ľ.: Výživa a hnojenie rastlín: Trvale udržateľné systémy v poľnohospodárstve. Nitra: SUA in Nitra, 1997: 104 pp. (in Slovak).
12. MACÁK, M., NOZDROVICKÝ, L., ŽITŇÁK, M.: Vplyv granulometrického zloženia priemyselných hnojív na kvalitu práce rozhadzovača. Agrochémia, 51, 2011: 11–15, (in Slovak).
13. NOZDROVICKÝ, L., MACÁK, M., FINDURA, P.: Effect of the fertilizer particle size distribution on the transversal uniformity distribution. In New Trends in Design and Utilisation of Machines in Agriculture, Landscape Maintenance and Environ-

ment Protection: Proceedings of the International Scientific Conference. CULS Prague, Prague, 2009: 210–218.
14. ŠIMA, T., NOZDROVICKÝ, L., KRIŠTOF, K., DUBEŇOVÁ, M., KRUPIČKA, J., KRÁLIK, S.: Method for measuring of N2O emissions from fertilized soil after the using of fertilizer. Poljoprivrednatehnika. 38, 2012: 51–60.
15. ŠIMA, T., KRUPIČKA, J., NOZDROVICKÝ, V.: Effect of nitrification inhibitors on fertiliser particle size distribution of the DASA 26/13 and ENSIN fertilisers. Agronomy Research, 11(1), 2013: 111-116.
16. ŠIMA, T., DUBEŇOVÁ, M.: Effect of crop residues on CO2 flux in the CTF system during soil tillage by a disc harrow Lemken Rubin 9. Res. Agr. Eng., 59, 2013: S15-S21

Corresponding author:
Ing. Josef Krupička, CSc.,Department of Agricultural Machines,Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6, Prague, 16521, Czech Republic, phone: +420 22438 3127,e-mail: krup@tf.czu.cz