Int. Agrophys., 2011, 25, 201-204

INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Note

Influence of moisture content on the angle of repose of nitrogen fertilizers

J.J. Turan[1], P.J. Findura[2], I.G. Djalović[3], A.D. Sedlar[1], R.M. Bugarin[1], and T.V. Janić[1]*

[1]Department of Agricultural Engineering, University of Novi Sad, Dositeja Obradovića 8, Novi Sad, Serbia
[2]Department of Machines and Production Systems, Slovak University of Agriculture, A. Hlinku 2, Nitra, Slovakia
[3]Institute of Field and Vegetable Crops, M. Gorkogo 30, Novi Sad, Serbia

Received May 18, 2010; accepted October 11, 2010

A b s t r a c t. This paper presents laboratory investigations of grain size distribution, content change, as well as the change of static and dynamic angle of repose of mineral fertilizers Carbamide ($CO(NH_2)_2$), calcareous ammonium nitrate (NH_4NO_3 + $CaCO_3$, 60:40), and ammonium nitrate (NH_4NO_3) depending on the hygroscopic influence of environment *ie* on the increased moisture of the fertilizers. Using charts, the functional dependence and the statistical data were analyzed. The conclusions are satisfactory, suggesting ways to overcome the discussed problem, and motivate further investigations in this field.

K e y w o r d s: nitrogen fertilizers, moisture, angle of repose

INTRODUCTION

Mineral fertilizers are used in solid or liquid state of matter. Due to that, handling and distribution of mineral fertilizers demands various technologies and machines (Turan and Findura, 2009). The feature of mineral fertilizer to absorb moisture from surrounding air due to their hygroscopic nature is very often a problem during application and handling of mineral fertilizer.

Storage and packaging technology (in bulk or in sacks) influence dissipation just as certain physical traits of fertilizer do. Many physical properties of granular fertilizers are measured by industry, including particle size distribution (Królczyk and Tukiendorf, 2008; Paré *et al*., 2009; Vozárová, 2005), fertilizer dissolution (Hofstee and Huisman, 1990), bulk density (Kara and Hofster, 2000; Medvedev and Lyndina, 2004) and field spreading homogeneity (Hoffmeister, 1979). In addition, granules must have sufficient mechanical strength to withstand normal handling and storage without significant fracturaing and creation of excessive dust (Paré *et al*., 2009). High crushing strenght and abrasion resistance are required to prevent formation of fine particles and caking problems (Hofstee and Huisman, 1990). Density properties are used to calculate the volume necessary to store, transport, handle (Turan and Findura, 2009) and calibrate fertilizer field applicators. Water sorption affects nutrient dissolution rate (Allaire and Parent, 2004) and granule crusting *ie* packaging requirements. One of important physical traits of solid mineral fertilizers is moisture (Banaj *et al*., 2009; Helong *et al*., 2009; Nozdrovicky *et al*., 2009; Zinkevičius, 2008). Kara and Hofstee (2000) found that orifice diameter orifice shape, particle diameter, powder type, environmental relative humidity, but not environmental temperature, affected the flowability of fertilizers through orifices. In this paper a function of moisture change with time in mineral fertilizers is given and the influence of fertilizer moisture on flowing behaviour and on the static and dynamic angle of repose is discussed. Environment humidity has a significant impact on the quality of fertilizer application has environment humidity, which motivated Hong *et al*. (2006), to investigate the influence of moisture absorption on the quality of operation of pneumatic fertilizer spreaders.

The goal of this paper is to define the upper boundary for fertilizer moisture which still prevents caking of fertilizer *ie* the free-flowing property of material.

MATERIAL AND METHOD

The investigation of nitrogen mineral fertilizers, Carbamide ($CO(NH_2)_2$), calcerous ammonium nitrate – CAN (NH_4NO_3 + $CaCO_3$, 60:40), and ammonium nitrate – AN (NH_4NO_3) was conducted in laboratory conditions. The following equipment was used in laboratory conditions: electronic scale with 0.01 g precision, sieves (Standard prEN 13739-1.2), electric dryer, psychrometer, apparatus for measurement of static and dynamic friction angle (Mohsenin, 1980).

*Corresponding author's e-mail: jturan@polj.uns.ac.rs

The grain size distribution of the fertilizers (Standard prEN 13739-1.2) was determined based on screening on sieves of round cross-section (1, 2, 3, 4 and 5 mm). The mass of the particular fractions were determined on laboratory scales. Each sample weighed 1 000 g, and five samples were prepared for each fertilizer type.

Static and dynamic angle of repose were measured for each of the tested fertilizers in ten replications at a defined fertilizer moisture. Moisture of the tested fertilizers was measured in a dryer for each of the 10 samples which contributed to the statistical validity of data. The fertilizer were exposed to humid environment (relative air humidity was φ=0.55). The results were processed using standard statistical methods (Mead *et al*., 1996) and showed in diagrams.

At the beginning of measurements, the initial fertilizer moisture was measured, and subsequently checked after every 24 h of exposure to the environment (humid air, while fertilizer parameters were measured again with an appropriate number of replications).

The results of the measurements were used to plot diagrams of relationship between fertilizer moisture content and the time of exposure to humid environment, as well as the diagrams of relationship between static and dynamic angle of repose for various moistures of mineral fertilizer.

RESULTS AND DISCUSSION

Applying standard statistical methods the data were processed and shown in Table 1. The values shown represent mean values, while for some fractions, standard deviations are given in parentheses.

The grain size distribution of the analyzed fertilizers complies with the basic norm for percentage grain size distribution of mineral fertilizers. Fractions of 2-3 mm are predominant with 50 to 83% of content. The under 1 mm fraction share is below 1%, while large particles with 5 mm diameter make up less than 1%. Only in the case of ammonium nitrate the sum of small (below 1mm) and large fractions (above 5 mm) reaches a value above 1%. The largest standard deviation was recorded for Carbamide fertilizer, ranging up to 13.83 in the case of 2-3 mm fraction share.

The function of hygroscopic moisturizing of fertilizer over time of exposure to external influences (Fig. 1) is expressed as a second degree polynomial, where the regression coefficients range from 0.9974 to 0.9953.

One of the important segments of mineral fertilizer properties are the static and dynamic angle of repose. The angles of repose were determined using equipment which is dedicated to such tests (Mohsenin, 1980). Static angle of repose defines the difference between the pouring and flowing materials and defines the visual property of a pile during pouring on a flat surface. Knowledge of the dynamic angle of repose is important for defining caking *ie* for avoiding conditions of uneven dosing of mineral fertilizer in application, which causes uneven soil nourishment on the surface (Rahnavard *et al.*, 2009).

Analyzing Fig. 2 one concludes that an increase in the moisture content of fertilizer, also causes an increase of static angle of repose. This increase of static angle of repose is most prominent in Carbamide fertilizers, although Carbamide and AN fertilizers reach moisture equilibrium at approximately 0.3% d.b. Another characteristic of CAN fertilizer is a larger static angle of repose (0.57 rad) at the initial value of moisture. CAN fertilizer absorbs moisture up to 1.27% (d.b.) where the static angle of repose increases to (0.66 rad). Regression coefficients which define the quality of function approximation equal 0.9882, 0.8209, and 0.6803 for Carbamide, AN, and CAN respectively. These high values are logical, because moisture absorption stops once the point of material saturation is reached (at the tangential point of function), which is best described by logarithmic function.

As opposed to the static angle of repose, the dynamic angle is inherently smaller. This also proved true in this investigation. For Carbamide, the dynamic angle of repose was smaller than the static one by (0.03 rad), while for CAN and AN fertilizers the difference was (0.05 rad). The function used to approximate the change of dynamic angle of repose with moisture content was logarithmic, as in the case of the static angle of repose (Fig. 3), with a relatively high regression coefficient for Carbamide (0.9808), while in the case of CAN and AN the regression coefficients were (0.682) and (0.7307), respectively.

Table 1. Grain size distribution of the fertilizers

Fertilizer	Diameter (mm)					
	<1	1-2	2-3	3-4	4-5	5<
Carbamide	0.47 (0.49)	26.34 (9.50)	61.25 (13.83)	10.71 (4.93)	1.10 (2.35)	0.13 (0.34)
Calcerous ammonium nitrate	0.92 (0.29)	17.57 (4.50)	49.97 (4.28)	28.01 (5.20)	2.67 (2.63)	0.86 (0.77)
Ammonium nitrate	0.35 (0.67)	2.73 (1.72)	83.14 (9.66)	12.90 (8.10)	0.47 (1.59)	0.41 (1.60)

Standard deviation values in parentheses.

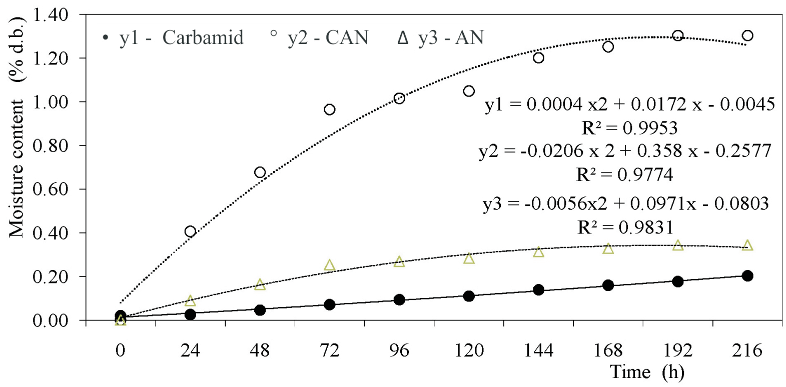

Fig. 1. Change of moisture content with time.

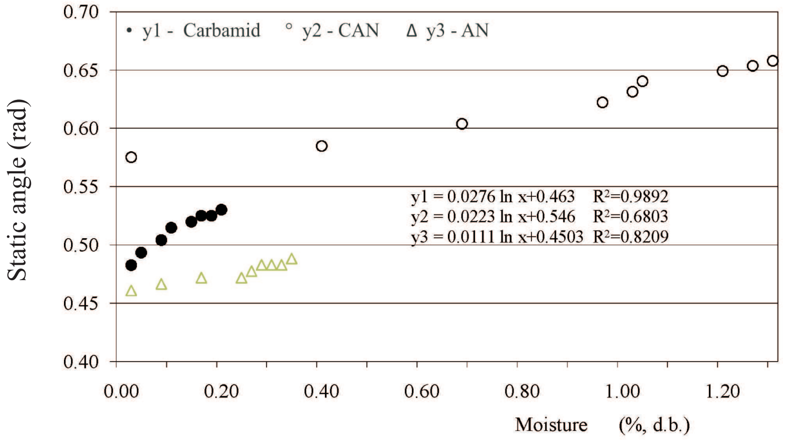

Fig. 2. Static angle of repose depending on humidity.

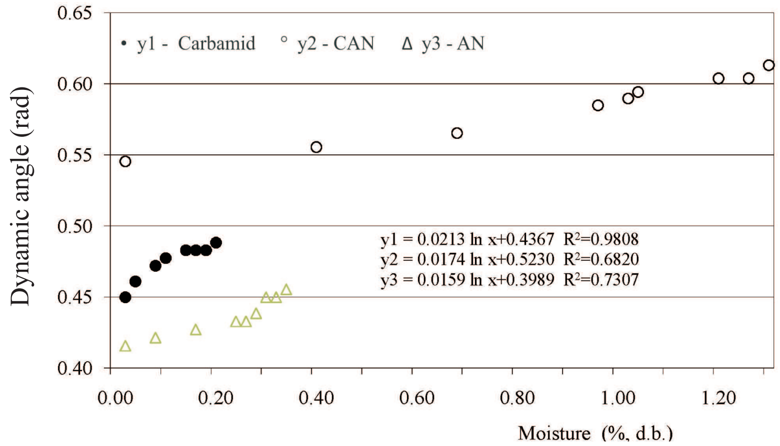

Fig. 3. Dynamic angle of repose depending on humidity.

Analysis of differences in regression coefficients for static and dynamic angle of repose leads to the conclusion that the somewhat higher share of the 3-4 mm fraction results in a higher angle of repose which is specially emphasized for CAN fertilizers.

CONCLUSIONS

1. Grain size distribution of the tested fertilizers conforms to standard prEN 13739-2. Fractions of the size of 1 to 5 mm are dominating with 98.22% in CAN, and 99.4% in Carbamide, and 99.24% in AN fertilizer.

2. As a physical property moisture content in fertilizers represents an important property which impacts the behaviour of mineral fertilizers during an even dripping into the doser of fertilizer spreader, thus influencing precision of fertilization norm and proper spreading across the treated area.

3. Moisture equilibrium is established at 0.20, 0.32, and 1.30% for Carbamide, AN, and CAN fertilizers, respectively.

4. Angles of repose, static and dynamic, are functionally dependent on moisture of mineral fertilizer and follow logarithmic behaviour, which was confirmed by this investigation with high probability (0.68) for CAN fertilizer. For Carbamide, this probability is (0.98) for both static and dynamic angle of repose. For AN fertilizers, these values for static and dynamic angle of repose equal (0.82) and (0.73), respectively.

5. In comparison with Carbamide and AN, the values of static and dynamic angle of repose for CAN fertilizer are higher by for more than (0.1 rad) which must be taken into account during handling of this fertilizer.

6. Based on the results of this analysis it can be concluded that Carbamide and AN fertilizers showed the highest resistance to changes of physical properties due to external influences, while CAN proved to be the least resistant of the three regarding the changes caused by exposure to humid environment.

7. Physical properties are not critical for the selection of mineral fertilizer for soil nourishment,considering the crucial importance of chemical properties and price of fertilizer reduced to unit mass of active nitrogen. However, knowing physical properties allows easier handling and greater precision in application, which is specially important for environment protection.

REFERENCES

Allaire S.E. and Parent L.E., 2004. Physical properties of granular organic-based fertilisers: Dynamic properties related to water. Biosys. Eng., 87, 225-236.

Banaj D., Kovačević V., and Tadić V., 2009. Bogballe spreader testing using Croatia produced fertilizers. Proc. Meet. Technology and Management to Increase the Efficiency in Sustainable Agricultural Systems, September 1-4, Rosario, Argentina.

Helong Yu, Guifen Chen, and Dayou Liu, 2009. Research and application of precision fertilization on maize. Proc. Conf. Computer and Computing Technologies in Agriculture, October 18-20, Beijing, China.

Hoffmeister G., 1979. Physical Properties of Fertilizers and Methods for Measuring them. Kluwer Academic Press, Dordrecht, The Netherlands.

Hofstee J.W. and Huisman W., 1990. Handling and spreading of fertilizers. Physical properties of fertilizer in relation to particle motion. J. Agric. Eng. Res., 47, 213-234.

Hong J.H., Kim Y.J., Chung J.H., and Rhee J.Y., 2006. Moisture absorption of granular fertilizer and its distribution characteristic by a pneumatic applicator. Proc. Meet. ASABE, July 9-12, Portland, OR, USA.

Kara M. and Hofstee J.W., 2000. Factors affecting the flowability of fertilizers throught orifices. Int. Agrophysics, 14, 67-72.

Królczyk J. and Tukiendorf M., 2008. Research on the impact of mass fractions of multi-element granular structure on the mixing process. Int. Agrophysics, 22, 45-52.

Mead R., Curnow R.N., and Hasted A.M., 1996. Statistical Methods in Agriculturae and Experimental Biology. Chapman Hall Press, London, UK.

Medvedev V.V. and Lyndina T.E., 2004. Mathematical planning in experiments on 'soil-fertilizer-yield' interactions. Int. Agrophysics, 18, 31-38.

Mohsenin N.N., 1980. Physical Properties of Plant and Animal Materials. Gordon and Breach Press, New York-London-Paris.

Nozdrovický L., Macák M., and Findura P., 2009. Influence of granulometric composition of mineral fertilizers on traversal distribution of application. Proc. Int. Sci. Conf. New Trends in Design and Utilisation of Machines in Agriculture, Landscape Maintenance and Environment Protection, May 5-7, Prague, Czech.

Paré C.M., Allaire S.E., Khiari L., and Nduwamungu C., 2009. Physical properties of organo-mineral fertilizers. Can. Bios. Eng., 51, 321-327.

Rahnavard A., Ashrafi Z.Y.H., Alizade M., and Sadeghi S., 2009. Studies on the effect of fertilizer application and crop rotation on the weed infested fields in Iran. J. Agric. Technol., 5 (1), 41-50.

Turan J. and Findura P., 2009. Mineral fertilizer distribution overlap. Contemporary Agric. Eng., 35(1-2), 9-15.

Vozárová V., 2005. Thermophysical properties of granular food materials. Int. Agrophysics, 19, 187-192.

Zinkevičius R., 2008. Influence of soil sampling for precision fertilizing. Agron. Res., 6, 423-429.