Johannes Marquering, Hasbergen, and Heinz Dieter Kutzbach, Hohenheim

Distribution quality of centrifugal broadcasters

Techniques for the evaluation of the spreading of heterogeneous bulk blend fertilizers

When heterogeneous bulk blend fertilizers are spread using centrifugal broadcasters, segregation on the spreading vane and during the flight phase may occur. CV surfaces allow the alteration of lateral distribution for different spread patterns to be evaluated while physical properties change. For the assessment of segregation during the flight phase, throwing width distribution is calculated from the measured physical properties. These characteristic throwing width distributions enable the mixability limits of fertilizer components to be determined.

Dr. sc. agr. Dipl.-Ing. Johannes Marquering is the director of electronics development at the company Amazonen-Werke in Hasbergen, Postfach 51, 49202 Hasbergen-Gaste; e-mail: *jmarquering@amazone.de*.
He earned his doctorate as an external doctoral student under the supervision of Professor Kutzbach at the Institute of Agricultural Engineering of Hohenheim University.

Keywords

Centrifugal broadcaster, bulk blend fertiliser, spread patterns, CV-surface, segregation

For the spreading of mineral fertilizer, centrifugal broadcasters are used almost exclusively today. Modern machines allow single-component fertilizers and homogeneous multi-nutrient fertilizers to be spread with even lateral distribution at working widths of up to 48 m [1].

In the future, mineral fertilizing will be characterized even more than before by the goal of spreading the nutrients at low cost and such that they specifically meet the requirements of the plants. In addition, an increase in efficiency is being striven for by spreading different nutrients simultaneously in one operation. Bulk blend fertilizers produced from single components therefore provide a nutrient composition adapted to the plant- and soil conditions.

When bulk blend fertilizers are spread using centrifugal broadcasters, different physical properties cause the danger of the fertilizer components being segregated during acceleration within the machine and during the flight phase, provided that the broadcaster was filled properly [2]. Segregation processes during acceleration within the machine have hardly been examined so far. For the characterization of possible segregation during the flight phase, the grain size spectrum has generally been employed as an assessment criterion thus far [3].

Theoretical Considerations about Segregation

The lateral distribution of a fertilizer spreader is mainly influenced by flight behaviour and the prevailing conditions while the grains leave the spreading vanes [4]. The throwing angle [5] allows the friction conditions between the fertilizer and the spreading vane to be determined and, hence, the prevailing conditions while the grains leave the spreading vane. In bulk blend fertilizers, the alteration in the friction behaviour of the mixed components due to different friction coefficients must be examined in addition to possible segregation. For the calculation of the common throwing angle of a mixture, both concentration and a correction factor must be considered (eq. 1). This correction factor integrates true density and the grain size of the components into the calculation (eq. 2).

$$\alpha_{AM}(\kappa) = \kappa\,(\alpha_{A2} - \alpha_{A1}) + \alpha_{A1} + k(\kappa) \qquad (1)$$

Gleichung 2 einsetzen (2)

with κ = correction factor
α_{AM} = mean throwing angle
α_{Ai} = throwing angle of the compo nent i
κ = concentration
ρ_{Ri} = true density of the component i
d_i = grain diameter of the component i

After the fertilizer has left the spreading vane, it is impossible to influence the trajectory. Flight behaviour is mainly influenced by the throwing parameters (speed and direction), the kinetic energy stored in the grain, and the physical properties (grain size, c_W-value, density).

The flight behaviour of fertilizer grains can be described through differential equations. They allow the throwing width to be calculated (eq. 3 and eq. 4).

Gleichung 3 einsetzen (3)

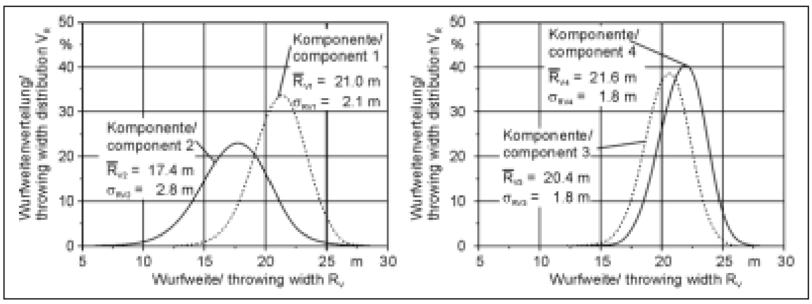

Fig. 1: Distribution of throwing widths

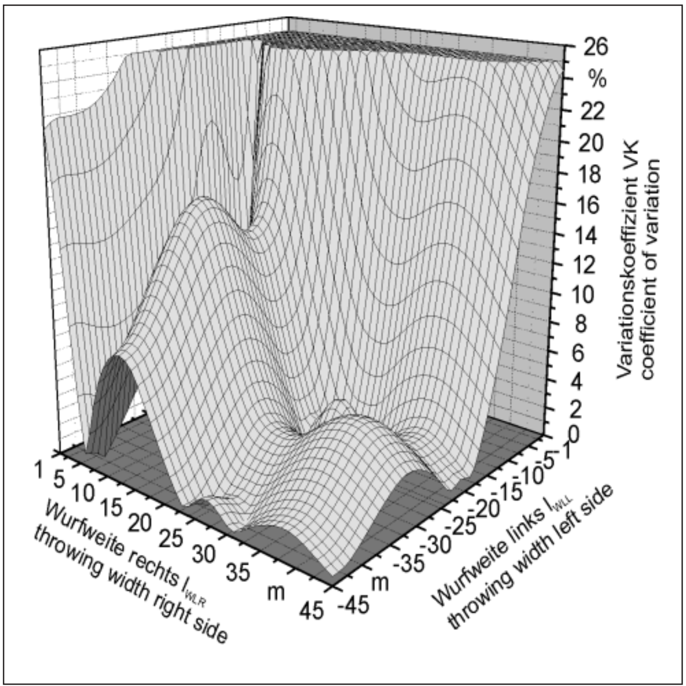

Fig. 2: CV-surface of triangular spread pattern

Gleichung 4 einsetzen (4)

with R = throwing width
z = throwing height
g = gravitational acceleration
c_W = air resistance coefficient
m = grain mass
ρ_L = air density
A_{Korn} = surface exposed to air flow

Based on physical properties determined in laboratory experiments, throwing width distribution can be calculated for potential components (*fig. 1*).

Sensitivity of Fertilizer Spreaders

Depending on the design characteristics of the fertilizer spreaders, different spread pattern types can be generated, which react in a more or less sensitive manner to alterations in the physical properties of the fertilizer.

In two-disc centrifugal broadcasters, these spread pattern types include [5]: triangular, trapezoid, as well as sinusoid and trapezoid spread patterns with sinus flanks.

Both the triangular and the sinusoid spread patterns are typical of centrifugal broadcasters at smaller working widths and fertilizers with good flight characteristics.

Trapezoid spread patterns, however, are predominant in boom spreaders. At large working widths and if fertilizer with poor flight characteristics is used (small, light grains), the spread patterns of centrifugal broadcasters become more and more similar to this spread pattern type.

In order to be able to evaluate the influence of alterations in the physical properties on lateral distribution, mathematical descriptions have been developed for the different spread pattern types.

Experimental studies showed that at identical machine settings different physical properties mainly lead to an alteration in the throwing widths.

For different left and right throwing widths (l_{WRR} and l_{WRL}) of the total spread pattern, the coefficient of variation was calculated with the aid of the mathematical descriptions so that a CV surface was obtained (*fig. 2*). It shows the quality of lateral distribution for the possible throwing width combinations of a spread pattern.

As in the case of the variation coefficient curve [6], the sensitivity of a spread pattern to alterations in physical properties can be estimated using CV surfaces [5]. If the CV-value changes only slightly at different throwing widths (l_{WRR} and l_{WRL}), the spread patterns are robust. The more sensitive a spread pattern is, the more difficult it becomes to spread bulk blend fertilizers consisting of components having different physical properties with good lateral distribution.

Realization of the Experiments and Results

In spreading experiments with bulk blend fertilizer, lateral nutrient distribution at different working widths was examined. This required the fertilizer quantities collected in the test bed to be chemically analyzed. Bulk blend fertilizers, whose components featured identical throwing width distribution with regard to the mean value and standard deviation, were able to be distributed at working widths of up to 36 m with even nutrient composition over the entire working width (*fig. 3*). At different throwing width distributions of the components, segregation occurred during the flight phase.

The results can be summarized as follows: The larger the differences in throwing width distribution, the smaller the working widths achievable without segregation.

Outlook

In the future, the development efforts of the manufacturers of centrifugal broadcasters must focus on a machine which reacts in a robust manner to alterations in the physical properties of mineral fertilizer.

When choosing the components, the operators of fertilizer mixers must give increased attention to the flight properties of the components used. Only if throwing width distribution is approximately identical does even nutrient distribution result when bulk blend fertilizers are spread over large working widths using centrifugal broadcasters.

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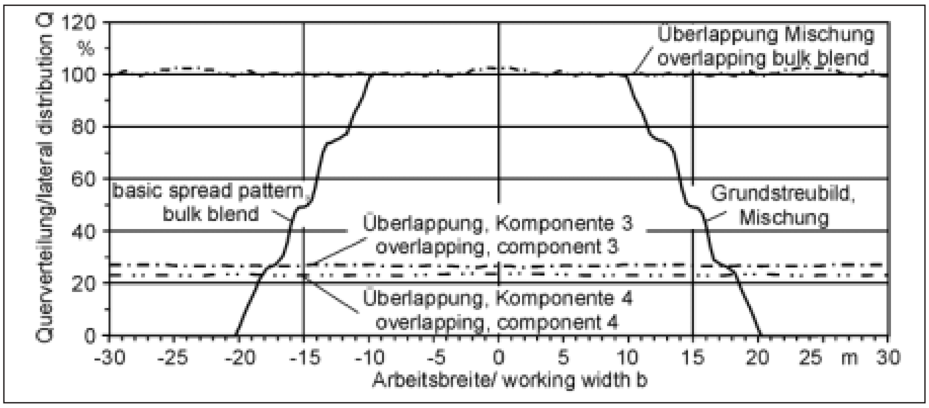

Fig. 3: Spread pattern for a working width of 30 m , even nutrient distribution