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FUTURE DEVELOPMENT OF FERTILIZATION[1]

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RESUME

Les exigences de précision dans les propriétés d'épandage seront de plus en plus marquées dans l'avenir. Pour des raisons d'économie et d'environnement, le concept futur de la fertilisation demandera une efficacité accrue des nutriments.

Pour atteindre cet objectif, une nouvelle technologie de la fertilisation sera nécessaire. La communication traitera de :

- *Impact des propriétés physiques des engrais sur l'épandage*
- *Un nouveau concept de fabrication d'engrais NPK avec des équilibres N:P:K choisis*
- *Modes de culture spécifiques au site avec emploi du positionnement et de la localisation des engrais conduite par ordinateur.*

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I. INTRODUCTION

The agricultural policy in Europe has taken a drastic change during the 1990's. The EU agricultural policy is now much more market-oriented and it is adjusting to world market prices. At the same time, the developments in agricultural policy has increasingly led to a stronger link with environmental policy.

For European agriculture this development implies a continuing demand for a better overall effectiveness of agriculture itself, and hence a modification of the structure of agriculture. This, however, is not sufficient on its own.

Agriculture in the 1990's is characterized by the consumers' demand for high-quality agricultural products, with due regard to the correct use of various materials, and particularly man-made chemicals, which include fertilisers.

Whereas quality has previously been determined by the processing industry in the form of measurable properties like protein content, bread volume, size and uniformity of grains, the focus in future will be put on less well-defined issues, e.g. the environment including utilization of fertilizers and natural water resources.

This development increases the demand for an accurate distribution of nutrients in the field. Previously, this only related to economy; however this is no longer sufficient.

Today's goal is to make the use of fertilizers more effective, and to get a higher utilization of nutrients and thereby indirectly to the benefit of the environment.

1.1 Precision calls for quality

In order to obtain an accurate spreading, it is necessary to use only the best fertilizer spreaders capable of distributing the fertilizer evenly and precisely. Moreover, it is absolutely necessary that the physical properties of spreading are satisfactory in order to obtain the right dosage rate from the spreader all the time and an even distribution of fertilizers over the total working width of the spreader.

In other words, striping in fields due to uneven spreading must not occur when using site specific farming.

2. SPREADABILITY

In Europe there is a clear tendency towards steering the consumption of fertilizers so that plants get exactly what they need and when they need it.

[1] The right NPK ratio; physical properties for even distribution; site specific farming/computer controlled fertilizer application.

Each year prognoses for nitrogen requirements are systematically made in some European countries and the results are added to each farmers fertilizer plan (this is mandatory in Denmark, Finland, and Germany). The N-prognosis recommends a plus/minus adjustment in 5 kg N steps, usually between - 20 to + 20 kg N/ha.

In future planning of fertilizer requirements, it therefore will be very difficult to accept a C.V. for each single nutrient of more than 15% in the field, when taking into account environmental considerations.

When considering spreadability in the context of the use of farmyard manure, then uneven distribution has been a major factor. Trials with new types of spreaders with sliding tubes show that today it is possible to distribute farmyard manure (slurry) with a C.V. of 5-6% - the same level as the best distribution of commercial fertilizers.

Accurate spreading of fertilizers depends on the type of spreader, the setting up of the spreader and the fertilizer used. Trials made by DLG, Germany, clearly show how different kinds of fertilizers influence the settings used on the spreader.

Considerable differences in the spreading abilities of different fertilizer types can be seen even in modern 2-disk spreaders.

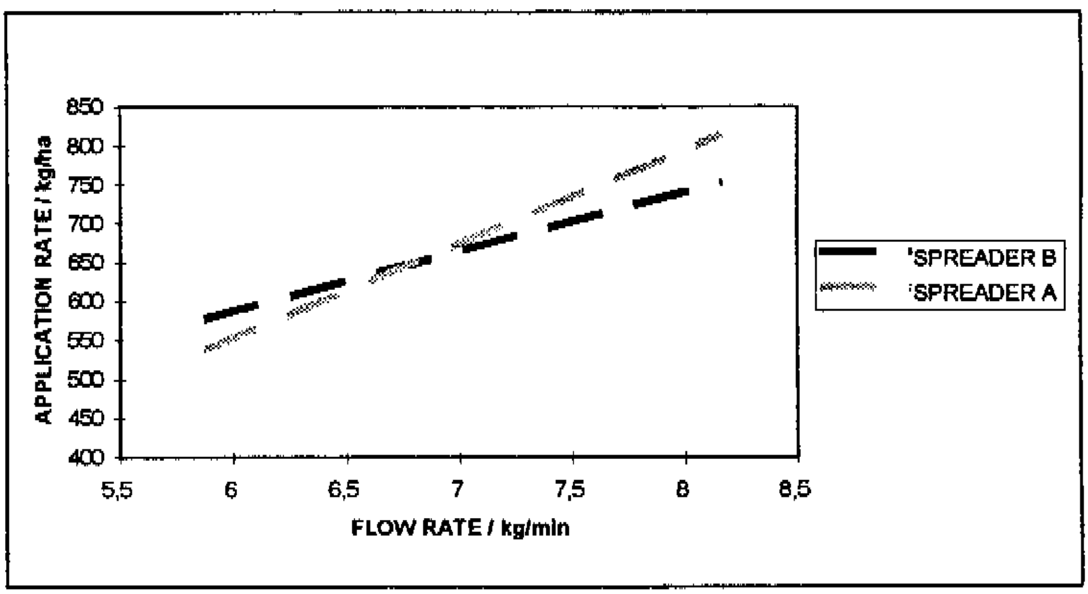
2.1. Physical properties and spreading

Modern spreaders with a high capacity and a large bout width use large quantities of fertilizers. Well-known parameters such as size distribution, mass median diameter (d50), bulk density, particle strength, shatter resistance and flow rate are important.

Predicting the results of spreading based on physical properties of fertilizer is difficult. The most commonly used parameters are d50, flow rate, and particle size range. The latter value can either be determined from a sieve analysis or by some optical imaging technique.

When making a spreading trial, two figures are reported: density and coefficient of variation (C.V.) Density through the spreader in gravimetric feeding systems equates well with the flow rate (Figure A). C.V. is more related to the spreader itself, but in some cases breaking or abrasion of granules explain the variations in C.V. between different fertilizers.

Figure A - Application rate through a spreader versus the analyzed flow rate - target rate 700 kg/ha



In modern high speed centrifugal spreaders with a gravimetric feed system, the spreading operation can be divided into two functions in high speed centrifugal spreaders with a gravimetric feeding system: One is the flow of the granules on to the spinning disc, and the other is how granules are thrown out from the spinning disc. The behaviour of the granules in the former case can be described by measuring the flow rate, and in the latter case by measuring the shatter resistance. These two parameters are discussed below.

2.2 Flow rate

Flow rate is measured by letting the fertilizer flow freely from a vessel (a funnel or a straight-walled vessel). The time taken for a fertilizer to flow through the vessel is measured. The value is expressed in kilograms per minute. In some cases it may be convenient to divide the figure by bulk density, and to express the figure as cubic meters per minute.

Flow rate is truly an empirical figure. It is affected by the bulk density, granule size distribution and internal friction between the granules. There are other means of measuring flow rate, for example by using the shearing box method which measures the internal friction of the granules. However, this method is time consuming and requires special equipment as well as skilled personnel.

2.3 Shatter Resistance

Increasing the bout width of centrifugal spreaders means increasing the angular velocity of the spinning disc. The impact on the fertilizer by the vane on the disc increases as well. This will make high demands for the dynamic strength of the fertilizer granules. If the granules break into smaller pieces when leaving the spinning disc, the spreading result can be unpredictable. Part of the granules may turn out to be dust, which is a nuisance for the farmers, and a potential risk for the environment. Broken particles have different trajectories than whole particles. When the size distribution is changed, the whole result is changed.

Routine analysis of fertilizer quite often included particle strength, thus giving useful information about the product. However, shatter resistance is either not analysed at all or it is analysed only for special purposes. This is quite natural, since commercial equipment is available for measuring the particle strength, but the equipment for measuring shatter resistance is in-house built equipment, which often has been built so that it would emulate the conditions during pneumatic transport or on a spinning disc. The value for shatter resistance is often mostly an empirical one, and it is not as clear as the value for crushing strength.

2.4 Kemira Agro's Product Types according to their Spreading Properties

A fertilizer producer cannot guarantee that the physical properties of a certain grade are the same in all future due to development in technology. Changes in raw materials and processes may differ, which cause fluctuations. Same grades produced by different plants may have totally different physical properties.

To give some indication of the spreading properties of a fertilizer, Kemira has developed a system for classifying its own products. The classifications are based on mass median diameter (d50), particle size range variation coefficient and flow rate. As a result, six different fertilizers types are defined. Fertilizers of the same type will require approximately similar spreader settings.

Typical characteristics of the product types:

	Flow rate	Size range	Mass median diameter
Type I	low	small	small
Type II	medium	wide or medium	small
Type III	medium or high	tight or wide	small and medium
Type IV	medium or high	tight or wide	big
Type V	fast	medium or tight	small and medium
Type VI	fast	medium or tight	big

3. THE NPK RATIO

3.1 Bulk Blends in Europe

The advantage of bulk blends, compared with complex fertilizers, is the flexibility. One of the disadvantage of bulk blends, however, is the uncertainty of whether the actual content concurs with the declaration.

The main problem in traditional bulk blends is segregation. At the time of application, segregation will have occurred either in the hopper or when the blend flows out of the hopper of a fertilizer spreader. Different sized and shaped particles travel at different speeds and land at varying distances from the point of distribution.

In Europe several tests of the quality of bulk blended fertilizers have been made at farm level. The results of these tests demonstrated large segregations of each of the components both across and in the length of the driving direction

The overall conclusion from a test made by The Danish National Advisory Service in 1994 was: when using bulk blends, it is recommended that consumers chose the raw materials very critically and that the farmer handles the blended fertilizer correctly in order to avoid segregation. The more times the fertilizer is reloaded, the bigger the spreading width, the longer the time of transportation in the field, the bigger the segregation will be.

3.2 Strong demand for good physical properties of fertilizers

In order to avoid segregation in bulk blends from the time of production until the application in the field, strict requirements with respect to physical properties are very necessary: primarily particle size (d50 = median particle diameter), distribution (Va = size range variation coefficient), particle strength, flowability and density.

In order to achieve good and reliable spreading properties similar to those of complex fertilizers, the requirements of physical properties for the single components in bulk blended fertilizers usually increase.

This is so due to the risk of segregation of nutrients in bulk blends when storing, handling and spreading. Segregation is always unfortunate when spreading. However, the problem deteriorates if distribution of nutrients is uneven as well.

3.3 High quality granular mixes

Kemira has developed a new approach - *Kemistar®* - to create high grade mixes securing accurate spreadability even after handling and storage.

With a high quality granular mix, complex NPK's are replaced by products made by blending of a limited number of standardized components.

3.4 Formulation flexibility

It is obvious that the highest degree of flexibility in the product formulation is achieved with components containing only one plant nutrient in the highest possible concentration.

However products obtained by mixing such components very often suffer from bad quality mainly due to different particle size, shape and also inter-particle chemical and physical reactions.

A high quality granular mix is made by mixing a limited number of standard components with similar physical properties. The components, called building blocks, always consist of minimum 2 nutrients either primary or secondary nutrients and always nitrogen.

The main building blocks all contain nitrogen and another nutrient i.e. NMg, NP, NK, NS and NPK.

As an example, nutrient ratios in the main building blocks are:

NPK	: low N, low P, high K
NK ($^{+}$Cl)	: low N, high K
NK ($^{-}$Cl)	: low N, high K
NS	: low N, high S
Nmg	: low N, low Mg
NP	: low N, high P

These components fulfill the required formulation flexibility for nearly all the needs in agriculture.

In the Kemistar concept - as this system is known within Kemira - it is also possible to add other micro nutrients as B, Mo and Co.

3.5 Formulations

With the above mentioned formulations, it is possible to cover almost all needs for NPKs - also extreme grades that are difficult to produce as complex NPKs.

Only NPK fertilizers containing less than 6% N cannot be produced, and likewise fertilizers with very special declarations.

3.5.1 *Uniformity*

It is very important that each component used in a high quality granular mix remains uniform, and well matched to the other components.

The most important parameter when specifying building blocks is that the combination of size and density is such that no segregation occurs, and thus the correct proportion of nutrients is maintained throughout handling, storage, transportation and spreading.

Different markets e.g. have different size distributions. For instance, the size distribution (d50) in the UK is normally lower than in Continental Europe.

3.5.2 *Particle size distribution*

A change in particle size, no matter what type of fertilizer, causes a change in spreading properties, requiring adjustment of the spreader with regard to dosage/ha to ensure an even spreading.

A big difference in particle size of mixed products presents a major risk for segregation during handling and storage. To minimize segregation it is vital that particle size distribution is relatively homogenous and have well matching d50's, more than 95% between 2-4 mm.

3.5.3 *Flow rate*

Flow rate is a measure of smoothness and roundness of fertilizers and also of the surface structure of fertilizers. The flow rate depends on the type of fertilizer and also to a large extent, on the method of production and coating.

A high quality mixed granular product has well matched flow rates.

3.5.4 *Safety*

In many bulk markets in Europe, only C-Class AN fertilizers and unclassified fertilizers are sold. For NK and NPK fertilizers, self-sustaining decomposition is often the critical safety issue. Producers are requested to examine the thermal stability of these fertilizers by testing them in accordance with a standard trough heating in a given period of time.

In many European countries, there is a tendency towards using so-called «V type» NPKs: high nitrogen low phosphorus and high potassium. These products are often products exhibiting self-sustaining decomposition (B Class).

The Kemistar concept offers several sophisticated possibilities to produce NPK types as C-Class fertilizers which might otherwise be B-Class.

This can be done inter alia by introducing components such as dolomite, ammonium sulphate instead of ammonium nitrate and by changing the water solubility of phosphate.

In practice, several B-Class fertilizers can therefore be changed into a C-Class.

Requirements for the physical properties of Kemistar®

Examples on specification on high quality components for mixing:

Chemical content:	according EC tolerances.
Sieve analysis:	D 50 3.35 mm (min. 3.2 max. 3.5 mm)
Size distribution:	>4,75 mm < 0,2 % max. 2% 4,00-4,75 mm < 0,5 % max. 4% < 2,00 mm< 1,0 % max. 2% D 50 3,35 mm min 3,2 mm max. 3,5 mm
Flowability:	Approximately same surface conditions.
Hardness (N):	> 60 min 50
Post reactions:	None
Dust mg/kg:	< 200 max. 500
Caking:	free flowing
Self sustaining decomposition (cm/h):	0
Hardness (N) after 30 thermal cycles:	min 30
pH:	6 min 5
Dust Formation:	max. 750 mg/kg

Tests have demonstrated that high quality granular mixes can be transported and stored without segregation. Investigations in different spreading halls and in fields have also demonstrated that there are no significant variations in the nutrient content from start of the spreader to the end. In addition, there is no segregation of nutrients in the spreading width.

4. SITE SPECIFIC FARMING

It is a fact that fields differ in soil type and content of nutrient. This means that the yield in many fields vary a great deal from one area to another. Therefore, the amount of nutrients absorbed by crops in different areas differs too. With even fertilization, there are areas where excessive fertilization results in loss of nutrients, and other areas where deficiency means a smaller and consequently poorer economy for the farmer due to lack of nutrients.

For many years, both tests and experience has led to the development of models to calculate which types and amounts of nutrients are necessary to apply in different situations.

In many cases, the type of soil, even within a given field, varies so much that applying the same amount of, say, nitrogen, to the whole field would be an obvious mistake. Maybe there is a hollow with a very high content of humus or maybe two or more fields with different nutrient contents have been made into one.

We now have available the technical possibilities to automatically provide for such special conditions within the individual fields.

In 1996 site specific farming is used by several farms. The system adjusts automatically the dosage of fertilizer according to the specific needs - the condition of site specific farming of course being that the position of the machines in the field is always known. **We call this system «graduated cultivation».**

4.1 Overall graduated cultivation possible

In principle all kinds of activities in the field may be graduated - not just fertilizer, but also liming, weed control, fungus control, sowing, watering, soil preparation, etc. However, greatest interest is concentrated on the nitrogen.

4.2 Nitrogen and sulphur

During quite a big part of the plant growth, sulphur and nitrogen in the soil is available as water soluble sulphate and nitrate respectively, both of which can be leached from the soil. This is why a graduation of nitrogen and sulphur is so obvious.

4.3 Phosphorus, potassium and magnesium

In good fertile land, only small amounts of phosphorus, potassium and magnesium are leached. By far the bigger part of the P, K and Mg which is removed from the fields is removed with the crop. So, here it is natural to use the yield map in order to fertilize according to the substitution principle. On light types of soil it will be possible to adjust for the leaching of potassium. It is also possible to define the demand for P, K and Mg via soil tests. But the increased yield for graduating with P, K and Mg can hardly pay the price of a complete analysis.

4.4 Lime

Lime may be the most obvious factors for graduation. Liming affects the accessibility to the nutrients of the soil, e.g. manganese. By adding the same amount of lime, the field which simply gets more lime than necessary, will again lead to the risk of creating a deficiency of manganese resulting in a considerably lower yield.

Such varied application of lime will necessitate an analysis of the pH value of the soil and of the variation of the type of soil.

4.5 Gain-economic-environmental

Improvements with site specific farming may give advantages to both the farmer and the environment as the yield can be increased and the input of fertilizers, lime and pesticides can be reduced.

Trials made by the Danish National Advisory Service has shown that the gain by graduated application of nutrients and lime will total about 200-300 kr/ha (USD 40-60/ha), and add to this a gain of may be 50 kr/ha for pesticides.

4.6 Test with site specific farming increased profit

For the past 4 years Denmark has made trials with graduated fertilization.

The graduation has been based on min N-measurements before the fertilization.

Test in winter wheat in 1993 showed an increased yield of abt. 2Hkg/ha when graduating. In all 148 and 160 kg N/Ha were respectively applied for graduated and equalized fertilization. In tests in winter wheat in 1994 the graduation gave more than 2 Hkg with 112 and 120 kg N/Ha respectively for graduated and equalized fertilization.

In 1995 the test in winter wheat showed an increased yield of almost 2 Hkg/ha for a graduated application of 188 kgN/ha compared to an equalized application of 210 kg N/ha.

The test clearly proved that the increased yield obtained by graduated fertilization was biggest when the nitrogen amount was less than the optimal demand.

The results are substantiated by the Danish Ministry of Agriculture and Fisheries trials which have reached almost the same conclusions:

Method	Applied kg N/Ha	Yield Hkg/ha
Normal	160	60
Graduated	148	63

A better utilization of nutrients must necessarily lead to a reduced loss of nutrients via leaching. Trials have shown that after harvesting of a crop cultivated by graduated nitrogen fertilization there will be less nitrate in the soil than usual.

In all but one case the crop left less nitrogen in the soil after graduated fertilization.

4.7 Graduation on field level

Via GPS signals from the American Ministry of Defence, a perfect accuracy is achievable today. It is well-known technology and some car types are already equipped with GPS as a standard. These signals are the first conditions for Site specific farming and the second condition is a fertilizer card.

The fertilizer card indicates how to distribute fertilizers in the field. Kemira has financed a project at research centre FAL in Braunschweig, Germany, which has resulted in a PC programme for production of fertilizer cards.

At first, the total fertilizer requirement of the field is to be supplied to the programme KemiLORIS (Local Resource Information System). This information is available from the fertilizer plan already made. On the basis of the average fertilizer requirement and the other inputs about the field such as knowledge of yield and soil type variations, the programme works out the correction factors and multiplicates them with the average need of fertilizers.

Today, this programme is being tested in Germany, England and Denmark. Kemira is still working to improve the results of site specific farming.