„Towards new concepts in nutrient management: urban, suburban and alternative agriculture"

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At present, 50% of the world's population lives in cities and this number will increase in the future. Accordingly, the food demand in the fast growing cities will rise; soil fertility decreases and agricultural land will be lost to housing. This development will make the concept of urban agriculture more and more important within the next years. In Cuba, urban organic agriculture is practiced in the so called "organoponicos" which provide healthy food to people in the cities. This concept may be a promising example for other regions in which a sufficient food supply for urban population is urgently required.
Though the focus of the conference was on the topic of "urban farming", and here the use of recycled bedding materials for crop production and recycled fertiliser materials were key questions, fertiliser management in agricultural production was another major issue. Accordingly, the symposium was divided into the following sessions:

Session I: Organic and inorganic fertilization in urban and suburban agriculture
Session II: Fertilisation aspects in horticulture plants, vegetables and non-food crops
Session III: Fertilisation aspects in organic farming
Session IV: Nutrient cycling with waste products and agronomical sustainability of their application
Session V: Nutrient management and its implications on plant disease development and control
Session VI: Plant-beneficial micro-organisms interactions

Many of the presentations focused on the matter of phosphorus in agriculture, the urgent need of phosphorus recycling and the benefits and problems resulting of the agricultural use of manure. This underlines that the project "Baltic Manure" deals with issues which are not only of high interest for the Baltic Sea Region but also a worldwide concern.

In Session II "Fertilisation aspects in horticulture plants, vegetables and non-food crops", Ewald Schnug (President of CIEC and Head of the Institute of Crop and Soil Science JKI Germany) underlined in his keynote speech "P-recycling and sustainable agriculture - The enigma of fertiliser P utilisation", the importance of a sustainable phosphorus use to ensure closed P cycles and the protection of this finite resource. Since agriculture is the largest consumer of P worldwide it has to be one major aim of agricultural research to develop fertiliser recommendations to obtain a balanced P-application which avoids both, undesired surpluses in the soil and nutrient mining. This leads to minimal P losses on the one hand and high yields on the other hand. The key factor of those fertiliser recommendations is the long-term utilisation rate of fertiliser P. On physically, chemically and biologically intact soils it amounts to 100%, provided that the P in the fertiliser is water-soluble or, if applied to acidic soils (pH: < 5.8), citrate soluble. Granted that the P supply in the soil is sufficient and additional P application does not lead to an increase of yield, it is strongly recommended to fertilise according to the estimated P-off take by harvest products.

A specific problem organic farming has to face with view to P-fertilisation is P-mining which diminishes soil fertility and sustainability. Easily soluble P-forms are banned in organic farming, therefore phosphates with a low solubility are applied to the soil. Unfortunately, they do not enter the site-specific P-cycle to a full extend since a complete utilisation cannot be expected. One possibility to solve this problem is the use of *in situ* digestions where materials with a characteristically low P solubility (e.g. rock phosphates or meat and bone meal) are granulated with elemental sulphur. The release of sulphuric acid during the microbial sulfoxidation increases the P-solubility of the material significantly.

In his key-note speech "Towards new aspects of fertilisation in food and no-food crops" Francesco Montemurro (Agricultural Research Council, Italy) emphasised the importance of the agricultural use of manure to ensure food safety in the future. However, to guarantee a sustainable manure application it has always to be considered that manure is a very heterogeneous product and that its characteristics (e.g. elemental composition, water and nutrient content) are strongly affected by parameters such as species and age of the animal, feeding regime, collection and storage method. The influence of those factors on the characteristics of manure is one major object of investigation within the Baltic Manure-project. Besides its heterogeneity, further aspects have to be considered to ensure a safe and sustainable application of manure and to prevent undesired nutrient surpluses in the soil. Generally, manure has a high C:N ratio which is undesirable in the field of plant nutrition because after the direct application to the soil, the excess of C leads to a temporal unavailability of N. This increases the risk of N losses into the water-bodies and thus the risk of eutrophication. Additionally, the nutrient ratios of manure are usually different from those required by common crops. Hence, manure application might easily result in nutrient inputs which excess particular crop requirements and consequently lead to significant nutrient surpluses in the soil.

One promising pre-treatment technique that can positively influence the quality of manure in comparison to the untreated material is composting (see figure 1).

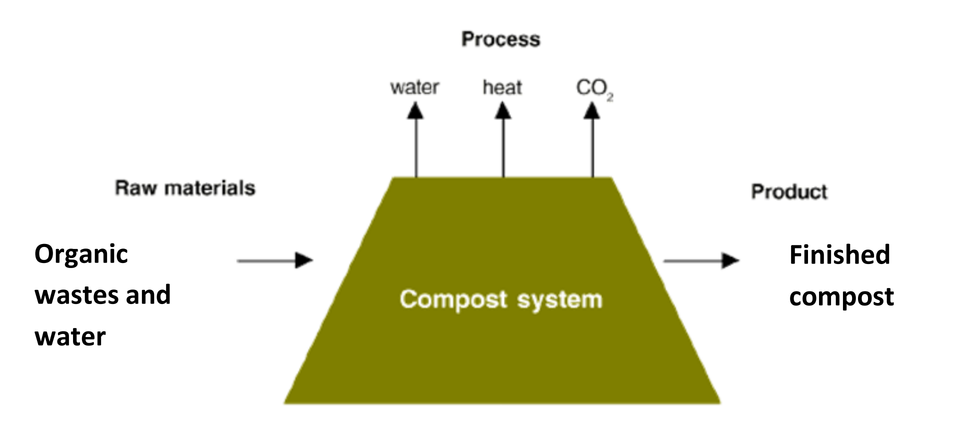

Fig. 1: The principle of composting (Montemurro, 2012)

Compost can be defined as: *"a stabilised and sanitised product of 'composting' which is the biodegradation process of a mixture of organic substrates carried out by a microbial community composed of various populations, both in aerobic conditions and solid state"* (Montemurro, 2012).

The composting process reduces the number of weed seeds, weight, moisture content and odour, as well as volume and particle size which facilitates the agricultural application. Furthermore, composting stabilises the organic matter and leads to a slower release of N which diminishes the risk of N-leaching. Thus, the composting of organic materials has many advantages: It helps to recycle urban or agro-industrial wastes (municipal solid waste, agro wastes etc.), it can act as a link between agriculture and other economic sectors and it can contribute to the concept of sustainable agriculture. The on-farm composting of manure requires just a few basics: air, water and space, feedstock (e.g. livestock or crop residues) and bulking materials to thicken the feedstock (e.g. sawdust or pruning wastes). However, no matter which product is used for fertilisation, compost or manure, it is essential choose an adequate amount of the product and an appropriate frequency of application according to a specific fertilisation plan. The fertilisation rates have to match the temporal crop nutrient demand and since the nutrient ratio usually differs from those required by common crops it can be useful to use mineral fertilisers in combination with organic fertiliser products. Furthermore it was emphasised that the site-specific variability of the particular field has to be considered to prevent undesired nutrient surpluses and/or deficiencies in the soil it was emphasized when organic or inorganic fertiliser products are applied. Algorithms for the variable-rate application of mineral multi-nutrient fertilisers have already been developed (see table 1).

Tab. 1: Algorithms for a balanced variable-rate application of a mineral PK fertiliser in a three-year crop rotation (Haneklaus & Schnug, 2006)

Year	**Type of fertilizer**	**Algorithms for**	
		K	**P**
1	PK	K_{OPT}[1]	$P_{P:Kmax}$[2]
2	PK	$K_{P:Kmin}$	$P_{OPT} = P_{tot}$[3] –
3	K	$K_{OPT} = K_{tot} – (K_{yr1} + K_{yr2})$	

note:; [1]OPT = optimum variable rate application; [2]P:K= variable rate fe according to widest/narrowest (max/min) P:K (1:X) ratio resulting in fertilizer expenditure; [3]tot = variable nutrient rates for crop rotation

One aim within work package 4 of the project "Baltic Manure" is to develop corresponding algorithms for manure and manure-derived products. The heterogeneity and thus varying parameters such as water content and nutrient concentrations complicate the development of those algorithms.

The agricultural use of residues and waste products has a long tradition and is one key factor to reach the aim sustainable agriculture. The waste products used comprise manure, slurry, biogas slurries, crop residues, food industry residues, carcass, meant and bone meals, sewage sludge, ashes and slag. It has always to be considered that the consumer protection, production of healthy food and water and soil protection are preserved when applying these products. The investigations of the fertilising effects of different waste products were subject of the presentation “Nutrient recycling with waste products in cropping systems” of Bettina Eichler-Löbermann (University Rostock, Germany). The study was done in collaboration with the Central University “Marta Abreu” Las Villas (Cuba). The main focus of the study was put on phosphorus and it investigated the fertilising effect of biomass ashes, biogas residues and sewage sludge products in pot and field experiments. Generally, the tested products showed the potential to increase the bio-available P pool in the soil and thus to promote plant growth. Some products showed even effects comparable to fully-water soluble TSP. Additionally, an influence on microflora and microbial activity was detected which can have an effect on various soil characteristics. Generally, the results varied widely, depending on the P content and form of the products, the soil type and the test crops.
The P efficiency of manure or compost can be increased by using plant growth-promoting rhizobacteria (PGRB). Bettina Eichler-Löbermann presented results of a long-term field experiment where the effect of two strains of PGPR (*Pseudomonas fluorescens* strain DR 54 and *Enterobacter radicincitans* sp. nov. strain DSM 16656) and organic fertilisation (cattle manure and biowaste compost) on P uptake, soil P pools and soil enzyme activities were investigated. Results showed that the application of organic fertilisers generally increased growth and P uptake of the test plant maize as well as the soil P pool. Responses derived from the PGPR application were less pronounced but nevertheless, effects on the soil P pool after the inoculation with *Pseudomonas flurescens* were observed. In contrast, the inoculation with *Enterobacter radicincitans* had no significant effect on the P content in the soil. The study also showed that an interactive effect of PGPR application and organic fertilisation did not exist which indicates that organic fertilisation does not support the PGPR performance.
The problem of undesired nutrient losses as a result of manure application and possible ways to reduce those losses were described by Georges Hofman (Ghent University, Belgium). The livestock density in Flanders is very high. Therefore, this region has to face the massive problem of undesired nitrate losses. On January 1st 2011, the 4th Action Programme for the implementation of the Nitrate Directive was imposed for this region. Since the obligatory measures have not led to the fulfilment of the goals of this Directive (i.e. a concentration of less than 50 mg NO_3^-/L in all surface and ground waters), farmers are advised to further adapt their farming practice concerning nutrient management. Necessary changes of a new Action Programme comprise:

- The use of NO_3^- N threshold values as a guidance system
- Obligatory measurements of mineral N in soil profile in spring
- Obligatory N advise

- Measurements of residual mineral N in autumn
- Reduction of maximum allowed N application

Those practices should ideally result in a substantial reduction of the NO_3^- and P-concentration in Flemish water bodies.
Besides undesired nutrient losses, the risk of an input of pathogens into soils as a result of the agricultural use of manure has to be considered, as well. In his presentation "Residues from anaerobic digestion – fertiliser value or pathogen risk?" Heribert Insam (University of Innsbruck, Austria) presented the results of a study which investigated the influence of anaerobic digestion on different parameters of manure with the focus on pathogens. Today, anaerobic digestion is a very promising method to produce energy from various organic wastes. A co-product of this process, the digestate, can be used as an organic fertiliser. It adds organic matter and nutrients to the soil and helps to save mineral fertilisers. It was assumed that anaerobic digestion makes the digested slurry a superior organic fertiliser in comparison to the corresponding undigested product (i.e. cattle manure). With regard to results of a lab-scale experiment it was hypothesised that the digestion of manure might lead to a reduced survival of pathogen compared to the undigested manure as well as to a higher ammonia and nitrate availability. However, the digestion process might indeed reduce the number of pathogens but does not sanitise the product completely (see table 2).

Tab. 2: Influence of anaerobic digestion (AD) on inactivation of pathogens contained in manure (Whittle & Insam, submitted)

	Inactivation by AD		**Inactivation by pasteurisation**
Organism	**37°C**	**55°C**	
Escherichia coli	+	++	+++
Salmonella spp.	-	++	+++
Clostridium spp.	-	+	+
Brucella abortus	-	+++	+++
Bacillus anthracis	-	-	-
Mycobacterium bovis	-	++	+++
Aphtovirus	-	+	+++
Lyssavirus	-	-	+++
Cysticercus bovis	+	++	+++

Additionally, due to the higher availability, the leaching of nitrate seems to be higher in those soils amended with the digestate. It was summarised that digested slurries are valuable soil amendments but special attention has to be paid on sanitation and the timing of application.
The problem of inorganic pollutants in organic raw materials can be effectively solved by the combustion of nutrient-rich waste products. In his presentation "Renewable calcined phosphates – an efficient fertiliser option for organic farming?", Ludwig Herrmann (Outotec, Finland) presented a very promising technique which allows the production of mineral phosphate fertilisers from P-rich materials, such as sewage sludge ashes or manure. The

combustion of sludge and manure yields energy, concentrates nutrients and provides a raw product which is free from organic pollutants.
The process comprises the following steps (see also figure 2): Ash is heated and fed to a thermal reactor where it is mixed with solid additives and exposed to 1.000°C. Additives decompose and release HCl which reacts with the metals contained in the ash. Toxic heavy metals such as cadmium, lead and mercury are almost completely removed while the concentrations of non toxic metals like zinc and copper can be reduced up to >60%. The solid fractions of the additive (i.e. magnesium, sodium or potassium) react with phosphates and provide P-compounds which are not water soluble but completely soluble in 2% citric acid.

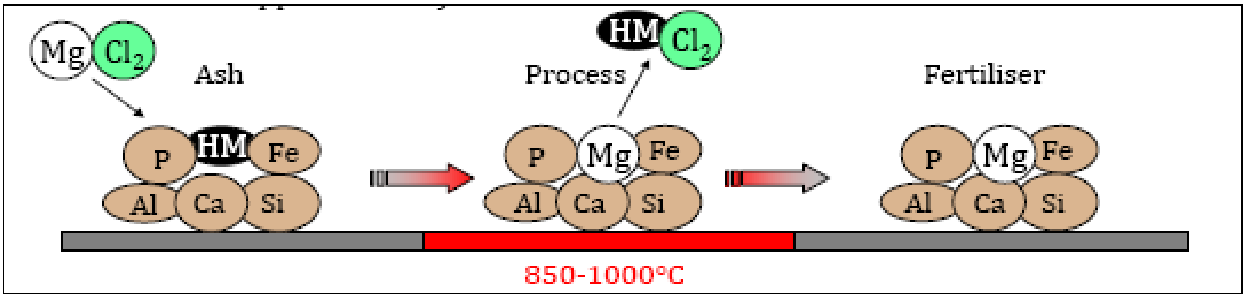

Fig. 2: Thermochemical treatment of nutrient-rich ashes (Adam, 2008)

Furthermore, most of the primary-, secondary- and trace nutrients are preserved within the treated ash. Growth tests with PhosKraft®, a marketable fertiliser produced from such treated ashes showed a fertilising effect close to a Thomas-phosphate. Within the framework of Baltic Manure it is planned to analyse thermochemically treated manure ashes regarding heavy metal concentration and P-speciation and to add the obtained data to the project-database.
In the presentation “Baltic Manure project – Strategies of an exemplary P management“ Silvia Haneklaus (JKI, Germany) described the scopes of the EU-project Baltic Manure. Agriculture is the largest consumer of P and diffuse P losses as a result of an imbalanced fertiliser application contribute to a large extend to the eutrophication of water bodies such as the Baltic Sea. The Baltic Sea Basin is an area of intensive, and intensifying agricultural production with about 36 million units of cattle, 67 million units of pigs, and 190 million units of poultry in the region. Particularly on big livestock enterprises a proper use of manure is regularly not ensured. It was stated that the aim of the partly EU-financed project Baltic Manure is the development of a holistic concept for manure and P management to avoid surpluses with a view to P input in feeding and P fertilisation and which elaborates new opportunities for processing and utilisation of manure that are suitable to recycle P without compromising environmental demands.
In the presentation “Baltic Manure Project - challenges and opportunities for P fertilisation on farms”, Judith Schick (JKI) gave an outline of the particular aims of work package 4 of Baltic Manure and presented first results. It is one aim to elaborate guidelines for a demand-driven use of mineral and organic phosphorus (P) on agricultural production fields. Studies include for instance the comparability of different extraction methods used in the member states of the Baltic Sea to determine the plant available P pool in the soil and to calculate P

losses through erosion and run-off. Other relevant issues for a sustainable use of P which avoid equally P mining and P surplus are the assessment of a site-specific optimum P status of soils to satisfy the P demand of crops and the development of algorithms to match the small-scale spatial variation of plant available P in soils with variable rates of organic and mineral fertilisers. The implementation of these codes for best P practice is expected to deliver a significant contribution to reduce diffuse P losses to the environment. It can be assumed that recycling of P and thus the use of recycled P fertiliser products will play a key role in future sustainable P management. However, conditions need to be strictly defined for their use in order to foreclose negative environmental impacts. Another aspect is that the percentage of plant available P in recycling products is determined. In the Baltic Manure project the already existing data base for mineral, organic and recycled fertiliser products will be extended and standards will be defined for recycled P products with a view to P speciation in order to be suitable for fertilisation.

The participation in the CIEC Symposium initiated highly valuable discussions about handling of manure with respect to different production systems. In general, the research community showed great interest in the activities of the Baltic Manure group and some have been already aware of the project. The invitation on behalf of the Baltic Manure team to organize the 21st CIEC Symposium in Helsinki was accepted *unisono* by the CIEC Presidium. The topic of the next Symposium "Making the Most of Manure" has been identified as one of the most challenging issues with a view to fertilization and was highly welcome by the participants of the Symposium. In particular, colleagues from riparian states of other marine bodies (for instance from Belgium, Italy, Canada, China and the UK) expressed their interest in actively participating in the next Symposium in Helsinki. Thus it is fair to conclude that the organization of the next CIEC Symposium by the Baltic Manure team offers an ideal platform to present the outcome of the project to the international science community, politicians and representatives of the fertilizer industry.