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Guidelines for use of recycled fertilizer products in precision fertilization

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Preface

The guidelines are based on experiments carried out in CIRCWASTE project [1] LIFE-IP CIRCWASTE-FINLAND, Life IP on waste – Towards circular economy in Finland, Action C.8.2. in years 2017 and 2018. The machine constructions were planned and built in collaboration and with support of Finnish machine manufacturers, IT companies working with agricultural applications and forerunner farmers. The basic idea was to utilize already commercially available machinery and digital tools, and to show how technology can contribute to nutrient recycling in agriculture and thus to wider circular economy. The field demonstrations took place in two practical farms; Olli Alikärri's farm in Somero and in Toivon Tila in Salo. The experiment provided valuable experience that we would like to share to readers through this guideline report.

Great thanks to all contributors and collaborators for making this experiment and experience possible!

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Circwaste-hanke saa EU:lta rahoitusta, jolla hankkeen materiaalit on tuotettu. Materiaaleissa esitetty sisältö edustaa kuitenkin ainoastaan hankkeen omia näkemyksiä, joista EU:n komissio ei ole vastuussa.

Introduction

This report gives guidelines for the use of recycled fertilizers in precision farming from a technical point of view. Agronomic aspects such as the nutritional impact of recycled fertilizers on the plant growth or yield are omitted.

It has been proposed in public discussion that the recycled plant nutrients should be mixed to virgin nutrients when producing fertilizers in order to increase their use in agriculture. This report describes a method where the recycled and virgin fertilizers are mixed in the fertilizer machine during the field operation while aiming at optimal site-specific plant nutrition.

Combined seed drilling is the most common seeding and fertilization method for cereals in Finland. The combined seed drilling integrates seeding and fertilizing to the same work task. Both, seeds and fertilizers are placed to the soil few centimetres below the ground level, close to each other. In this way the fertilizer nutrients are easily and efficiently available for plants, which is important in the farming conditions of short growing period.

In some cases, so called split application of nitrogen is chosen as fertilization strategy, where the total amount of nitrogen fertilizer is split to 2 or three doses to be applied during the growing season; at seeding, in the 3-4 leaf stage and at heading stage. The split application adapts the nitrogen dosing according to the growing conditions during the growing season. The aim is to optimize protein content of grain and to minimize nitrogen residues in the soil, especially in field sites of high yield risks. In split application, fertilizers are applied to the growth as soil surface spreading by granule spreaders or hose applicators (for liquid) or foliar spraying by plant protection sprayers (liquid).

In precision farming, plant nutrients are applied to the plants timely and site specifically according to plants' needs, taking account the site-specific yield potential, soil fertility and moisture conditions. The aim is to increase yields and their quality and to avoid excessive use of fertilizers in any part of the field. This increases the profitability and decreases the risk of nutrient emissions from the field. It is important that also recycled fertilizers are used using precision farming practices.

Precision farming and site-specific application of nutrients require that at least each main nutrient can be applied individually to each field site (or zone). Since each fertilizer has its own fixed nutrient composition, there is a need to include several different fertilizers to the fertilizer application system. Precision farming practices benefit if the nutrients from different fertilizers can be brought together and applied to a site as individual fertilizer mixes. The requirement for precision fertilizers is that they are effective as plant nutrient immediately or their timely effect is predictable (Figure. 1).

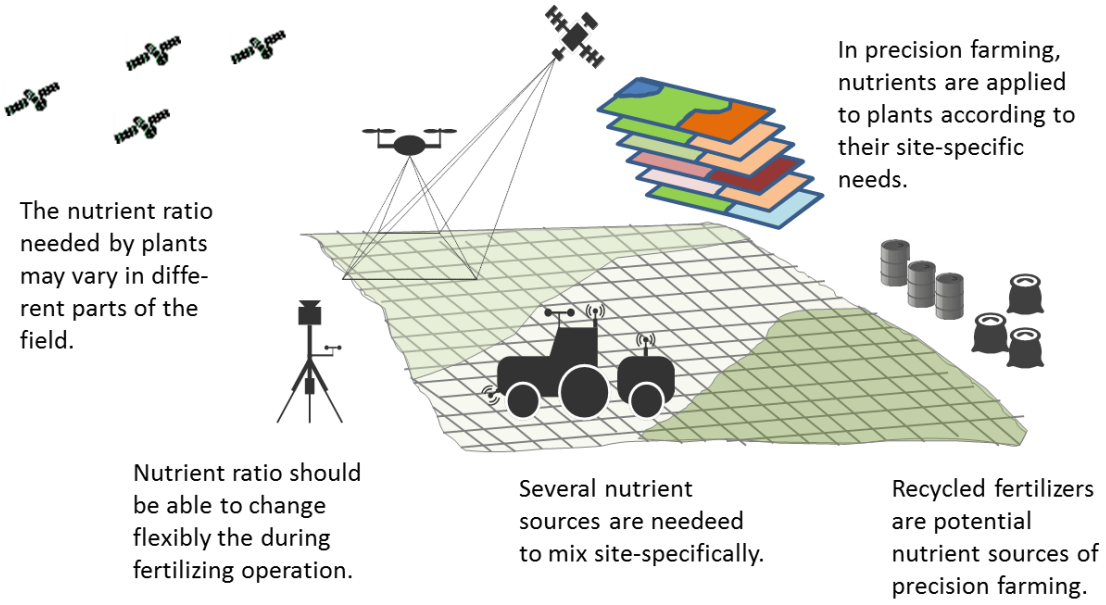


Fig. 1. Principles of precision fertilization and role of recycled fertilizers.

This report is based on experiments carried out in CIRCWASTE project[1] in years 2017 and 2018. In 2017, there were only two commercial recycled fertilizers available fulfilling the requirements for a precision fertilizer; ammonium sulphate and Bio-Kali. Ammonium sulphate is a source of nitrogen and sulphur, and Bio-Kali is a source of potassium. Both are liquid fertilizers. All commercially available recycled solid fertilizers at the time of the experiment were considered rather as soil improvers than precision fertilizer from their functional point of view, and so they were not included to the experiment. So, this report describes how recycled liquid fertilizers can be used parallel to granular fertilizers to fulfil requirement of precision fertilizing in combined seed drilling operations. The introduced machine automation system is enabled by novel technologies based on open standard ISO11783, known as ISOBUS.

Recycled liquid fertilizers

The availability of recycled fertilizers containing e.g. soluble phosphorous and some micronutrients may be uncertain. Therefore, it is important that traditional granule fertilizers made of 'virgin' raw materials can be used alongside the recycled fertilizers. In this way the nutrient compositions of overall fertilization can be optimized for the plant and the growing site.

Liquid form fertilizers are a good alternative as additional nutrient source in combined seed drilling, since the liquid tanks can be placed fairly freely to suitable locations in the machinery combinations. The liquids can be conducted with hydraulic pressure and hosing to desired application spot in coulters. Liquids are also easy to dose accurately. The industrial IBC chemical plastic containers of 1 m^3 volume (Figure 2) serve well as fertilizer storing equipment in farms, and also as additional fertilizer tanks in the machinery (Figure 3).

[1] LIFE-IP CIRCWASTE-FINLAND, Life IP on waste – Towards circular economy in Finland, Action C.8.2

Fig. 2. Industrial IBC chemical plastic containers of 1 m^3 volume used to store recycled fertilizers.

Fig. 3. Industrial IBC chemical plastic containers of 1 m^3 volume used as recycled fertilizer tanks on the machinery work set.

Depending on the origin, processing and storing as well as delivery methods of the recycled fertilizer, the nutrient contents of the fertilizer lot delivered to the farm may vary. In precision farming, it is necessary to know the nutrient composition and concentration of a fertilizer batch accurately. Also other physical and chemical factors such as pH, viscosity, homogeneity and presence of impurities like trash or clumps are necessary to know. These factors have impact on the machine construct and its functions, i.e. corrosion resistance, actuator mechanisms, etc. Also, they may affect storing conditions, whether the containers should protect from freezing or microbiological fermentation or spoilage. In many cases, it is practical to obtain recycled liquid fertilizers only the amount that is needed during one growing season.

Technical construction

The demonstrated precision combined seed drill machinery system was built on the commercially available, ISOBUS enabled precision combined seed drill by adding two liquid fertilizer application systems on it, including ISOBUS controls and fertilizer tanks. ISOBUS machines are based on an open standard ISO 11783 for system integration between tractors and implements.

In the Finland, the commonly used fertilizers in combined seed drilling are granules, and the machinery is constructed accordingly. Adding extra tanks to the work set for recycled fertilizers may be challenging. However, liquid tanks can be located pretty freely to the different distances from the application coulters in the machinery construct, since liquids are easy and accurate to dose from different distances using hydraulic pumps and hoses (Figure 4).

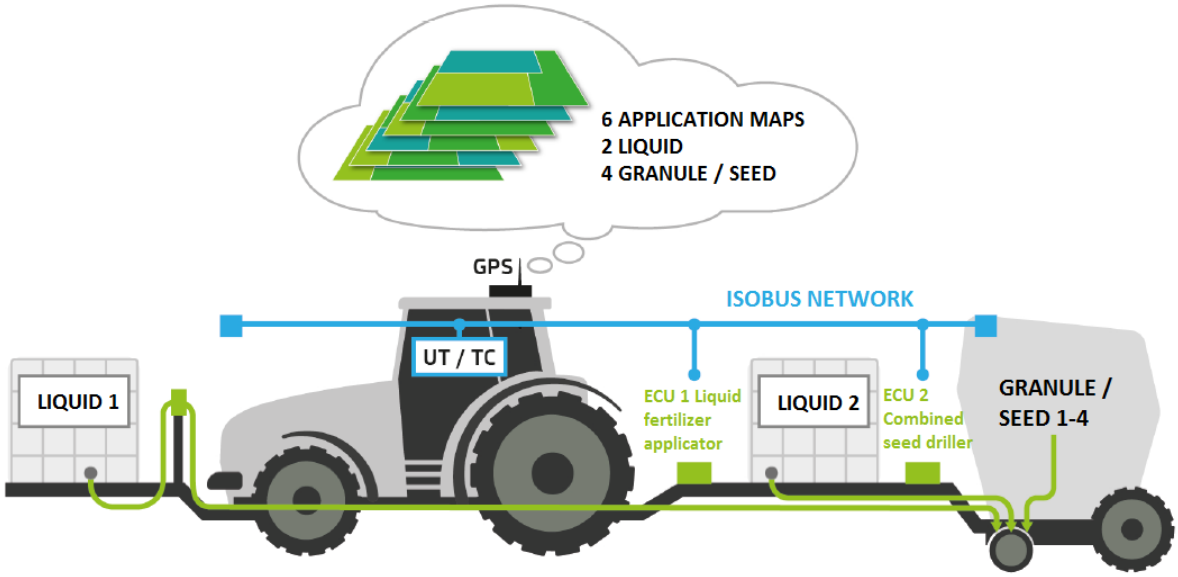


Fig. 4. An illustration of the tractor-combined-seed-drill work set with added application system for recycled liquid fertilizers. The system utilizes ISO11783 standard for automated functions.

The liquid fertilizer applicator system consists of five components. Containers for liquid fertilizers, pumping system, transfer tubing and manifolds, nozzles and control system. This is the basic construction that can be observed from any such system. Some systems may, in addition, include a system for mixing the liquid in the container tank. The design of these components is dependent on the application concept and properties of used substances.

Planning of fertilizing

The planning of precision fertilization task to a certain field starts with identifying the in-field variety affecting the yield potential. Field variation can be obtained and treatment zones perceived from aerial images, terrain maps or possible yield maps from several previous years (Figure 5). The variation of soil type, pH, organic matter and nutrient contents, availability of water and field's

elevation model are factors to detect per zone. The optimal nutrients contents are then planned per zone. If the previous data from the zone indicates high yield risk, part if the nitrogen can be applied later during the growing season as split application. Next the suitable fertilizers are chosen for use and their doses per zone are determined (Table 1).

Fig. 5. An example of the prescription map for precision fertilizing of winter wheat with two treatment zones. The zones were fertilized according to the table 1. (Olli Alikärri's field, the plan made with AgriSmart /Suonentieto Oy).

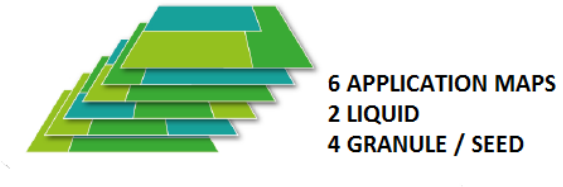


Fig. 6. Prescription maps per fertilizer type (+ seed)

Table 1. An example of fertilizer and nutrient application plan per treatment zone in the field of Figure 5.

Zone	Startti P kg/ha	Bio-Kali l/ha	AMS l/ha	HeVi3 kg/ha	GC kg/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha
1	60	300	132	0	35	*23*	*16*	*19*	*16*
2	30	200	262	20	40	*32*	*10*	*19*	*32*

When generating the task for the machine automation, each applied fertilizer type gets its own prescription map with treatment zones indicating the amount of planned fertilizer (Figure 6). Executing the plan of table x requires five parallel prescription maps for fertilization; 3 granular and 2 liquid for recycled fertilizers Bio-Kali and AMS. The planning is made using dedicated software application. In this case, the prescription map is transferred to ISOBUS task file that follows ISO11783 standard.

Working with the machinery and fertilizers

The recycled fertilizers are transported to the field side before the field operation, together with granular fertilizers and seeds. The 1 m^3 IBC containers stand well different weather and field conditions. The 1 m^3 IBC container can be handled with tractor's front loader that is equipped with truck fork. In the experiment, two IBC containers are located onto the work set. The first one is located on the front three point hitch of the work set's tractor. The work set is able to change the container itself, if the container is placed in the loading area in a way that the work set has enough room to maneuver. The second IBC container is located on the drawbar of the combined seed drill (Figure 7). The container can be loaded on the work set by another tractor's front loader.

Fig. 7. An industrial IBC container is located on the drawbar of the combined seed driller.

When the field work starts, the task file with prescription maps is enetered to the task controller (TC) of the machinery. The task controller commands the the electronic controller units (ECU) in the tractor-combined seed drill work set to adjust the fertilizer feed according to the prescription map in each zone when the work set drived forward in the field (Figure 8). It is good to notice that the accuracy and performance of positioning (GPS) has effect on the spatial application accuracy of fertilizers. The procedure is the same when applying recycled liquid fertilizers by precision foliar spraying. While carrying out split application, the canopy sensor based on-line control of fertilizer application is possible[2].

[2] For example: Yara N-sensor https://www.yara.my/crop-nutrition/farmers-toolbox/n-sensor/ or Claas Crop sensor https://www.claas.co.uk/products/easy-2018/precision-farming/crop-sensor-isaria?subject=CUK_en_UK

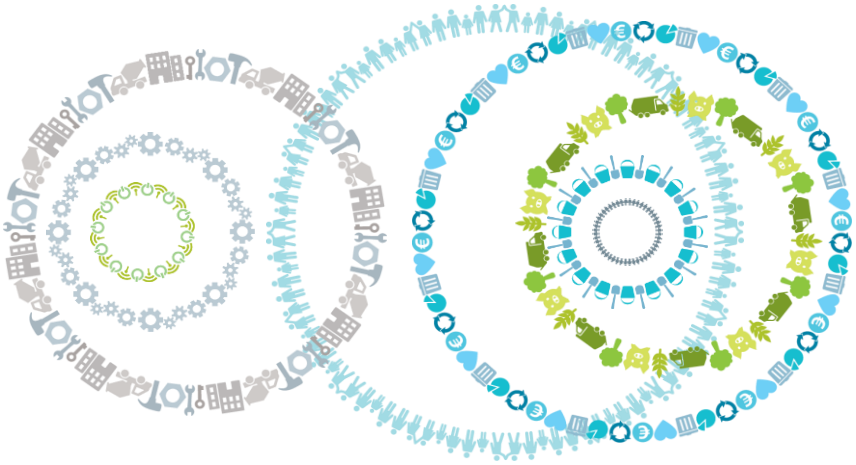
Fig. 8. As an example, ISOBUS compatible Valtra C3000 Task controller as a user interface for the machine combination.

While working, it is necessary to monitor the functioning of the machinery. When new fertilizer types are used the application system and its feeders need to be checked frequently. Especially, impurities like trash or clumps may cause blockage in the liquid strainers and nozzles of the application system. Some liquid fertilizers may need mixing before starting the field work, but during the field operation the fertilizer moves in the container usually keep mixed enough without separate mixing system.

The 1 m^3 IBC containers served well as fertilizer tanks in the machinery also from the re-loading point of view. The recycled fertilizer tanks get empty and need re-loading at the same pace as granular fertilizer tanks of the combine seed driller. In that sense working in the field is fluent. When liquid fertilizers are used in the field operation, it is necessary to rinse the liquid application system immediately after finishing the field work. This prevents the liquid fertilizer to dry to the pumps, hoses and nozzles and possibly to cause clogging the system before the next field operation. This routine also reveals the possible defects of the systems occurred during the work.

Conclusions

Recycled fertilizers can be utilized in precision farming either in liquid or granular form. Precision combined seed drilling and foliar spraying are both possible. However, the nutrient composition and concentration per fertilizer batch is essential to know. Planning and machinery can as such adapt to varying quality, when it is known. The fertilizer should be also homogenous in structure and free of impurities to enable perfect functioning and precision in fertilizer application. ISOBUS enables building automation machinery constructions that integrate several existing fertilizer applicators and functional features into one automation work set.



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