LIFE15 IPE FI 004

CIRCWASTE
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Report from the cultivation demonstrations of the second growing season

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Summary

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Combined seed drilling is the most common seeding and fertilization method for cereals in Finland. Thus, it is important to introduce the use of recycled fertilizer in this context. Precision farming practices benefit if different nutrients from different fertilizers can be brought together and applied to a site as individual fertilizer mixes.

Liquid form fertilizers are a good alternative as additional nutrient source, since the liquid tanks can be installed fairly freely to the machinery combinations and lead the fertilizers to desired place through hosing. Liquids are also easy to dose accurately. In some cases, liquid nitrogen fertilizers are applied to the cereal growth as so called split application during the growing season to raise protein content of grain or to minimize nitrogen residues in the soil in those field sites having yield risks. There have not been many liquid fertilizers in the market in Finland to fulfil the need of precision farming, so the possibility to use recycled liquid fertilizers is very interesting.

This report describes the actions taken to demonstrate the use of recycled liquid fertilizers in precision combined seed drilling. Commercially available ISOBUS compatible tractor-combined seed driller system was modified to include liquid fertilizer tanks, pumps, hoses, coulters and ISOBUS controller. The field demonstrations in year 2018 included two precision combined seed-drilling events. The first one was carried out in the spring Toivon Tila, Salo,South-West Finland, where 9,5 hectares of barley was sawn. The second took place in Luke Vihti research farm, where another 12 hectares of wheat were seeded. The experiment was demonstrated, utilizing simulations, to wider audience in Toivon Tila's traditional winter crop day in June 2018.

Contributers:
Junkkari Oy, Epec Oy, Valtra Oy, Suonentieto Oy, Happowa Oy, Lilja Farms Oy,
Finnamyl Oy, Envor Group Oy, Jussi Knaapi, Olli-Pekka Ruponen, Tilasiemen Oy / Aki Riskin pakkaamo, Tilasiemen Oy / Pelto-Paturi Oy, Tracegrow Oy / Viljelijän Berner

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Contents

1. Introduction

Combined seed drilling is the most common seeding 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 nutrients in the fertilizer are easily and efficiently available for the growing plants. Combined seed drilling is common in the Nordic farming conditions due to a short growing period. Normally, the cereal growth is fertilized only once, at the seeding time. In some cases, so called split application of nitrogen is used to raise protein content of grain or to minimize nitrogen residues in the soil when there is a risk for the growth to fail.

To demonstrate the use of recycled fertilizers in cereal cultivation, it is important to show how recycled fertilizer can be used in combined seed drilling. 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. In the Nordic countries, the commonly used fertilizers are granules, and the machinery is constructed to apply them. However, it may be tricky to design several granule fertilizer tanks to these machines. So, liquid form fertilizers are a good alternative as additional nutrient source. Liquid tanks can be installed 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. There have not been many liquid fertilizers in the market in Finland to fulfil the need of precision farming, so the possibility to use recycled liquid fertilizers is very interesting.

The use of liquid fertilizers in combined seed drilling required modification in the machine construct, where liquid fertilizer tanks, pumps, hoses and controllers were added to the commercially available tractor and combined seed-driller system. The seed driller manufacturer provided also a set of coulters that were capable for liquid application.

The field demonstrations in year 2018 included two events. The first one was carried out in May 2018 in Salo in Toivon Tila, a private farm in the South-West Finland. In this event the machinery, its functionalities and actual precision combined seed-drilling work using recycled fertilizers were introduced in the field to the audience. The second demonstration took place also in Toivon Tila in June 2018, in a connection of a field day where several agricultural suppliers presented their products and services. In this event, recycled fertilizers and machinery were introduced to the audience in an outdoor stand, and the functionalities of the machinery and precision combined seed-drilling were demonstrated by simulations and videos. In the simulation, the machinery repeated the earlier executed and recorded seeding operation from the computer. The audience was able to observe the progress of field work from the monitors in the tractor cabin and the functioning of recycled fertilizer pumps and seed and granular fertilizer actuators in the combined seed drill on-line. The machinery was used and recycled fertilizers were applied also in Luke Vihti’s research farm (Vakola), where 12 hectares of wheat was seeded and fertilized with the machinery system.

2. Field demonstration in the spring 2018

2.1. Demonstration site and setup

In May 2018 the field demonstration took place in a 9,5 ha field in Toivon Tila farm in Salo, the South-West Finland (Figures 1a and 1b). The soil type (texture) of the demonstration field was sandy clay. The field had in-field variation in surface contour, organic matter content and the depth of the topsoil layer (Figures 2a and 2b).

Fig. 1a and 1b. Landscape pictures from the Toivon Tila's demonstration site in May 2018.

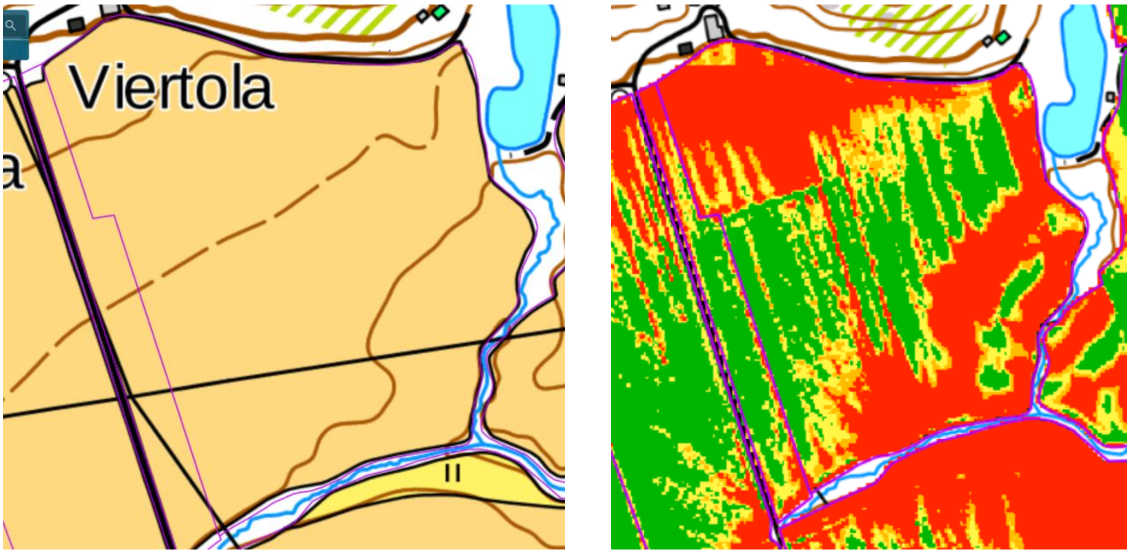

Fig. 2a and 2b. A topographic map of a demonstration field (Toivon Tila's field block named Viertola) with elevation contour lines on the left and the RUSTLE erosion sensitivity map on the right. The erosion sensitivity map is influenced by the slope angle of the soil surface and the soil type (clay content). Red = high erosion risk, green = low erosion risk.

The cultivated grain was Vertti barley. The aim of the precision application of seeds and fertilizers was to obtain a coeval ripening of the barley growth in different parts of the field, despite the in-field variation of the soil. The main variables influencing the site specific seeding and fertilizing plan were nitrogen and anticipated soil moisture in different parts of the field. The aim was to achieve even nitrogen and water input per barley plant over the field, in rain-fed conditions. This was induced by adjusting the nitrogen fertilizer and seed rates site-specifically. To improve soil structure and to prevent soil erosion cover crops were seeded in some parts of the field as a tailored seed mix. The amount of applied seed mix rate was varied according to the erosion risk.

The demonstration field was divided into ten treatment zones (sub-fields), each having tailored prescription for seed and fertilizer application (Figure 3).

Fig. 3. Toivon Tila's Viertola demonstration field divided to ten different treatment zones. Total area 9,7 ha. Picture is a snapshot from AgriSmart planning software.

Fertilizers

The precision fertilizing aimed at tailored treatment in each zone by mixing a zone-specific fertilizer cocktail to each of them. The used fertilizers included recycled ammonium sulphate (AMS) (Envor Group Oy), Bio-Kali (Finnamyl Oy) and Tracemix (Tracegrow Oy/Viljelijän Berner), and non-recycled Yara Mila Y3, Yara Mila Y5 and Yara Bela Suomensalpietari (Yara Suomi Oy).

Ammonium sulphate is a source of Nitrogen and Sulphur (9-0-0-10) and Bio-Kali source of Potassium (1,2-0,25-4,5-0). Tracemix was an additional treatment to test, and it is a source of Manganese, Zink, Potassium and Sulphur (Mn-Zn-K-S: 5,4-4,7-0,8-5,0).

Yara Mila Y3 (23-3-8-3) and Yara Mila Y5 (22-5-5-1,2) (Yara Suomi Oy) granular fertilizers were used as sources of phosphorous and a partial source of nitrogen and potassium. In some treatment zones the fertilizer mix was completed with Yara Bela Suomensalpietari (27-0-1) to achieve high enough nitrogen application rate without increasing the Sulphur application rate too high.

Seeds

In the demonstration used seeds were barley Vertti[BOR] (Tilasiemen Oy/Aki Riskin pakkaamo) as main crop and a seed mixture of tall fescue (47 %), timothy (16 %), Italian ryegrass (16 %), alsike clover (8 %), red clover (8 %), white clover (6 %) (Tilasiemen Oy/Pelto-Paturi Oy) as cover crop.

The application rates and total amounts of different fertilizers and seed per treatment zone and the nutrient contents of the fertilizer mixes are listed in the tables 1-4.

Table 1. Fertilizer and seed application rates (kg/ha) per treatment zone.

Input/area	Unit	Headland		Headland						Headland			
Zone		**1**	**2**	**2**	**3**	**4**	**5**	**6**	**7**	**7**	**8**	**9**	**10**
Y5	kg/ha	0	288	0	320	0	0	0	0	0	0	0	0
Y3	kg/ha	320	0	400	0	400	320	400	320	320	320	320	320
Saltpetre	kg/ha	41	47	30	13	0	26	0	26	41	20	26	20
AMS	l/ha	122	280	0	173	0	170	0	170	122	170	170	170
Bio-Kali	l/ha	0	244	0	200	0	0	0	0	0	0	0	0
Tracemix	l/ha	0	0	0	0	300	300	0	0	0	0	0	0
Vertti	kg/ha	130	200	200	220	220	200	220	200	200	175	200	220
Grass mix	kg/ha	16	11	11	9,5	9,5	11	9,5	11	11	14	14	9,5

Table 2. Nutrient application rates (kg/ha) per treatment zone.

Nutrient/area	Unit	Headland		Headland						Headland			
Zone		1	2	2	3	4	5	6	7	7	8	9	10
N	kg/ha	96	104	100	91	92	96	92	96	96	94	96	94
P	kg/ha	10	14,4	12	16	12	10	12	10	10	10	10	10
K	kg/ha	26	26	32	25	32	26	32	26	26	26	26	26
S	kg/ha	25	38	13	25	13	31	13	31	25	31	31	31
Mn	kg/ha	0	0	0	0	0,45	0,45	0,45	0,45	0	0	0	0
Zn	kg/ha	0	0,65	0	0,67	0,51	0,51	0,51	0,51	0	0	0	0

Table 3. Applied amounts of fertilizers and seeds per treatment zone and entire field.

Input/zone	Unit	Headland		Headland						Headland				**Entire**
Zone		**1**	**2**	**2**	**3**	**4**	**5**	**6**	**7**	**7**	**8**	**9**	**10**	**field**
Area	**ha**	**0,9**	**1,4**	**0,35**	**2,7**	**1**	**0,35**	**0,5**	**0,4**	**0,25**	**0,55**	**0,75**	**0,3**	**9,45**
Y5	*kg*	0	403	0	864	0	0	0	0	0	0	0	0	**1267**
Y3	*kg*	288	0	140	0	400	112	200	128	80	176	240	96	**1860**
Saltpetre	*kg*	37	66	11	35	0	9	0	10	10	11	20	6	**215**
AMS	*l*	110	392	0	467	0	60	0	68	31	94	128	51	**1399**
Bio-Kali	*l*	0	342	0	540	0	0	0	0	0	0	0	0	**882**
Tracemix	*l*	0	0	0	0	300	105	0	0	0	0	0	0	**405**
Vertti	*kg*	117	280	70	594	220	70	110	80	50	96	150	66	**1903**
Grass mix	*kg*	14	15	4	26	10	4	5	4	3	8	11	3	**106**

Table 4. Applied amounts of nutrients per treatment zone and entire field.

Nutrient/zone	**Unit**	Headland		Headland						Headland				**Entire**
Zone		1	**2**	2	**3**	**4**	**5**	**6**	**7**	7	**8**	**9**	**10**	**field**
N	*kg*	86	145	35	247	92	34	46	38	24	52	72	28	**899**
P	*kg*	9	20	4	43	12	3	6	4	2	5	7	3	**119**
K	*kg*	23	36	11	68	32	9	16	10	7	14	19	8	**254**
S	*kg*	22	53	4	68	13	11	6	12	6	17	23	9	**244**
Mn	*kg*	0,0	0,0	0,0	0,0	0,5	0,2	0,2	0,2	0,0	0,0	0,0	0,0	**1,0**
Zn	*kg*	0,0	0,9	0,0	1,8	0,5	0,2	0,3	0,2	0,0	0,0	0,0	0,0	**3,9**

2.2. Recycled fertilizers in the demonstration

In the demonstration used fertilizers were Bio-Kali, produced by Finnamyl Oy, and recycled ammonium sulphate (AMS), produced by Envor Group Oy (Figure 3). Bio-Kali was used as a source of potassium (K) and AMS as a source of nitrogen (N) and sulphur (S). Further description of the properties of Bio-Kali and AMS as presented by manufacturers is presented in Table 5.

According to the chemical analyses carried out from the fertilizer samples from 2018 demonstrations, Bio-Kali's pH was around 4,4-5,5, potassium content 2,2-4,3 % and dry matter content 34 %. Also, the measured nitrogen and phosphorous contents in the raw Bio-Kali were 1 % N (0,98 % soluble) and 0,18-0,34 % P (0,16-0,31 % soluble). Bio-Kali needed mixing before the use. In the demonstration used AMS contained 7,7 % of N, all in a soluble form.

As an 'add-hoc' technical trial, a liquid recycled micronutrient fertilizer Tracemix (source of Mn, Zn, K, S) from Berner Oy was also applied used for small area. Tracemix is produced form used batteries. According to the producer, Tracemix liquid contains 4,6-6,1 % Mn, 5,4-6,8 % Zn, 1 % K and 6-7 % S.

The recycled fertilizers were used alongside traditional granule fertilizers made of 'virgin' raw materials, which were especially the source of phosphorous.

Table 5. Properties of Bio-Kali and recycled AMS according to the manufacturers. Figures were used in the planning of the field demonstration.

Bio-Kali

by Finnamyl Oy

- Concentrated potato cell sap, the side product of potato starch industry
- Nutrients:
  - Total N 1,3 %
  - Soluble N 0,85 %
  - P 0,25 %
  - K 4,5 %
  - Ca 0,04 %
  - Mg 0,28 %
- Dry matter 42 %
- pH 4,5-5,6
- Volume weight 1 kg/dm3

Ammoniumsulphate (AMS)

by Envor Group Oy

- Nitrogen that is stripped from waste waters
- Nutrients (35% AMS):
  - Total N 9%
  - Soluble N 8,9 % (Ammonium N)
  - S 10,2 %
- pH 7,1
- Volume weight 1,2 kg/dm3

Fig. 4. Bio-Kali containers on the front of the picture and an AMS container on the seeding machine in the service area of the Toivon Tila demonstration site.

2.3. Machinery and equipment

The work set used in the demonstration was the same as the first two demonstrations in 2017 (Deliverable C.8.2.1[1]), only the GPS was changed. The work set included ISOBUS compatible tractor, combined seed drill and devices. Combined seed drill was Junkkari M300 Plus, which has four site-specifically controllable containers for inputs; 1 for cereal seed, 1 for granule fertilizer, 2 for small seed (cover crops) or granule micronutrients (Figure 5).

Fig. 5. Junkkari M300 Plus combined seed drill with four site-specifically controllable containers; 1 for cereal seed, 1 for granule fertilizer, 2 for small seeds (cover crops).

[1] Pesonen et. al. 2018. Report from the cultivation demonstrations of the first growing season. CIRCWASTE Deliverable C.8.2.1

The combined seed drill was equipped with special disc coulters that enabled additional two hoses to be mounted to them for liquid recycled fertilizers application (Figure 6). Liquid fertilizer application required nozzles to the tips of the application hoses in the coulter end. Happowa Oy's nozzles were used in the construct.

Fig. 6. Additional hoses for liquid fertilizers (thin white hoses) assembled to the combined seed drill (left). Special disc coulters, where liquid fertilizer hoses are attached to, enabling placement application of additional two liquid fertilisers (right).

The additional ISOBUS compatible controllers for liquid fertilizer pumps were constructed by Luke for site-specific application of liquid recycled fertilizers (Figure 7). The controllers were built using Epec 3724 Control Unit and software development tools provided by Epec Oy.

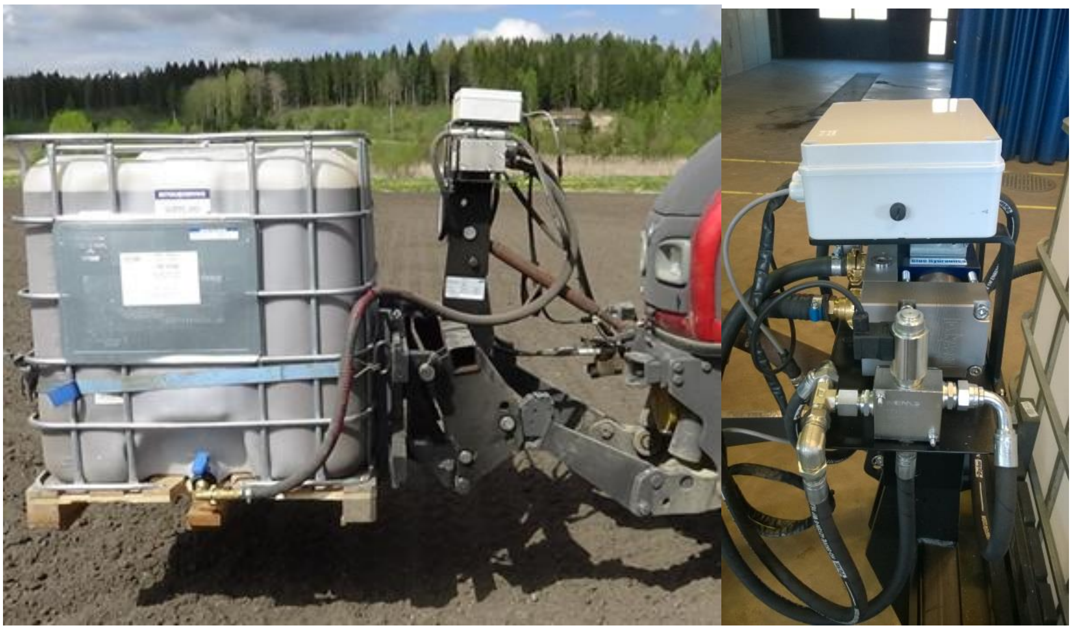

Fig. 7. Bio-Kali container in the front of the tractor (left) and the ISOBUS compatible controller (grey box) and liquid fertilizer pump for Bio-Kali application.

Tractor of the work set was Valtra T163 which was equipped with ISOBUS functionalities. The user interface of the ISOBUS automation system/machine combination was Valtra's ISOBUS compatible C3000 Task controller (Figure 8).

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

Summary of the machinery and devices used in the demonstration 2018:
ISOBUS (ISO 11783 standard) machine combination for precision combined seed-drilling (Figure 9):

- Junkkari M300 Plus; ISOBUS implement ECU that is able to control four site-specifically controllable containers for inputs (1 fertilizer, 1 grain seed, 2 x small seeds for cover crops)
  Coulters capable for liquid application to soil
- EPEC & Luke ISOBUS implement ECU to site-specific control of 2 pumps for liquid fertilizer application
  Epec 3724 Control Unit + software development tools
- Happowa nozzles for liquid fertilizers
- Valtra T163 + C3000 task controller and virtual terminal
- Garmin GPS 19xNMEA 2000

Fig. 9. The CIRCWASTE work set used in the field demonstration as a whole, enabling site-specific control of six independent inputs; seeds and fertilizers. Bio-Kali tank is located in the front of the tractor and AMS tank between the tractor and drilling machine.

2.4. Field work and demonstrations

The field demonstration in Toivon Tila took place on the 14th and 15th of May 2019. The demonstration was open to audience and Toivon Tila had invited visitors to the site on the 14th of May (Figure 10). Farmers in the region were busy with their own farm tasks at the time, so the audience consisted mainly of media, companies and different organizations' representatives. Used fertilizers and their planned cocktails per treatment zone, and the machinery with its functionalities were introduced to the audience on the site. The audience was able to observe the actual field work in practise.

Fig. 10. Audience in the field demonstration event on the 14th of May 2018 in Viertola field, Toivon Tila.

The machinery and the built precision application mechanisms of recycled liquid fertilizers worked well. The recycled liquid fertilizers (AMS, Bio-Kali and Tracemix) were consumed the planned amounts in the demonstration, which indicates that the application functioned correctly.

It was noticed that there was a design flaw in the hydraulic relief system of the liquid fertilizer applicator flow control, that caused work pressure needed for lifting the coulters and driveline markers to drop. To compensate this flaw, the operator had to drive the headland turns and start new driving lines with lower speed than in normal seeding. The weather was very warm and the top soil of the field was prone to dry too much for optimal seeding. The texture of the top soil was such that it formed clogs to the coulters (Figures 11a and 11b). This phenomenon had not occurred with any other soils. The coulters had to be checked frequently after every driving line, which slowed down the field operation. Also, the sulphate in AMS liquid caused corrosion in brass parts used in the distribution system. The corrosion was extensive enough to cause component failures. It was considered that these shortcomings can be mitigated by changing the components to more suitable material, like stainless steel. All encountered shortcomings were considered possible to be mitigated by improving the design.

Fig. 11a and 11b. The machinery combination used in the field demonstration in a service break at Toivon Tila (left) and a typical soil-seed-fertilizer aggregate formed in the coulters and clogging them frequently (right).

The figure 12 illustrates the logged data of AMS application in the demonstration field. The colour scale is from dark blue to red, meaning application rates from 0 to 300 l/ha. In the left side of the map can be seen long blue and red stripes aligned with the driving direction, and actual treatment zones are difficult to perceive. On the right side of the map the zones can be clearly seen, and the stripes in the zone borders are short. The reason for this difference is that in the left side the site-specific application control based on basic GPS positioning, and in the left side EGNOS GPS correction signal was utilized. This shows the meaning of GPS accuracy in precision farming.

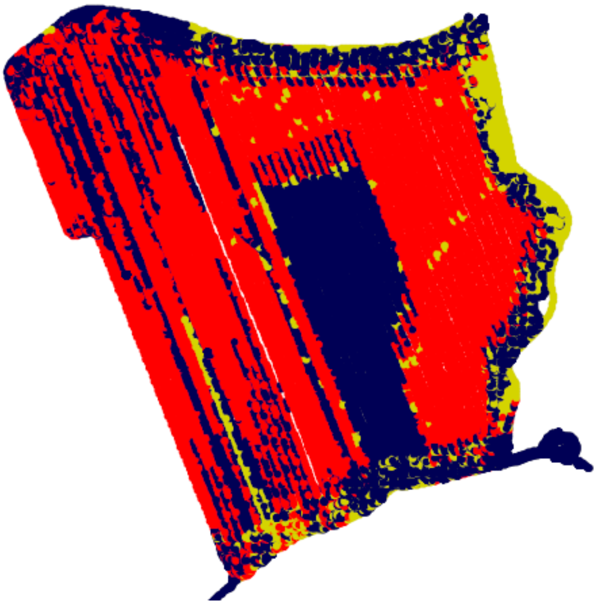

Figure 12. Realized AMS application in Viertola, Toivon Tila, illustrated from the logged data of the work set.

After the field demonstration in Toivon Tila, 12 ha of wheat were seeded with the CIRCWATE machinery in Hovi field in Luke Vihti's research farm Vakola (Figure 13). The field was the same as in previous year's demonstrations, but now only half of the area was seeded with the CIRCWASTE machinery. AMS and Bio-Kali were used as liquid fertilizers. The field was divided in 42 meters stripes, of which every second was treated using site-specific seed and fertilizer application and rest with conventional manner. The idea was to observe the possible differences in treatments during the growing season by remote sensing and yield mapping. However, the weather was so dry after seeding that sprouting was very uneven between the different in-field zones and partly within the zones. Due this variation, it was impossible to define more delicate differences induced by site-specific fertilizer application. Technically, the combined seed drilling operation was carried out smoothly, without coulter clogging problems that were observed in Viertola, Toivon Tila, even though the surface of the soil was very dry also in this field. So, the reason for clogging problem in Viertola was the different soil type. In this light, the field demonstration gave important information for the improvements in possible next development stages of the machinery system.

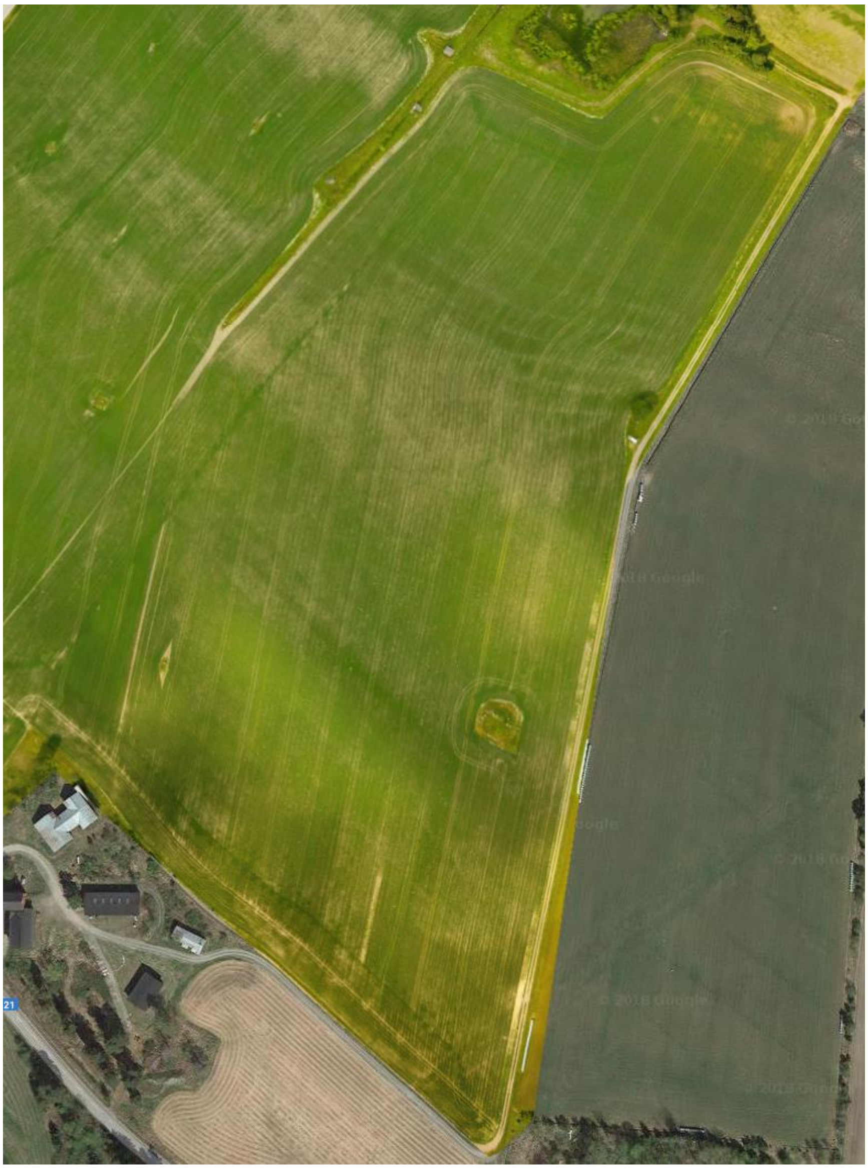

Fig. 13. Drone image of the Hovi field on the 16th of June 2018. Uneven sprouting between the in-field zones can be still seen in July form the image.

3. Dissemination

In addition to actual field demonstration day, the CIRCWASTE machine combination, used fertilizers and the whole concept of operation were introduced to a wider audience in Toivon Tila's field day in Salo on the 20th of June 2018. The audience consisted of farmers in the region, supply chain actors, advisors, research and press (Figure 14.). The audience had a possibility to see the machinery with its technical instrumentations on the farm yard. In the spring carried out precision combined seed drilling work in Viertola field was running as a simulation all the time. The seeding and fertilizing field operation was repeated using in the real field work recorded machine data. The progress of the field operation was able to follow from a map in the laptop screen and the screen of the ISOBUS terminal (Universal Terminal, UT). The site-specific fertiliser and seed application rates per input was able to follow also from the ISOBUS UT, when the tractor moved from one treatment zone to another in the simulation. The controllers of the actuators of the machinery were on, and the audience was able to observe, how actuators adjusted i.e. the fertilizer feeders according to the new application rate when the machinery crossed an application zone border line in the simulation. Also the samples of used fertilizers were introduced to the audience.

In addition a video showing the precision combined seed drilling work in the field was presented to the audience. The site-specific seeding and fertilisation plan of the Viertola field was available as a handout, and a tour to the Viertola field was arranged for interested. At that time the growth of the field was already in the start of the straw elongating stage, and the visitors were able to observe the outcome of the seeding and fertilisation operation.

Figure 14. Audience in the Toivon Tila's field day on the 29th of June 2018.

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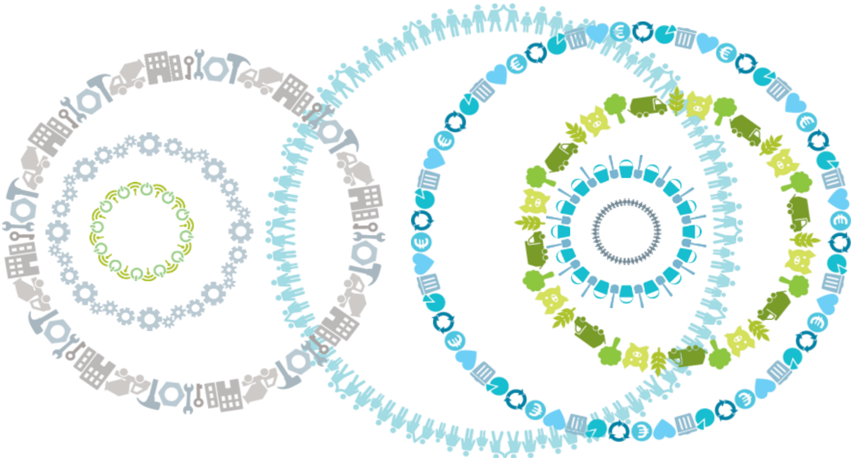

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