Documentation of fertilizer precision in headland

Tested on request by Future Cropping

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Documentation of fertilizer precision in headland

New method for documentation of fertilizer application

Prepared for
Future Cropping, Innovation Fund Denmark

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August 2019
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Innovationsfonden

FUTURECROPPING

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2. Introduction

The use of centrifugal spreaders has for many years been the most common used technology by the farmers for applying fertilizer in the field. During the last years, section control and VRT (Variable-rate technology) has been adapted of many of the manufactures of fertilizer spreaders to improve the precision, but what is the potential of improvement with section control, VRT technology, boom spreaders and other new and/or alternative technologies?
The purpose of this test was to determine the precision of fertilizing headlands when using a centrifugal fertilizer spreader without section control and thereby make data available for evaluating new technologies compared to a traditional spreading method.

Fertilizers spreaders are typical evaluated by measuring the coefficient of variance (CV) according *to EN 13739-2 Agricultural machinery — Solid fertilizer broadcasters and full width distributors - Environmental protection — Part 2: Test methods*. The test complies, when possible, with the EN standard to make comparable data available

3. Brief summary and assessment

The results indicate that there is a general tendency to applicate a lower rate in the headland area with the utilized type of fertilizer, when the spreader is handled according to the instruction manual, however, it is up to the driver to comply with the instruction.

The result show that the mean application rate of fertilizer in a 38-meter headland is close to the wanted rate over the hole area. In single point of measurements in the headland the distribution of fertilizer with a varying angle of degree of headland, show that the wanted rate is uneven, and use of section should control according to the standard can increase the yield, especially at headlands below 60°.

4. Test product

The 'no name' fertilizer spreader is a 'commonly used disc spreader' without section control and used according to the manufactures instruction and spread chart.

Spreading type:	double disc
Disc rotation direction	outside-in
Mounting	Lift-mounting
Spreading width	12-36 m
Hopper volume	1500 liters

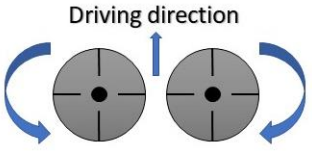


Figure 1. Disc rotation direction

5. Test method

The tests were conducted at Test Center Bygholm, Horsens. A test facility equipped with a heating and dehumidifying plant which ensures constant minimum temperature at 12 °C and maximum relative humidity of 50%.

The spreading patterns were tested by running the spreader across the measuring area at a speed of 4 km/h. The working width was 24 meters at an application rate of app. 300 kg/ha. The fertilizer was a Danish Agro NS 27-4 (7032508-1).

Figure 2. Bridge for driving across the measuring area consisting of 112 collectors in transverse direction

All measurements were carried out in an area consisting of 112 collectors. Each collector has the dimensions 0.50 × 0.50 m and a depth of 0.80 m.

Following four test-steps were conducted to obtain data which is used to determine the applicated amount of fertilizer in the 'area of interest' which is from the border in the headland and app. 2x working width into the field.:
Step:

1. 1 test run for determine *EOS* spreading pattern (Spreader set to spreading at headland)
2. 1 test run for determine *Normal* spreading pattern (Spreader set to spreading in the field)
3. 13 test runs for determine the 3D spreading pattern while *stopping* spreading at driving *toward* headland

4. 13 test runs for determine the 3D spreading pattern while *starting to spread* at driving *away from* headland

Step 3 and step 4 consists of 13 individual test runs each. The Spreading was *started* (step 3) or *stopped* (Step 4) respectively at 13 differently distances from collector trays:

-2.5m> 0m> 2.5m> 5m> 7.5m .....>27.5m (13 steps all in all)

Data from step 3 are merged into one data set to determine the 3D spreading pattern (displayed at figure 4) and in this way, imitate a driving *toward* the headland.

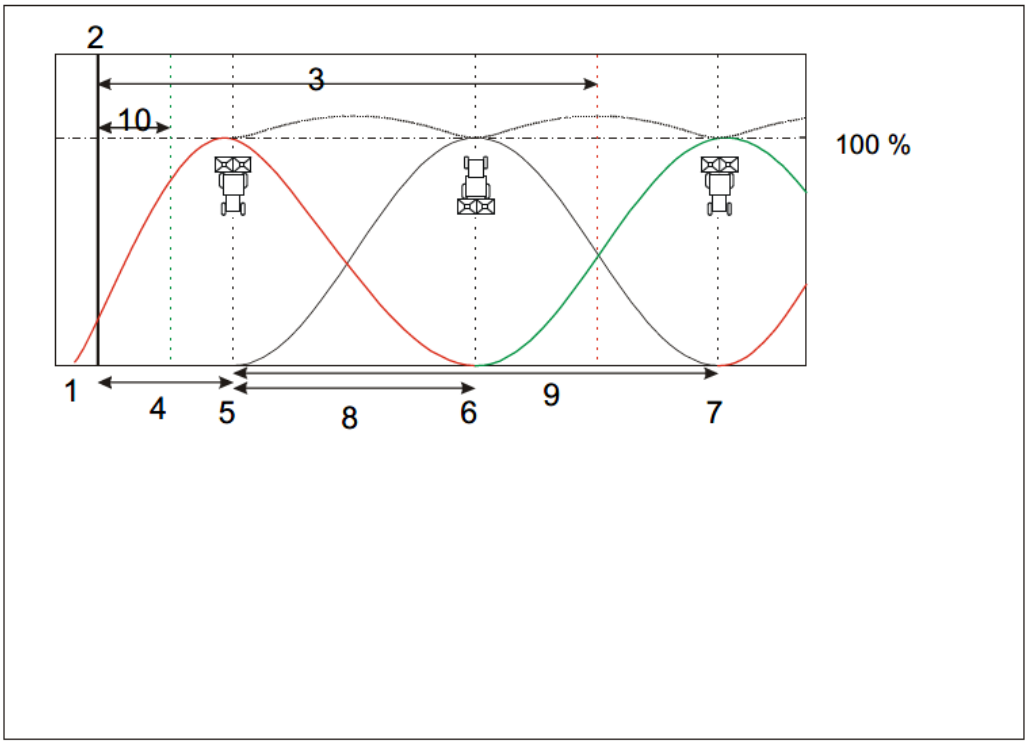
In the same way are data from step 4 are merged into one data set to determine the 3D spreading pattern (displayed at figure 5) and in this way, imitate a driving *away from* the headland.

Figure 3.
Red circle: Wood Blocks to indicate distance to collector trays and load cells (-2.5m> 0m> 2.5m> 5m> 7.5m .....>27,5m).
Green circle: Marker arm mounted on fertilizer spreader which indicate middle of spreader disc
Yellow circle: Collector trays with load cells

The red circle in Figure 3 shows the wood blocks with the given distance to collector trays and load cells (-2.5m> 0m> 2.5m> 5m> 7.5m .....>27.5m). The green circle shows a marker arm, installed on the spreader, which is aligned with the center of the spreading discs. When the marker arm passes the first block in test run 1, the second block in test run 2, the third block in test run 3, ... etc., the spreader is stopped or started respectively to the test (driving *toward* or *away from* headland).

Coefficient of Variation (CV) is calculated based on test results from 'normal spreading' and Coefficient in the Transition width (CT) is calculated as illustrated in EN 13739-1 (see below) based on test results from 'normal spreading' and 'EOS spreading'.

prEN 13739-1:2002 (E)



1 Fertilizer limit
2 Border
3 Transition width
4 Border distance
5 Edge tramline
6 First field spreading tramline
7 Second field spreading tramline
8 Working width
9 Throwing width
10 Edge width

According to the standard EN 13739, the impact of effect of yield are defined as:

Acceptable level of CV is 15 %. Coefficient of variation in the interval 15 - 30% will typical affect the yield. Above 30% will typical be able to be seen on the crops. (EN 13739 (CEN, 2003)).

The standard do not define levels for environmental impact from high and low level of fertilizer distribution in the headland.

6. Test result

EOS Spreading data
The result of EOS spreading (spreading at borders) with spreader settings according to the manufactures spread chart caused an unsatisfying distribution pattern and thereby a high CT value. Due to this, it was necessary to repeat the test with adjusted/optimized settings to achieve an optimal EOS spreading.

Table 1. EOS Spreading result (spreading at borders)

Description	Unit	result
EOS (Spreading at borders)		
Test 1. Spreader settings according to spread chart		
CT in transition area	CT	22.5
MAX in edge area	%	153.2
Test 2. Spreader settings adjusted		
CT in transition area	CT	15.1
MAX in edge area	%	97.3

See next page for detailed test result of EOS spreading. (20190402-007)

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Schüttesvej 17, Building 67-04

DK 8700 Horsens

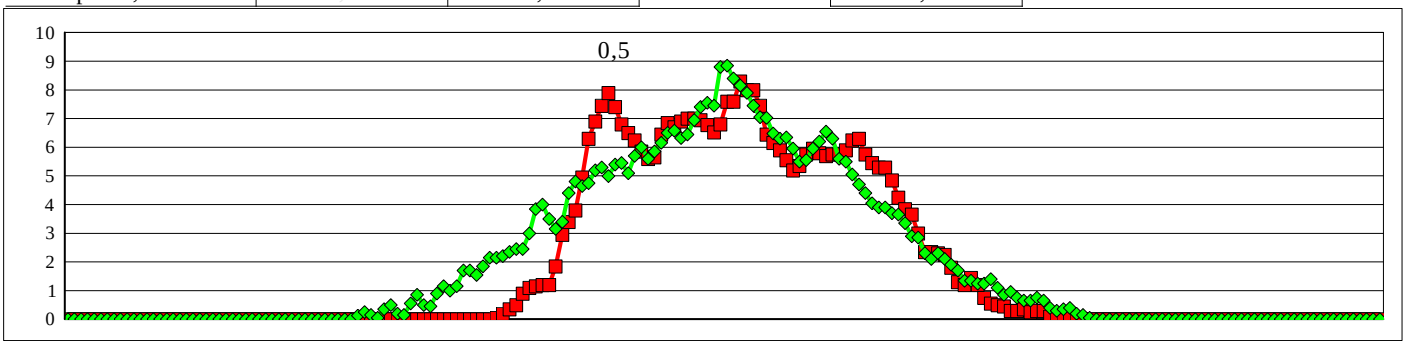
ERR

NS 27-4 (Achema)

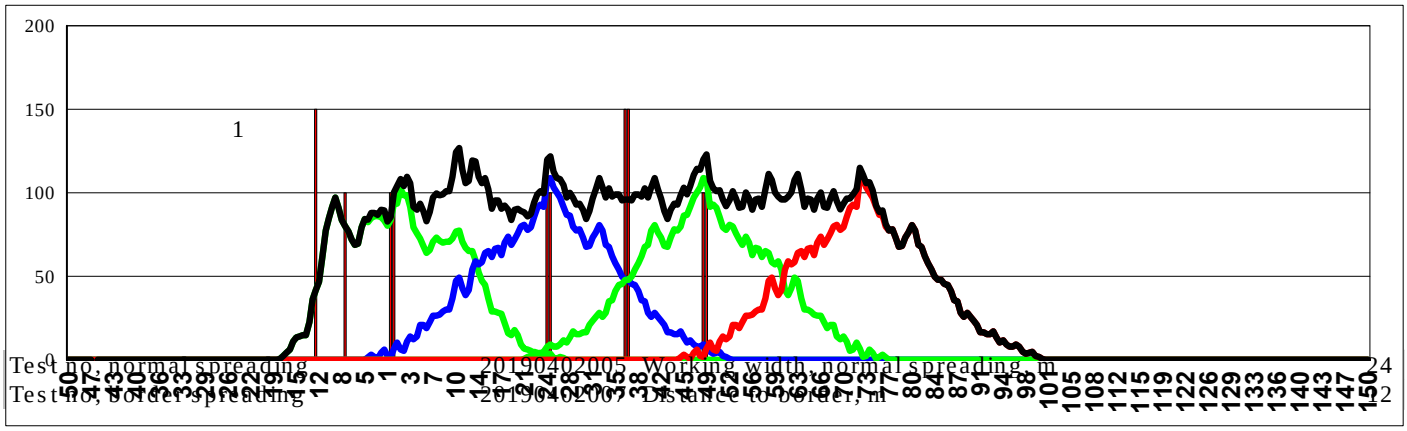
Date 5.5.2019

Time 16:38:49

Filnummer	20190402007	20190402007		20190402005	0
	Left	Right		Normal 1	0
Working width, m	24	24			
Distance to border, m	12				
Spreading type	EOS	EOS			
Wanted amount	300	300		300	
Application rate, kg/ha	300,7			324,9	
	Left	Right			
Opening	0,0	55		55	
Gear	0	1		1	
Disc type, left	0				
Disc type, rigth	0				
Vane pos, left	0				
Vane pos, rigth	0	0		0	
Inclination, deg	0	0		0	
Drop point	0,0	´9 / 6		1	
Disc speed	0 / 0	770	990 / 0	990 / 0	
PTO speed	0	700 / 0		900 / 0	
Mounting heigth, cm	0				
Speed, km/h	0,00	12,00		12,00	



			0,0	6,0	9,5	12,5
85,6	85,6	85,6	85,6	69,0	91,7	36,3



Test no, normal spreading 20190402005 Working width, normal spreading, m 24

Test no, border spreading 20190402007 Distance to border, m 12

Max in edge area	% (max 120)	97,3	Y = Loss from 100 m / ha, 0/00 (max 3)	7,0
CT in transition area	(max 25)	15,1	Distance to fertilizer limit, m	6,0

FERTILISER 2025 NS 27-4 (Achema)

Remark NORMAL

05-05-2019 16:39:25

BYGHOLM 2019.123

Normal Spreading data

The result of 'normal spreading' is shown in table 2 as a result of 4 repetitions.

Table 2. Normal spreading

Description	Unit	result
Normal spreading		
Spreader settings according to spread chart		
Wanted rate	**kg/ha**	**300**
Application rate	**kg/ha**	**315.9**
Deviation max	**%**	**26,3**
Deviation min	**%**	**-24.9**
CV	**%**	**9.2**

See next pages for detailed test results of normal spreading. (20190412-004, 20190412-018, 20190412-046, 20190412-060)

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NS 27-4

Date of calc. 29.4.2019 11:41

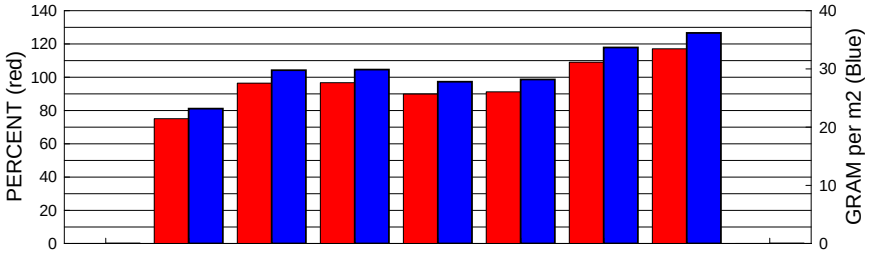
Test number 20190412004

Normal

Spreading 2019 / 4 / 12 / 1 / 4

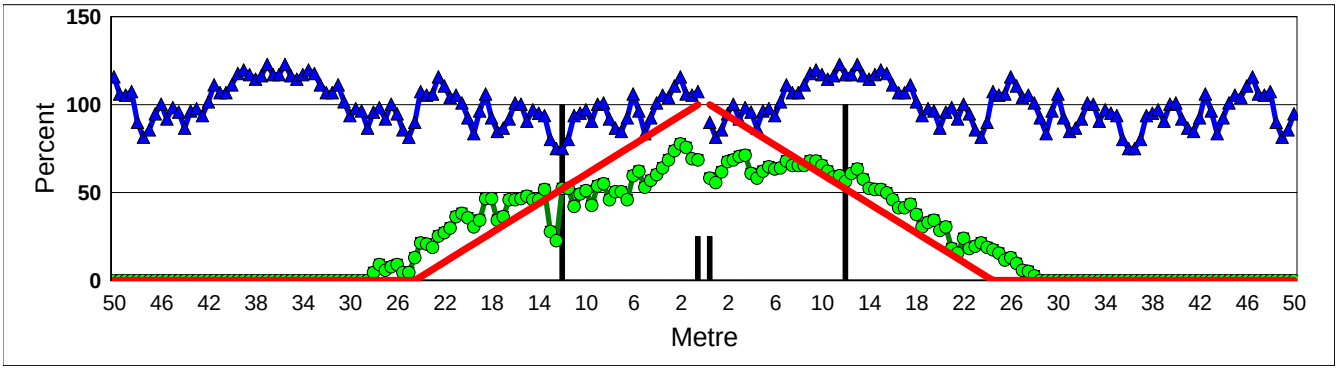
Spreader ID no		
Working width	24	m
Wanted rate	300	kg / ha
	48	kg / min
	Left	Right
Opening	0	
Gear - dosage	1	
Disc type		
Vane type	0	
Vane pos	0	0
Drop point	4	
Pto speed	900 / 0	rpm
Disc gear	0,000	ratio
Disc speed	990	rpm
Mount hight	85	cm
Tilt	0	degree
Tilt,	0	cm
Speed-act/sim	4,00	km/h
Distance to disc		cm
Number of runs	1,00	

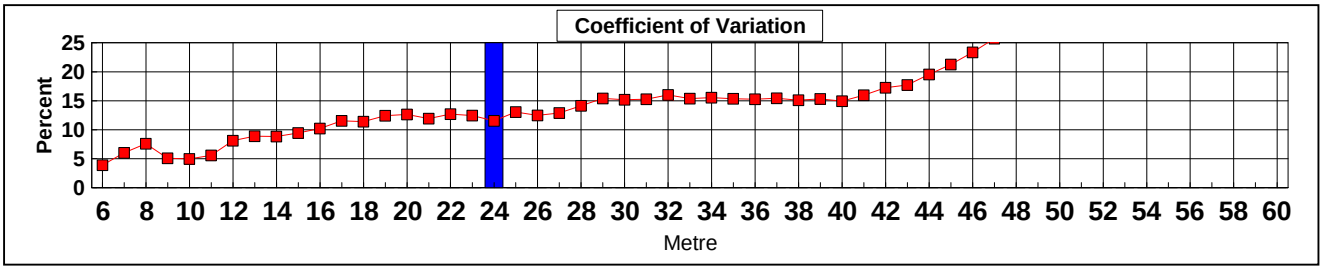
CV	11,54	%	
Deviation, max	22,94	%	
Deviation, min	-24,94	%	
Left / Right (SINGLE)	47,9 52,1	%	
Left / Right (DOUBLE)	47,9 / 52,1	%	% of intended
Application rate	309,1	kg/ha	103
Flow rate	49,45	kg/min	
Collected grams in test	370,90	gr	



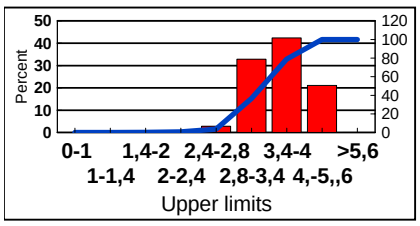
Dist	-12	-8	-4	0	4	8	12	
%	0,0	75,1	96,4	96,7	89,9	91,2	109,0	117,1	0,0
Gram	0,0	23,2	29,8	29,9	27,8	28,2	33,7	36,2	0,0

Remarks: **Std**





Fertiliser 2031



NS 27-4

Bulkdensity	944,5	gr/l
Flowability	4,2	Kg/min
Angle of repos	0,0	degree
D10	2,5	mm
D50	3,0	mm
D90	3,7	mm

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NS 27-4

Date of calc. 29.4.2019 11:48

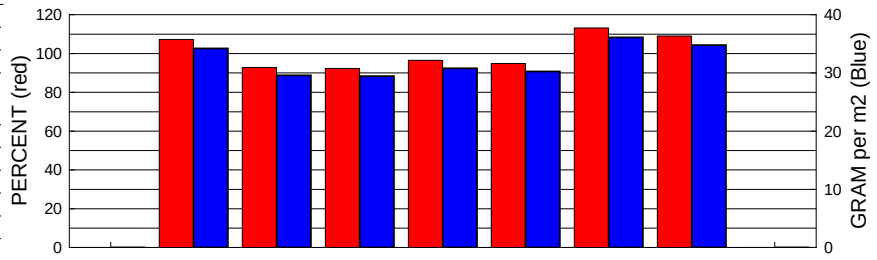
Test number 20190412018

Normal

Spreading 2019 / 4 / 12 / 1 / 18

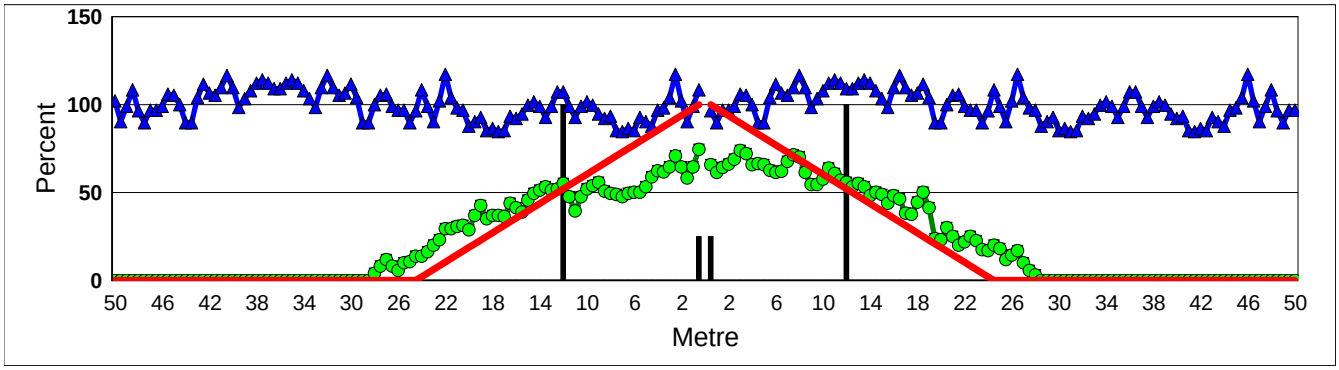
Spreader ID no		
Working width	24	m
Wanted rate	300	kg / ha
	48	kg / min
	Left	Right
Opening	0	
Gear - dosage	1	
Disc type		
Vane type	0	
Vane pos	0	0
Drop point	4	
Pto speed	900 / 0	rpm
Disc gear	0,000	ratio
Disc speed	990	rpm
Mount hight	85	cm
Tilt	0	degree
Tilt,	0	cm
Speed-act/sim	4,00	km/h
Distance to disc		cm
Number of runs	1,00	

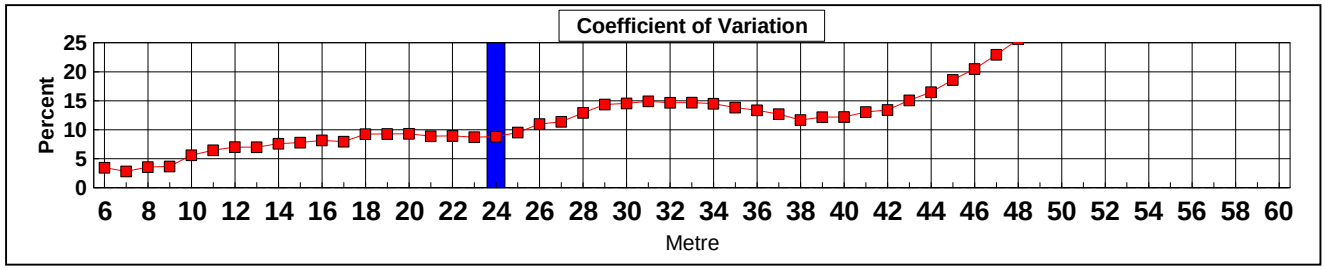
CV	8,81	%	
Deviation, max	17,26	%	
Deviation, min	-15,34	%	
Left / Right (SINGLE)	47,5 52,5	%	
Left / Right (DOUBLE)	47,5 / 52,5	%	% of intended
Application rate	318,9	kg/ha	106
Flow rate	51,03	kg/min	
Collected grams in test	382,73	gr	



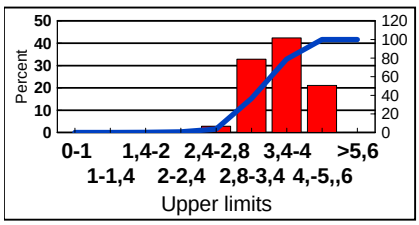
Dist	-12	-8	-4	0	4	8	12	
%	0,0	107,2	92,8	92,3	96,6	94,8	113,2	109,1	0,0
Gram	0,0	34,2	29,6	29,5	30,8	30,3	36,1	34,8	0,0

Remarks: **normal**





Fertiliser 2031



NS 27-4

Bulkdensity	944,5	gr/l
Flowability	4,2	Kg/min
Angle of repos	0,0	degree
D10	2,5	mm
D50	3,0	mm
D90	3,7	mm

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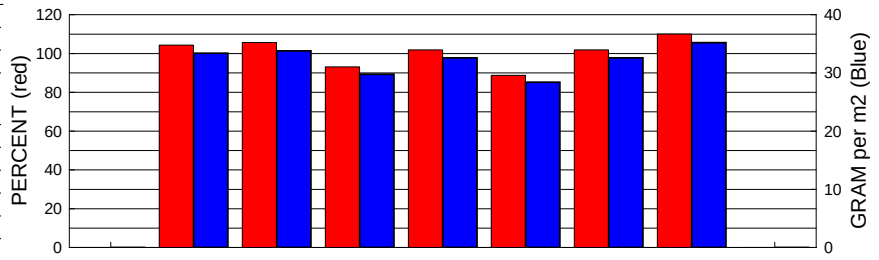
NS 27-4

Date of calc. 29.4.2019 12:07

Spreading 2019 / 4 / 12 / 1 / 46

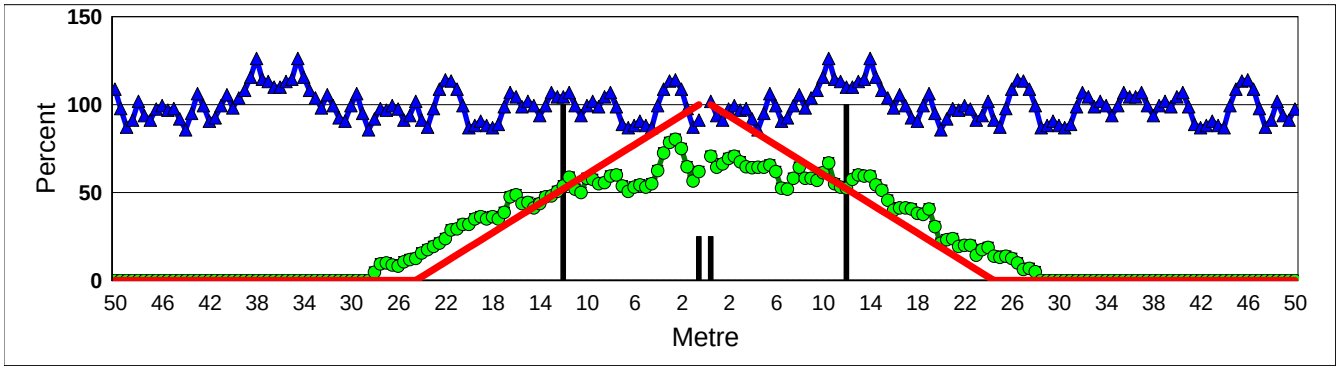
Test number	20190412046	
	Normal	
Spreader ID no		
Working width	24	m
Wanted rate	300	kg / ha
	48	kg / min
	Left	Right
Opening	0	
Gear - dosage	1	
Disc type		
Vane type	0	
Vane pos	0	0
Drop point	4	
Pto speed	900 / 0	rpm
Disc gear	0,000	ratio
Disc speed	990	rpm
Mount hight	85	cm
Tilt	0	degree
Tilt,	0	cm
Speed-act/sim	4,00	km/h
Distance to disc		cm
Number of runs	1,00	

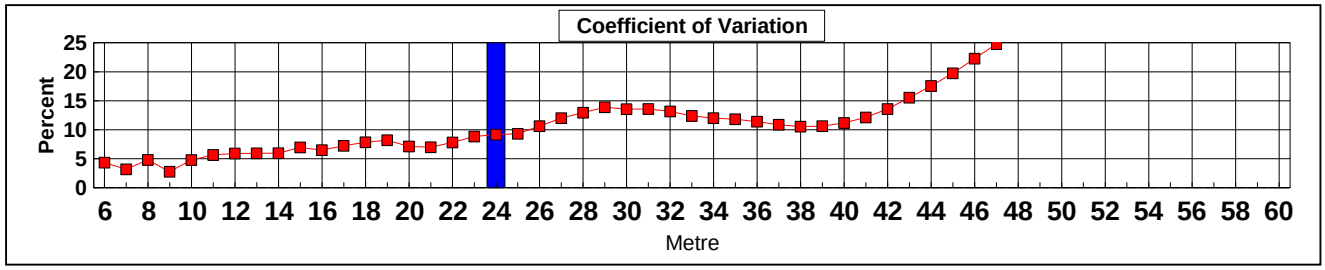
CV	9,17	%	
Deviation, max	26,29	%	
Deviation, min	-14,35	%	
Left / Right (SINGLE)	49,2 50,8	%	
Left / Right (DOUBLE)	49,2 / 50,8	%	% of intended
Application rate	319,9	kg/ha	107
Flow rate	51,18	kg/min	
Collected grams in test	383,88	gr	



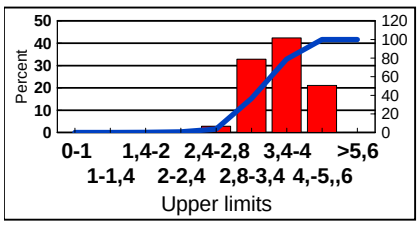
Dist	-12	-8	-4	0	4	8	12	
%	0,0	104,4	105,7	93,2	101,9	88,8	101,9	110,0	0,0
Gram	0,0	33,4	33,8	29,8	32,6	28,4	32,6	35,2	0,0

Remarks: **Normal**





Fertiliser 2031



NS 27-4

Bulkdensity	944,5	gr/l
Flowability	4,2	Kg/min
Angle of repos	0,0	degree
D10	2,5	mm
D50	3,0	mm
D90	3,7	mm

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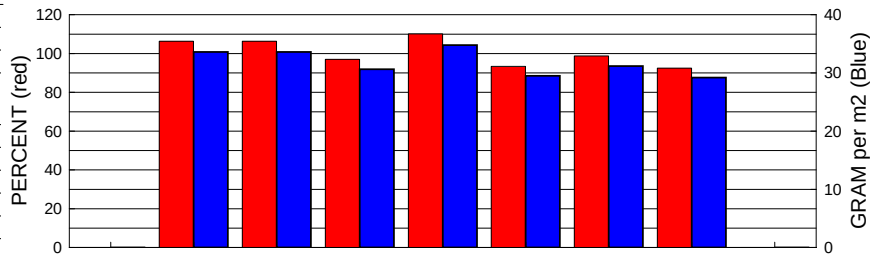
NS 27-4

Date of calc. 29.4.2019 12:13

Test number	20190412060	
	Normal	
Spreader ID no		
Working width	24	m
Wanted rate	300	kg / ha
	48	kg / min
	Left	Right
Opening	0	
Gear - dosage	1	
Disc type		
Vane type	0	
Vane pos	0	0
Drop point	4	
Pto speed	900 / 0	rpm
Disc gear	0,000	ratio
Disc speed	990	rpm
Mount hight	85	cm
Tilt	0	degree
Tilt,	0	cm
Speed-act/sim	4,00	km/h
Distance to disc		cm
Number of runs	1,00	

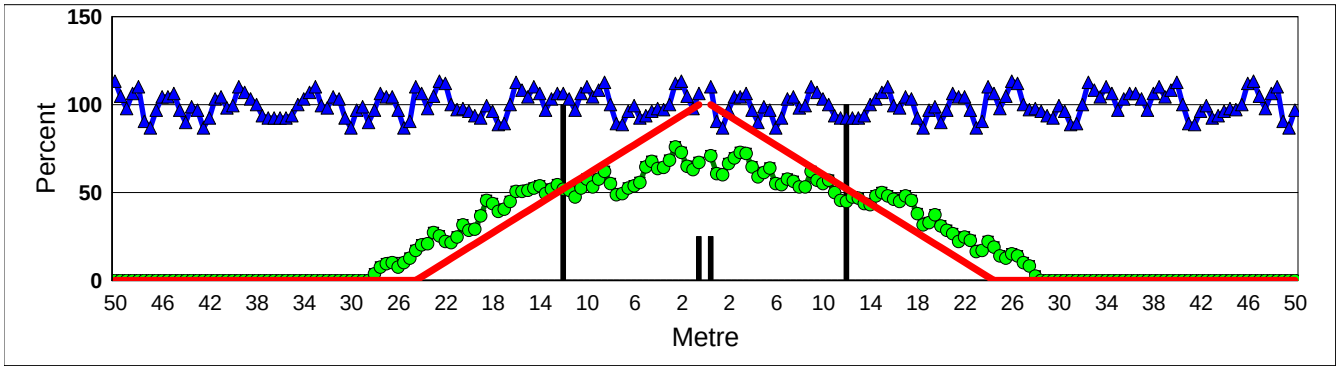
Spreading 2019 / 4 / 12 / 1 / 60

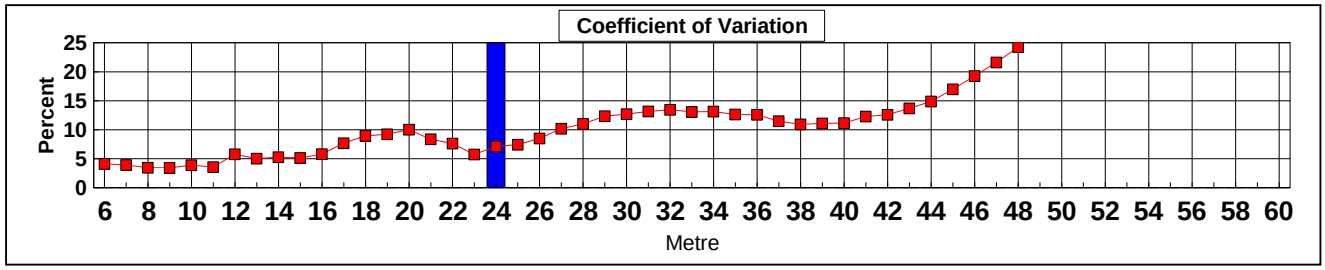
CV	7,14		%	
Deviation, max	13,35		%	
Deviation, min	-13,25		%	
Left / Right (SINGLE)	50,4	49,6	%	
Left / Right (DOUBLE)	50,4 / 49,6		%	% of intended
Application rate	315,8		kg/ha	105
Flow rate	50,53		kg/min	
Collected grams in test	379,00		gr	



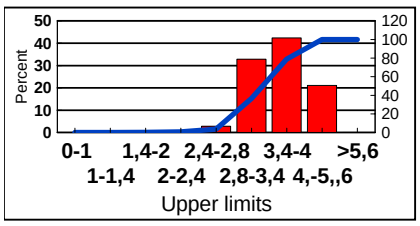
Dist	-12	-8	-4	0	4	8	12	
%	0,0	106,4	106,4	97,0	110,2	93,4	98,8	92,5	0,0
Gram	0,0	33,6	33,6	30,7	34,8	29,5	31,2	29,2	0,0

Remarks: **Normal**





Fertiliser 2031



NS 27-4

Bulkdensity	944,5	gr/l
Flowability	4,2	Kg/min
Angle of repos	0,0	degree
D10	2,5	mm
D50	3,0	mm
D90	3,7	mm

Data from spreading when driving toward headland

The results from test runs when driving *toward* and *away from* the headland are merged to determine the 3D spreading pattern in both directions. These 3D spreading pattern are shown in the following charts.

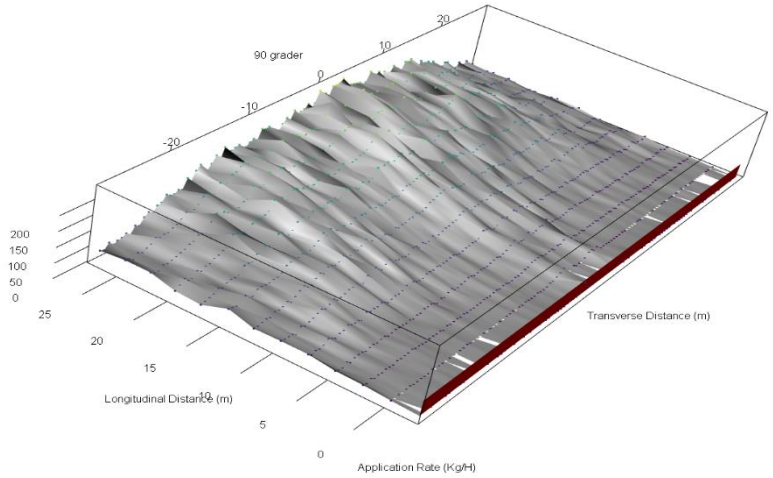


Figure 4. 3D spread pattern. Spreader stopped - driving toward headland.

Data from spreading when driving away from headland

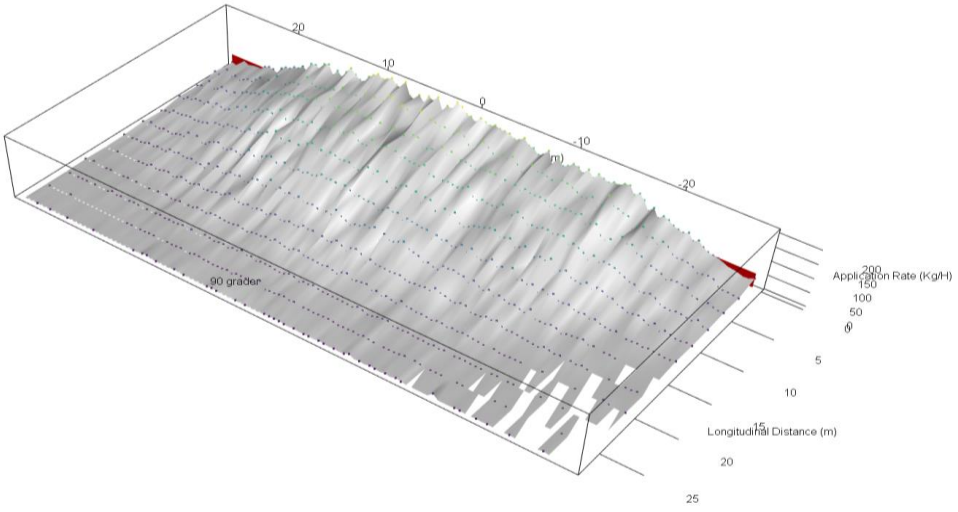


Figure 5. 3D spread pattern. Spreader started - driving away from headland.

The spread pattern for 'the area of interest' can be determined by merging all data into 5 different headland angles. The data is merged into a grid of 1x1 meter where after CV and application rate is calculated. Below is an example of data merged into a headland angle of 75°.

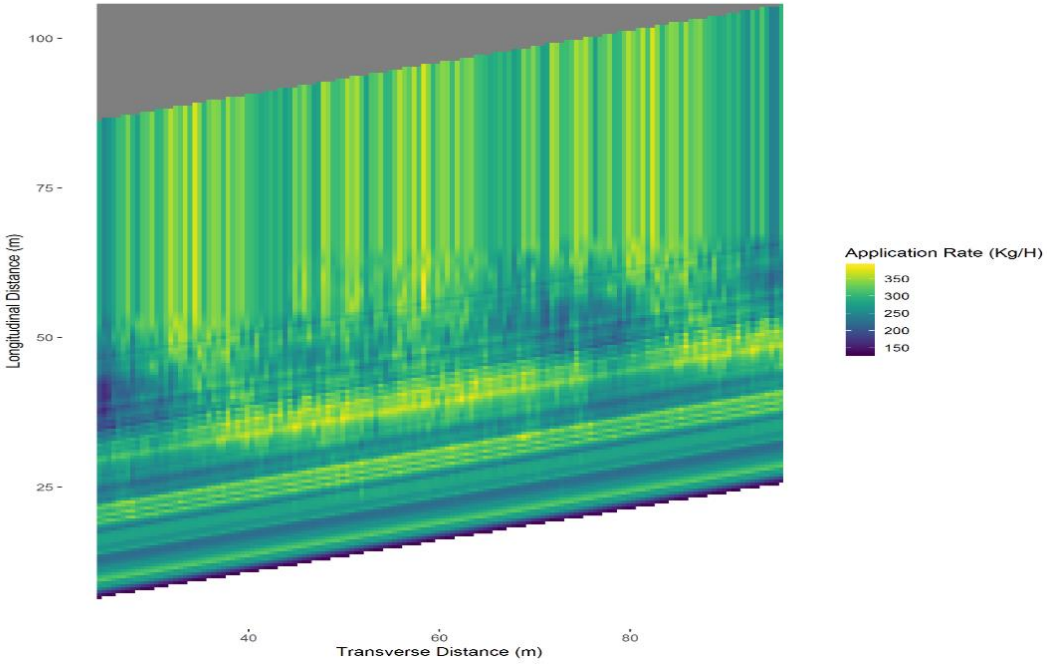


Figure 6. Example of 2D spread pattern in Headland Angle of 75°.

The following results are based on tests according to the spread charts for normal spreading and a corrected EOS spreading (spreading at border). Calculation angles: 90°, 75°, 60°, 30° and 15°.

Table 3. results from spreading at headlands with 5 different degrees (90°, 75°, 60°, 30° and 15°.)

Description	Unit	result
distribution in headland area		
Normal spreading - settings according to spread chart **EOS - settings adjusted**		
90° headland		
Wanted rate	kg/ha	300
Mean Application rate	kg/ha	307,0
CV (5-40 meter from headland border into field)	% [Average]	11,9
75° headland		
Wanted rate	kg/ha	300
Mean Application rate	kg/ha	299,8
CV (5-40 meter from headland border into field)	% [Average]	12,2
60° headland		
Wanted rate	kg/ha	300
Mean Application rate	kg/ha	298,9
CV (5-40 meter from headland border into field)	% [Average]	14,9
30° headland		
Wanted rate	kg/ha	300
Mean Application rate	kg/ha	299,3
CV (5-40 meter from headland border into field)	% [Average]	29,3
15° headland		
Wanted rate	kg/ha	300
Mean Application rate	kg/ha	312,9
CV (5-40 meter from headland border into field)	% [Average]	14,9

Coefficient of variation (CV, table 3) is calculated as a 'Local CV' means that it is the variation of the mean application rate in the field. It is calculated by looking at data-grids of 1 meter in parallel direction from line of headland border and into the field. (See figure 7)

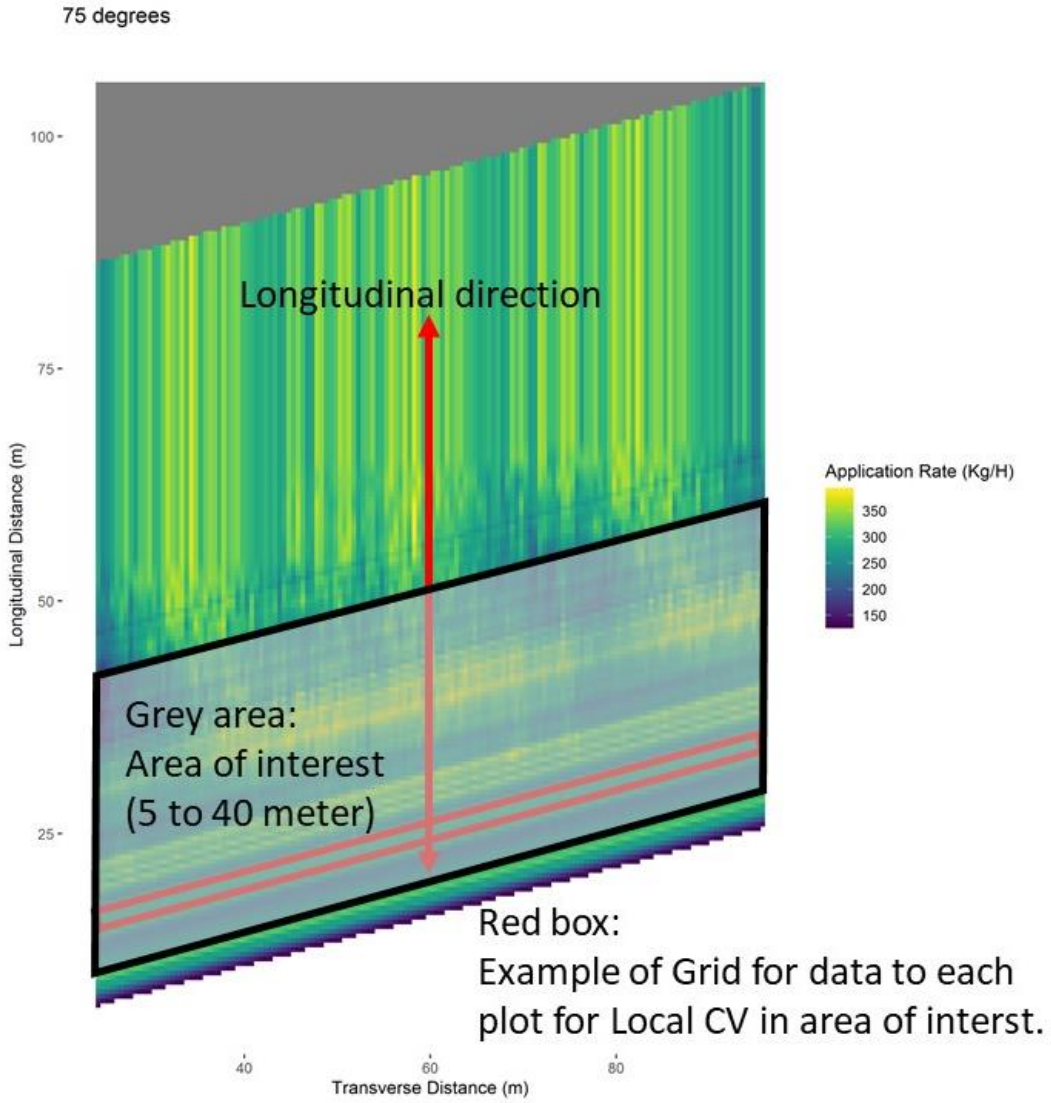
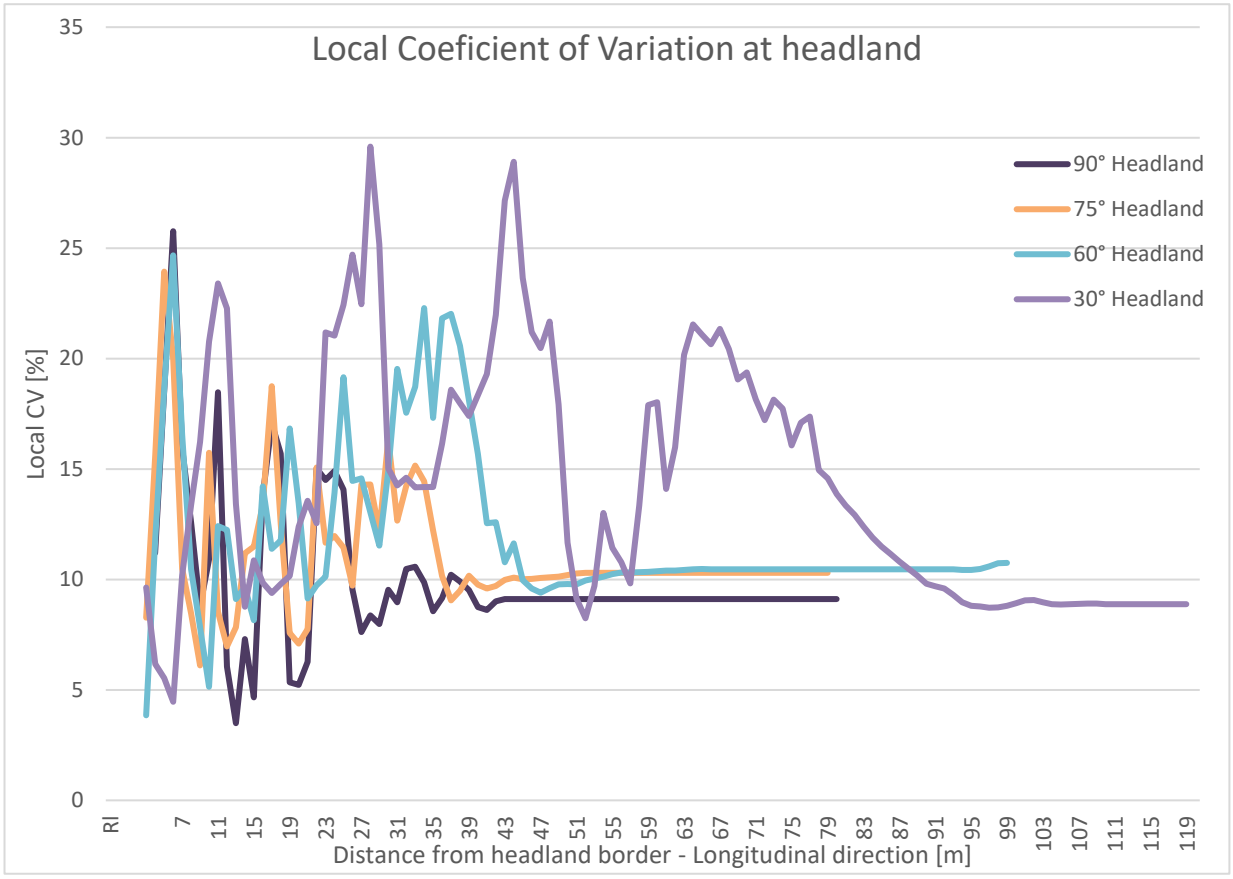
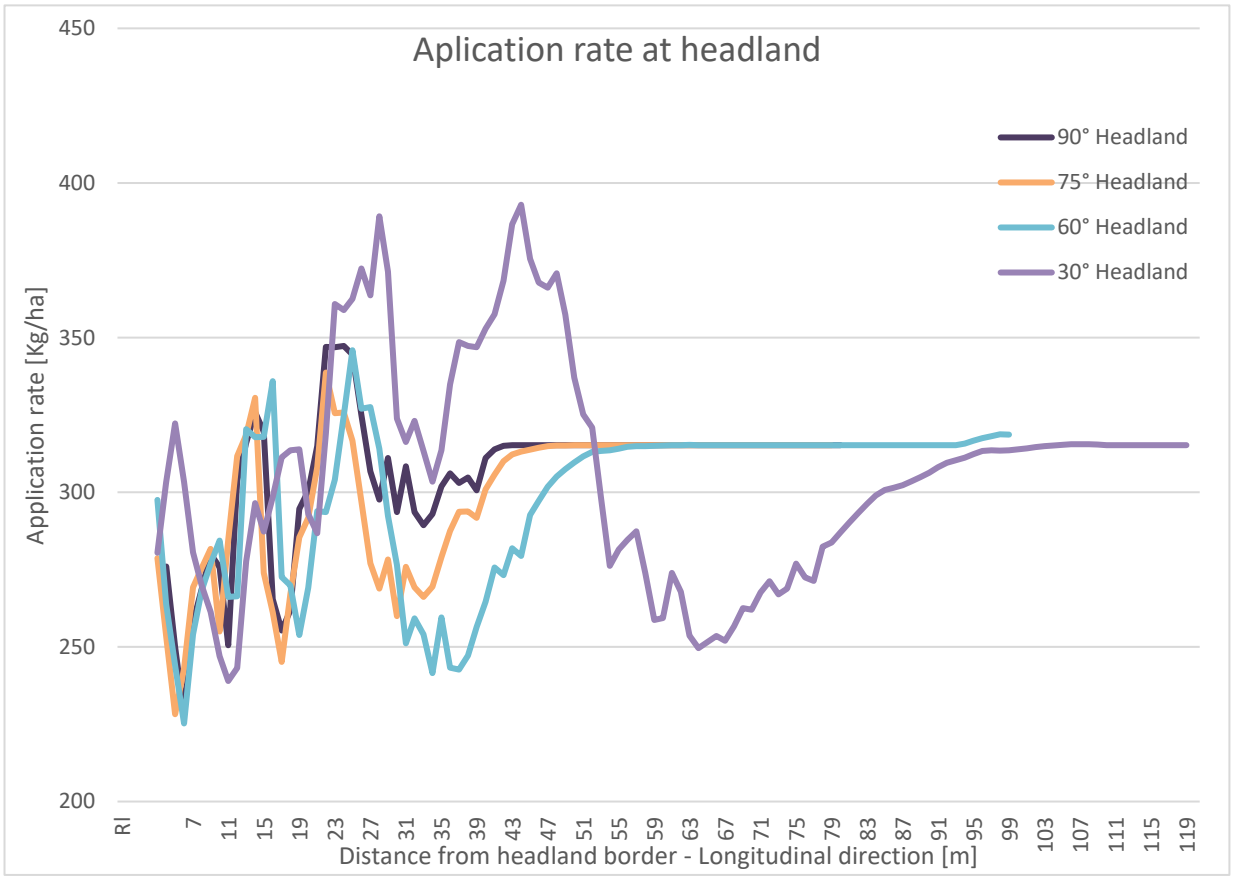


Figure 7. Example of Data-grid for calculate local CV and application rate in headland.


Local Coeficient of Variation at headland
Local CV [%]
35
30
25
20
15
10
5
0
RI
7
11
15
19
23
27
31
35
39
43
47
51
55
59
63
67
71
75
79
83
87
91
95
99
103
107
111
115
119
Distance from headland border - Longitudinal direction [m]
90° Headland
75° Headland
60° Headland
30° Headland

The application rate is calculated in the same way as Local CV.



Distribution in the headland is calculated from 0 to 38 meter from border and into the field.

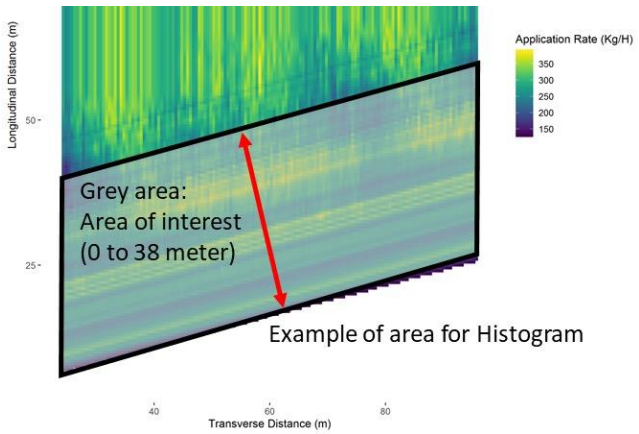
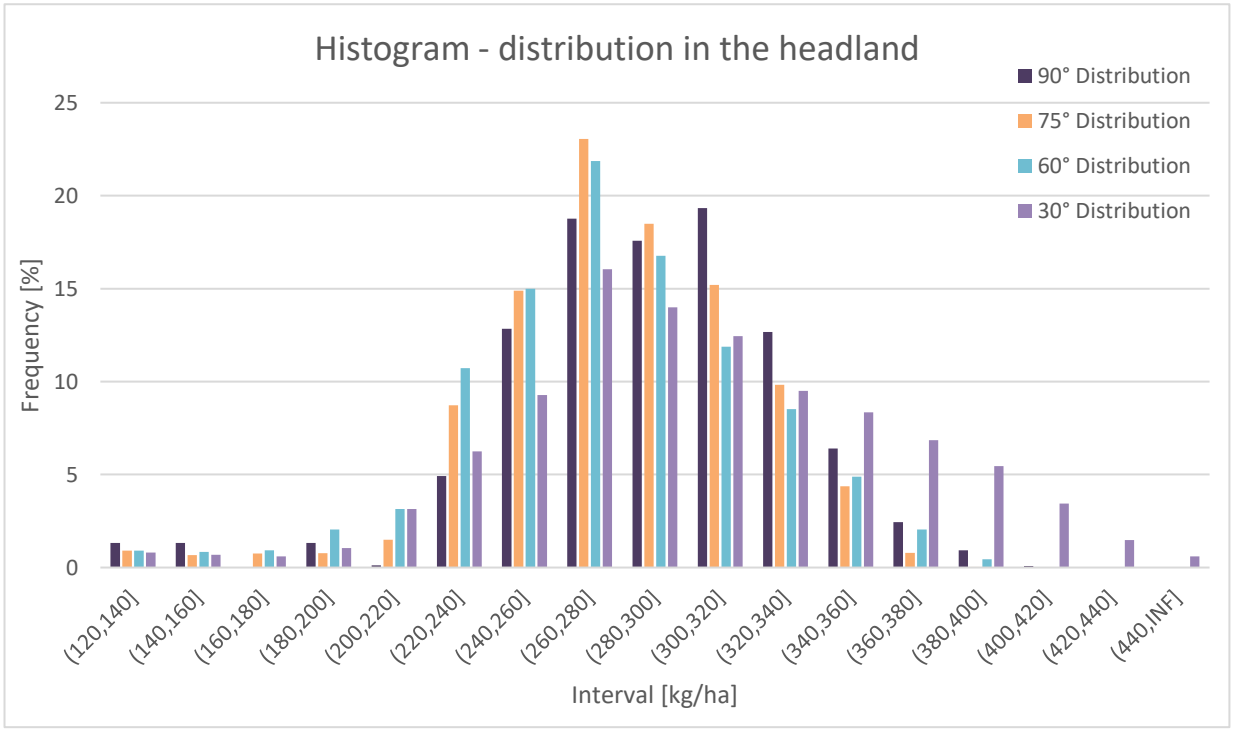


Figure 8. Area of data for Histogram. Example from 75° headland

The histogram below displays the distribution of application in intervals of 20 kg/acres at different angles of headland.



7. Summary

The EOS spreading (spreading at headland) with fertilizer spreader set according to the spread chart leads in this case to an abnormal high CT why a new test of EOS spreading with adjusted/optimized settings were conducted.

The results indicate that there is a general tendency to applicate a lower rate in the headland area with the utilized type of fertilizer, when the spreader is handled according to the instruction manual, however, it is up to the driver to comply with the instruction.

Looking at the CV at longitudinal direction 12 meters from headland border (middle of headland tram-lines) and further into the field shows that a headland angle above 75° can be handled without remarkable yield decrease, according to EN 13739: At 60° headland are the CV above 15 % in an area of app. 8-10 meter in longitudinal direction. At 30° headland are the CV above 15 % in an area of app 30-35 meter

The test results show that spreading without section control with the utilized type of fertilizer has no significant difference compared to the wanted rate on the whole area of 38 meters, when the spreader is handled according to the instruction. However, section control can increase the yield, especially at headlands below 60°.