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Aspects of Applied Biology

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https://www.aab.org.uk/aspects-of-applied-biology/

Aspects of Applied Biology ***99****, 2010*
International Advances in Pesticide Application

Precision of a sensor-based variable rate sprayer

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Summary

When spraying plant protection products (PPP) the used amount per spraying is generally based on a pre set dose. Most often fields with variations in crop development are treated uniformly while spraying some patches in these fields would have been sufficient. In order to deal with the variations in crop development and site-specific variations in a field, a sensor-based spray technology was developed; SensiSpray. The system consists of sensors to detect crop variation and a spray system to automatically change spray volume. Electronics and software were developed to use the output signal of the sensor NTech GreenSeeker to adapt spray volume. For the variation of spray volume (50–550 L ha^{-1}) Lechler VarioSelect nozzle bodies were used fitted with four different low-drift venturi flat fan nozzles. Spray deposition measurements were performed to test the sprayer accuracy in adapting spray volume based on the reflection signal per section, using a fluorescent dye (Brilliant Sulpho Flavine) added to the spray liquid. By moving diagonally over stripes of grassland, varying in greenness, longitudinal accuracy and lateral variation in spray deposition was quantified. The system showed to be able to adapt spray volume within 1–2 m in the direction travelled. In the 2007–2009 seasons different potato fields were sprayed and a general use reduction in PPP for potato haulm killing was *c*. 50%, maintaining efficacy.

Key words: Canopy density, sensor, spray technique, crop development, spray volume

Introduction

Crop protection products (CPP) are used in agriculture to protect the crop against pests, diseases and weeds. The use of CPP assures high yields at harvest and high quality agricultural products. Several sprayings of CPP are done per crop per season. The used amount of CPP per spraying is generally based on the advised dose and generally does not take into account what is to be sprayed, the target. During the growing season generally the dose is not adapted to changes in crop canopy structure (Scotford & Miller, 2005). More often the whole field is treated uniformly although spraying some patches in the field would have been sufficient. In order to deal with variations in crop development and site-specific variations in the field, a sensor based spray technology was developed; SensiSpray.

The system was built on a boom sprayer and consists of sensors to detect crop variation and a spray system to automatically change spray volume and therefore CPP dose depending on the sensor signal (Fig. 1) and an application specific dosing model. The sensors used were NTech GreenSeeker sensors that measure crop reflection. The Normalised Differential Vegetation Index (NDVI) output signal of these sensors was used (Schwab *et al*., 2005). A control unit, electronics and software were developed to use this output signal of the GreenSeeker sensors to adapt spray volume. To vary the spray volume Lechler VarioSelect nozzle bodies were used fitted with four different low-drift venturi flat fan nozzles (Böttger & Langner, 2003). Seven sensors were placed on a 27 m working width boom sprayer. Each sensor controlled the spray volume of a boom section of 3–4.5m wide.

Fig. 1. VarioSelect nozzle holder and GreenSeeker sensor placed on the spray boom, sprayer sprays a high volume above green grass (right) and a low volume above desiccated grass (left).

Spray deposition measurements were performed to test the sprayer's accuracy in adapting spray volume based on the crop reflection signal per section. A grassland field was prepared in 24 m wide strips next to each other with difference in biomass by extra N fertilization, mowing and herbicide treatment. Treatments resulted in distinct differences in biomass and vegetation colour and therefore reflection. The sprayer was passing across the strips at an angle of 45° at a speed of 6 km h^{-1} to get a clear view on the individual section changes on the sprayer boom. Measuring spray deposit was done using a fluorescent dye (Brilliant Sulpho Flavine) added to the water in the spray tank. The individual section sensor reacts on the change in reflection and spray volume was adapted per boom section.

To demonstrate the potential use of the SensiSpray system it was used in potato haulm killing spraying (Kempenaar & Struik, 2007). The variation in the field of the greenness (amount and activity of green biomass) of the potato canopy at desiccation spraying before harvest was used to vary spray volume of the herbicide used. The spray volume and dose adaptation was based on dosing algorithms of the Minimum Lethal Herbicide Dose Potato Haulm Killing system (MLHD PHK) relating reflection measurements with minimum dose needed to kill off potato canopy (Kempenaar *et al*., 2004). In the 2007 and 2008 season different potato fields were sprayed and a general use reduction in CPP for potato haulm killing was *c*. 50%. In the 2008 season preliminary SensiSpray was also tested in late blight (*Phytophthora infestans*) control in potatoes, adapting spray volume (dose) to the crop development during the early growing season.

Material and Methods

Spray technique

The SensiSpray system was built on a boom sprayer and consists of sensors to detect crop variation and a spray system to automatically change spray volume depending on the sensor signal. NTech

GreenSeeker sensors that measure crop reflection in the red and the near infrared wavelengths from which a NDVI output signal was used. Electronics and software were developed to use the output signal of the GreenSeeker sensor to adapt spray volume. For the variation of spray volume Lechler VarioSelect nozzle bodies were used fitted with four different low-drift venturi flat fan nozzles (Lechler IDK 12001, 120015, 12002, 120025). On a 27 m working width boom sprayer (Hardi New Commander Twin Force) seven sensors were placed, one for each boom section to control spray volume per section of 3–4.5 m wide.

Table 1. *Nozzle combinations, spray volume (L ha^{-1}) at 3 bar spray pressure, dose rate (L ha^{-1}) and NDVI level*

Combination	NDVI	Spray volume		Dose	IDK	IDK	IDK	IDK
		L ha^{-1}	%	L ha^{-1}	12001	120015	12002	120025
0	0	0	0	0				
1	0.28	78	14	0,42	X			
2	0.34	118	21	0,64		X		
3	0.39	160	29	0,87			X	
4	0.44	196	35	1,06	X	X		
5	0.44	198	36	1,07				X
6	0.50	238	43	1,29	X		X	
7	0.55	276	50	1,49	X			X
8	0.55	278	50	1,51		X	X	
9	0.60	316	57	1,71		X		X
10	0.66	356	64	1,93	X	X	X	
11	0.66	358	65	1,94			X	X
12	0.71	394	71	2,13	X	X		X
13	0.77	436	79	2,36	X		X	X
14	0.82	476	86	2,58		X	X	X
15	0.93	554	100	3.0	X	X	X	X

Spray deposition measurements

Spray deposition measurements were performed to test the sprayer accuracy in adapting spray volume based on the reflection signal per section. A grassland field was prepared in 20 m wide bands which were next to each other extra fertilized, mowed and treated with a herbicide to create differences in vegetation colour and therefore reflection.

The sprayer was driven at 6 km h^{-1} over the field in an angle of 45º, pulled by a tractor, fitted with a RTK-DGPS guidance system, to show the individual section changes on the sprayer boom. Travelling distance was 200 m, the track was run two times to do the measurements as two repetitions. Spray pressure was 3 bar and sprayer boom height was 0.50 m above crop height. In order to quantify the spray deposition at changes in crop type and within a constant crop reflection area different collector orientation were placed in the grass strips. Collectors used were filter material (1.00 m × 0.10 m; Technofil TF280) placed on individual PVC plates (A) at an angle of 45° with driving direction, 10 collectors next to each other on a 1 m^2 tempex plate with length direction in the driving direction, and 10 collectors in a row placed at grass strip edges in the longitudinal direction 3 m /7 m before after boundary and lateral to the driving direction over the total width of 30 m with the centre underneath the centreline of the driving track (Fig. 2). To correlate the position of the collectors with the actual volume rate sprayed of the moving sprayer the position of the collectors was measured with RTK-DGPS (Fig. 3). The actual rate sprayed from the individual sections at the spray boom is logged in the sprayer computer and connected to the RTK-DGPS position of the tractor cabin.

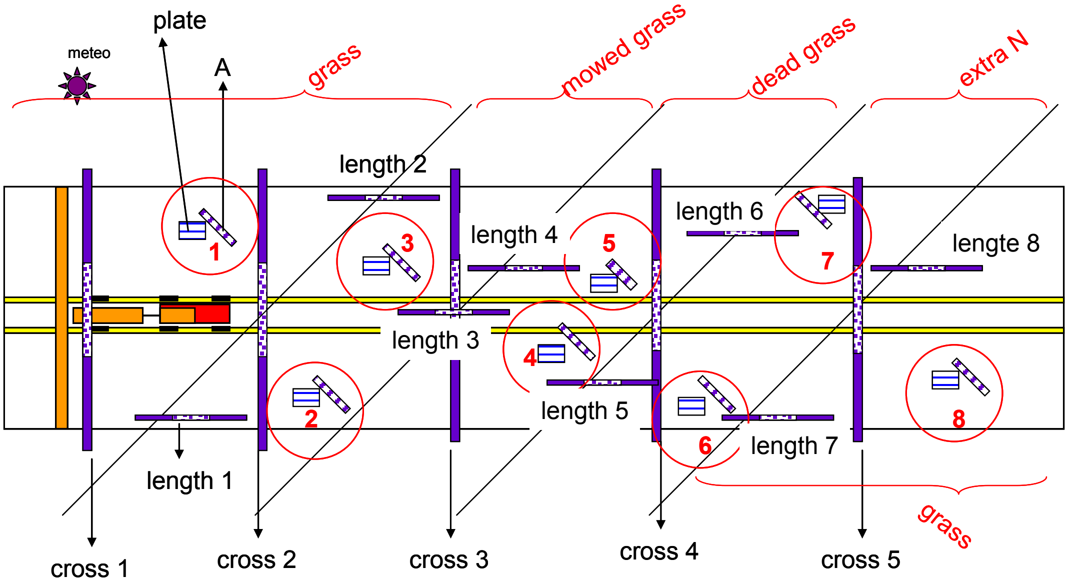

Fig. 2. Schematic presentation of the different grass strips in the test field and the position of the collectors placed.

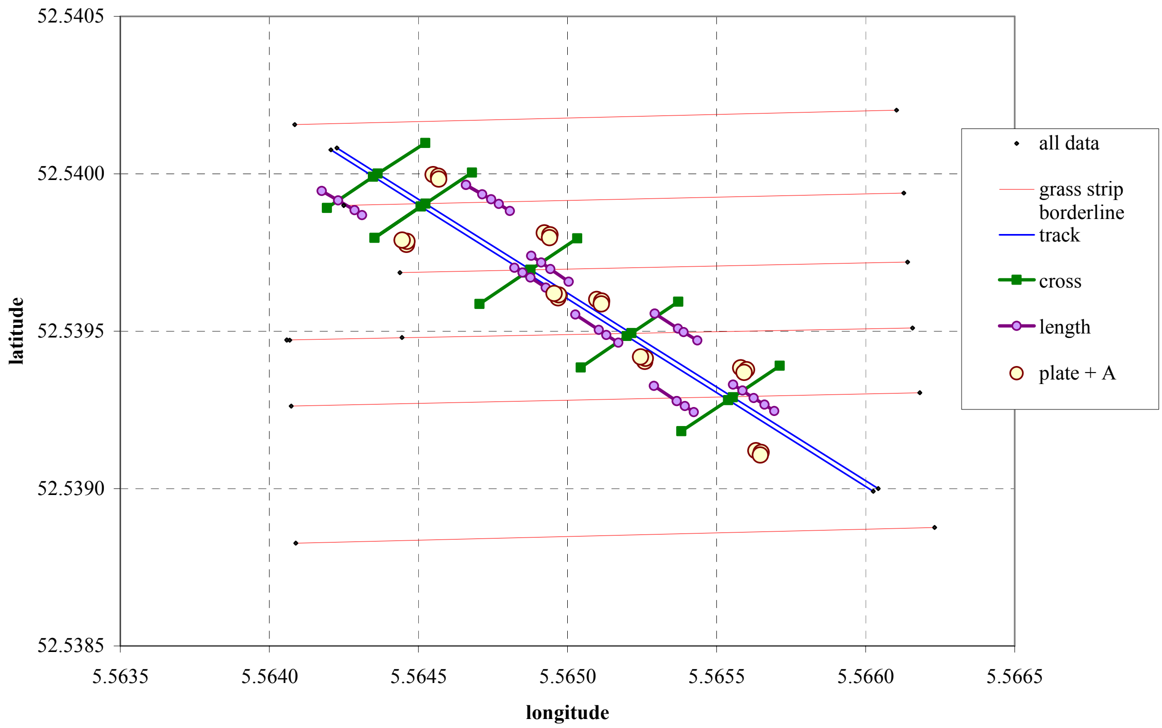

Fig. 3. Position of collectors in the field and position of spray track and grass strips measured with GPS.

Measuring spray deposit was done using a fluorescent dye (0.15 g L^{-1} Brilliant Sulpho Flavine; Chroma GmbH) added to the water in the spray tank together with 0.1% of Agral (Syngenta). After spraying the collectors were put individually in plastic bags, marked and stored in the dark. In the WUR-PRI spray laboratory the collectors were washed in 1 L of demineralised water and concentration of BSF was measured using a fluorimeter (Perkin Elmer LS45). Measured concentration was related to the measured tank concentration of BSF and a standard concentration curve to calculate spray deposition expressed as µL cm^{-2}.

The individual section sensor reacts on the change in reflection and spray volume was adapted per boom section. The spray volume and therefore dose adaptation was according to the changes in measured reflection expressed as Normalised Differential Vegetation Index (NDVI) of the different bands of grassland. Specifically for this spray deposition test the calculated dose of agrochemical

(3.3 L ha^{-1}) was linearly related to NDVI as: DOSE = - 0.7 + 4*NDVI.

During spraying average temperature was between 15.9°C and 17.5°C, relative humidity was 79%, wind speed was 1.7 m s^{-1} and 2.3 m s^{-1} during the two runs over the grass field. Wind angle was for the first run around 40° from left behind and for the second run right ahead.

Results

Crop reflection

NDVI recordings of the seven GreenSeeker sensors running over the different grass strips are presented in Fig. 4. From left to right NDVI value for standard grass was on average 0.6, for mowed grass 0.43, for dead grass 0.25, for extra N fertilised grass 0.89 and for standard grass land again 0.6. As the sprayer drove over the strip borders under a 45° angle the order of the sensors passing the borderline is clearly seen.

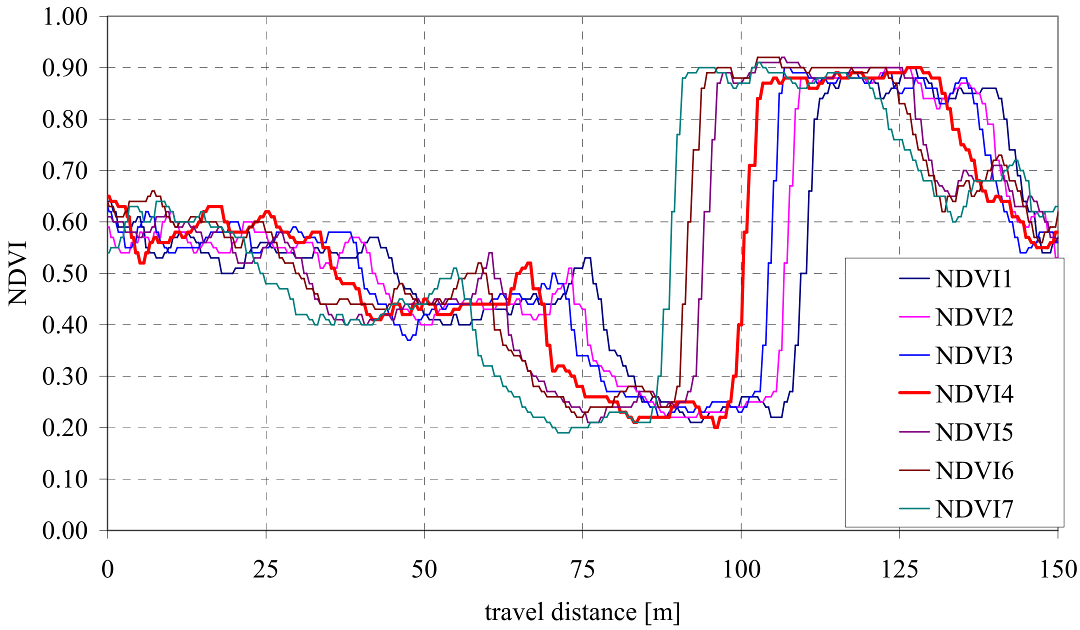

Fig. 4. NDVI of the seven GreenSeeker sensors running different grassland strips.

Spray deposition

At the borders of the different grass strips the spray deposition was measured both in the longitudinal direction and the lateral distribution.

Lateral distribution

Lateral distribution of realised spray deposition at the borders of the grass strips from grass to grass, mowed grass to grass, dead grass to mowed grass, grass to extra N-fertilised grass and dead grass to mowed grass are presented in Fig. 5. It is clearly seen that from the centreline of the sprayer either to the right or to the left within a width of 3 m the difference between the grass strip NDVI results in a change in spray volume. Especially the grass to extra N fertilised grass and the dead grass to mowed grass show large differences in right and left boom side spraying.

Longitudinal distribution

Longitudinal distribution of realised spray deposition at the borders of the grass strips from grass to mowed grass, mowed grass to dead grass, dead grass to extra N fertilised grass and extra N fertilised grass to grass are presented in Fig. 5. Especially the change in spray deposition from dead grass to extra N fertilised grass is very clear. Within a distance of 2 m the spray dose has been adapted to the changed NDVI measured by the GreenSeeker sensor.

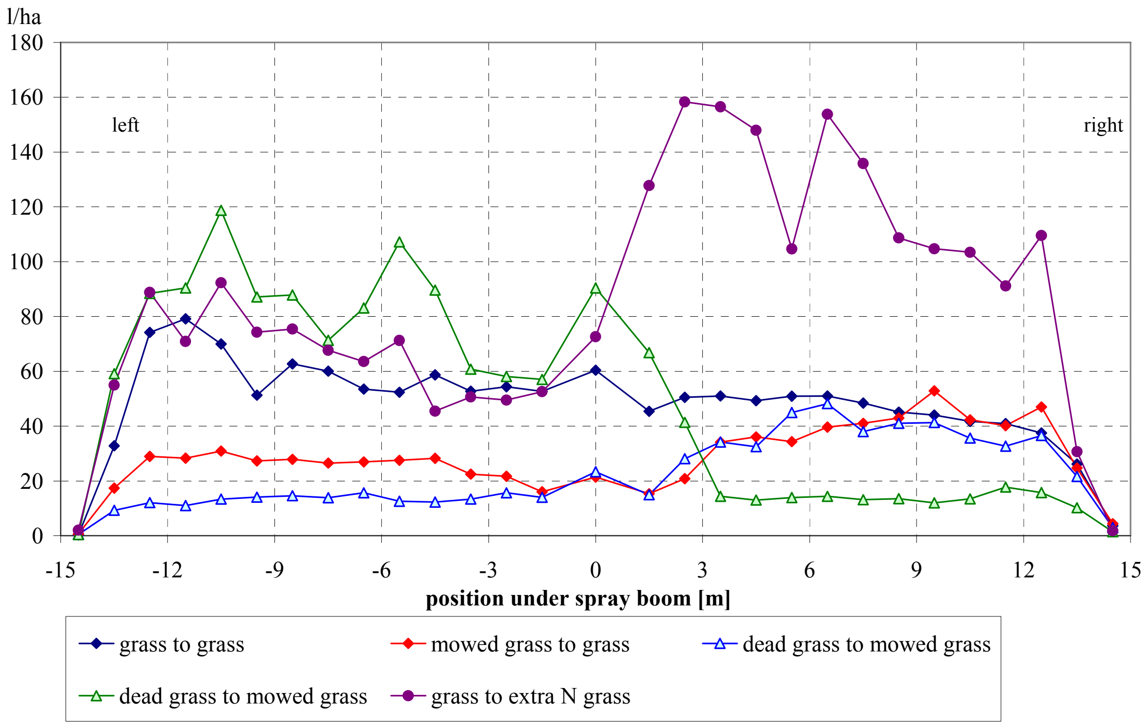

Fig. 5. Lateral distribution of spray deposition (L ha^{-1}) underneath a 27 m spray boom when passing the different border edges of grass strips under an angle of 45°.

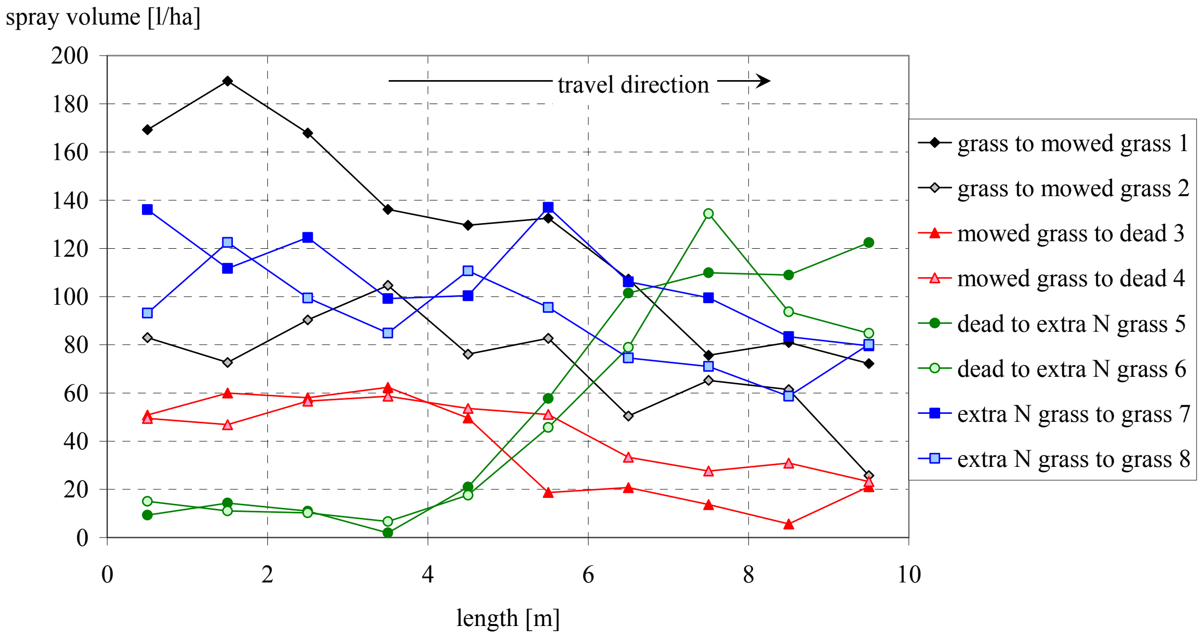

Fig. 6. Longitudinal distribution of spray deposition (L ha^{-1}) underneath a 27 m spray boom when passing the different border edges of grass strips at angle of 45° with the driving direction.

Length of spray volume adaptation depended on the position of the sensor relative to the position of the collector line.

Discussion and Conclusions

The spray volume and therefore dose adaptation was according to the changes in measured reflection (NDVI) of the different bands of grassland. The accuracy of the system to adapt spray volume was within 1–2 m from the borderline of the different grass bands. However a difference between the two passes over the same track was recorded in spray deposition. Spray deposition of the second pass was consequently lower although NDVI was recorded exactly similar. Also the expected spray deposition level following from the maximum target rate was not met. We hypothesize that the continuous switching of the nozzles in the VarioSelect nozzle holder based on the continuous changing GreenSeeker NDVI values reduces flow rate. Possibly the opening of a specific nozzle is slower than closing of another whereby gaps in spraying occur and flow rate is reduced. This is a point for further research and potentially software adaptation.

The different collector places and orientation used in the spray deposition measurements show that on average there is little difference between the measured spray deposition. The aim of the different collector orientation and places give however more information on the specific issues as absolute height of spray deposition (flow rate check) with the single (A) collectors; detailed lateral distribution (plates) as if a patternator is used in the field; or longitudinal and lateral distribution underneath changing spray volumes. For determining the accuracy of precision spray equipment this methodology has shown its value and could be an element for standardisation of measuring protocols (ISO/CD24543).

Potential use of SensiSpray

To demonstrate the potential use of the SensiSpray system it was used in potato haulm killing spraying. The variation of greenness in the field (amount and activity of green biomass) of the potato canopy at desiccation spraying before harvest was used to vary spray volume of the herbicide used. The spray volume and dose adaptation was based on calculation rules of the Minimum Lethal Herbicide Dose system (MLHD-PHK) relating reflection measurements with minimum dose needed to kill off potato canopy. In the 2007–2008 seasons different potato fields were sprayed with SensiSpray and the MLHD-PHK dosing algorithms, resulting in a reduction in CPP for potato haulm killing of *c*. 50% compared to conventional practice, while biological efficacy remained good. As an example of the experienced variation in crop canopy and NDVI reflection the results of the dose variation sprayed for a high and a low variable field of potatoes is given (Fig. 7). Average dose for the high variation potato strip was 0.85 L ha^{-1} of herbicide and for the low variation strip 0.77 L ha^{-1}. Lowest dose was 0.5 L ha^{-1} for both strips and highest dose respectively 1.9 L ha^{-1} for the high variation strip and 1.5 L ha^{-1} for the low variation strip, resulting in coefficients of variation of 25% and 20% respectively. Conventional dose of potato haulm killing herbicide for the field was advised as 2 L ha^{-1} because of the desiccation stage of the crop canopy whereas advised label dose was 3 L ha^{-1}.

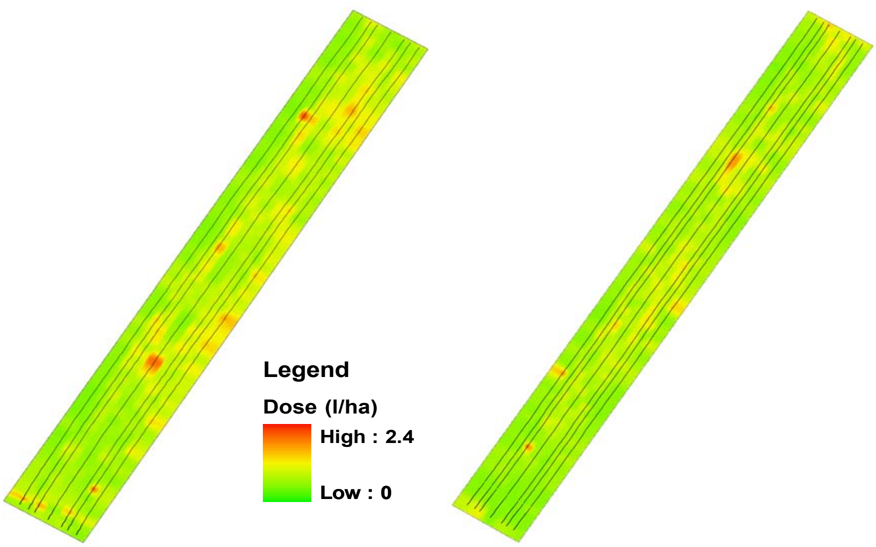

Fig. 7. Sprayed dose (L ha^{-1}) during potato haulm killing of a strip of a potato field with high variation and low variation in greenness of the crop canopy with the SensiSpray sprayer.

During the 2008 season first tests were done in late blight (*Phytophthora infestans*) control in potatoes adapting spray volume to the crop development at the beginning of the growing season. At the first three fungicide applications spray volume and dose was reduced. First results show no difference in disease development between conventional spraying and canopy adapted dose spraying with the SensiSpray system with good protection against late blight. The NDVI measurements in the SensiSpray project yielded much information on spatial and temporal variation of crop biomass in potato, wheat, tulip and onion crops, and how to use this successfully in a site specific pesticide dosing system.

Acknowledgement

The authors greatly acknowledge the financial support provided by the Ministry of Agriculture Nature and Food Safety and SenterNovem (SMT programme).

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