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Plant-specific and canopy density spraying to control fungal diseases in bed-grown crops

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Abstract

Matching spray volume to crop canopy sizes and shapes can reduce the use of plant protection products, thus reducing operational costs and environmental pollution. Developments on crop adapted spraying for fungal control are highlighted in arable crop spraying. A plant-specific variable volume precision sprayer, guided by foliage shape and volume (canopy density sprayer; CDS) was developed for bed-grown crops to apply fungicides. Sensor selection to quantify crop canopy and spray techniques to apply variable dose rates are evaluated based on laboratory measurements. Sensor-nozzle combination delay time was determined for the different nozzle settings and combinations. Optimal sensor-nozzle distances could be determined to specify sprayer design. Based on the laboratory experience a prototype CDS sprayer was built using either a Weed-IT or a GreenSeeker sensor to detect plant place (fluorescence) or size (reflectance). Variable rate application was either done with a pulse width modulation nozzle or a Lechler VarioSelect switchable four-nozzle body. Spray volume could be changed from 50-550 l/ha in 16 steps. Spray deposition, biological efficacy and agrochemical use reduction were evaluated in a flower bulb and a potato crop during field measurements using a prototype CDS sprayer. Spray volume savings of a prototype plant-specific sprayer are shown to be more than 75% in early late blight (*Phytophthora infestans*) control spraying in potatoes. In flower bulbs (lily) it was shown that in fire blight (*Botrytis* spp.) control on average spray volume could be reduced by 45%. In a potato crop biological efficacy was maintained at the same good level as of a conventional spraying. In a flower bulb crop biological efficacy of the CDS was lower than of conventional spraying, which means that spray strategy and dose algorithms need further research.

Keywords: crop development, sensor, spray technique, spray distribution, spray volume, biological efficacy

Introduction

In crop spraying the goal is to achieve a uniform spray deposition all over the crop canopy structure or soil surface. Losses to the soil underneath the crop and outside the field, through spray drift are to be minimised. It is known that sprayer settings are important for spray distribution in crop canopy. Matching spray volume and direction to crop size and shape can reduce chemical application, thus reducing operational costs and environmental pollution. Manual or sensor actuated sprayers have shown potential reductions in agrochemical use of 30% and more. Sensors quantifying crop parameters such as quantity of biomass and photosynthesis activity are already commercially available. Sensors to evaluate the plant stress (MLHD, 2004; Polder, 2004) or spectral analysis of the crop canopy parameters (Bravo *et al.,* 2003; Schut, 2003; Vrindts *et al.,* 2003; Scotford and Miller, 2004) open the potential for more target oriented spraying in crop protection. Spray systems treating individual plants based on fluorescence (Rometron, Weed-IT) as used on pavements (Kempenaar *et al.,* 2006) or canopy reflection information (Ntech, GreenSeeker) used for fertilising are already developed. Precise application techniques recently developed able to vary dose rates are obtained by Pulse Width Modulation nozzles (Weed-IT) and multi-nozzle holders (Lechler VarioSelect) with switchable number of nozzles varying in flow rate (Dammer and Ehlert, 2006); respectively in a continuous (50-300 l/ha) and a stepwise way (50-600 l/ha in 16 steps). Based on these possibilities we can achieve smaller units of treatment in the field. In spraying crop protection products this will lead from a full boom width treatment to section wise and even nozzle wise variable applications. This paper describes an example in which the different elements of precision farming are combined in a Canopy Density Sprayer (CDS) for bed-grown crops like flower bulbs and potatoes which is under development (Zande *et al.,* 2005).

Materials and methods

A Canopy Density Sprayer (CDS) for bed-grown crops like flower bulbs and potatoes is under development. This CDS prototype spraying system combines detailed crop information (fluorescence and spectral reflectance) with very accurate application techniques. The system sprays only when there are crop plants under the spraying nozzle(s) (Figure 1). When leaves emerge from the soil only the leaves are sprayed: the sprayer operates as a patch sprayer. When the crop develops it forms rows and the CDS becomes a band sprayer. When the crop canopy covers the whole bed, only the bed will be sprayed but not the paths in between. When the crop develops to its maximum height (flowering) spray volume will be adapted to crop height or total leaf area to cover total leaf area uniformly. Expected reductions in agrochemical use vary from 25% in the full-developed canopy to more than 90% in the initial leaf stage based on crop growth development evaluations during the growing season of flower bulb crops grown on beds (Zande *et al.,* 2008).
Canopy adapted spraying systems are momentarily tested in prototype versions in potato and flower bulb crops to apply fungicides against late blight in an early potato crop and fire blight in a lily flower bulb crop.

Plant-specific spraying against late blight in potatoes
The first experiments with plant-specific spraying against late blight in potatoes were done in autumn 2007 (WUR-PPO experimental farm, Lelystad) and were repeated in the 2008 growing season. In this experiment it was shown how much chemicals can be saved by switching on and off nozzles when spraying against late blight (*Phytophthora infestans*) and whether biological efficacy remained comparable with conventional application methods. A prototype using Weed IT sensor-spray elements was built for this purpose enabling the spray to be placed in 10 cm bands and 5 cm length direction accuracy. The machine was prepared to work at a width of 2.25 m, on

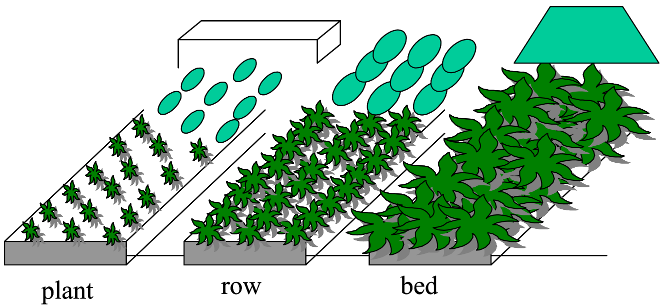

Figure 1. Schematic presentation of the development of a Canopy Density Sprayer for bed grown crops.

the top of 3 potato ridges (Figure 2). The conventional spraying machine (Figure 3) used TeeJet XR11004 nozzles (3 bar spray pressure) at 50 cm nozzle spacing applying a spray volume of 300 l/ha (5 km/h). Boom height between the soil and the crop canopy was 75 cm. The fungicide applied (Shirlan) was made as a tank mix in a jerry can and placed on a 'Spider 15' balance with an accuracy of ten grams. The amount of spray volume used was determined by weighing the jerry can with the chemicals before and after every treated field (2.25×10m). The average used dosage (l/ha) of every field was compared to that used in conventional spraying.
The experiment contained seven treatments; untreated plus six treatments sprayed with Shirlan (fluazinam) to protect the crop against late blight (*Phytophthora infestans*). Fields were sprayed with both conventional and Weed-IT spray techniques at dose rates of 75% (0.3 l/ha) and 25% (0.1 l/ha) of recommended dose (0.4 l/ha).
After the treatments, leaves were picked to analyze them in the laboratory for protection against late blight. The leaves were inoculated with a few drops of a *Phytophthora* spore suspension and *Phytophthora* development on the leaves was visually evaluated after 6 days.

Plant specific and canopy reflection dependent spraying against fire blight in flower bulbs
In the flower bulb crop lilly a prototype CDS sprayer (Figure 4) was used to apply the fungicide Allure (1.6 l/ha) in a plant specific way using Weed-IT elements and a canopy density way using a

Figure 2. Pulse width modulation nozzles.

Figure 3. Conventional sprayer applying 300 l/ha.

Figure 4. Prototype Canopy Density Sprayer for bed grown crops used in a lilly crop; left in early growth stage still individual plants; right in late growth stage with fully covered bed.

SensiSpray (Zande *et al.,* 2009) element of 1.5 m wide working width. Maximum dose rates were varied between full dose and half dose by adapting tank mix concentration. In the Weed-IT sprayer TeeJet 400067 flat fan nozzles were used with a nozzle spacing of 0.10 m. Individual plants were sprayed based on the Weed-IT green sensor. The SensiSpray sprayer was equipped with Lechler VarioSelect nozzle bodies at 0.50 m spacing containing 4 Lechler ID9001 venturi flat fan nozzles, able to switch and therefore apply spray volumes in steps of 130, 260, 390 and 520 l/ha depending on the measured NDVI of the Greenseeker sensor. For the conventional application one of the nozzles of each VarioSelect nozzlebody was replaced with a TeeJet XR11004 flat fan nozzle. All systems operated at 3 bar spray pressure. Driving speed was for the conventional and SensiSpray applications 3.6 km/h and for the Weed-IT 3.0 km/h, thereby all applying around 530 l/ha.
During the growing season crop protection against fire blight (*Botrytis* spp.) was done with weekly scheduled fungicide applications of the conventional, Weed-IT and SensiSpray spray techniques at two maximum dose rates (4 replications). Used spray volume per individual field (1.5×7 m) was quantified by weighing the sprayed amount on the sprayer. Fire blight (*Botrytis* spp.) infection was monitored during the growing season using a 0-10 scale. 10 means no infection, 9 is 5% of plants infected, 6 means 40% of plants infected, and 0 a means complete desiccated crop, with no green area left.

Results

Field test of a CDS sprayer in potato leaf blight control

First experiments of late planted potatoes in autumn 2007 showed that the measured quantity of sprayed volume during applications on the different dates varied between 75% and 84%.These savings coincided with measured crop coverage of soil surface. No difference in protection against late blight was found between the spray techniques and dose rates, except for the Weed-IT 75% dose on October 23 which was significantly lower than the other techniques. From these first experiments it was concluded that individual plant spraying gave equal good protection against late blight with use of less than 25% of the standard applied amount of fungicide.
In the 2008 experiments early season sprayings resulted in a reduction of sprayed volume of the Weed-IT application of between 25% and more than 50% for individual sprayings (Figure 5) compared to the conventional applications.
Measured spray deposition on plant canopy differed for the Weed-IT application from the conventional spraying as average spray deposition was lower (Table 1). However variation between depositits on plant parts related to the switching of the nozzles of the Weed-IT showed no larger

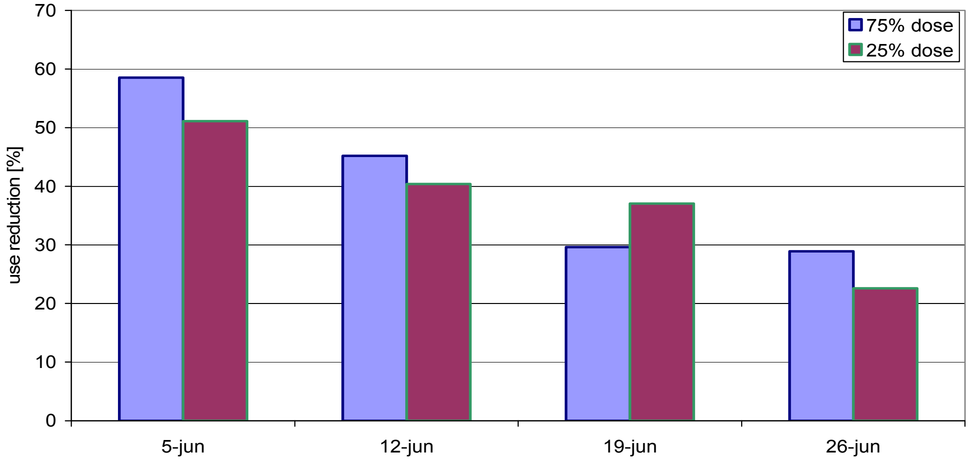

Figure 5. Use reduction of fungicide (% compared to conventional) in early potato late blight control using a Weed-IT sprayer for plant specific application.

Table 1. Spray deposition (µl/cm^2) for conventional and plant specific Weed-IT application of fungicides in potatoes early in the season on different places of the plant, top of plant canopy and soil surface underneath.

Spray technique	Spray deposition [µl/cm^2]								
	On plant						Above crop canopy	Soil surface	
	front	centre	left	right	back	sum		Top ridge	Between ridge
Conventional	0.89	1.00	0.82	0.78	0.72	0.85	1.34	0.55	1.08
Weed-IT	0.65	0.78	0.65	0.46	0.62	0.63	0.36	0.40	0.49

variation than of the conventional spraying. Spray deposit on soil surface was lower for the Weed-IT spray system as expected.

In late blight control during early sprayings there was no difference in biological efficacy between conventional and Weed-IT sprayings for the 75% dose (Table 2). At first instance the 25% dose had a lower protection level for both applications techniques. After two additional sprayings the difference in protection level was less for the conventional spraying but still clear for both dose rates of the Weed-IT sprayings. This suggests that there is a higher risk with the plant-specific spraying, which probably is related to the difference in spray deposit. Further research is needed on this subject.

Field test of a CDS sprayer in fire blight control in lily

The prototype CDS sprayer equipped both with a Weed-IT and a SensiSpray spray boom was in 2008 used for a season long spraying of fungicides against fire blight (*Botrytis* spp.) in a lily crop. The canopy related dosing of both systems was active throughout the season. For all applications between early June and mid August spray volume reduction (Figure 6) for the Weed-IT system was between 40% and 55% compared to conventional application (530 l/ha). The two late August

Table 2. Protection against late blight (Phytophthora infestans) expressed as % infected potato leaf area for conventional and Weed-IT plant specific application of 75% and 25% of advised dose (0.4 l/ha) of Shirlan at early season spraying dates.

Objects	Infected leaf area (%)			
	5-jun	12-jun	19-jun	26-jun
Untreated	99.7	98.6	97.8	99.1
Conv 75%	12.1	13.9	3.4	0.6
Conv 25%	22.9	29.8	5.8	3.1
Weed-IT 75%	20.0	14.5	3.8	1.6
Weed-IT 25%	23.4	29.5	10.8	7.4
lsd0.05	6.8	7.1	3.8	2.8

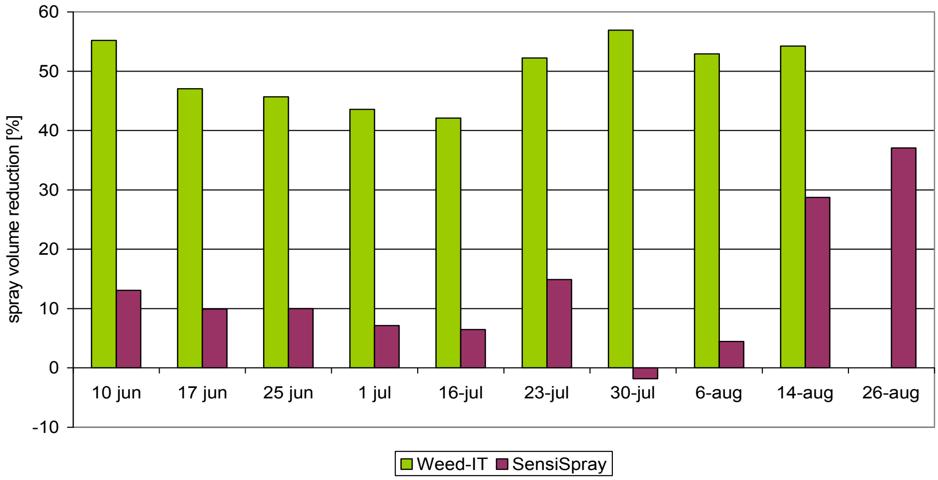

Figure 6. Spray volume reduction (% compared to conventional 530 l/ha) for Weed-IT and SensiSpray CDS spray techniques during the 2008 growing season of a lily crop.

sprayings could not be done because no green tissue was left. The SensiSpray system resulted only in around 10% reduction in spray volume during early season sprayings. This because of the set NDVI (GreenSeeker) and dose relation (spray volume) algorithm which was inappropriate for the lily crop development. Also at last sprayings in August there was an increase in spray volume reduction because of a decrease of green leaf tissue at the end of the season. This desiccation of the lily crop was however more for both the Weed-IT as the SensiSpray applications than for the conventional applications.

Spray deposition (µl/cm^2) in the lily crop was measured early July when crop height and soil coverage was maximum. On top of the canopy there was little difference between the spray techniques (Figure 7). In the middle leaf level the Weed-IT had a higher sprayer deposition than the conventional spraying and the SensiSpray (being lowest). At the lowest leaf level spray deposition of the Weed-IT and the conventional spraying were comparable and of the SensiSpray lowest.

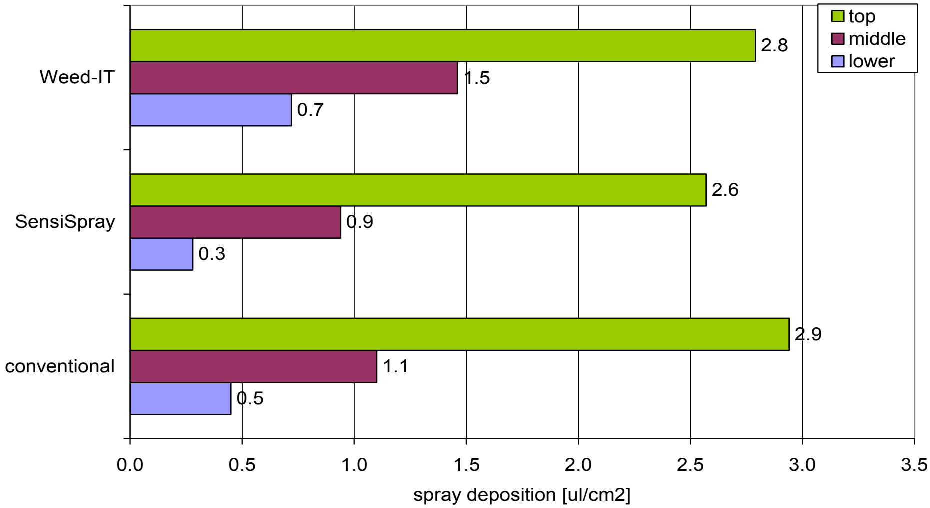

Figure 7. Spray deposition ($\mu l/cm^2$) in a lily crop divided in top, middle and bottom leaf layers for a conventional spraying, and Weed-IT and SensiSpray CDS spray techniques.

Biological efficacy was evaluated throughout the growing season. First detection of fire blight was late July in all objects (Table 3). In the Weed-IT and SensiSpray fields there was a rapid decline in green area because of fire blight infestation. This resulted in the end at harvest time also in lower average bulb weights, especially of the SensiSpray system. As the dose-spray volume algorithm of the SensiSpray was used throughout the season it is now discussed whether it should be adapted in order to improve spray deposition depending on growth stage and GreenSeeker NDVI signal. This is subject for further research.

Discussion

Canopy Density Spraying on bed-grown crops, like potatoes and flower bulbs, have shown a potential reduction in PPP use, especially with first sprayings of the crop early in the growth season. Also when

Table 3. Protection against fire blight (*Botrytis* spp.) expressed as scale infected lily leaf area for conventional, SensiSpray and Weed-IT plant specific application of 100% and 50% of advised dose (1.6 l/ha) of Allure at last season spraying dates and relative bulb yield.

Spray technique	Dose allure 1.6 l/ha	Fire blight development				Relative bulb yield [% of 2]
		25-jun	23-jul	14-aug	26-aug	
Control		no disease	9.8	1.8	0.0	77
Conventional	100%		9.8	8.5	6.8	100
Conventional	50%		9.8	8.8	7.5	97
Weed-IT	100%		9.8	6.5	2.0	89
Weed-IT	50%		9.8	7.3	4.0	87
SensiSpray	100%		9.8	7.8	5.5	51
SensiSpray	50%		9.8	8.0	6.8	50

the crop covers soil surface completely but still develops in crop height and leaf mass, a reduction in PPP is possible maintaining biological efficacy. Further development of Canopy Density Spray systems and more target oriented sprayings can be realised when diseases are detected before visual appearance. Sensor evaluation shows potential in this direction. The evaluation of combinations of sensor and spray systems on the market show that some steps are still to be made before a good working Canopy Density Spray system is fully operational in practice (Zande *et al.,* 2008). First field tests of a prototype plant-specific fungicide application with a CDS-prototype (Weed-IT) show a reduction of 75-84% in agrochemical use for the first 3 fungicide applications maintaining a good protection against late blight in potato. Potato plants were still individually standing and crop coverage during these applications was around 30%. In lily flower bulb spraying use reductions were obtained between 10-50%. However biological efficacy of CDS spraying decreased compared to conventional spraying. Algorithm development to put better relations between crop reflection measurements and required dose are suggested for further research.

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References

Bravo C, Moshou D, West J, McCartney A and Ramon H, 2003. Early disease detection in wheat fields using spectral reflectance. Biosystems Engineering 84(2): 137-145.

Dammer KH and Ehlert D, 2006. Variable-rate fungicide spraying in cereals using a plant cover sensor. Precision Agriculture 7: 137-148.

Kempenaar C, Groeneveld RMW and Uffing AJM. 2006. Evaluation of Weed IT model 2006 MKII: spray volume and dose response tests. Plant Research International, Note 418, Wageningen.

MLHD, 2004. Minimum Lethal Herbicide Dose, MLHD online; manual for the herbicide dose calculation module V2.0. Opticrop, Plant Research International, Wageningen. http://mlhd.opticrop.nl/.

Polder G, 2004. Spectral imaging for measuring biochemicals in plant material. PhD Thesis Wageningen Agricultural University, Wageningen. 150pp.

Schut AGT, 2003. Imaging spectroscopy for characterization of grass swards. PhD Thesis Wageningen University, Wageningen, the Netherlands. 264pp.

Scotford I.M. and P.C.H. Miller, 2004. Combination of spectral reflectance and ultrasonic sensing to monitor the growth of winter wheat. Biosystems Engineering 87(1): 27-38.

Van de Zande JC and Achten VTJM, 2005. Precision agriculture in plant protection technique. Annual Review of Agricultural Engineering 4(1):217-228.

Van de Zande JC, Achten VTJM, Michielsen JMGP, Wenneker M and Koster, AThJ, 2008. Towards more target oriented crop protection. International advances in pesticide application. Aspects of Applied Biology 84:245-252.

Van de Zande, J.C., V.T.J.M. Achten, C. Kempenaar, J.M.G.P. Michielsen, D. van der Schans, J. de Boer, H. Stallinga, P. van Velde and B. Verwijs, 2009. SensiSpray: site-specific precise dosing of pesticides by on-line sensing. In: Van Henten, E.J., Goense and D. Lokhorst, C. (eds). Precision Agriculture 09. Wageningen Academic Publishers, the Netherlands, pp. 785-792.

Vrindts E, Reyniers M, Darius P, DeBaerdemaeker J, Gilot M, Sadaoui Y, Frankinet M, Hanquet B and Destain M-F, 2003. Analysis of soil and crop properties for precision agriculture for winter wheat. Biosystems Engineering 85(2): 141-152.