Verification and accuracy of a task-map based variable rate boom sprayer

International Advances in Pesticide Application

Zande, J.C.; Hoog, D.C.; Michielsen, J.M.G.P.; Snoussi, M.; Stallinga, H. et al

https://www.aab.org.uk/product/aspects-147-international-advances-in-pesticide-application-digital/

Aspects of Applied Biology ***147****, 2022*
International Advances in Pesticide Application

Verification and accuracy of a task-map based variable rate boom sprayer

By J C VAN DE ZANDE, D C DE HOOG, J M G P MICHIELSEN, M SNOUSSI, H STALLINGA and F SIJBRANDIJ

Wageningen Plant Research, Wageningen UR – P.O. Box 16 – 6700 AA Wageningen, The Netherlands
Corresponding Author Email: jan.vandezande@wur.nl

Summary

In precision spraying one of the applications is soil herbicide spraying based on information from a soil map, like organic matter or clay content variability in the field. Variable rate applications are performed based on this soil map variability information. The effect of variable rate application of spray volume based on an uploaded task-map in a precision sprayer on spray deposition is evaluated. This is done for one typical setup of a sprayer under practical field conditions spraying a predefined task map six times in two driving directions with two levels of grid resolution of the uploaded map. Spray volume was varied between 360 L ha^{-1} and 440 L ha^{-1} over 75 m track length in distinct steps with a nominal spray volume of 400 L ha^{-1} and adjusted by means of spray pressure regulation. Results show that on average, measured spray deposition was higher than as intended by the to be applied spray volume as defined by the task map. The stepwise profile of different spray volumes could hardly be found. As logged data from the spray computer of the sprayed tracks indicated that the applied spray volume and the individual steps in spray volume change were very well coinciding with the set values of the task-map it is discussed where differences in outcome can come from. It is suggested to develop a test bench to evaluate precision sprayers before going in the field.

Key words: Precision spraying, weed control, soil map, variable dose, sprayer test

Introduction

In precision agriculture, crop protection is often one of the tasks that offers the opportunity to vary the application rate based on measurable plant (Kempenaar *et al*., 2014*b*; Michielsen *et al*., 2010), soil (Kempenaar *et al*., 2014*a*) or pest and disease parameters. One of those information sources is for example the variability of clay content in the upper soil layer. Some soil herbicides vary in efficacy depending on the clay content of the soil. When clay content is measured in the field in detail using specific sensors (Veriscan), the variation in clay content can be presented in a map showing the variability in different classes. Such a clay content map is used to vary the dosage of the herbicide (e.g. Boxer) in the field depending on the occurrence of the clay content in specific areas in limited steps (Kempenaar *et al*., 2014*a*, 2017). The strategy at this moment is that a general reduced dose is advised to be used over the whole field based on average clay content with local variation in steps of 5% or 10% of advised dose rate based on local mapped clay content (Fig. 1).

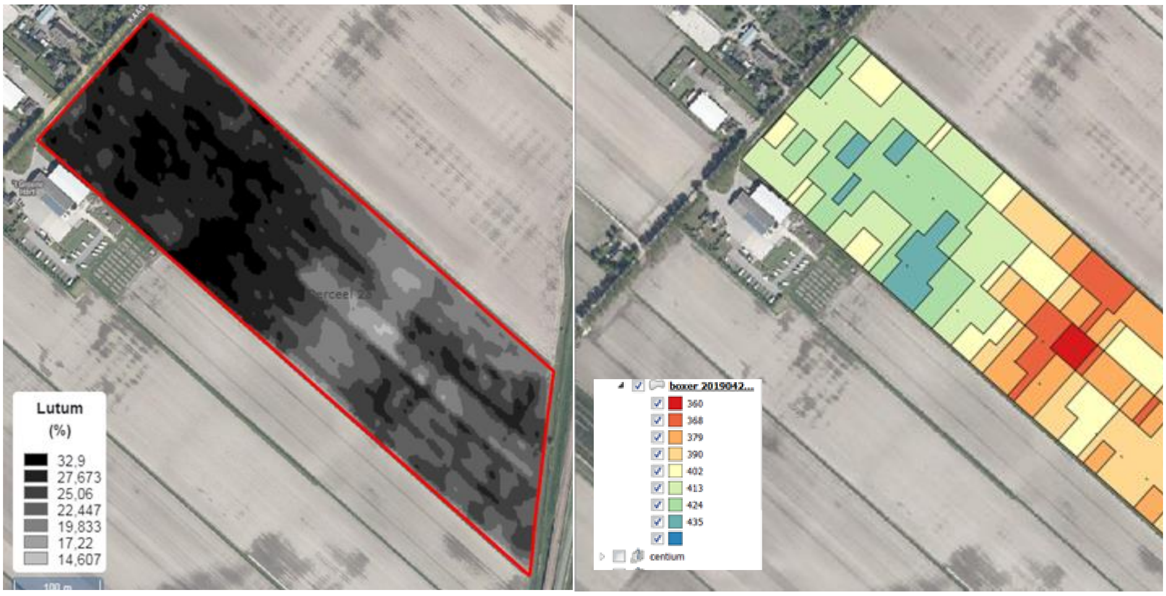

Fig. 1. Example of variation of clay content (% lutum) in a field (left) and a task map (spray volume L ha^{-1}; average 400 L ha^{-1} with 3.6 L ha^{-1} Boxer) based on local clay content variability (right).

For a specific situation (Fig. 1), a boom sprayer with a working width of 40m was used applying a spray volume of 400 L/ha. Variable dose was realised using an AgLeader spray computer adjusting spray volume based on adaptation of the spray pressure in such steps that +/- 5% (20 L/ha) and +/10% (40 L ha^{-1}) steps could be made based on an incorporated task-map.

To test the accuracy, precision and applied dose rate a task-map was prepared over 80 m length and 20 m wide (one side of the spray boom) consisting of the following steps: start at 100%; 10 m 95%; 20 m 90%; 20 m 100%; 20 m 110%; end with 100% dose. Spray deposition over the 80 m length was measured spraying a fluorescent tracer solution and 1 m length collectors at ground surface over the 80m length alongside the sprayer and underneath the boom end.

Earlier spray deposition measurements of a sensor-based variable rate sprayer showed a precision and accuracy of change in applied dose of 1–2 m in the travel direction (Michielsen *et al*., 2010). This paper describes the precision of the variable rate application verified by the measured spray deposition at ground surface related to the intended dose indicated by the uploaded task-map in the spray computer.

Materials and Methods

Spray technique

A trailed boom sprayer (Kverneland iXtrack; 40 m working width) was used to perform the spray deposition tests. The standard spray computer on the sprayer (Kverneland) was used in combination with a precision spraying terminal (AgLeader) to transfer task map information to actual spray application actions as adapting spray pressure to change spray volume based on actual position (GNSS) in the field. Default spray volume was set to 400 L ha^{-1} at 6 km h^{-1}, with a fluorescent tracer (Acid Yellow; AY250, 0.4 g L^{-1}); added for measuring spray deposition on collectors. Spray boom height was 50 cm and nozzle spacing 50 cm. Spray nozzles implemented were Agrotop TD-XL 110-05 operated standard at 3.0 bar spray pressure with variations between 2.4 bar and 3.6 bar for resp. lowest (360 L ha^{-1}) and highest (440 L ha^{-1}) spray volume.

Spray deposition measurements

Six spray deposition measurements were performed (14 May 2019) on the headland of a potato field in practice (Fig. 1). Spray deposition measurements were done driving on the headland three times in one direction (North-East; collectors 75 to 1) and three times in the other direction

(South-West; collectors 1 to 75) spraying alternatively only the left- or right-hand side spray boom (Fig. 2). Two accuracy levels of the task map (1 m × 1 m and 10 m × 10 m) were uploaded in the spray computer and each level was sprayed in threefold. To evaluate spray deposition two lines of collectors (Technofil TF-290, 100 cm × 10 cm) were laid out over a length of 75 m, one on top of the potato ridge next to the sprayer wheel (row 2) and the other on top of a potato ridge in the centre of the outmost section (row 1) of the sprayer boom (Fig. 2).

After spraying the collectors were picked up, bagged, coded and stored for analysis in the laboratory. In the laboratory the collectors were washed with deionised water and the solution measured with a fluorimeter (Perkin Elmer LS55; λex=450 nm en λem=500 nm) to quantify AY250 concentration. From the quantified AY250 concentrations the deposition on collectors was calculated in μL cm^{-2} and as percentage of applied volume rate.

Fig. 2. Lay-out of the spray deposition collectors in the field on top of the bare potato ridges.

Task map

A task map with the changes in spray volume in forward trajectory distance was made in the GIS system (QGIS, Akkerweb). The task map was transferred to the AgLeader terminal. In the standard setting, as generally used by most farmers, this is done in a 10 m × 10 m grid resolution and in the 'professional' option in a 1 m × 1 m grid resolution. The task map units in the GIS system are oriented in the travel direction of the sprayer whereas in the precision spray terminal the grid orientation is always north-south. The actual position (GNSS) of the sprayer boom is used to switch between map unit settings of spray pressure to adapt spray volume. The positions of the spray volume steps in the field were checked with those defined on the task map (Fig. 3) and were indicated in the field with RTK-GPS and marked. The changes in spray volume steps indicated on the AgLeader terminal were checked with the RTK-GPS spray boom position in the field and with the marked intended spray volume steps for both driving directions, showing a deviation of 40–80 cm in the direction of travel. So total difference in switch point position for spray volume change of the map units in the one or other driving direction in the field could be up to 1.60 m.

Data analysis

The results of the measurements were described by different parameters characterising the height of spray deposition (μL cm^{-2} and % of nominal spray volume 400 L ha^{-1}) and the accuracy in spray deposition (difference between target deposition and measured deposition) of the precision spraying system, the standard deviation (STD) and the Coefficient of Variance (CV) were also calculated for these parameters.

Distance (m)	Volume (L ha^{-1})	Dose (%)
0	400	100
5	400	100
5	380	95
15	380	95
15	360	90
35	360	90
35	400	100
55	400	100
55	440	110
75	440	110
75	400	100

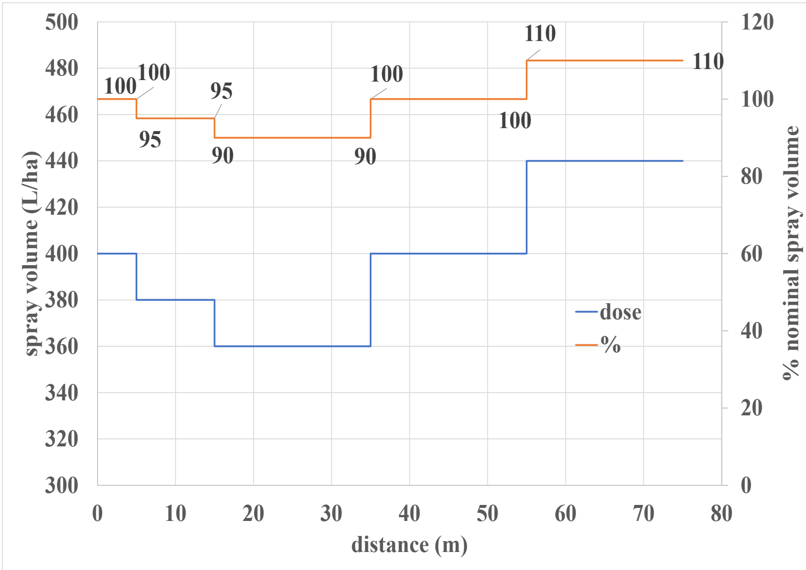

Fig. 3. Overview of steps made in the task map; left table with distance (m), spray volume (L ha^{-1}) and dose relative to nominal volume of 400 L ha^{-1}; right presented graphically (travel direction from left or right).

Results

Spray deposition

The results of the measured spray deposition for the six measurements are presented in Fig. 4. It is shown that large deviations in spray deposition occur from the intended as described in the target map (inp×ut, red line). In general, measured spray deposition is higher than intended target rate. Large differences do also occur between the spray deposition on row 1 and row 2, resp. at the boom end and alongside the sprayer wheel. This difference can partly be explained by sprayer boom movement (although visually determined as low). Measurement M6 looks to be closest to the target deposition pattern for both rows measured. The spray deposition pattern is for all measurements

Table 1. *Spray deposition (µL cm^{-2}), applied dose (% of nominal; 4 µL cm^{-2}) and absolute difference between target dose and applied dose (%) of task map applied variable trajectory (mean values, standard deviation (STD) and coefficient of variance (CV) of these parameters). Map resolution 1m × 1 m, measured over 75 m length in two rows and 1 m collector length*

Exp. Direction	Row	Mean µL cm^{-2}	Mean dose [%]	Mean Abs diff [%dose]	STD µL cm^{-2}	STD dose [%]	STD Abs diff [%]	CV µL cm^{-2} dose[%]	CV Abs diff [%]
M1-SW	row 1	5.03	126	29	0.83	21	21	17	72
	row 2	5.30	132	33	0.64	16	16	12	48
	avg	5.16	129	31	0.73	18	18	14	60
M2-NE	row 1	4.49	112	21	1.04	26	19	23	93
	row 2	4.89	122	28	1.05	26	18	21	63
	avg	4.69	117	24	1.04	26	19	22	78
M5-SW	row 1	5.07	127	32	1.70	43	36	34	113
	row 2	5.38	134	36	2.04	51	47	38	131
	avg	5.22	131	34	1.87	47	42	36	122
avg	row 1	4.86	122	27	1.19	30	25	24	93
	row 2	5.19	130	32	1.24	31	27	24	81
	avg	5.03	126	30	1.22	30	26	24	87

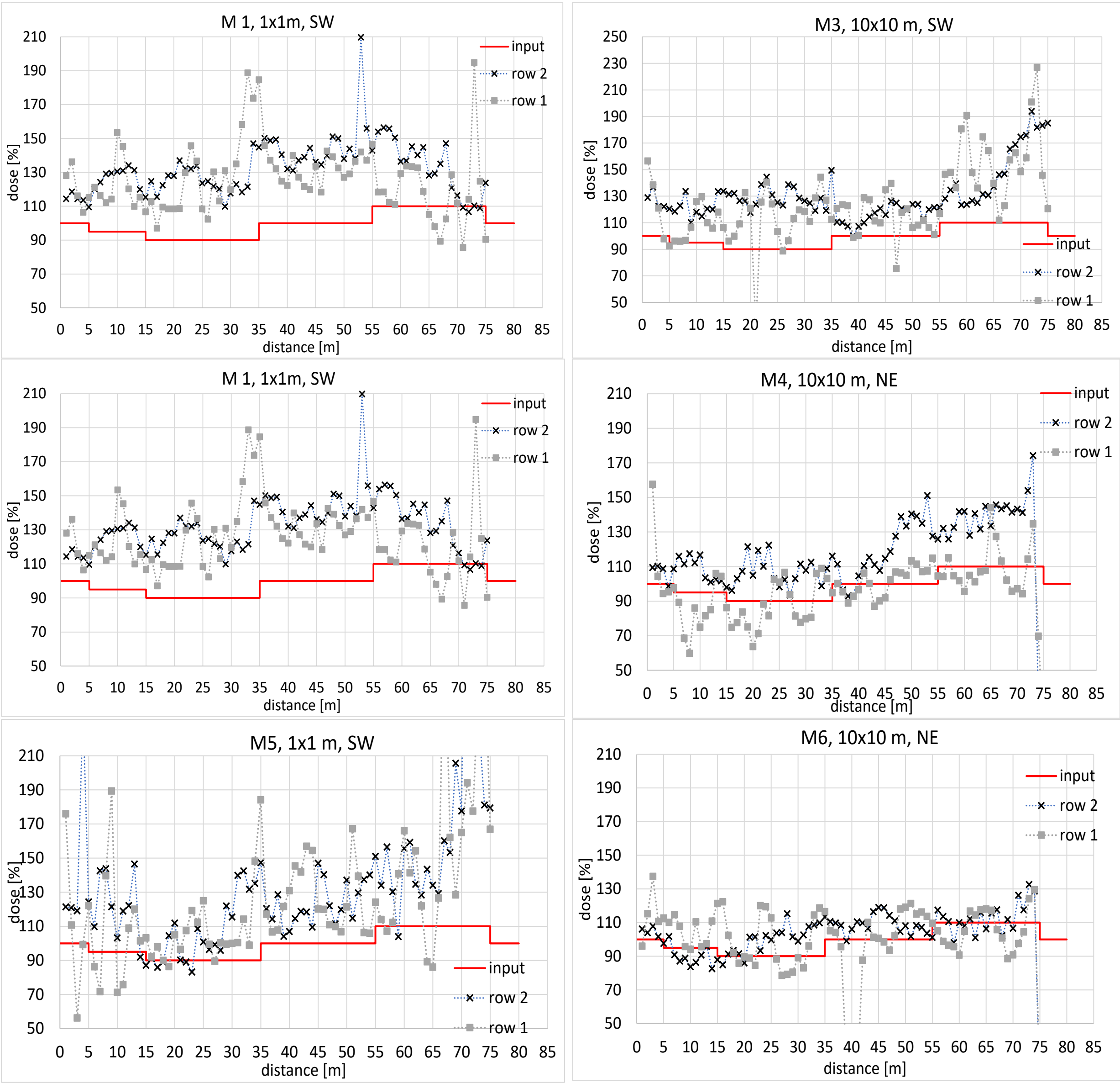

Fig. 4. Spray deposition (% of nominal spray volume 400 L ha^{-1}) on 2 rows of collectors over a 75 m trajectory following a target map (red line input) for a 1 m × 1 m resolution (left; three repetitions M1, M2, M5) and a 10 m × 10 m resolution (right; three repetitions M3, M4, M6) of the uploaded task map. Driving directions North-East (NE) and South-West (SW).

very variable over trajectory distance. The individual levels of target dose for 10 m or 20 m length parts of the task map units seem never to be met. The individual steps in the stepwise increase and decrease of the target application rate is difficult to detect in the spray deposition patterns and hardly found.

In order to quantify the presented spray deposition patterns (Fig. 4) in evaluation parameters for precision spraying, the mean values of the spray deposition, the dose as relative to the nominal spray volume of 400 L ha^{-1} (4 µL cm^{-2}) and the absolute difference in measured and target deposition per collector are presented in Table 1 for the 1 m × 1 m grid resolution of the task map and in Table 2 for the 10 m × 10 m grid resolution. Also, standard deviation (STD) and Coefficient of variation (CV) of these parameters are presented to give a better idea of the variability of the measured spray deposition patterns.

For the 10 m × 10 m grid resolution of the task map the average spray deposition was 4.47 µL cm^{-2}which is closer to the intended average spray deposition (4.0 µL cm^{-2}) and lower than of the 1 × 1 m grid resolution of the task map (5.03 µL cm^{-2}); resp. 112% and 126% of average applied dose.

Table 2. *Spray deposition (µL cm⁻²), applied dose (% of nominal; 4 µL cm⁻²) and absolute difference between target dose and applied dose (%) of task map applied variable trajectory (mean values, standard deviation (STD) and coefficient of variance (CV) of these parameters). Map resolution 10m x 10 m, measured over 75 m length in 2 rows and 1 m collector length*

Exp. direction	Row	Mean			STD			CV	
		$\mu L\ cm^{-2}$	dose [%]	Abs diff [%dose]	$\mu L\ cm^{-2}$	dose [%]	Abs diff [%]	$\mu L\ cm^{-2}$ dose[%]	Abs diff [%]
M3-SW	row 1	4.98	125	28	1.16	29	22	23	80
	row 2	5.23	131	31	0.77	19	18	15	57
	avg	5.11	128	30	0.97	24	20	19	68
M4-NE	row 1	3.85	96	12	0.78	19	13	20	105
	row 2	4.66	116	22	0.98	24	17	21	74
	avg	4.25	106	17	0.88	22	15	21	90
M6-NE	row 1	3.99	100	16	0.96	24	19	24	120
	row 2	4.13	103	10	0.63	16	12	0.6	12
	avg	4.06	102	13	0.79	20	15	12	66
avg	row 1	4.28	107	19	0.96	24	18	22	102
	row 2	4.67	117	21	0.79	20	15	12	48
	avg	4.47	112	20	0.88	22	17	17	75

The absolute difference in dose between the measured spray deposition and the target deposition was for the 10 m × 10 m grid resolution 20% and for the 1 m × 1 m grid resolution 30%. Standard deviation of the absolute difference in dose was for the 10 m × 10 m grid resolution 17% and for the 1 m × 1 m grid resolution 26%. In general, it can be said that height of spray deposition and difference from the target rate as defined in the task map was better for the 10 m × 10 m grid resolution of the task map than of the 1 m $\mu L\ cm^{-2}$ 1 m grid resolution.

Discussion

At first sight the results look very disappointing. The height of the measured spray deposition is always similar or higher than of the target rate. A closer look at the log-files of the spray terminal gave additional information on the measured forward speed during the different measurements. This showed that forward speed varied between 5.6 km h^{-1} (M5) and 6.6 km h^{-1} (M6) with measured speeds of 6.0 (M1), 6.5 (M2) and 6.1 km h^{-1} (M4); for M3 no log data were available.

Measured flow rate in the sprayer and calculated applied rate coincides reasonably well with the target rate over distance (Fig. 5), even the spray volume steps over track distance can be determined from the information logged by the spray terminal. So electronically, the system itself seems to have operated as intended. Clearly also the peak at the beginning of the track seen as start increase of spray pressure and regulating and decreasing to the set value as of the target map can be seen in a peak in applied spray volume at start of the spray track (Fig. 5). The length effect of these start peaks is for this sprayer in the order of 15–20 m. From the logged applied rate information, it is suggested that within 5–10 m distance the applied volume is adapted to the new level of the target rate. It can further be questioned whether the nozzle-pressure relation in the spray terminal was correct. But afterwards, at a later date no information was available anymore for a check.

Although the measured spray deposition differed from the intended spray volume steps as defined by the task map, and suppose this happened also when spraying in practice, no effects were found in efficacy of the applied soil herbicide. For more years similar weed control was reported for the task map sprayed fields as for the fields sprayed in the standard way with an uniform advised dose for the whole field (Riepma & Kempenaar, 2020). Herbicide use reductions monitored were 13–35% on average.

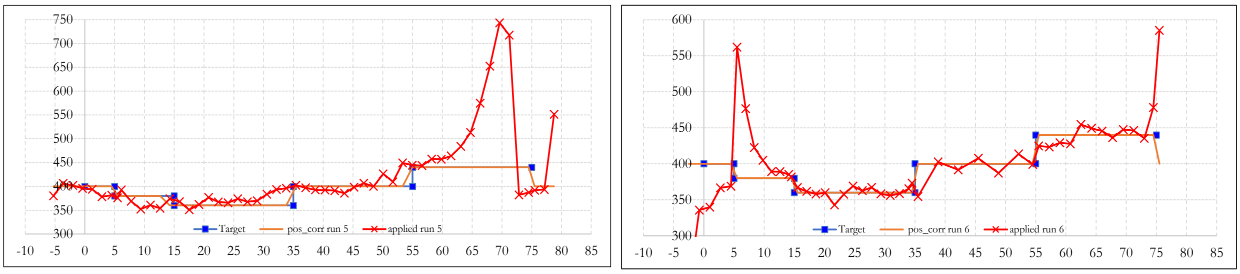

Fig. 5. Comparison of target rate (L ha^{-1}) and applied spray volume (L ha^{-1}) over track distance from the log file of the spray terminal for measurement 5 (left; 1 m × 1 m grid, driving direction right-left) and measurement 6 (right; 10 m × 10 m grid, driving direction left-right).

It can be discussed what the value of the reported data is. We measured only for one sprayer with its own typical setup developed for precision spraying based on multiple components form different manufacturers, partly purpose built. Are the presented data therefore unique for this sprayer only or are the data also representative for (first) series of developed task map-based sprayers for precision spraying?

Measurements of this kind are time consuming and costly. To evaluate more sprayers and see how they perform in precision, accuracy and dose application, it is suggested to develop a test method to be able to do quick scan measurements before going in the field. Therefor the idea rose for developing a stationary measuring system in which we virtually can drive to a field following the predefined spray tracks and spray with adapting the spray volume following an uploaded task map in the spray computer. Flow rate at individual nozzles distributed over more sections along the spray boom can record the changes in flow rate in time. Flow rate data can be compared then with track position and to be applied spray volume based on the task map; and an evaluation of the relevant spray parameters can be made. Question remains what the best parameters are to quantify the effectiveness of precision sprayers. Further discussion on these issues and development of standard methodologies are therefore suggested.

Acknowledgements

The Research presented in this paper is part of the Public Private Partnership project Innovative Efficient Application Technologies (PPS KV 1406044) and financed by Topsector Tuinbouw & Uitgangsmateriaal, Dutch Horticultural Board (Productschap Tuinbouw), and various other companies and organisations. We would like to thank Jasper Roubos (Abbenes, NL) for allowing us to use his potato field, the sprayer and operating the sprayer during experiments.

References

Kempenaar C, Heiting S, Michielsen JMGP. 2014*a*. Perspectives for site specific application of soil herbicides in arable farming. In: *Proceedings of ICPA conference*, Sacramento, USA, July 2014. Paper 1414, https://www.ispag.org/icpa.

Kempenaar C, Van Evert F K, Been T H. 2014*b*. Use of vegetation indices in variable rate application of potato haulm killing herbicides. In: *Proceedings of ICPA conference*, Sacramento, USA, July 2014. Paper 1413, https://www.ispag.org/icpa.

Kempenaar C, Been T, Booij J, Van Evert F, Michielsen J M G P, Kocks C. 2017. Advances in Variable Rate Technology Application in Potato in The Netherlands. *Potato Research* **60**:295–305.

Michielsen J M G P, Van de Zande J C, Achten V T J M, Stallinga H, Van Velde P, Verwijs B, Kempenaar C, Van der Schans D, De Boer J. 2010. Precision of a sensor-based variable rate sprayer. *Aspects of Applied Biology* **99**, *International Advances in Pesticide Application*, pp. 21–28.
Riepma J, Kempenaar C. 2020. *Variabel doseren van bodemherbiciden 2018–2019: Evaluatie van NPPL toepassingen*. Wageningen, Netherlands: Wageningen University and Research. 8 pp.