FACULTY OF SCIENCE
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Sensors for Herbicide Efficacy Assessment

(Site-Specific Weed Management Working Group of EWRS)

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Abstract

Nine sensor systems scanned diquat symptoms on barley and oilseed rape ten days after spraying to compare sensor output. Crops were sown in four densities and diquat was applied with a logarithmic sprayer. Only two RGB image systems are used here to illustrate how to compare *ED50* parameters in response to crop density. *ED50* for the system measuring the excess green index by continuous samples from 40 m altitude dropped somewhat in response to density in both crop species. *ED50* for green foliage coverage at discrete samples from 1.5 m altitude did not show the same trend for both crops, for oilseed rape, *ED50*, however, dropped with increasing density.

Introduction

Sensors measure different characteristics of the canopy of crop and weeds and their phenological stages of development affect sensor measurements as do ambient light and soil conditions. Spraying increasing field rates of herbicides will influence sensor measurements. A RGB camera to estimate excess green colour index (ExG) has been used to quantify crop symptoms to herbicide treatments (Rasmussen *et al*., 2013). An algorithm segments high resolution RGB images into cereal and weed foliage cover (Nikon-GFC) in site-specific weed management has been developed (Berge *et al*., 2012). It was expected that different indices based on RGB images were related. RGB-cameras sense intensity and saturation of visible leaf colour.

The Site-Specific Weed Management (SSWM) working group arranged a workshop at the research farm Højbakkegård, Denmark 28-31 May 2012. The objective was to compare sensor systems on barley and oilseed rape of different densities and with increasing rates of four herbicides (Streibig et al., In preparation). The hypothesis was that herbicide symptoms could be quantified by different sensor systems. This poster only shows a fraction of the numerous measurements that were carried out.

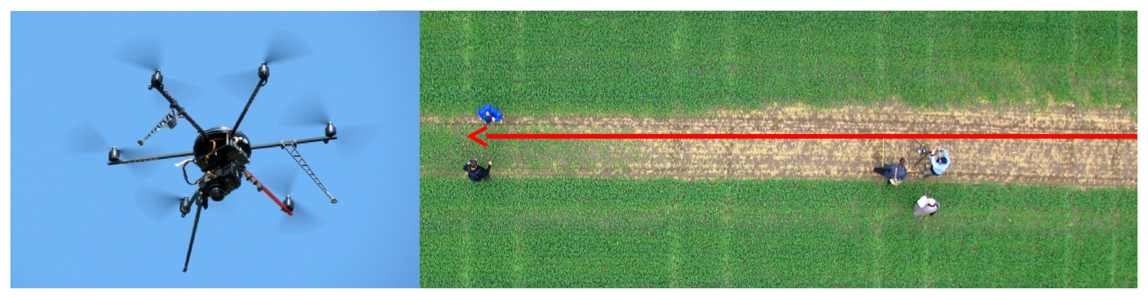

Figure 1 Diquat plot with 120 barley plants m-2. The Nikon-GFC group is taking pictures on the ground.

Materials and Methods

Field experiments with spring barley and oilseed rape was laid out as a split plot design with species as main plot and seed densities as subplots of 3 m x 35 m on which diquat was applied with a logarithmic sprayer (Tind *et al*., 2009). The herbicide was sprayed 18th of May 2012 (BBCH 20) and sensor measurements were taken under cloudy conditions 30th and 31st of May 2012 (BBCH 25) (Table 1).
Sensor output was analysed within each crop x density combination. The response and dose were normalized between 1 and 0, respectively, in order to easily assess the regression quality among sensors, particularly the upper limit ,*D*, and the lower limit, *C*, (Eq (1)). The responses (*Y*) on doses (*x*) at various sowing densities were in most instances described by a log-logistic model (Ritz & Streibig, 2005).

Table 1 The sensor systems used in the SSWM field experiments and their indices and acronyms. Only the red indices were used here

Sensing system	Index	Index acronym
Visual assessment in field	Green foliage coverage	Manual-GFC
RGB camera (Nikon D300S) mounted on a tripod; images analysed by the Weedcer algorithm (Berge et al., 2012)	Green foliage coverage	Nikon-GFC
RGB camera (Canon G12) mounted on an unmanned hexakopter	Excess green colour index	Hexa-ExG
A multispectral (RGB-NIR) camera system developed by University of Southern Denmark	Green foliage cover	SDU-GFC
VideometerLab system from Videometer A/S, Denmark (http://www.videometer.com)	Green foliage coverage	Videometer-GFC
Ultrasonic sensor from Pepperl+Fuchs (Mannheim, Germany) (UC2000-30GM-IUR2-V15)	Plant height	UM18-index
HandySpec Spectrometer Systems from Tec5 AG, Germany (http://www.tec5.com)	Red reflection point Normalized vegetation index	Tec5-NDVI
LMS111 laser system from SICK AG Waldkirch, Germany (http://www.sick.com)	Foliage index	LIDAR-FI
ISARIA spectrometer from Fritzmeier Umwelttechnik GmbH & Co.KG, Germany http://www.umwelt.fritzmeier.de)	Red reflection point	ISARIA-REIP

$$Y = C + \frac{D-C}{1+\exp[b\cdot(\log(x)-log(ED_{50})]} \qquad \text{Eq (1)}$$

ED_{50} is the dose required to half the sensor response between the *D* and *C*, and *b* is the relative slope around ED_{50}.

Results and Discussions

A subplot of 120 barley m^{-2} sprayed with diquat is seen in Fig. 1 with the group taking images denoted Nikon-GFC (Table 1) (Berge *et al*., 2012). The logarithmic sprayer started spraying at the right hand side. Before the end of the strip at 35 m the decreasing field rate was evident as the crop became greener. An image was taken for every 5 m which add up to a total of seven herbicide rates converted to field rate ha^{-1}.

Figure 2 shows the dose-response curves for sensor system Hexa-ExG for two barley densities and Table 2 shows the corresponding regression parameters. There were a total of more than 13,000 observations each representing a column of pixels in the image taken from an altitude of 40 m by a hexakopter (Fig. 1) mounted Canon G12 camera (Rasmussen *et al*., 2013).

In Table 2 and Fig. 2 the lower limits were rather high (0.52 and 0.50), whilst the upper limits were close to each other. The ED_{50} were in both instances estimated with high precision.

The relationship between the ED_{50} and the density of barley and oilseed rape showed the same trend; the ED_{50} values dropped in response to density (Fig. 3). Obviously, the increasing crop density gave a more uniform canopy. A parallel explanation could be that the density dependent competition decreased the ED_{50}. With the lower densities the unknown proportion of soils versus green canopy is a confounding factor and may be partly caused by the relative leaf area index.

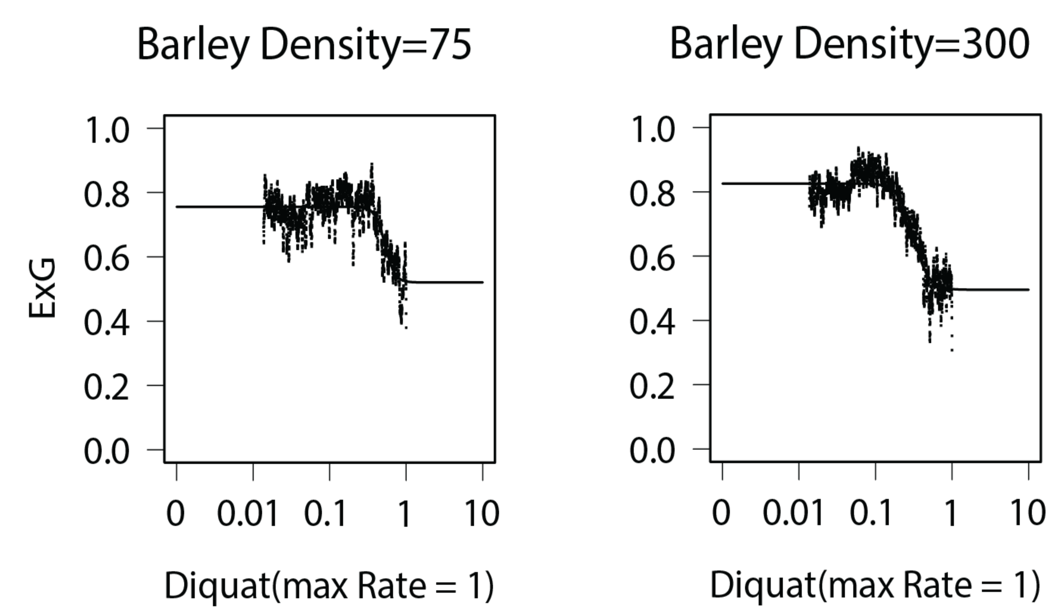

Figure 2 The dose response curves derived for Hexa-ExG for two barley densities. Note the max dose rate of diquat was 1, and the extension of the dose rate to 10 was only to show the estimated lower limits,*C*, (See Table 2)

Table 2 Regression parameters (four parameter log-logistic model) for density 75 and 300 barley m-2 (Fig. 2) treated with diquat

Parameter Name	Density	Parameter	Standard Error
Slope b	75	6.7	0.38
	300	4.3	0.11
Lower Limit C	75	0.52	0.540
	300	0.50	0.0030
Upper Limit D	75	0.76	0.001
	300	0.83	0.001
ED50	75	0.53	0.008
	300	0.31	0.003

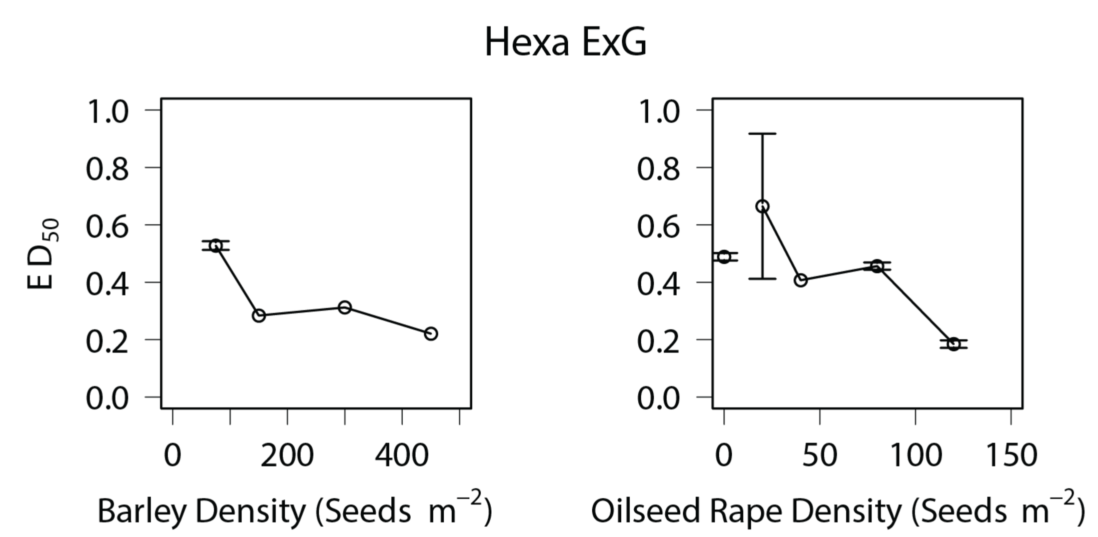

Figure 3 Distribution of *ED50* in response to diquat at various barley (left) and oilseed rape (right) densities. Vertical bars are 95 % confidence intervals of *ED50*

The *ED50* was not estimated at zero barley density, which represents the natural weed flora, due to very low weed infestation. The zero density *ED50* representing the natural weed flora was estimated for oilseed rape (Fig. 3).

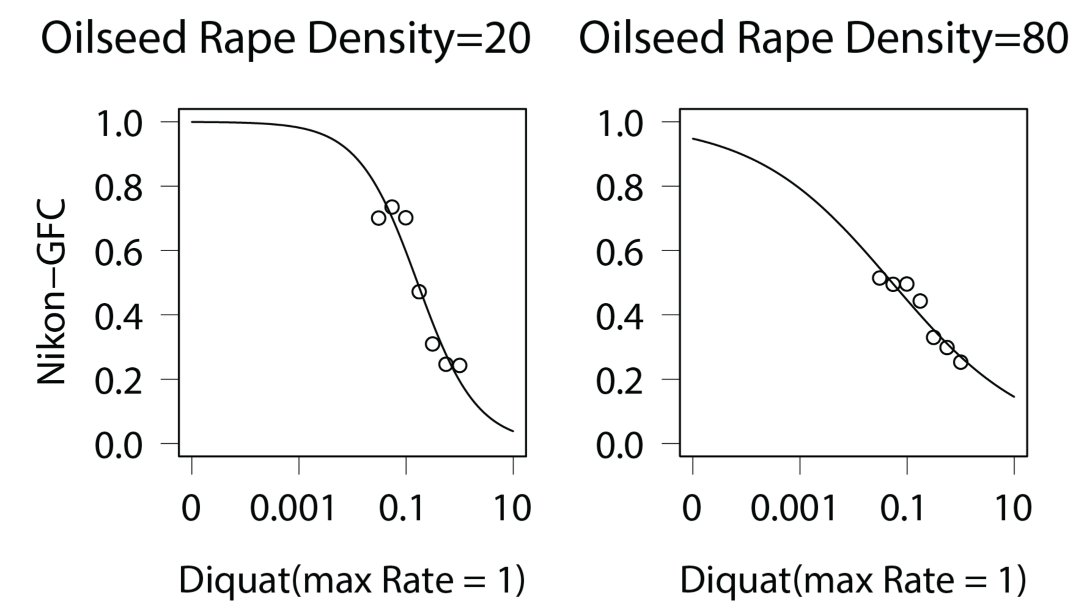

Figure 4 Two dose-response curves derived from Nikon-GFC index for diquat in oilseed rape. Note that the whole range of effect was not covered for either density

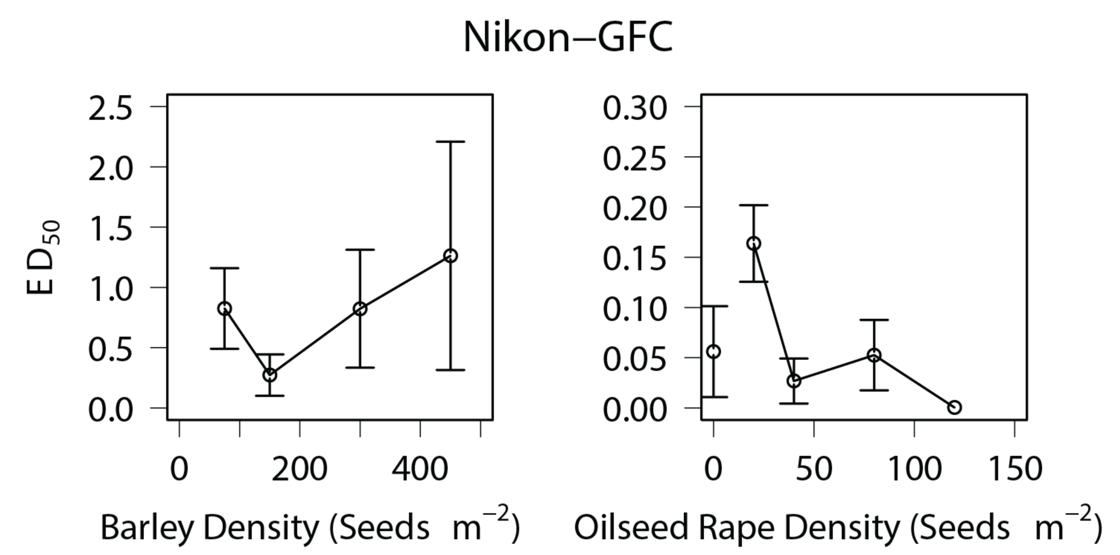

Figure 5 Distribution of *ED50* in response to diquat at various barley (left) and oilseed (right) densities. Symbols as in Fig. 3.

The Nikon-GFC dose-response curves had fewer observations than Hexa ExG (Fig.4). This is reflected in the confidence interval of *ED50* (Fig. 5) that were higher than those of Hexa-ExG (Fig. 3). Confidence intervals of Nikon-GFC *ED50* were overlapping for barley (Fig. 5), but for oilseed rape in Fig. 5 we got the same trend as with Hexa-ExG (Fig. 3). As was the case for Hexa-ExG for barley (Fig. 3) there was only little weed infestation at zero crop density and the *ED50* could not be estimated.
The precision of the *ED50* gave a good indication of the quality of the data being captured. Two ExG responses (Fig. 3) gave similar results, the higher the crop densities the lower the *ED50* as was the case for Nikon-GFC index in oilseed rape in Fig. 5.

Acknowledgement

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