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Review

Evaluation of sensors for poplar cutting detection to be used in intra-row weed control machine

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ABSTRACT

For Short Rotation Coppice (SRC) cultivation, it is common practice to use herbicides during the first year, even if mechanical weeding is becoming an alternative practice for environmental and agronomic reasons. Much attention was paid to non-chemical weeding within the rows, but the low level of efficiency of available machinery has led to the development of automatic systems that are capable of weeding the spaces in the row and avoiding the plants.

In the framework of this study, a photoelectric and a capacitive sensor (the latter specifically developed for identifying poplar cuttings), was tested. A small platform pulling the sensors was moved along a monorail in order to assess the capability of the sensors for localizing cuttings along the row. The study was conducted on one-year old poplar cuttings. At this stage the plants have little mechanical strength and are unable to withstand the impact of traditional mechanical probes situated on the retractable elements of weed control machinery (hoes, cultivators). Each sensor identified the plant according to its own functional parameters. The divergence between the response of the sensors and the actual position of the cuttings allowed for the accuracy assessment of detection.

The capacitive sensor showed a higher amplitude of response in presence of a poplar cutting than the photoelectric sensor. No significant differences were observed for the various distances (0.15, 0.20 and 0.25 m) of the detection system from the row and for the different speeds (1.0 and 1.5 km h^{-1}) of the rail.

The first results showed that the testing apparatus accurately detected poplar cuttings at the same speed used by common mechanical weed control machines. The sensors tested proved to be suitable to be included in intra-row weeding machines. This will be the main goal of future activities, an interesting prospect for firms producing agricultural machinery for biomass crops.

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Nomenclature

A	amplitude of the sensor signal in presence of the poplar (m)
C_f	capacitance establishing the fixed frequency of the oscillators (F)
C_s	additional capacitance due to the sensing metal plate approaching the cutting (F)
D	deviation between the real position of the poplar and the response of the sensor (m)
M	centre of the sensor signal (m)
R	resistor (Ohm)
R_{MS}	true poplar position (m)
S	surface area of the capacitance armatures (m^2)
S_1	point from where the sensor response is high (an obstacle is present) for more than 0.02 m (m)
S_2	point from where the sensor response is low (no obstacle) for more than 0.02 m (m)
T_1	point where the signal became higher than the threshold (m)
T_2	point where the signal became lower than the threshold (m)
d	distance between the armatures of the capacitor (m)
f	oscillating frequency of the circuit (Hz)
k	constant depending on the circuit design characteristics
Δf	$f_f - f_v$ (Hz)
h	ground clearance (m)
ε	absolute air permittivity (F/m)

Subscripts

c	capacitive sensor
f	fixed oscillator
p	photoelectric sensor
v	variable oscillator

1. Introduction

The strong competition among weeds for water, nutrients and sunlight has a detrimental effect on both crop yield and product quality (Oerke, 2006; Slaughter et al., 2008). The strong reliance on chemical weeding may cause environmental and ecological drawbacks, such as the selection of resistant weeds (Bastiaans et al., 2008; van der Weide et al., 2008; Cordill and Grift, 2011). The most impressive case concerned the glyphosate-based herbicides (Beckie, 2011; Cordill and Grift, 2011). In fact the repeated use of this herbicide led to the development of Glyphosate-resistant (GR) weeds a few years after the introduction of GR crops (Shaner and Beckie, 2014).

The lack of acceptance of herbicide-based agriculture has encouraged the implementation of policies limiting chemical weeding. The effects of the regulations established by the European Union (EU Agricultural Pesticides Directive 91/414/EEC; Thematic Strategy on the Sustainable Use of Pesticides, EC 2010) should lead to a withdrawal of approximately 20% of active ingredients among which several herbicides used for weed control in the cultivation of cereals, carrots, onions and oilseed rape (Hillocks, 2012).

In many cases, it is possible to reduce the use of pesticides with regular soil tillage. In winter wheat, Rueda-Ayala et al. (2011) observed that the largest yield response to harrowing was comparable to that obtained with herbicide treatment. Lundkvist (2009) outlined the role of timing in oats, spring wheat and peas. In fact weed control by means of combined pre and post-emergence harrowing achieved the best results on the total number of weed plants. However in spring barley Rasmussen et al. (2008) underlined other factors affecting crop/weed selectivity, such as the number of passes, the driving speed and the row spacing at advanced growing stage, whilst the time of weeding had low impact.

The non-chemical control of weeds is more difficult within the row as it is in accessible with a hoe. Therefore, it is essential to develop alternative weed control mechanisms and there are great opportunities for sustainable agriculture and for sectors such as organic farming (covering over 7.5 million hectares in the European Union – Willer, 2010), which require new approaches for controlling intra-row weeds due to the ban of herbicides. To this aim, various types of machinery were proposed, such as harrow, finger and torsion weeders, and weed blowers (van der Weide et al., 2008). However their use is limited due to various technical limitations: strong competition of herbicides; scarce interest of the farmer; high risk of crop damage; need of favourable soil conditions; possible damage to soil structure due to the frequency of farm operations. For these reasons, a number of useful systems for autonomous robotic weed control (Slaughter et al., 2008; Shaner and Beckie, 2014) have been developed in recent years.

The automatic systems were studied following two approaches: crop detection and weed recognition. The first approach exploits the greater uniformity of crop plants in order to distinguish weeds (Lee et al., 2010). The recognition systems include the interruption of light (van der Weide et al., 2008) or laser beam (Cordill and Grift, 2011) or even row guidance systems using two kinds of sensors alternately: machine vision and global positioning systems (Slaughter et al., 2008). In another study, Midtiby et al. (2012) used the plant stem emerging point (PSEP) for detecting single crop leaves and predicting where the corresponding PSEP is located, thus overcoming the problem of seed orientation.

Systems based on weed recognition rely on morphologic features (leaf or plant shape) or colour and spectral reflectance techniques. Although they appear to have good potential in ideal conditions, some weaknesses remain due to the specificity of site-crop-weed combination, the lack of robust methods for resolving occlusion, leaf damage and other visual “defects” (when working on the geometrical shape of the green elements), the need of a compromise between increasing sensitivity and the risk of misclassification between weed and crop (Slaughter et al., 2008; Lee et al., 2010).