Cyperus esculentus Clones

Subjects: Others | Agriculture, Dairy & Animal Science
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Cyperus esculentus (yellow nutsedge) is one of the world's worst weeds as it can cause great damage to crops and crop production. To eradicate *C. esculentus,* early detection is key—a challenging task as *it* is often confused with other *Cyperaceae* and displays wide genetic variability.

Keywords: reflectance ; logistic regression ; partial least squares–discriminant analysis ; random forest ; yellow nutsedge ; weed classification

1. Introduction

Cyperus esculentus L. (yellow nutsedge) is a perennial C4 weed of the Cyperaceae family that originated from (sub) tropical areas and is listed as the sixteenth worst weed in the world [1]. In 1982, C. esculentus was detected for the first time in Limburg, the easternmost province of Flanders (northern part of Belgium) [2]. Since then, the species has moved in west through Flanders; it now covers an estimated agricultural area of 16,000 ha and is still spreading [3]. Cyperus esculentus is also spreading rapidly in Central Europe because of accidental introductions and subsequent expansion [4]. The species is hard to eradicate because of its enormous capacity for multiplying and spreading, and its low sensitivity to control measures [1]. Cyperus esculentus produces seeds and hard tubers at rhizome tips [5]. Tuber dispersal is generally regarded more important for the spread of this species than seed dispersal [6]; a single mother tuber is able to produce more than 1900 shoots and nearly 6900 tubers in an area of 3.2 m^2 in one year [7]. These tubers can stay dormant in the soil for several years; laboratory analysis showed a half-life of 5.7 months for tubers buried at 0.2 m [8], making eradication very hard [9]. Bohren and Wirth [10] summarized potential control methods for C. esculentus control, including cultural, mechanical and chemical methods; which is recommended depends on the infestation degree and spatial distribution. Initial small infestations can be controlled by removing all plant parts and infested soil, while heavy ones rely mostly on chemical weed control, or, in the worst case, require long fallows. Controlling C. esculentus is most effective when depleting existing tubers and preventing the formation of new ones [11] and relies on yearly repeated herbicide applications [12][13]. Pereira et al. [12] reviewed the suitability of different herbicides tested for combatting C. esculentus and designated the poor and temporary control, provided by most chemicals, as one of the reasons for failure. A combination of pre-emergence or preplant incorporated and postemergence herbicides have proven to be effective [14][15]. Another problem that farmers face when controlling C. esculentus is its genetic variability. There exist four wild varieties of Cyperus esculentus: var. esculentus, var. heermannii, var. leptostachyus Boeckeler and var. macrostachyus Boeckeler [16]. Mulligan and Junkins [17] stated that there exists evidence of significant genetic differences among C. esculentus populations and that these differences are relevant to the control of the species. De Cauwer et al. [3] observed large interclonal differences in herbicide sensitivity in Belgian C. esculentus clones. Additionally, although successful trials have been completed [13][18], eradication success greatly depends on early detection and treatment [19]. As young growth stages are more susceptible to chemical treatment [20][21][22], and misclassification can result in an enormous number of tubers, it is necessary to adequately and quickly determine this species. In addition, because of its risk to agriculture, farmers in Belgium are required by law to control C. esculentus. When C. esculentus is detected on a field, it is illegal to grow root, tuber or bulb crops and to remove infested soil; farmers are obliged to clean machinery when leaving an infested field and take appropriate control actions [23]. The European and Mediterranean Plant Protection Organization (EPPO) has included the weed on the list of invasive alien plants, against which action should be taken to prevent the spread within its member states [24].

However, C. esculentus is often confused with other Cyperaceae. Bearing in mind the species diversity of this family, and the implications this weed has for farmers, there is a strong need for a cheap and portable detection system. Reflectance spectroscopy is built on the idea that different plant species, or in extension, varieties, might induce distinct spectral features which can be used in species discrimination. It has proven to be able to distinguish between different weed-crop combinations [25][26][27][28][29][30][31][32], between different co-occurring species [33][34][35] and even between different clonal populations of one species [36]. Hyperspectral spectrometers measure reflectance with a very high spectral resolution and are able to detect small differences in reflectance. Hyperspectral sensors sensitive in the range of 400–900 nm have been used for classifying different varieties of maize [37]. A hand-held spectrometer with a leaf clip having a built-in integrating sphere is a good alternative to computer-based scatter corrections [38][39], limiting the time needed for preprocessing. As a result, the combination of a hand-held spectrometer with hyperspectral resolution and a leaf clip with an integrating sphere seems to be a suitable setup for recognizing C. esculentus. Although hyperspectral spectroradiometers are much cheaper than most imaging sensors, they are still expensive for farmers, especially when used for only one—very economically important—weed. Spectroradiometers with fewer wavelengths offer a more affordable solution.

2. Description

The objective was to classify *C. esculentus* clones and morphologically similar weeds. To that end, hyperspectral reflectance was tested as a measure to discriminate between (I) *C. esculentus* and morphologically similar *Cyperacea* weeds, and between (II) different clonal populations of *C. esculentus*. The robustness of the models created for Experiment I was checked using two datasets (III): data of Experiment II and a dataset consisting of *C. esculentus* samples from an infested maize field in Lede, Belgium. To develop a low-cost tool for farmers in the future, a study was done to appoint particular wavelengths in Experiment I that are able to discriminate between *C. esculentus* and other weeds (IV). Classification results of this study were compared against simulated results from a commercially available multispectral camera with four spectral bands.

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