Hyperspectral Classification of Cyperus esculentus Clones and Morphologically Similar Weeds

Subjects: Others | Agricultural Sciences & Agronomy
Created by: Marlies Lauwers

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. In this study, the objective was to classify C. esculentus clones and morphologically similar weeds. Hyperspectral reflectance between 500 and 800 nm was tested as a measure to discriminate between (I) C. esculentus and morphologically similar Cyperaceae weeds, and between (II) different clonal populations of C. esculentus using three classification models: random forest (RF), regularized logistic regression (RLR) and partial least squares–discriminant analysis (PLS–DA). RLR performed better than RF and PLS–DA, and was able to adequately classify the samples. The possibility of creating an affordable multispectral sensing tool, for precise in-field recognition of C. esculentus plants based on fewer spectral bands, was tested. Results of this study were compared against simulated results from a commercially available multispectral camera with four spectral bands. The model created with customized bands performed almost equally well as the original PLS–DA or RLR model, and much better than the model describing multispectral image data from a commercially available camera. These results open up the opportunity to develop a dedicated robust tool for C. esculentus recognition based on four spectral bands and an appropriate classification model.

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. In 1982, C. esculentus was detected for the first time in Limburg, the easternmost province of Flanders (northern part of Belgium). 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. Cyperus esculentus is also spreading rapidly in Central Europe because of accidental introductions and subsequent expansion. The species is hard to eradicate because of its enormous capacity for multiplying and spreading, and its low sensitivity to control measures. Cyperus esculentus produces seeds and hard tubers at rhizome tips. Tuber dispersal is generally regarded more important for the spread of this species than seed dispersal; a single mother tuber is able to produce more than 1900 shoots and nearly 6900 tubers in an area of 3.2 m² in one year. 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, making eradication very hard. Bohren and Wirth 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 and relies on yearly repeated herbicide applications. Pereira et al. reviewed the suitability of different herbicides tested for combating 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. Mulligan and Junkins 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. observed large interclonal differences in herbicide sensitivity in Belgian C. esculentus clones. Additionally, although successful trials have been completed, eradication success greatly depends on early detection and treatment. As young growth stages are more susceptible to chemical treatment, 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. 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.
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, between different co-occurring species, and even between different clonal populations of one species. 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. A hand-held spectrometer with a leaf clip having a built-in integrating sphere is a good alternative to computer-based scatter corrections, 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.

In this study, 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 Cyperaceae weeds, and between (II) different clonal populations of C. esculentus. The robustness of the models created for Experiment I was checked using two datasets: 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. Classification results of this study were compared against simulated results from a commercially available multispectral camera with four spectral bands.

References

1. Holm, L.G.; Plucknett, D.L.; Pancho, J.V.; Herberger, J.P. The world’s worst weeds; University Press: Honolulu, HI, USA, 1977.
2. Verloove, F. Manual of the Alien Plants of Belgium. Available online: http://alienplantsbelgium.be/ (accessed on 1 October 2019).
3. De Cauwer, B.; De Ryck, S.; Claerhout, S.; Biesemans, N.; Reheul, D. Differences in growth and herbicide sensitivity among Cyperus esculentus clones found in Belgian maize fields. Weed Res. 2017, 57, 234–246.
4. Follak, S.; Aldrian, U.; Moser, D.; Essl, F. Reconstructing the invasion of Cyperus esculentus in Central Europe. Weed Res. 2015, 55, 269–297.
5. Wills, G.D. Description of purple and yellow nutsedge (Cyperus rotundus and C. esculentus). Weed Technol. 1987, 1, 2–9.
6. Stoller, E.W.; Sweet, R.D. Biology and life cycle of purple and yellow nutsedges (Cyperus rotundus and C. esculentus). Weed Technol. 1987, 1, 66–73.
7. Tumbleson, M.E.; Kommedahl, T. Reproductive potential of Cyperus esculentus by tubers. Weeds 1961, 9, 646–653.
8. Stoller, E.W.; Wax, L.M. Yellow nutsedge shoot emergence and tuber longevity. Cambridge Univ. Press behalf Weed Sci. Soc. Am. 1973, 21, 76–81.
9. Stoller, E.W.; Nema, D.P.; Bhan, V.M. Yellow nutsedge tuber germination and seedling development. Weed Sci. 1972, 20, 93–97.
10. Bohren, C.; Wirth, J. Implementation of control strategies against yellow nutsedge (Cyperus esculentus L.) into practice. Julius Kühn Archiv 2018, 458, 188–196.
11. Nelson, K.A.; Renner, K.A. Yellow nutsedge (Cyperus esculentus) control and tuber production with glyphosate and ALS-inhibiting herbicides. Weed Technol. 2002, 16, 512–519.
12. Pereira, W.; Crabtree, G.; William, R.D. Herbicide action on purple and yellow nutsedge (Cyperus rotundus and C. esculentus). Weed Technol. 1987, 1, 92–98.
13. Stoller, E.W.; Wax, L.M.; Silfe, F.W. Yellow nutsedge (Cyperus esculentus) competition and control in corn (Zea mays). Weed Sci. 1979, 27, 32–37.
14. Felix, J.; Newberry, G. Yellow nutsedge control and reduced tuber production with S-metolachlor, halosulfuron plus dicamba, and glyphosate in furrow-irrigated corn. Weed Technol. 2012, 26, 213–219.
15. Edenfield, M.W.; Colvin, D.L.; Brecke, B.J.; Shilling, D.G.; Mclean, H.H. Weed management in peanut (Arachis hypogaea) with pyridate and SAN 582 Systems. Weed Technol. 2001, 15, 13–18.
16. Schippers, P.; Ter Borg, S.J.; Bos, J.-J. A Revision of the infraspecific taxonomy of Cyperus esculentus (Yellow Nutsedge) with an experimentally evaluated character set. Syst. Bot. 1995, 20, 461–481.
17. Mulligan, A.; Junkins, B.E. The biology of Canadian weeds. 17. Cyperus esculentus L. Can. J. Plant Sci. 1976, 56, 339–350.
18. Yu, J.; Boyd, N.S. Weed control with and strawberry tolerance to herbicides applied through drip irrigation. Weed Technol. 2017, 31,
19. Ransom, C.V.; Rice, C.A.; Shock, C.C. Yellow Nutsedge (Cyperus esculentus) growth and reproduction in response to nitrogen and irrigation. Weed Sci. 2009, 57, 21–25.

20. Stoller, E.W.; Wax, L.M.; Matthiesen, R.L. Response of yellow nutsedge and soybeans to bentazon, glyphosate, and perfluidone. Weed Sci. 1975, 23, 215–221.

21. Abouziena, H.F.H.; Omar, A.A.M.; Sharma, S.D.; Singh, M. Efficacy comparison of some new natural-product herbicides for weed control at two growth stages. Weed Technol. 2009, 23, 431–437.

22. Singh, S.; Singh, M. Effect of growth stage on trifloxysulfuron and glyphosate efficacy in twelve weed species of citrus groves. Weed Technol. 2004, 18, 1031–1036.

23. Departement Landbouw en Visserij Praktijkgids Gewasbescherming. Available online: https://lv.vlaanderen.be/nl/plant/gewasbescherming/praktijkgids-gewasbescherming (accessed on 4 November 2019).

24. FAVV ADVIES 07-2015: Ontwerp van Koninklijk Besluit tot Opheffing van het Koninklijk Besluit van 12 mei 2011 Betreffende Specifieke Maatregelen om Knolcyperus (Cyperus esculentus L.) te Bestrijden en de Verspreiding Ervan te Voorkomen (dossier SciCom 20). Available online: http://www.afsca.be/wetenschappelijkcomite/adviezen/2015/ (accessed on 1 October 2019).

25. Gerhards, R.; Oebel, H. Practical experiences with a system for site-specific weed control in arable crops using real-time image analysis and GPS-controlled patch spraying. Weed Res. 2006, 46, 185–193.

26. Borregaard, T.; Nielsen, H.; Nørgaard, L.; Have, H. Crop-weed discrimination by line imaging spectroscopy. J. Agric. Eng. Res. 2000, 75, 389–400.

27. Herrmann, I.; Shapira, U.; Kinast, S.; Karmieli, A.; Bonfil, D.J. Ground-level hyperspectral imagery for detecting weeds in wheat fields. Precis. Agric. 2013, 14, 637–659.

28. Shapira, U.; Herrmann, I.; Karmieli, A.; Bonfil, D.J. Field spectroscopy for weed detection in wheat and chickpea fields. Int. J. Remote Sens. 2013, 34, 6094–6108.

29. Gao, J.; Nuyttens, D.; Lootens, P.; He, Y.; Pieters, J.G. Recognising weeds in a maize crop using a random forest machine-learning algorithm and near-infrared snapshot mosaic hyperspectral imagery. Biosyst. Eng. 2018, 170, 39–50.

30. Slaughter, D.C.; Giles, D.K.; Fennimore, S.A.; Smith, R.F. Multispectral machine vision identification of lettuce and weed seedlings for automated weed control. Weed Technol. 2008, 22, 378–384.

31. Pérez, A.J.; López, F.; Benlloch, J.V.; Christensen, S. Colour and shape analysis techniques for weed detection in cereal fields. Comput. Electron. Agric. 2000, 25, 197–212.

32. Dyrmann, M.; Karstoft, H.; Midtiby, H.S. Plant species classification using deep convolutional neural network. Biosyst. Eng. 2016, 151, 72–80.

33. Harrison, D.; Rivard, B.; Sánchez-Azofeifa, A. Classification of tree species based on longwave hyperspectral data from leaves, a case study for a tropical dry forest. Int. J. Appl. Earth Obs. Geoinf. 2018, 66, 93–105.

34. Wang, C.; Zhou, B.; Palm, H.L. Detecting invasive sericea lespedeza (Lespedeza cuneata) in Mid-Missouri pastureland using hyperspectral imagery. Environ. Manage. 2008, 41, 853–862.

35. Taylor, S.; Kumar, L.; Reid, N.; Lewis, C.R.G. Optimal band selection from hyperspectral data for Lantana camara discrimination. Int. J. Remote Sens. 2012, 33, 5418–5437.

36. Fernandes, A.M.; Melo-Pinto, P.; Millan, B.; Tardaguila, J.; Diago, M.P. Automatic discrimination of grapevine (Vitis vinifera L.) clones using leaf hyperspectral imaging and partial least squares. J. Agric. Sci. 2015, 153, 455–465.

37. Chivasa, W.; Mutanga, O.; Biradar, C. Phenology-based discrimination of maize (Zea mays L.) varieties using multitemporal hyperspectral data. J. Appl. Remote Sens. 2019, 13, 017504.

38. Gratton, E. Method for the automatic correction of scattering in absorption spectra. Biopolym. Orig. Res. Biomol. 1971, 10, 2629–2634.

39. Dazzi, A.; Deniset-Besseau, A.; Lasch, P. Minimising contributions from scattering in infrared spectra by means of an integrating sphere. Analyst 2013, 138, 4191–4201.

**Keywords**

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

Retrieved from https://encyclopedia.pub/1772