Use of Vegetation indices to detect plant diseases

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Abstract: Today's agriculture is not only confronted with the production of food and animal food, but also with aspects of environmental protection. In today's crop production, there is an increasing pressure to reduce the use of pesticides, to decrease the environmental impact and to lower potential production costs. It is therefore imperative that pesticides are only applied when and where needed. Disease control might be more efficient if disease patches within fields could be identified and fungicides applied only to infected areas. Recent developments in optical sensor technologies indicate the potential to enable direct detection of foliar diseases under field conditions ([We03]). In the context of this study different vegetation indices were evaluated for their potential to detect and identify different plant diseases. The influence of *Erysiphe graminis* (powdery mildew) and *Septoria tritici* (leaf blotch disease) on canopy refectance of winter wheat was analyzed in various field trials. Canopy reflectance was measured every 7 days starting from May until mid of July depending on the development of the plants. Reflectance measurements were carried out with a fieldspectroradiometer Field Spec® Hand Held (ASD, Inc. Boulder, CO, USA). Reflectance data was evaluated according to known vegetation indices in allegorized specified reflectance bands. Vegetation indices were evaluated for their suitability to detect differences in vitality between healthy and diseased plants and were used to compare the effectiveness of different sensor systems for the purpose of disease identification. From a multiplicity of existing vegetation indices the indices able to detect the relevant plant diseases were selected.

Introduction

The maximum yield of plants, determined by their genetic potential, is seldom achieved. Factors such as insufficient water or nutrients, adverse climatic conditions, plant diseases, and insect damage limit growth at some stage. Especially plant diseases are one of the main reasons for loss in yield and quality. Approximately 30 % of the world harvest is lost on an annual basis due to biotic stress factors ([HG00]). The most widely used method in pest and disease control in arable crops is still to spray pesticides uniformly over fields at different times during the cultivation cycle. However, most disease infestations are not evenly distributed across the field but occur in patches. Pesticides should be targeted only on those places in the field where they are needed.

A simple and cost-effective optical device would allow disease patches to be identified and thus controlled [Mo05]. Various attempts using multispectral sensors and satellite images in detection of diseased crops have been made ([Ka74], [PG77]). During the last decade, vegetation indices based on simple combinations of visible and near-infrared reflectance, such as the normalized difference vegetation index (NDVI) and simple ratio (SR), have been widely used by the remote sensing community to monitor vegetation from space, both on regional and global scales. For the analysis of the FieldSpec measurements the vegetation indices MCARI proposed by [Da00], TCARI proposed by [Ha02], OSAWI proposed by [RSB96] and the vegetation index NPCI proposed by [Pe94] were used in this study.

2 Materials and Methods

2.1 Field experiments

To measure reflectance changes under leaf blotch and powdery mildew in the field, a field experiment was conducted during the growing period of 2005 and 2006 at the Experimental Station "Ihinger Hof" (48°44´ N, 8°56´E; 687 mm, 7.9 °C) of the University of Hohenheim, Stuttgart, Germany. Winter wheat cv. Monopol and Empire were planted. The variety Empire is classified as a high resistant variety, whereas Monopol has a very low resistance against diseases in general (Bundessortenamt, 2005). The inoculum steps I1 = no inoculum = control, I2 = 50 % inoculum, I3 = 100 % inoculum were applied. The trial was set up as randomized block design with three replications.

The plots were inoculated with leaf blotch in the spring at GS 32 by strewing infected wheat grain into the plots (CBS 292.69, Germany). Plants were inoculated with powdery mildew (*Erysiphe graminis* 150, powdery mildrew resistant gene Pm1, 2, 3a, 3c, 3d, 4a, 4b, 5, 6, 7, 8 and 17 obtained from the Federal Biological Research Centre for Agriculture and Forestry, Kleinmachnow, Germany) at GS 30 and 31 by putting infected plants between the plants in the field. Measurements started seven days after the inoculation. To detect the spectral differences between healthy and diseased wheat leafs, the hyperspectral spectroradiometer "FieldSpec HandHeld" by ASD (Analytical Spectral Devices) was used to collect canopy reflectance data. The FieldSpec Hand Held spectroradiometer has a wavelength range of 325 nm to 1075 nm with an interval of 1.6 nm and a viewing angle of 25 degrees. The spectroradiometer was located two meters above the canopy. According to [LBD03] causes the measuring viewing angle (a) of 25 degrees a field of view (A) of 62 cm^2 with a field of view radius '(R) of 44 cm. To compare healthy and diseased wheat plants with the experimental field area, six spectroradiometer measurements were made in each plot.

These measurements were averaged to one spectral curve for each inoculum step and each variety. The intermediated results were used to appoint and evaluate vegetation indices.

2.2 Vegetation indices

For the analysis of the FieldSpec measurements the four vegetation indices MCARI [Da00], TCARI (Transformed Chlorophyll Absorption in Reflectance Index) [Ha02], OSAWI (Optimized Soil-Adjusted Vegetation Index) ([Hu88]) and NPCI (Normalized Pigment Chlorophyll Index) ([Pe94]) were used in this study. The indexes are given in equation 1-4.

$$MCARI = [(R_{700} - R_{670}) - 0.2*(R_{700} - R_{550})]*(R_{700}/R_{670}) \quad (1)$$

$$TCARI = 3*[(R_{700} - R_{670}) - 0.2*(R_{700} - R_{550})(R_{700}/R_{670})] \quad (2)$$

$$OSAVI = (1 + 0.16)(R_{800} - R_{670})/(R_{800} + R_{670} + 0.16) \quad (3)$$

$$NPCI = (R_{680} - R_{430})/(R_{680} + R_{430}) \quad (4)$$

where

R430	reflectance at 430 nm [%]
R550	reflectance at 550 nm [%]
R670	reflectance at 670 nm [%]
R680	reflectance at 680 nm [%]
R700	reflectance at 700 nm [%]
R800	reflectance at 800 nm [%]

3. Results and Discussion

The analysis of the reflectance data by the four vegetation indices indicated that there are significant differences between healthy and diseased plants. At the measurement date 04.07.06 powdery mildew diseased plants indicated differences between the control and the treatment 50 % as well as the treatment 100 % for the vegetation indices OSAWI and NPCI (Tab. 1). The value of OSAWI declined from 0.7814 to 0.6558 and the value of NPCI rose from 0.0510 up to 0.1860.

Vegetation Indices	MCARI		TCARI		OSAWI		NPCI	
Monopol 04.07.06								
Control	0.2413	a	0.1833	a	0.7814	a	0.0510	a
50%	0.1821	a	0.1634	a	0.6771	b	0.1755	b
100%	0.1728	a	0.1665	a	0.6558	b	0.1860	b
Empire 04.07.06								
Control	0.2413	a	0.1722	a	0.7790	a	0.1071	a
50%	0.2081	a	0.1674	a	0.7187	b	0.1578	a
100%	0.2178	b	0.1672	b	0.7359	a	0.1270	a

Tab.1: Used reflectance indices for the varieties Monopol and Empire on the measurement dates 04.07.06 inoculated with powdery mildew

Table 2 shows the vegetation indices for the disease leaf blotch at the measurement date 04.07.06. Differences between healthy and diseased plants were shown for the indices TCARI for the cultivar Monopol and MCARI, TCARI and OSAWI for the cultivar Empire.

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Vegetation Indices	MCARI		TCARI		OSAWI		NPCI	
Monopol 04.07.06								
Control	0.1775	a	0.1903	a	0.6883	a	0.2262	a
50%	0.1368	a	0.1749	a	0.5950	a	0.2990	a
100%	0.1487	a	0.1783	b	0.6251	a	0.2853	a
Empire 04.07.06								
Control	0.2042	a	0.1986	a	0.7251	a	0.2241	a
50%	0.1200	b	0.1538	a	0.5482	b	0.2378	a
100%	0.1414	b	0.1747	b	0.6145	b	0.2797	a

Tab.2: Used reflectance indices for the varieties Monopol and Empire on the measurement dates 04.07.06 inoculated with leaf blotch

4. Conclusion

All used vegetation indices were suitable to detect differences in the reflection between healthy and diseased plants. But there was no specific vegetation index for only one of the diseases. Also the sensitivity of the indices was not very high. More vegetation indices have to be tested.

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