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Snapshot Hyperspectral Imaging for Field Data Acquisition in Agriculture (in Raspberry Plantation)

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Abstract: A snapshot spectral camera with more than 100 spectral channels was used and tested. A native snapshot imaging spectrometer captures all spectra and the entire image at the same time without any time delay. It enables this imaging system to capture motion pictures and producing hyperspectral videos.
In our horticulture study a snapshot camera was applied to spectrally document, map and characterize a raspberry plantation under differently coloured shade nets to analyse usability, flexibility and to record spectro-phenological parameters. Leading raspberry producers are located in Eastern Europe and contribute at least 80% of the world's raspberry production (FAOSTAT, 2016). Due to agricultural climate change scenarios raspberry plantations are at risk because evapotranspiration will be challenged by solar radiation and temperature changes. We concluded that spectral field data acquisition and length of data evaluation could be significantly reduced by snapshot spectral imaging.

1 Introduction

Hyperspectral technique is a powerful asset to rapidly assess qualitative and quantitative parameters of vegetation (FENYVESI 2008; DEÁKVÁRI et al. 2008). It provides with a unique solution in complex agro-ecosystem monitoring (MILICS et al. 2008; MILICS et al. 2010; JUNG et al. 2017). It has high importance in soil condition and nutrient-supply analysis (CSORBA et al. 2012, 2014; FEKETE 2016). Hyperspectral imaging techniques are used in many agricultural applications. Spectral scanners have successfully mastered several applications; however scanning is facing some limitations when the test object and/or the camera are randomly moving. To eliminate all these limitations snapshot hyperspectral imaging technique can be successfully applied. In principle, this system is capturing the entire hyperspectral image during a single integration time (one shot takes about 1 ms). For this reason we used and tested a snapshot spectral camera with more than 100 spectral channels for a novel agricultural research project.
We applied the snapshot camera to spectrally document, map and characterize a raspberry plantation under differently coloured shade nets to analyse usability, flexibility and to record spectro-phenological parameters. Snapshot hyperspectral imaging provided us a rapid and easy-to-use data acquisition tool for spectral mobile mapping. It worked as non-invasive and non-destructive sampling method with extreme short data acquisition time.

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2 Materials and Methods

2.1 Experimental site

In order to find a reasonable solution to protect the plants and increase the stability of the production a raspberry plantation with different varieties was established. A sun protective shade tunnel system was constructed to create a test site at NAIK - Fruitculture Research Institute (FRI), Fruit Culture Research and Development Institute of Fertőd, Hungary. It provides opportunity to measure and evaluate relevant biological and physical parameters playing an important role in berry production (Keller et al., 2018). Experimental plantation (Figure 1) of three different raspberry varieties was set in two repetitions: covered and uncovered versions (Table 1).

Fig. 1: Experimental raspberry site at NAIK in Fertőd, Hungary

Each cover has characteristic interaction with light which is expected to generate different environmental conditions and also differences in plant growth and fruit quality. (Table 1).

Tab. 1: Covered and uncovered plantations with the concerned species

		Covered 1 2 3 4 5 6 7 8		Uncoverred 1 2 3 4 5 6 7 8
1. plantation	1. row	Julcsi	1. row	Julcsi
	2. row	Fertődi zamatos	2. row	Fertődi zamatos
	3. row	Eszterházai kétszertermő	3. row	Eszterházai kétszertermő
2. plantation	1. row	Fertődi zamatos	1. row	Fertődi zamatos
	2. row	Eszterházai kétszertermő	2. row	Eszterházai kétszertermő
	3. row	Julcsi	3. row	Julcsi

To measure the spectral conditions (JUDD et al. 1964) under the shade nets and the spectral response and features of plants with proximal sensing a portable spectroradimeter and a snapshot hyperspectral camera were used (Figure 2). Portable spectroradiometers can widely be used both in field and laboratory. It is adequate to carry out independent, fast and precise evaluations in an

economic way. The full-range device extends the range of the detectable visible light to NIR and SWIR covering the spectral range of 350 to 2500 nm. These spectrometers have successfully mastered several applications; however scanning is facing some limitations when the test object and/or camera are randomly or rapidly moving in time and space. In agricultural field and close-field applications weight and speed have high importance (JUNG et al. 2017).
Portable spectral field measurements were carried out in the control area and under two different types of tunnels. Data acquisition was made by using ASD FieldSpec 3 MAX portable spectroradiometer (350-2500 nm) with Plant Probe head and Cubert snapshot spectral camera (400-1000 nm) on randomly selected leaves (>100) .The same reference panel was used as a standard surface reflecting 95 % of all incident radiation for both acquisition methods.

Fig. 2: ASD FieldSpec 3 MAX (350-2500 nm) and Cuber UHD185 (400-1000 nm)

2.2 Indices

In order to compare the light utilization efficiency, the water and nitrogen management of plants under various shade nets contact measurements vegetation indices were calculated such as **P**hotochemical **R**eflectance **I**ndex – PRI (GAMON et al. 1992), **W**ater **I**ndex – WBI (PENUELAS et al. 1995), **N**ormalized **N**itrogen **I**ndex – NDNI (SERRANO et al. 2002) and **N**ormalized **D**ifference **V**egetation **I**ndex – NDVI (ROUSE et al. 1973).

3 Results

3.1 Phenological and chemical properties

Studying the phenological features of strawberry plantation we can state that the occurring differences are species-specific therefore the effect of shaded nets weren't or just partly observable. Well distinguishable discrepancies between the plantations could be observed during the blooming and ripening period. Within the covered plantation the blooming was started and finished earlier, while the ripening process indicated the opposite in case of some species (*Eszterházai* and *Julcsi*). In case of *Fertődi zamatos* the blooming and ripening begun later compared to other species. The blooming and ripening period of covered plantation shifted later. Higher yields were reached in case of covered plantations under white Raschel net. The highest yield was measured in case of *Eszterházai*, which was 16-36% higher than in outdoor fields. In the case of *Julcsi*, the yield growing was also occurred under cover with 13-18% rate. The *Fertődi zamatos* showed weaker results than in outdoor, uncovered plantations. In case of average berries, the volume was different. The largest average berries were found at *Julcsi* and

Eszterházai varieties. The volume of production was doubled compared to 2016, as a result of the growth of the plantation. The species-specific features are visible (Table 2).

Tab. 2: The mass of whole amount and the average berries during the last two years under different cover system

	2016		2017	
Coverage	Whole amount (g)	Average berries (g)	Whole amount (g)	Average berries (g)
White net	156 266	7,22	247 707	6,74
Black net	89 874	6,83	199 904	6,52
Control	85 499	7,17	206 167	6,31

3.2 Index responses

The processed spectral measurement dataset revealed a tendency of differences in case of photochemical reflectance index (PRI). Based on the dataset the light utilisation efficiency of all varieties under shade nets were higher than in the control plantation. Water index (WBI), normalized nitrogen index (NDNI) and normalized vegetation index (NDVI) did not show differences between treatments (Table 3).

Tab. 3: Different vegetation indices in case of different treatments

21.06.2017			
	White net	**Black net**	**Control**
PRI	0,019	0,047	0,016
WBI	0,984	0,985	0,989
NDNI	0,142	0,127	0,142
NDVI	0,822	0,830	0,822
02.08.2017			
	White net	**Black net**	**Control**
PRI	0,039	0,031	0,021
WBI	1,001	0,982	0,990
NDNI	0,138	0,139	0,150
NDVI	0,840	0,829	0,830

It means the soil preparation; nutrient supply and irrigation assure the favourable homogeneity of the plantation and the only variable between treatments is the difference of illumination. The images acquired with snapshot camera were used to evaluate the shade nets and open sky from below to describe the spectral distribution of the incident light. On the other hand, vegetation survey was performed to visualize reflective features of the vegetation and also the heterogeneity arising within plants. Differences between ratios of significant ranges playing important role in vegetation monitoring to indicate alteration of plant condition (Figure 3).

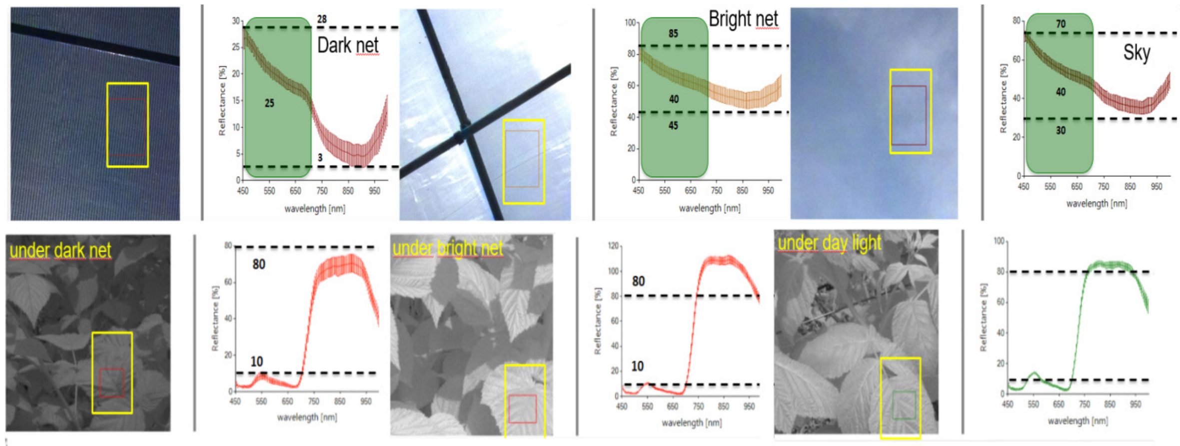

Fig. 3: Hyperspectral images describing the incident and reflected radiation in the VIS and NIR region

Generally the main indicators of different efficiency of production technologies are yield and fruit quality. Within the frame of the research correlations between shade nets and fruit size was observed. *Julcsi* reacted positively to the white coloured shade net in two consecutive years with extra 72% (2016) and 24% growth of yield. *Eszterházai kétszertermő* reacted with extra 140% (2016) and 104% of yield moreover with extra fruit size 4,6% (2016) and 36,69% (2017). *Fertődi zamatos* did not show such a significant reaction to the treatment.

4 Conclusions

A portable spectroradiometer and a snapshot hyperspectral camera with more than 100 spectral channels were used to spectrally map a raspberry plantation under different type of shade nets. It was also a purpose to test and document the usability, flexibility of such techniques in collecting spectro-phenological parameters in a hand-held way. An in-situ ambient monitoring system was also set up to collect temperature, humidity and radiation data. Spectral techniques provided opportunity to reveal such differences in natural light conditions that are usually not detected by traditional weather stations and make possible to study the correlation between light condition and plant growth in a more complex way.

The results show significant differences between plantations with or without shade net cover. Measured ambient parameters and spectral analysis of the vegetation revealed differences in plant condition and indicated the effect of shade nets and also the differences between the two experimental shade net materials. Shade nets can increase the yield and also increase the average berry size but the reaction to shade nets seems to be variety-specific. Yield reacted very positively to white shade nets in case of *Eszterházai kétszertermő* and *Julcsi* varieties, in two consecutive years. Fruit size reacted significantly positively in 2017. In case of *Fertődi zamatos* variety significant positive effect of shade materials was not confirmed. Variety-specific shade net-based production technology can offer a solution to improve yield, quality and production stability of raspberry. The tunnel system can be quickly deployed so it offers an immediate action to mitigate the effects of climate changes. It can also serve as an intermediate step towards agroforestry systems or remain a complementary technique with options to be used as spectral filters adjusted to plant needs or physical barriers for pests or to create a microclimate. Although the first synthesises already show useful correlations for the practice further crop years and additional measurements, analyses are necessary to identify the best production practice.

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