Estimation of moisture content in cucurbitaceae Seedlings using hyperspectral imagery

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Introduction

Various researches have been carried out for the environmental management of seedlings in nursery and attempted to develop non- destructive and rapid measurement methods using hyperspectral imaging technology. This research was conducted to develop moisture content prediction model of cucurbitaceae seedlings and estimate its performance using hyperspectral imagery.

Materials and methods

Sample

Table 1. Experimental plants

Seedling	Cucumber	Water melon
Variety	Ipchunakhab	Geumbo
Growth Days	18 days	27 days
Number	45	45

(a) (b)

Figure 1. Hyperspectral Image of Cucumber (a) and Water melon (b)

The seedlings used in the experiment were 45 cucumber seedlings and 45 watermelon seedlings provided Wonkwang university(Table 1.). Cucumber and watermelon seedlings were placed on five trays at nine each and leaves were prevented from overlapping each other.

Equipment and Site

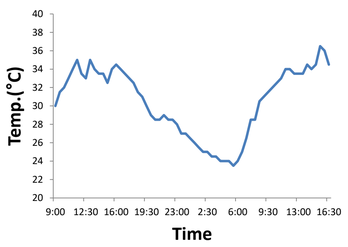
Figure 2. Hyperspectral Camera

- **Hyperspectral Camera**
device name : VNIR spectral camera PS
Manufacturer : Specim Spectral imaging Ltd, Finland
Photographed Wavelength Range : 400 ~ 1000nm (resolving power : 2nm)
- **Lens**
Lens name : V23 C-Mount (Specim, Finland)
Focal length : 23nm
Aperture : f/2.4
FOV(Field Of view) : 21.1 degrees

Wonkwang University Greenhouse

Latitude :35° 58'11.02"N
Longitude : 126° 57'43.23"E

Figure 3. Experiment place

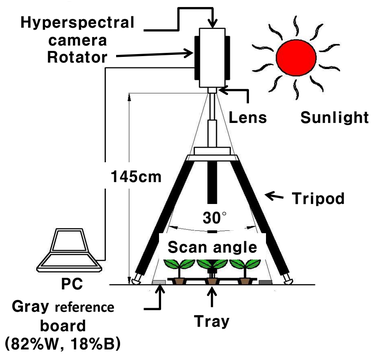


Greenhouse internal mean temperature

Daytime : 34℃
Night : 26℃

Figure 4. Temperature graph

Image Acquisition



The height of the camera was 145 cm from the ground. The hyperspectral images were obtained with image acquisition program (Spectral DAQ, Specim Spectral Imaging Ltd., Finland) by rotating the camera. In order to calibrate the sunlight, a reference standard (EzyBalance Grey/White Card 30", White balance 18%, Lastolite Ltd, England).

Figure 5. Configuration of camera and sample

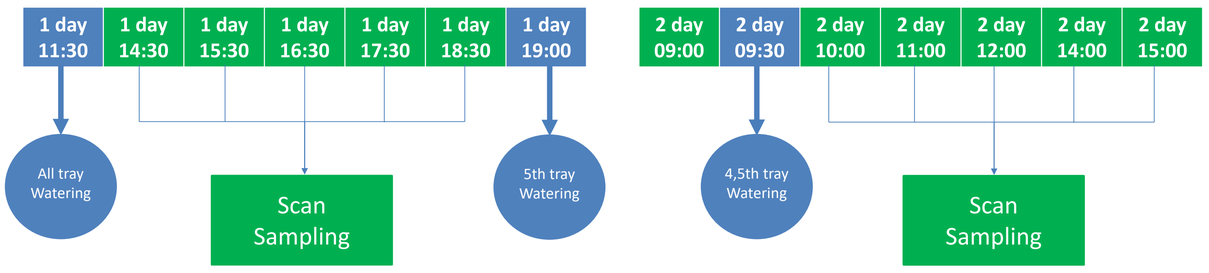


Figure 6. Schedule of Scanning and Sampling

Dry weight was measured after drying at 60 ℃ for 72 hours in a dryer. Moisture content was calculated from measured fresh weight and dry weight. After each image acquisition, three seedlings were randomly sampled to measure growth factors. After watering, three watering and three non-watered seedlings were sampled.

Image Processing

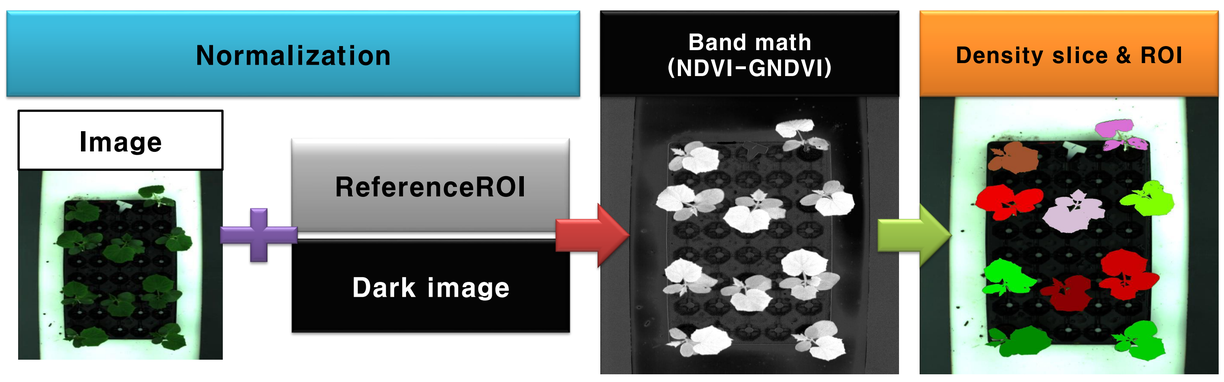


Figure 6. Image processing Mechanism

Using the image professing software (ENVI 5.2, Exelis Visual Information Solution, USA), the reflectance was corrected with black and gray references (Fig. 3) The vegetation index (NDVI-GNDVI) (Fig. 4) was applied to band math and the vegetation index is shown in equation (1)

$$\mathrm{NDVI} - \mathrm{GNDVI} = \frac{NIR - Red}{NIR + Red} - \frac{NIR - Green}{NIR + Green} \quad (1)$$

Finally, the reflectance data was calculated from the target area separated by density slice and ROI operations (Fig. 6).

Materials and methods

Analysis method

Figure 7. Statistics Mechanism

Statistical analysis was conducted with R program (software version 3.0.3, R Development Core Team, Vienna, Austria). Partial Least Squared Regression (PLSR) models were developed with mean reflectance and moisture content of the seedlings, The performance of the model was evaluated with Coefficient of determination (R^2), Root Mean Square Error (RMSE), Relative Error (RE) and Full-cross validation (Val) of the model.

Result and Discussion

Reflectance Data & Moisture Content

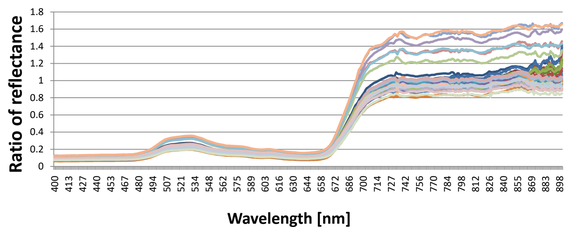


Figure 8. Reflectance Ratio graph.

Table 2. Moisture content

Parameters	Cucumber (n=45)	Water melon (n=45)
Moisture content [%] (Mean±S.D.)	91.6 ± 2.83	93.0 ± 1.84

The average moisture content of 45 seedlings of each variety is shown in Table 2. The moisture content of cucumber seedlings was 91.6 ± 2.83% and the moisture content of Water Melon seedlings was 91.6 ± 2.83%. After testing normality, one cucumber sample was excluded from the dataset, then PLSR models were finally developed.

PLS-Regression Models for Cucurbitaceae Seedlings

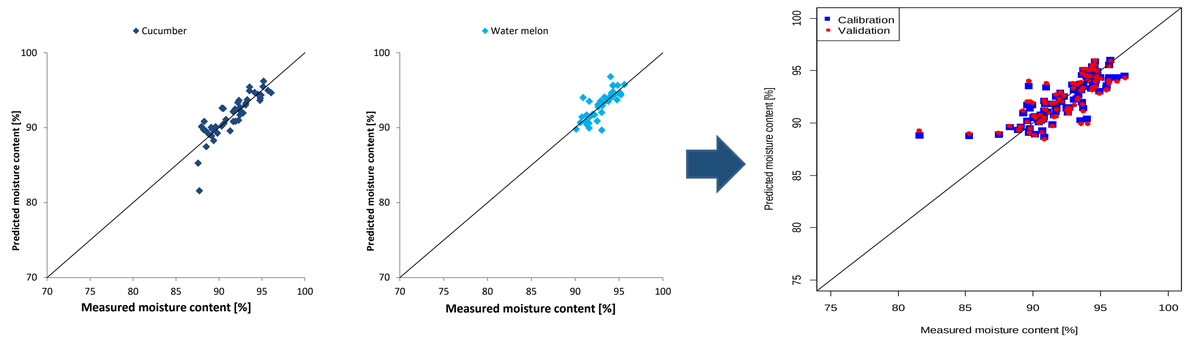


Figure 9. PLSR Graph of Cucumber (a) Water melon (b) and Susubitaceae (c).

Table 3. PLSR model of Cucumber and Water melon

Variety		Cucumber (n=44)	Water melon (n=45)	Cucurbitaceae (n=89)
Moisture content [%] (Mean±S.D.)		91.8 ± 2.41	93.0 ± 1.84	92.3 ± 2.48
LV		5	5	5
Cal.	R^2	0.79	0.66	0.67
	RMSE [%]	1.10	1.06	1.26
	RE [%]	1.20	1.14	1.36
Val.	R^2	0.63	0.45	0.54
	RMSE [%]	1.44	1.35	1.67
	RE [%]	1.57	1.45	1.81

The moisture content model of cucumber predicted 0.79 of R^2, 1.10% of RMSE, and 1.20% of RE. The model of watermelon predicted 0.66 of R^2, 1.06% of RMSE, and 1.14% of RE. The model combined with all samples (n=89) showed 0.67 of R2, 1.26% of RMSE, and 1.36% of RE. (Table 3.) The model of cucumber showed better performance than the model of water melon. This is because variables of cucumber are consisted of widely distributed variation, and it affected the performance better. Further, accuracy and precision of the cucumber model were increased when an insignificant sample was eliminated from the dataset. Finally, it is considered that both models can be significantly used to predict moisture content, as gradients of trend line are almost same and intersected.

Conclusion

It is considered that the accuracy and precision of the estimating models possibly can be improved, if the models are constructed by using variables with widely distributed variation. The improved models will be utilized as the basis for developing low-priced sensors

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