USING OF SPECTROMETRY TO MANAGE TERMS OF IRRIGATION DURING WINTERIZING

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Abstract

The aim of this work is monitoring of the changes of spectrometry leaves Citrus x limon at different times of irrigation and exposure to stress caused by drought or excessive watering for winterizing. The changes were monitored at the plant at different times of irrigation (everyday, each second day, each third day, and once a week). They monitor the changes in the visible spectrum and compared with leaves shed in order to monitor changes spectrometry, choose the correct term irrigation and compare them with stress exposed plants.

Key words: *spectrometry, irrigation, term, Citrus x limon, winterizing*

1. INTRODUCTION

Citrus x limon becomes more and more popular among ordinary Slovak plant growers and is not only of interest of a small group of people who are dedicated tropical respectively subtropical plants. The main reasons for planting are not only aesthetic elements of plants and pleasant scent, but also the possibility of home grown fruit that can be eaten and are not chemically treated.

The aim of the work is to determine the most ideal interval between irrigation terms of reaction plants, which are measured by spectrometer. The point is that we are trying to set dates as appropriate plants and not by moisture, respectively overdrying of the soil, as it is generally possible to determine the terms and amount of irrigation benefits, which is influenced by various factors of air temperature over the relative humidity after the soil substrate.

2. MATERIALS AND METHODS

2.1. Citrus x limon

Citrus are subtropical plants. Therefore, it is a problem to create for cultivation in Slovakia single universal instructions for their cultivation, mainly due to the different microclimatic conditions. To avoid failure, it is necessary to know the demands on the environment and what plants can we provide. Under natural conditions grow periodically, and do not require dormancy.

2.1.1. Ideal conditions for growing

Light- *Citrus x limon* is demanding intense but diffused light. When transferring from the interior to the exterior, and vice versa, it is necessary to plant gradually getting used to changing light conditions, so that the shock missed the growth period. They prefer shadowing by another plant, networks and the like. The apartment needs good lighting which is only by the window. Optimal placement is at the southeastern and southwestern window, but there would have been perfect if it was placed 1 m from the inside of the glass.

Temperature- requirements *citrus x limon* on heat are changing during the year

- -3 to-5 °C critical temperature
- 0 to 10 °C forced dormancy (November to February)
- under 13 °C stop growth
- 14 to 20 °C bloom, fruit ripening, they winterizing under lights

- 20 to 28 °C ideal grown in 2-3 growth period (March-October)
- 30 to 38 °C slowed growth
- over 38 °C stop growth
- over 50 °C critical temperature

Under natural conditions, the air temperature varies during the day about 6 °C. Consequently, if the plant is not placed in a well-ventilated room, does not have sufficient gains will vigorously overnight respiration substances that are formed during the day assimilation. The temperature in the apartments is satisfactory from spring to autumn, but during the winter the problem is to arrange for the majority of dwellings wintering in a bright room with a temperature of about 10 ° C.

Water- plant is demanding on the quality and quantity of water supplied. Nutrients dissolved in water will consume most vigorous growth. With decreasing temperature, are reduced water requirements. Watered after the substrate surface is dry, optimal morning with amount of water equal to about 1/10 of volume of vessel- so should reach about 70% of water saturation of the substrate. If water flows into the bowl it needs to spill to prevent continuous water intake and lasting wetting of the substrate, which would result in the roots do not have sufficient access to the air and there would rot the roots.

Rain water or drinking water can be used for watering, but that would be either one day stress relieved, or boiled. Hard well water is not suitable. The water temperature should be 3-4 ° C higher than the air temperature. As a result of hypothermia roots of a plant called up shock and at the same time when the air temperature rises, the plant will defend against evaporation waste sheets.

Air humidity- *Citrus x limon* is demanding to humidity. Satisfactory humidity of about 60% is at 20°C. The air humidity decreases with increasing temperature, and vice versa. Negative values so called panel home, in which during the winter while heating to 23 ° C is humidity 20-30%. We achieve sufficient value either by lowering of the temperature or spray dew on leaves (only a temporary solution).

2.1.2. Plant location

The plant is located on the window sill, which is oriented to the cardinal South- South West, which ensured the plant during the winter months sufficient number of hours of sunlight. The room has relatively stable temperature of 18-20° C, and relatively high humidity, which although was not measured, but it can be observed when the regular time from dusk after sunrise began dew windows from inside of the room.

Yellow ceramic wessel volume in which the plant is planted is 3.5 dl so that, to avoid the overheating of the root influenced by solar radiation.

The actual plant has the height of 27 cm, flourishing into the four main branches, in which, before the start of measurements was located 38 leaves.

2.2. Field spectrometer

The ASD FieldSpec® HandHeld™ 2 is a portable spectroradiometer that performs rapid, precise, non-destructive and non-contact measurements. The HandHeld 2 provides extremely accurate, quickly derived reflectance, radiance, and irradiance spectra in a variety of settings. An on-board, tilting color LCD display, integrated computing capability, large internal data storage, laser targeting and GPS compatibility combine to create a self-contained measurement system. It is portable and battery designed to be used outdoors in a variety of enviroments, as well as indoors in the laboratory (ASD, 2010).

The spectra data files collected by the HandHeld 2 can be imported to an external computer using the HH2 Sync application program. HH2 Sync is a PC-based software program for use with the HandHeld 2 to manage system presets and base file names, and exports calibration files to the HandHeld 2 (ASD, 2010).

There are two ways to control the FieldSpec® HandHeld 2 instrument and collect data:

- Standalone Mode- this mode uses only the internal control and data collection capabilities of the HandHeld 2.
- Tethered Mode- this mode combines the capabilities of the HandHeld 2 with the power of an optional external controller computer

Wavelenght range	325-1075nm
Wavelength Accuracy	±1nm
Spectral Resolution	<3nm do 700nm
Noise Equivalance Radiance (NEdL)	Standard HandHeld 2: 5x10-9 W/cm2/nm/sr @ 700 nm HandHeld 2 Pro: 5x10-10 W/cm2/nm/sr @ 700 nm
Integration Time	8.5 ms minimum (selectable)
Field-of-View	25° (Optional fore optics available)
Sampling Interval	1.5 nm for the spectral region 325-1075 nm.
Spectrum File size	Approximately 30 KB
Memory Storage	Up to 2.000 spectrum files

Table 1. Performance Specification HandHeld 2 (ASD, 2010)

2.3. Methodology

1) Selection of watering intervals with a dose volume of 10% of the total wessel, in the case when it is left at the bottom of the cup, water excess is discarding.
    a. Every day
    b. Every three days
    c. Every five days
    d. Once a week
2) Daily data collection between 13-14 hours due to the best lighting conditions
3) Collecting data using of Field spectrometer HandHeld2
    a. Perform the test lighting preview of the white reference panel where the reflectance spectrum of the white reference panel deviates significantly from 1, the optimization is performed.
    b. Measurements dark current and white references
    c. Regular updating, optimization, where the lighting conditions change significantly
    d. Measurement and storage spectrum
4) For each leaf was collected the set of spectral images, the program ViewSpecPro representative image is selected so as to best represents the letter. The probability of distortion of the images is minimizing by selection from a number of samples.
5) The spectral range shall be defined for samples that is observed both in the visible spectrum green part, for the purposes of monitoring the aging of the sheet will be marked the spectrum of the yellow and red spectrum.
6) During this measurement, the measurement takes place on the leaves shed.

7) Compared individual spectra are monitored and measured reflectance changes during different terms irrigation. They also are compared a samples of measurements when the plant is exposed to dry the leaves shed, then are compared changes over time
8) Evaluation of the best irrigation interval based on the results spectrometry

3. RESULTS

3.1. Measurements

Therefore, to achieve the spectro-radiometric measuring there are made the measurememts at 10 marked plants leaves to be differentiated according to the age and optical and physical-chemical properties (color, brightness, growth defects, defects caused by pests- *Cocccus hesperidum*). Data collection was performed by using of HandHeld 2 spectroradiometer operating in the range of 325-1075nm with an interval of collecting samples 1,5nm.

Spectroradiometer was mounted on a tripod in the distance between the plant and the lens in each sample of 30 cm and secured all the same lighting conditions of the leaf as for the angle of incidence of the light on it. Always prior to measurement, we targeted a reference white surface, if the audible noise spectra for extreme values, or the values were approximately equal to 1 (saturation), the optimization was carried out if the conditions were worthy or need to optimize, it was perfomed the data collection only of the dark current and white reference. Then we carried out the data collection with the individual leaves, with each leaf has been taken more samples with consequential analyse and the most suitable sample was chosen. Measurement errors may cause unforeseeable as once shading, distorted results due to sampling where the effects of a deliberate laser sheet, movement of the sheet, poor push trigger sampling and the fall of the slight displacement of the spectroradiometer (even if they were set on a tripod), which then did not take the sample from the correct leaf. The most common potential cause could be atmospheric changes. During the measurements was significantly changeable weather, which is normal for the winter months and early spring. These uncertainties could be caused by a lack of direct sun radiation, precipitation, or during bright cloudy day's rapidly changing intensity of natural lighting. To achieve the best angle of solar radiation from leaves the measurement has been made at the time of 13 to 14 hours because of the least change of the angle of incidence of sunlight on the leaves at the time for the best possible radiation intensity. The earlier hours were omitted because of the frequent occurrence of morning mist.

The measurements were not performed under artificial lighting. In all conditions has been set up the device properly, so that the measurement results would be the most correct. Especially during variable cloud was needed to optimalize the HadndHeld.

It is appropriate good establishing of reflective and transmissive spectra of leaves as a function of light absorption by chlorophyll, carotenoids, water, cellulose, proteins and the like. (Newnham and Burt, 2001; Dangel et al., 2003). Each plant has different spectral resolution, depending on the phenological cycle. (Gouranga and Harsh 2005, McCloy 2010; Papadavid et al. 2011)

Domain of optical observation starts at 400 nm in the visible range of the electromagnetic spectrum and over 2500nm shortwave infrared spectrum. The strong absorption of light by photosynthetic pigments prevails in the green spectrum (400-700). Leaf chlorosis causes an increase in reflection and transmission. Near infrared spectrum (NIR, 700-1100nm) is the part of the spectrum where is limited biochemical absorption that are limited to compounds that are mainly in the leaves, or the cellulose, lignin, and the structural carbohydrates (Wang et al. 2005).

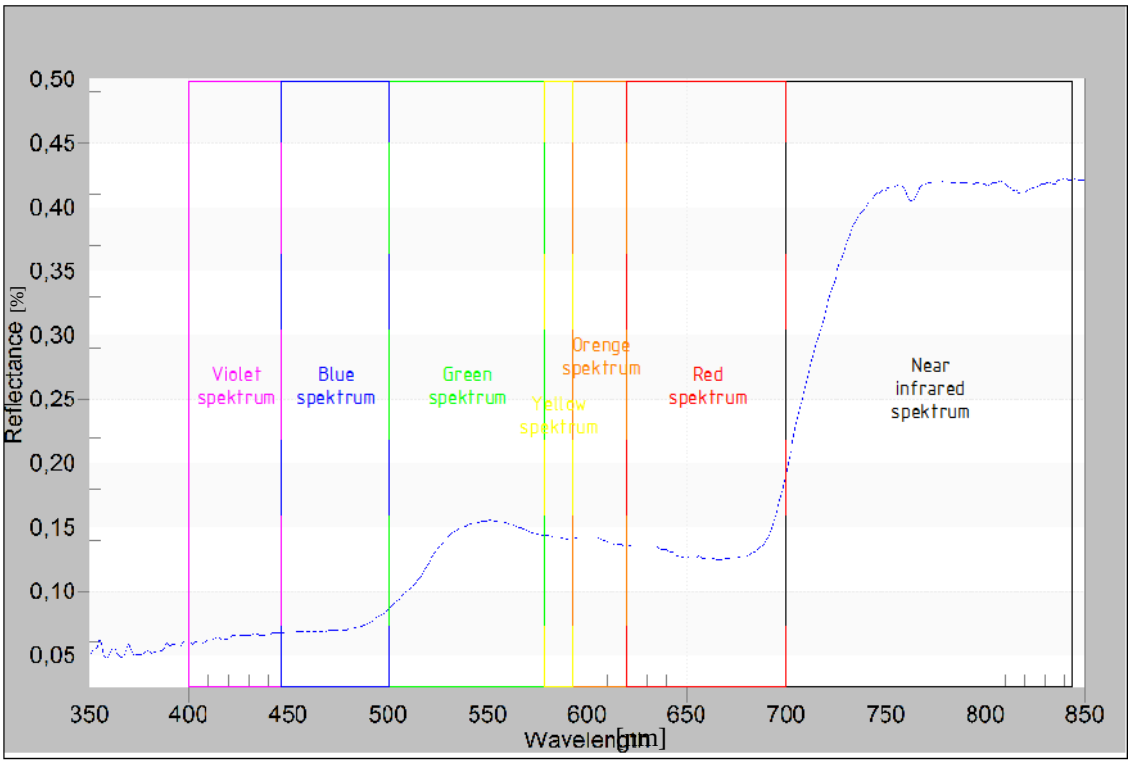


Figure 1 Graphic cross-section of the visible spectrum and near infrared spectrum

- Violet spektrum: 0.4 - 0.446 μm
- Blue spektrum: 0.446 - 0.500 μm
- Green spektrum: 0.500 - 0.578 μm
- Yellow spektrum: 0.578 - 0.592 μm
- Orange spektrum: 0.592 - 0.620 μm
- Red spektrum: 0.620 - 0.7 μm

Blue, green and red spectra are considered to be primary colours, or a wavelength of the visible spectrum, so that a combination can be formed the other colours of the visible spectrum. The visible spectrum can be seen in the context of the spectra when radiation is incident on the edge and is bent for light of a different size depending on the wavelength.

The chemical compound in leaves called chlorophyll strongly absorbs radiation red and blue wavelengths but reflects green wavelengths, so the leaves appear "greenest" in the summer, when chlorophyll content is at its maximum. In the autumn, when it is less chlorophyll in the leaves, there is less absorption and proportionately greater reflectance in the red spectrum, so that the leaves are red or yellow (yellow is a combination of red and green wavelength). The internal structure of healthy leaves act as excellent diffuse reflectors near-infrared wavelength. If our eyes are sensitive to reflection of the near infrared spectrum, service, it is very clear to us at these wavelengths. The measurement and monitoring of the NIR reflectance is one method that can detect the state of the vegetation health.

The leaves healthy *Citrus x limon* contained a large amount of chlorophyll, which gives the letter specific green colour. That is why the reflection is small in blue and red parts of the spectrum and the high reflection of the green part of the visible spectrum and NIR. If there is activity or damage to the leaves, chlorophyll content falls within the leaf structure changes. Consequently, this will be reflected

by the reduced reflectance in the green part of the spectrum and NIR. These reactions provide early warnings that the plant is exposed to stress conditions. The ratio of the reflected red and NIR spectrum is an excellent health vegetation index known as NDVI (normalized differential vegetation index). The index value is high in health plants due to high reflection in the NIR and low in red spectrum. Visually it can be established under stress by shades of green. Properly irrigated plant appears clearly if there is a deficiency of water, leaves are darker shade.

3.2. Data from spectrometry

Data collected by spectrometry were always 24 hours after irrigation, respectively, collected 24 hours apart, so that was created by a coherent set of data.

3.2.1. Daily irrigation

The first two days were intentionally omitted from the graph, because often especially for several plant species is the plant poured again. Therefore, data are shown from the following days reflecting permanent spillovers. During the 24-hour interval of irrigation there was a gradual reduction of reflection. *Citrus x limon* to excessive watering reacts with chlorosis, which causes a decrease in reflectance in the green spectrum, while there is also an increase in reflectivity in the yellow spectrum, where the percentage is not much difference between green and yellow spectrum. During each day there is a decrease in reflectivity, which is generally considered as a negative phenomenon. External phenomenon was visible by leaf fall.

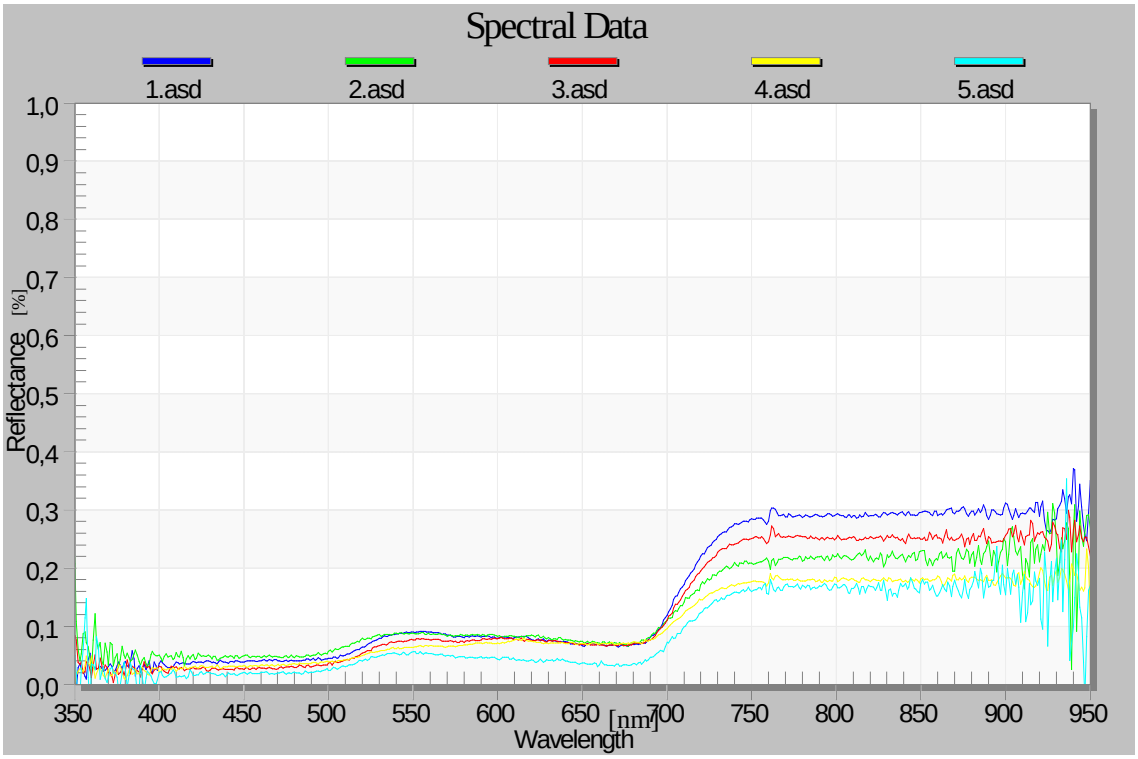


Figure 2 Graphic cross-section of the visible spectrum and near infrared spectrum determinet for daily irrigation

3.2.2. Irrigation after 3 days

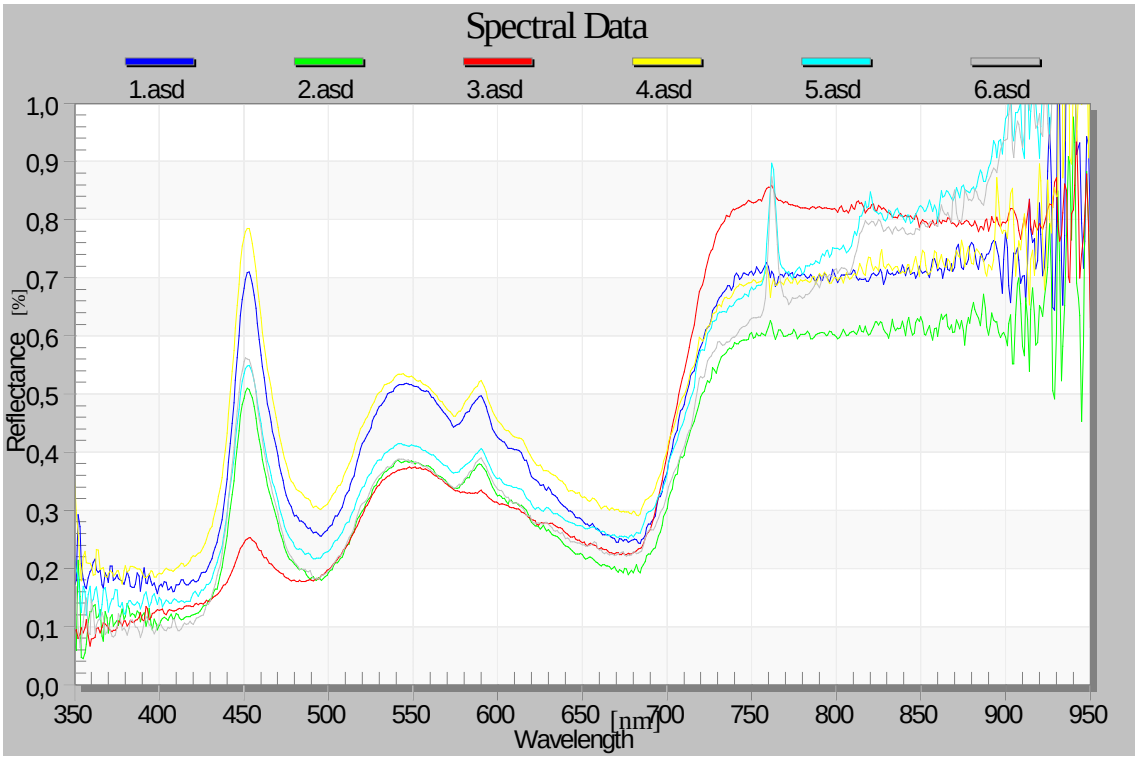


Figure 3 Graphic cross-section of the visible spectrum and near infrared spectrum determinet for irrigation every third day

24 and 48 hours showed no significant changes that are not obvious by naked eye and by measurements. Measured data after 3 days did not show the changes (line 3, red) when there was a decrease of reflection in the green spectrum. During the experiment, we spilled the plant on the third day, then again at 24 hours showed a value (fourth person yellow) which are comparable with measured 24 hours after watering in previous irrigation period.

3.2.3. Irrigation after 5 days

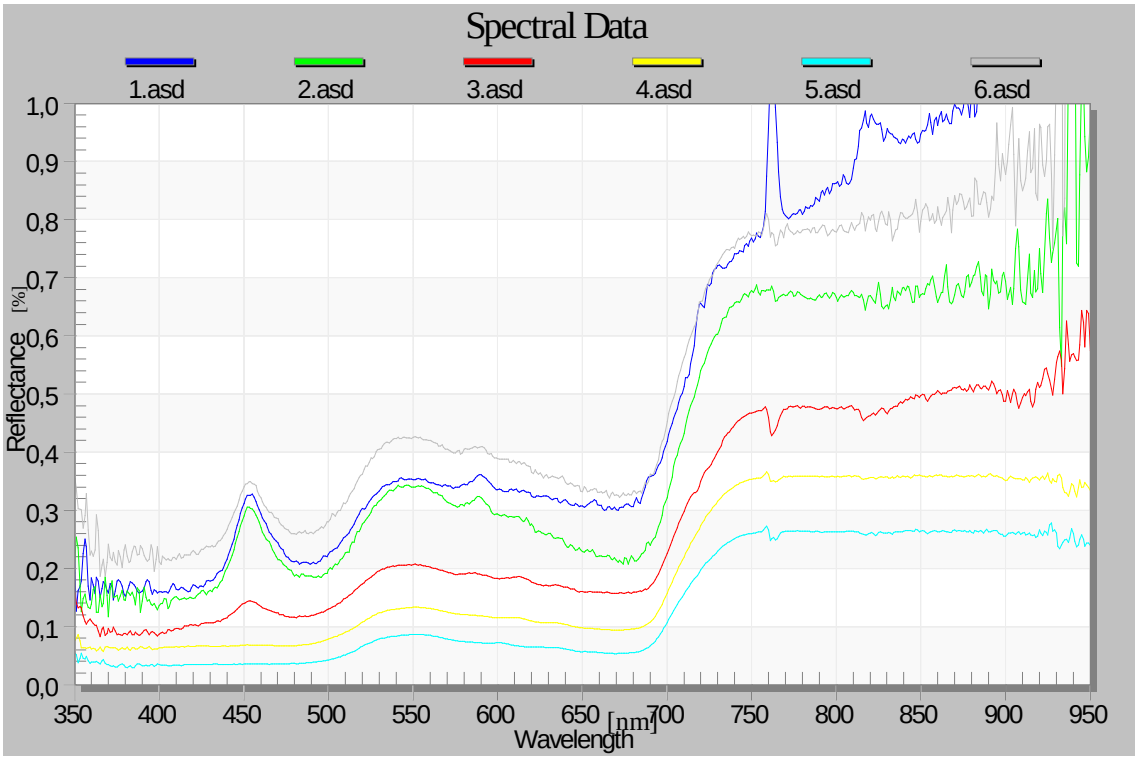


Figure 4 Graphic cross-section of the visible spectrum and near infrared spectrum determined for irrigation every fifth day

24 and 48 hours after watering there are no significant changes, but after 72 hours after watering was showed by spectrometer significant changes which would not be possible to see at the first researching. There was a general decline in the whole field of the visible light spectrum. 4 and 5 days after watering were changes on the leaves noticeable with the naked eye, which was also confirmed by data from spectroscopy. There have been significant changes in the colour of leaves which passed from green to slightly yellow indications, which was due to both a lack of water but also nutrients adopted by the plant dissolved in water. Regarding the ratio of green and yellow spectrum again their relationship began to settle which was caused by yellowing leaves.) There were measured data were about the same as after the previous irrigation after followed irrigation (line 6, gray). 5-day interval has proved to be acceptable at lower temperatures than 3 day interval.

3.2.4. Irrigation after 7 days

The first 2 days after irrigation did not show significant changes, progress was approximately the same as for 3 and 5 day intervals. The reflection along the spectrum declined with increasing of the days number without water supply. After irrigation (line 7, black) increased reflection, but did not reach values comparable to the previous irrigation.

Based on the measurements, we came to the conclusion that the most ideal watering intervals are every three days at 18 degrees stable conditions in a well ventilated area with high humidity. Period may be shortened by a day, if it is necessary to increase the room temperature at 20-23 degrees. If we could afford to reduce the temperature to 15 degrees, it is possible to extend the interval watering for 5 days, 1-3 days when there are no major changes, except for four days, it is possible to see on the plant the reactions due to dwindling water in leaves. Inappropriate for objective reasons is considering of daily interval, not only in terms of the measured data, but also the obvious needs of plants for water and also the 7 day period where, due to a period of time there was a deficit of water in the plant.

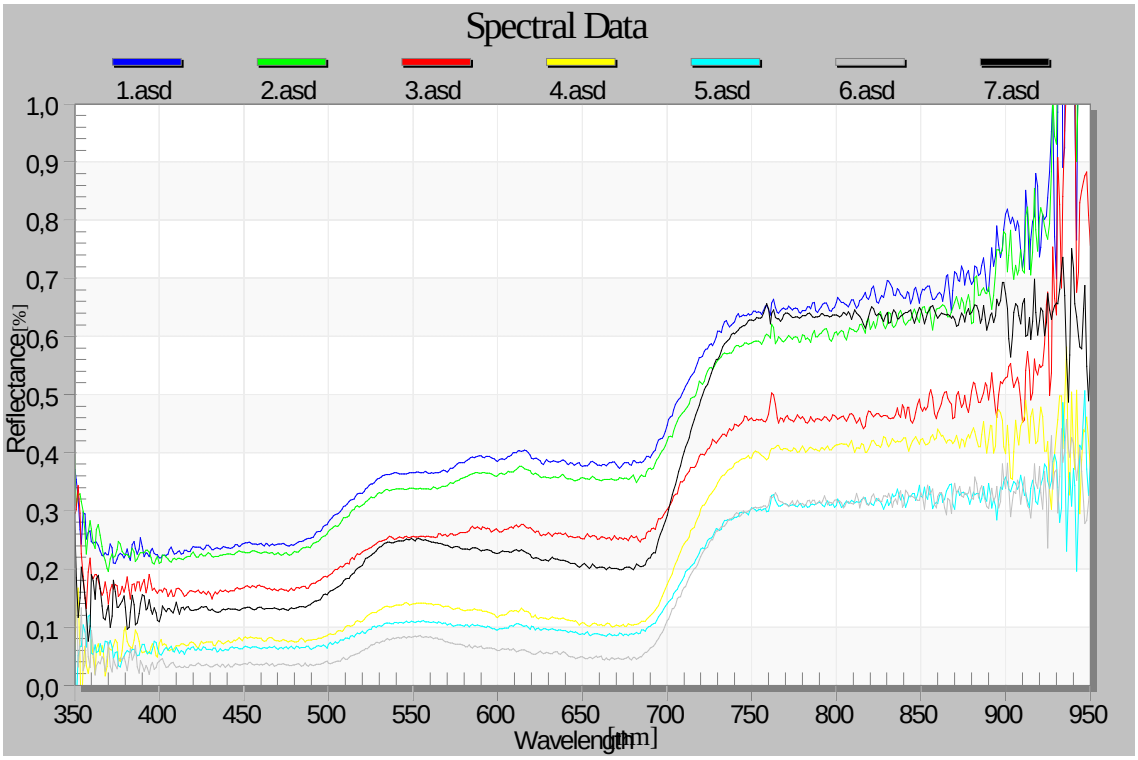


Figure 5 Graphic cross-section of the visible spectrum and near infrared spectrum determinet for irrigation every seventh day

3.2.5. Changes of spectra at removing leaves

The first day were not achieved at the level of the spectrum visible changes that would be caused by a lack of water that leaves would receive from the plant. The next day there was a change that was not expected, so that under the spectrum should be better in amount of water at the leaves than removed plants. Over the next days leaf visibly brightened, but instead of bright green is changed into yellow-green colour, which is also visible in Figure 6 as increased reflectivity spectrum of the whole field. For five days it was not possible to measure the spectral reflectance, as the leaves was dried to the extent that the actual sighting laser passes through the leaves and be clearly visible to the laying surface, so the result itself would mostly be measured reflectivity as the ground itself, and not the leaves.

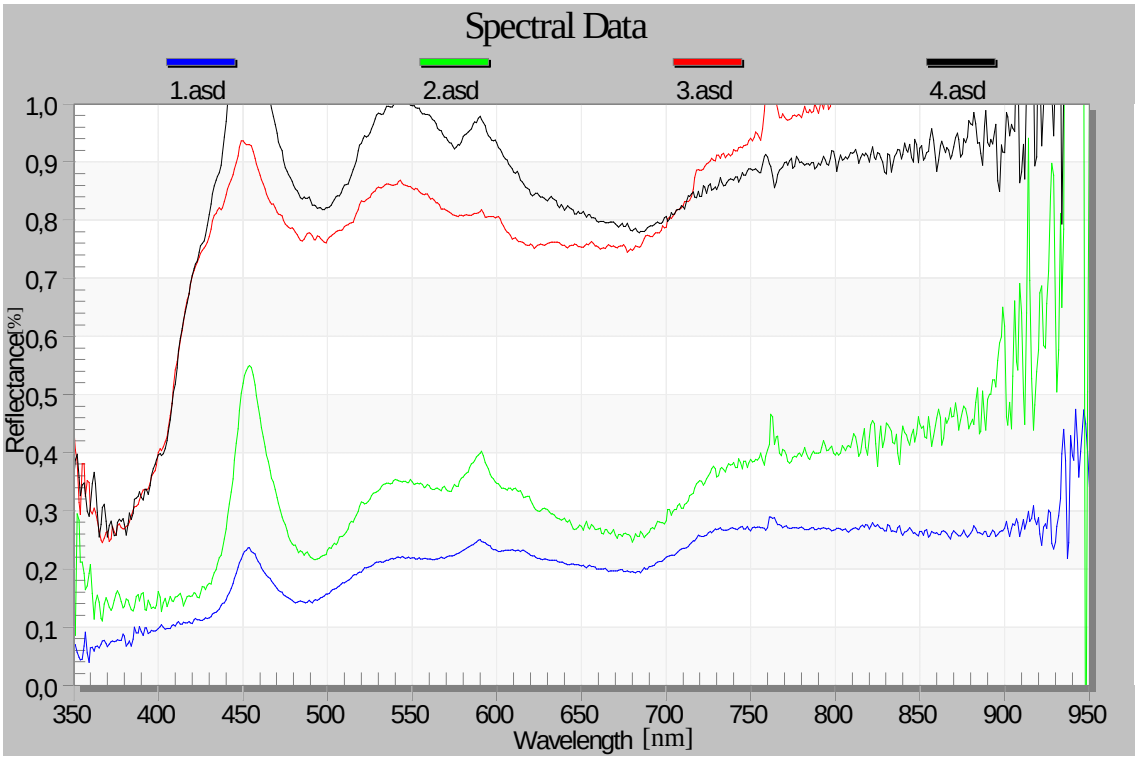


Figure 6 Graphic cross-section of the visible spectrum and near infrared spectrum determinet for removed leaves

4. SUMMARY

Based on measurements the facts were verified already known facts about approximate periodicity of irrigation during wintering. The most appropriate is a 5-day period, which qualify depends on the prevailing conditions of the room in which the plant is moderate (± 1 day). If it would be possible to have ideal conditions it would be more appropriate and longer interval. With increasing temperature and decreasing humidity of the air it could be on the contrary, to shorten the interval.

Absolutely improper interval consider daily watering during which a plant is exposed to this type of stress, he lost more than 50% of its leaves and even three weeks after the measurements did not show the signs that should condition the plants change for the better. Thus stress tested plant was significantly reduced resistance to pests and there was a significant increase of *Cocccus hesperidum*.

For comparison was also conducted a measure on mechanical removal of the leaves, whether it is possible to compare changes that have taken place on this leaves with changes on the leaves during stress induced by drought. Furthermore similar changes in the yellow range (due to the yellowing of leaves) did not avoid such changes in the rest of the spectrum. Exposed dry leaves showed a noticeable darkening due to stomatal closure and thus also increase the absorption of the green spectrum at removing leaves there was a general lightening and yellowing.

5. DISCUSSION

The academic literature but also the experience of spectrometry may be represented both in agriculture as well as in the cultivation of hobby when not in uniform references for cultivated crops, and it is necessary to take care of the crop on the basis of its reactions.

Over the past decades passed the spectrometry a long way and today there is not such a problem to acquire it at a relatively low entry cost, which the producer can return within a relatively short period

of time, whether the financing of intensive cultivation or the feeling of quality and honestly grown crops at home.

6. CONCLUSION

Using of shortwave radiation has many advantages for monitoring of the plants health. Firstly, it is a non-invasive and non-destructive method, this method can be used either indoors or outdoors, as in stable conditions provides reliable results on plant health. Particular green and NIR spectra provide good information about the needs of the plants to water, but in addition, may provide other information such as chlorosis (attributable to the biotic and abiotic elements) to prevent undesirable practices. Also, the method is not difficult to excessive knowledge of IT staff HadHeld2 and a matching software is simple, the outputs are clearly just the results can be used in practice.

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