Application of RFID Technology for Evaluation the Weather Condition in Soybean Plant Sown on Different Row Spacing

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Abstract. The effect of different row spacing (35 cm and 70 cm) on the development of soybean plants was studied using two soybean varieties, Lenka and ES Mentor. By using RFID technology, which includes a smart tag with a microchip, temperature, moisture and three sensors, an antenna and a reader, we measured temperature, humidity and light in the middle of the row space of each experimental field throughout the growing season. Besides, crop development, measurements of the morphological characteristics of the plants inventory of weeds and yield weight were made. We discovered that differences between soybean varieties were more pronounced than differences between different row spacing. The application of RFID technology was proved to be accurate enough in plant growing, so together with proposed improvements RFID would allow the farmer to control agricultural land more quickly and to respond in a shorter amount of time in comparison state meteorological station.

Keywords: RFID; soybeans; row spacing; weather data.

1 Introduction

RFID (Radio frequency identification) is an emerging technology that can have enormous opportunities in Agri-food sector. Technological developments in the area of networking devices, sensors and communication technology play significant role in sustainability of Agri-food sector. RFID is one of such pervasive technology, which is now increasingly utilized in food logistics, supply chain management, cold chain monitoring and retail (Ruiz-Garcia and Lunadei, 2011). Compared with traditional technologies like, barcode and data loggers, RFID shows several advantages. RFID devices do not require visual contact (Abad et al., 2009). They can be placed inside boxes, containers, embedded in any object or injected into animals (Finkenzeller, 2004). RFID tags can write 5 tags per second and have storage capacity: 1 MB in active tags and 4 kB in passive (EPC Global, 2008). RFID tag with associated hardware and software provides additional benefits such as real time monitoring, environmental sensing, tracing and tracking. Different types of sensor can be embedded with RFID

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Tags to collect information about various parameters like temperature (Amador and Emond, 2010), humidity (Abad et al., 2009), and light intensity (Abad et al., 2009).

Biosensor tags are also under development that could be used for detecting bacterial contamination of food products along the supply chain (Wentworth, 2003). The main purpose of our research was to use RFID technologies with sensors for measuring temperature, humidity in light intensity between soybean plants during the vegetation. Two varieties of soybeans 'Lenka' and 'ES Mentor' both of the same maturity class (00 were grown on 35 cm and 70 cm row spacing. We investigated the differences in plant development as well as temperature, humidity and light gradients between varieties and row spacing. Finally, we estimated the accuracy of RFID with the measurement of meteorological conditions on nearby meteorological station.

2 Material and Methods

The soybean experiment was carried out on the field owned by a local farmer, it is located in the municipality of Hoče-Slivnica (Slovenia). The plot 'Štuk' (46o30'28''N, 15o039'19''E) has 2.37 ha in area with the average altitude of 272 m and the average slope is 1% and 0.6 °, respectively.

For the purpose of the experiment, the south-eastern part of the parcel was selected and divided into four experimental sub-parcels with 1200 m2 each (Fig. 1). The fields were visibly divided by 0.75 m wide "border bands", where no crop was presented. The relatively large area of the experimental fields allowed for a more precise choice of location for the placement of the measuring devices and represented a more representative sample for the analysis of the results.

The prerequisite of soybeans was winter wheat, followed by white mustard after harvest. The experimental boxes were separated by wooden stakes, marked with variety and row spacing.

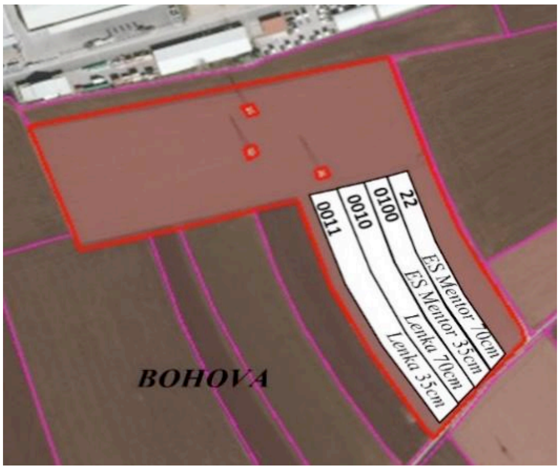

Fig. 1. Location of trial plots.

2.1 Description of Devices

We used a measuring system consisting of a semi-passive smart tag with an integrated circuit, in our case it was a SL900A microchip, which has an integrated temperature sensor and allows the connection of additional external sensors. Furthermore, the measuring system consists of sensors, antenna and battery. We collectively call this set a smart badge or Tag (Fig. 2). The measuring system also includes an antenna reader, in our case, the DRM-900A, which transfers data from a badge to a computer. The smart badge was equipped with a humidity sensor (EMD-4000) and an illumination sensor (TEMD6200FX01). The described RFID measuring system automatically measures and stores data every 2 hours. In this way, the memory was sufficient for 14 days of data storage. Battery life is up to five years, depending on weather conditions and measurement time interval. The data transmission range can be up to 100 m with a properly performing antenna, and the transmission starts when the radio frequency signal of the reader is received. The system operates at ultra-high frequencies (UHF 860-960 MHz) according to the master-slave principle.

Fig. 2. Smart badge with microchip, sensors, antenna and battery button.

2.2 Optical Sensor TEMD6200FX01

The sensor is a semiconductor element - a closed-polarized diode that converts light into electrical current. Sensor size is 2mm x 1.25mm x 0.85mm. The spectral sensitivity of the diode is adapted to the response of the human eye. EMD-4000 Moisture Sensor The sensor substance is a special polymer deposited on a bismuth coated ceramic substrate. The polymer changes the impedance in the presence of moisture. The smart badge excites an alternating current sensor and measures impedance as a function of relative humidity. The size of the sensor is 10 mm x 5 mm x 1.5 mm.

3 Results

3. 1 Comparison of morphological properties

As seen from Fig. 4 the highest average plant height was measured by 'Lenka' 35 cm (110.1 cm). The highest number of branches per plant was recorded with 'EC Mentor' 35 cm (57). The maximum distance of the first branch from the ground (13.5 cm) was measured by both varieties at a distance of 35 cm between the rows. The 'Lenka' variety had more shoots that are lateral at both interspace distances than the 'ES Mentor' variety.

Table 1. Comparison of physiological characteristics between 'Lenka' and 'ES Mentor' July 30, 2019.

Treatment	Height (cm)	Number of pods	Distance from soil (cm)	Number of buds
'Lenka' 35 cm	110.1^{a}	43.8^{b}	13.5^{a}	13.7^{a}
'Lenka' 70 cm	108.4^{a}	45.9^{b}	12.8^{b}	13.4^{a}
'ES Mentor' 70 cm	92.7^{b}	52.8^{a}	11.9^{c}	10.2^{b}
'ES Mentor' 35 cm	92.7^{b}	57.2^{a}	13.4^{a}	11.9^{b}

$^{a, b}$ sig. at p<0.05 Duncan test

3. 2 Measurements of temperature with RFID

Table 2 shows the average values of the individual sensor at each of three measurement intervals as well as the reference values obtained from the closest ARSO meteorological station Edvard Rusjan Maribor Airport (ARSO, 2019) located 850 m from our field. The data measured on the experimental plots of the 'Lenka' 35 cm in all intervals and 'ES Mentor' 35 cm in the second and third measuring interval correspond with the data obtained by ARSO, while all the other measurements were significantly lower. The reason for differences is the coverage by the soybean plants in those particular variants. Comparison between varieties for the 'ES Mentor' 35 cm variety shows a bigger coverage of the row space at a distance of 70 cm. Despite the average number of buds per plant of the 'Lenka' variety, this covered less row space. 'Lenka' 70 cm covered an average of 59.6% of row space, while the 'ES Mentor' 70 cm averaged 70.7% of row space, respectively.

Table 2. Temperature measurements with RFID.

Average temperature [°C]			
Treatment	June 30-July 14	July 15-July 30	July 31-Aug 14
ARSO	20.93^{b}	22.65^{a}	22.96^{a}
'Lenka' 35 cm	22.10^{a}	22.98^{a}	22.67^{a}
'Lenka' 70 cm	18.29^{b}	19.24^{b}	19.33^{b}
'ES Mentor' 70 cm	18.93^{b}	20.62^{b}	19.67^{b}
'ES Mentor' 35 cm	18.04^{b}	22.11^{a}	22.06^{a}

$^{a, b}$ sig. at $p<0.05$ Duncan test

3. 3 Measurements of humidity with RFID

Table 3 shows the average values of humidity for the individual sensors at each three measurement intervals. The data measured correlate opposed as the temperature development due to the differences in coverage between varieties and row spacing. Thus, the highest average relative humidity was measured in 'ES Mentor' 35 cm but did significantly differ only from 'Lenka' 35 cm as well as from the data of meteorological station. Later shows smaller values due to the open meadow in which the data very captured.

Table 3. Humidity measurements with RFID.

Average humidity [%]			
Treatment	June 30-July 14	July 15-July 30	July 31-Aug 14
ARSO	70.12^{a}	68.95^{a}	70.40^{a}
'Lenka' 35 cm	69.10^{a}	67.98^{a}	70.67^{a}
'Lenka' 70 cm	72.29^{b}	70.24^{b}	72.89^{b}
'ES Mentor' 70 cm	72.93^{b}	70.62^{b}	72.97^{b}
'ES Mentor' 35 cm	72.04^{b}	70.11^{a}	73.06^{a}

$^{a, b}$ sig. at $p<0.05$ Duncan test

3. 4 Measurements of light intensity with RFID

As seen from Table 4 the light intensity is significantly lower below the leaves in the zone of sensors in all varieties and row spacing. Additionally, from the first to the last measuring period the development of leaves decreased the light intensity significantly in the same treatment. However, in the second and third period the light intensity was significantly lower in 'ES Mentor' comparing to 'Lenka' in both row spacing. This corresponds also with the higher number of pods in 'ES Mentor' (Table 1).

Table 4. Light intensity measurements with RFID.

Average light intensity [lx]			
Treatment	June 30-July 14	July 15-July 30	July 31-Aug 14
ARSO	28500^{a}	29400^{a}	30800^{a}
'Lenka' 35 cm	9300^{b}	6400^{b}	4300^{b}
'Lenka' 70 cm	10050^{b}	6100^{b}	4500^{b}
'ES Mentor' 70 cm	8800^{b}	3700^{c}	3300^{c}
'ES Mentor' 35 cm	7800^{c}	4400^{c}	2800^{c}

$^{a, b,c}$ sig. at $p<0.05$ Duncan test

3.5 Yield of soybean

On October 13 the soybean was harvested and weighed directly on the field. It contained 12.5 % of moisture so later it had to be additionally dried out to storage moisture of 9 %. From Table 5, showing the yield of soybean with 9 % moisture, we can see that the 'ES Mentor' had significantly higher yield than 'Lenka' in both row spacing. On the other hand, there was no difference between the row spacing among the same variety, either.

Table 5. Yield of soybean with 9 % moisture

Treatment	Yield [kg/ha]
'Lenka' 35 cm	2367^{b}
'Lenka' 70 cm	2521^{b}
'ES Mentor' 70 cm	4637^{a}
'ES Mentor' 35 cm	4512^{a}

$^{a, b}$ sig. at $p<0.05$ Duncan test

4 Conclusions

The effect of different row spacing of two soybean varieties on development of plants was studied using RFID technology to measure temperature, light and humidity in the middle of row spacing. Since the growing phase R1, we estimated the height of the plants, the distance of the lower pods from the ground, the number of lateral buds and the number of pods per plant. We found that the row spacing did not have a significant effect on the development of the crop within the same variety. However, the biggest differences were observed between the two soybean varieties.

RFID showed to be a suitable tool for accurate measurements of temperature and humidity more accurately than the official meteorological station, which might serve for predicting the start of many fungal diseases on time.

The UHF-RFID technologies have also some disadvantages. Above all, the problem is the reliability of the connection, since electrically conductive materials represent a barrier to electromagnetic waves (reflection and wave absorption). Thus, moisture in plants is also a barrier. These problems do not have a Magnetic Assembly (HF) based badge.

The second problem represents the storage capacity of RFID as well as the reading and transferring of data every few weeks. The easiest way would be to read data from RFID in the field using a drone with a built-in UHF reader. The drone would be connected to a home computer via a WiFi network, which would determine, for example, the time, method or means of spraying, based on the built-in algorithms and data collected. If such a drone were equipped with hyperspectral imaging cameras, then algorithms could be installed to separate and detect the state of plants based on spectral signatures. This would give a reliable prediction of the necessary measures, which would be an effective contribution to the future vision of technologically advanced farms and smart villages.

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