7. LESSON
EXAMPLE OF YIELD SENSOR RESEARCH AND DEVELOPMENT

Yield sensor for forages harvested by tractor-mounted mowing machine

Mowing machine was equipped with electronic measured unit and DGPS signal receiver.

The mowing machine's conditioner shaft was fitted with a torque-meter.

Besides the torque-meter, the mowing machine was equipped with a curved impact plate mounted at the exit of the machine.

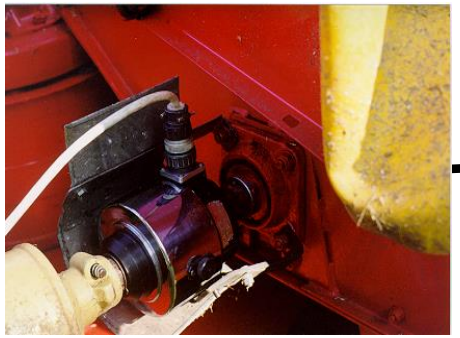
Measurement devices

DGPS receiver

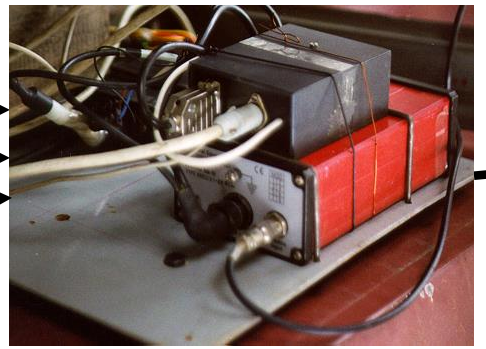
Antenna

Impact plate

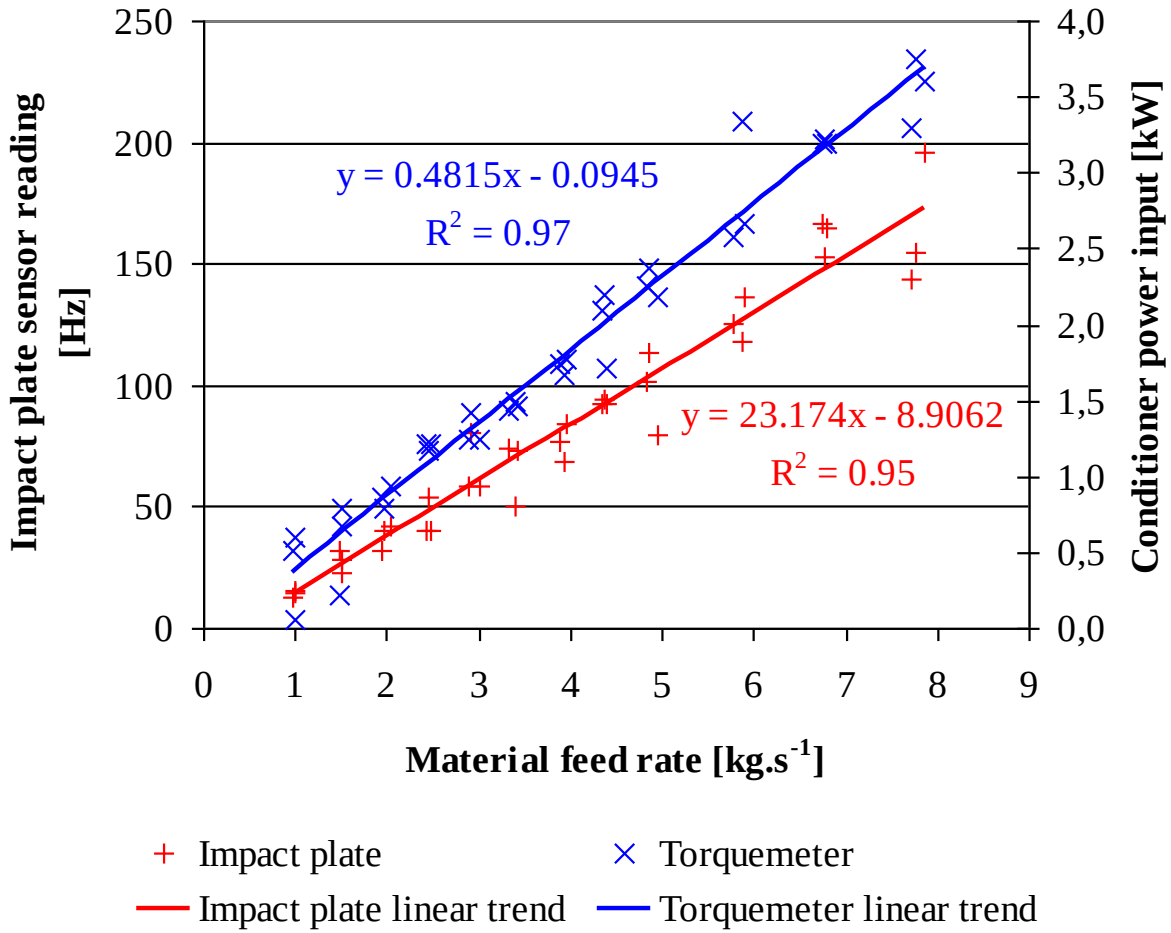
Torque-meter



Microcomputer

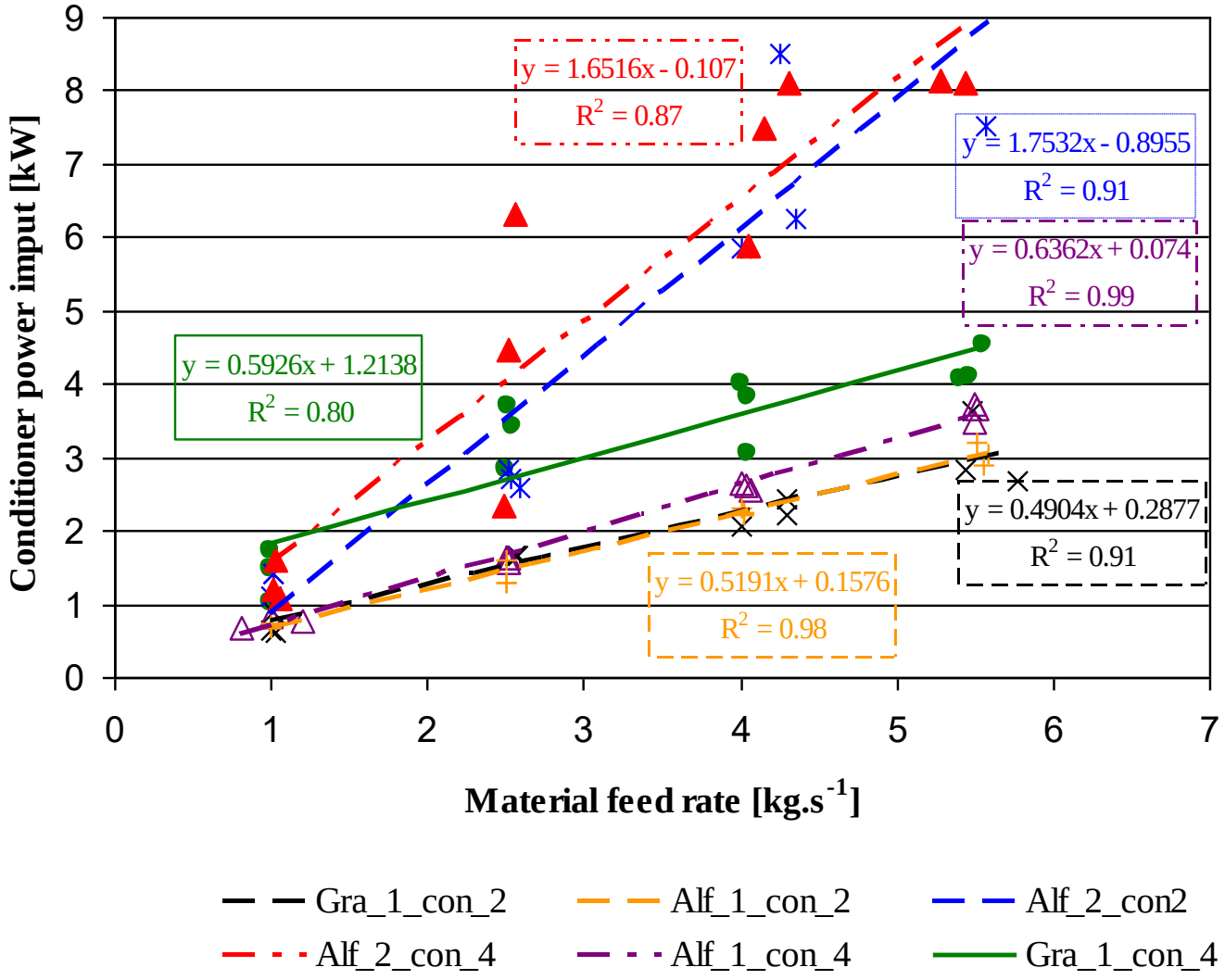


PC (notebook)



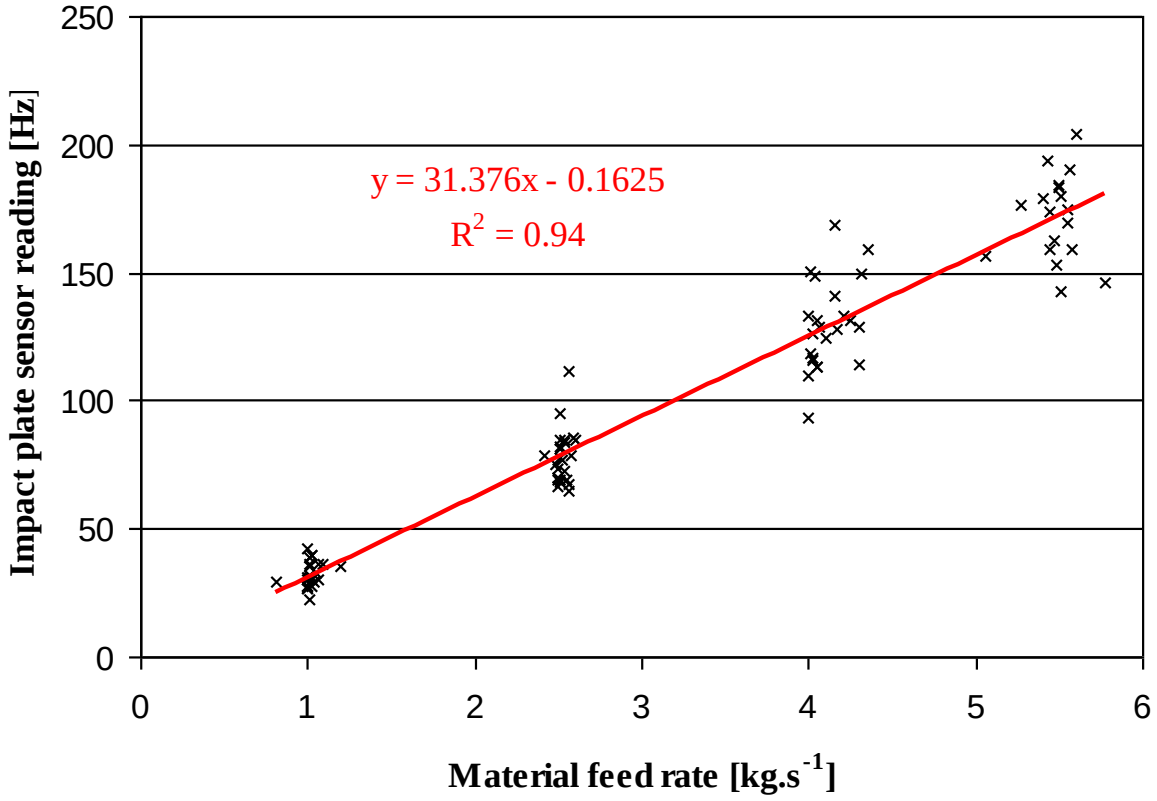
Dependence of conditioner's power input and output frequency of the apparatus measuring the impact force on material feed rate.

Exists a good linear relationship between conditioner's power input, output frequency of the apparatus measuring the impact force by means of the impact plate, and material feed rate through the mowing machine.



Graphic comparison of tested files from torque-meter measurement.

The effects of material changes (type, maturity) and mowing machine parameters (conditioning intensity) on the feed rate measurement accuracy by torque-meter



Dependence of the output frequency of the apparatus measuring impact force

The effects of material changes and mowing machine parameters on the feed rate measurement accuracy by impact plate

The results form torque-meter was influenced by crop variety & maturity and intensity of conditioning. The same influence was not observed for impact plate.

Obtained results from torque-meter and impact plate were compared with the results from hand measurements.

Organisation of infield measurement.

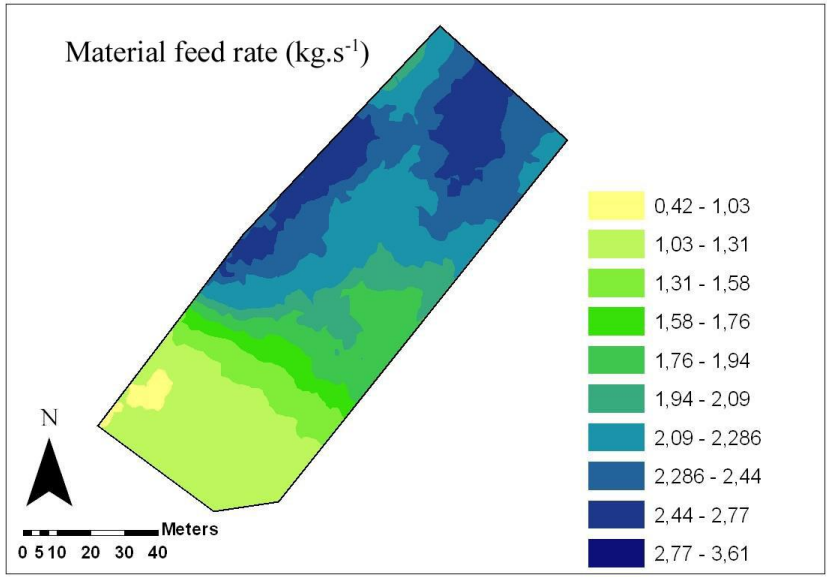
At every DGPS sample, the harvested row was marked by a plastic card.

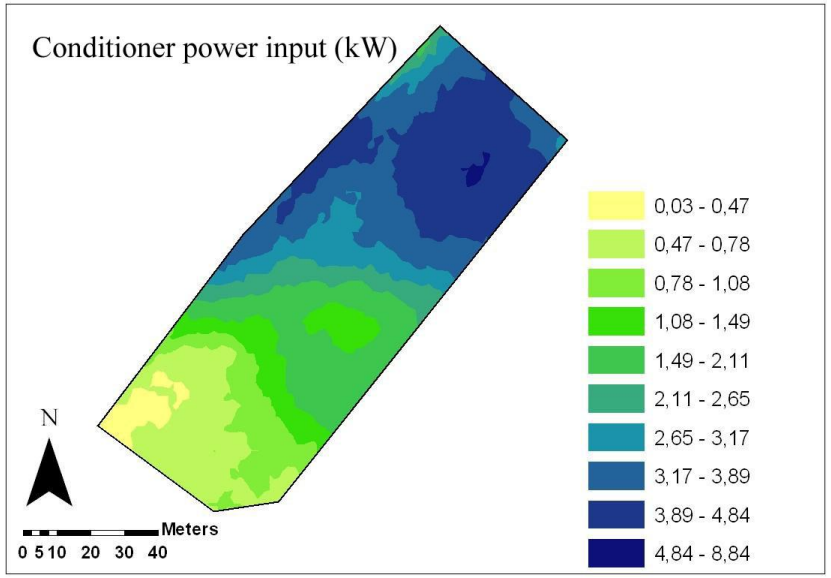
The correlation matrix of tested variables.

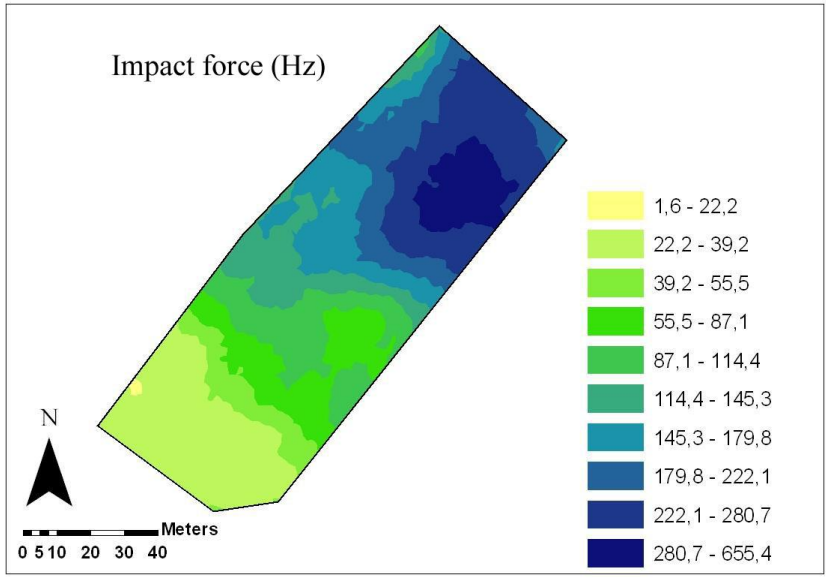
Variable	Conditioner power input (kW)	Impact plate sensor reading (Hz)	Material feed rate (kg s^{-1})
Conditioner power input (kW)		**0.84***	**0.73***
Impact plate sensor reading (Hz)	**0.84***		**0.63***
Material feed rate (kg s^{-1})	**0.73***	**0.63***	

* significant dependence at 99 % confidence level

- The results indicate a statistically significant correlation for all tested pairs of variables to a 99 % confidence level.
- The correlation was better for conditioner power input (0.73) than for impact plate sensor reading (0.63).
- Both measurement devices recorded very similar data.







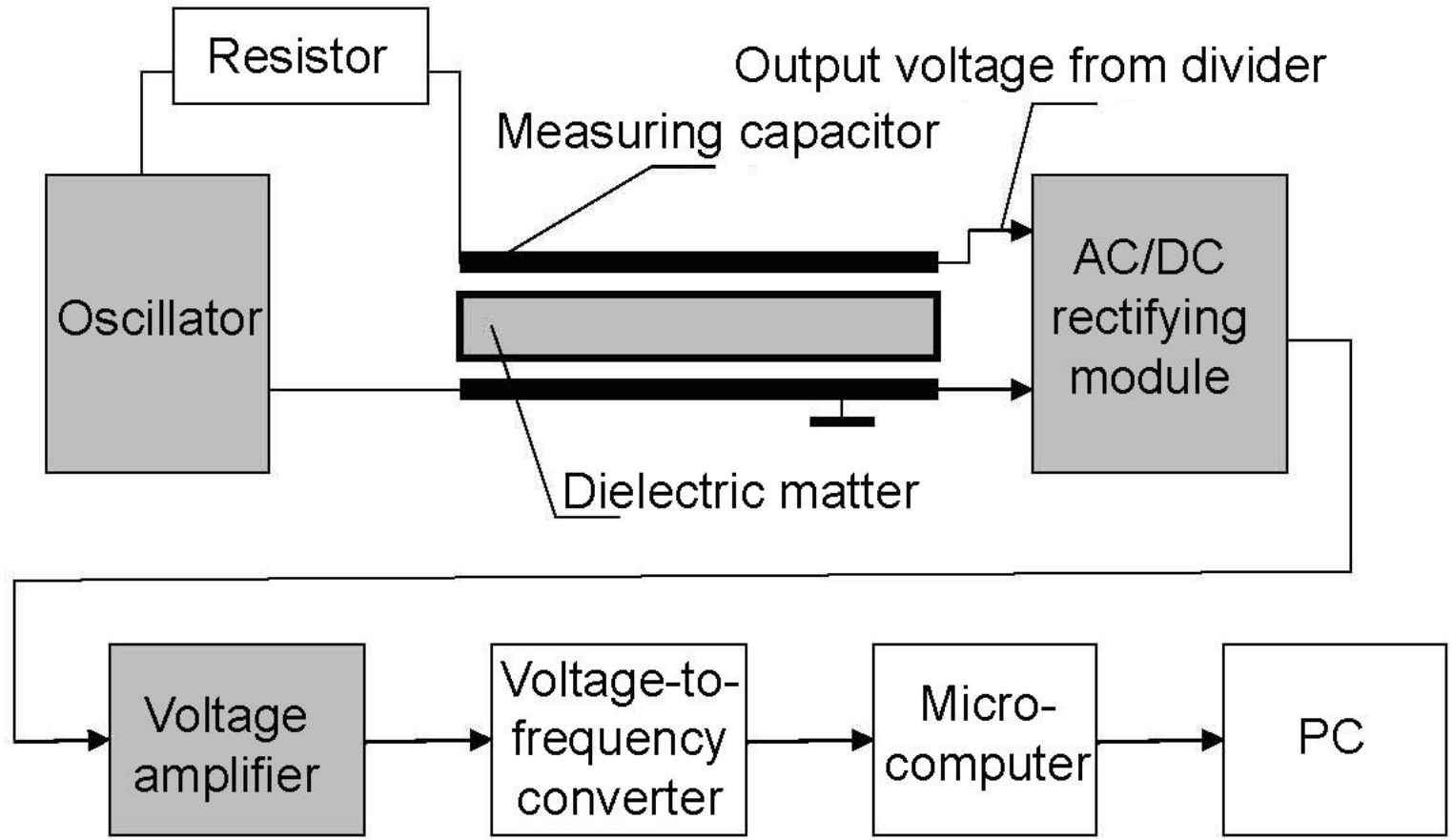
Visualisation of the data distribution was shown by the maps (plotted using the Kriging method). Similarities between the map of conditioner power input and material feed rate and between the map of impact plate sensor reading and material feed rate were found. The results showed that both principles of material feed rate measurement can be used for grass yield map creation under real field conditions.

Capacitance sensor techniques can be used for the determining different properties (moisture content etc.) of a range of plant materials.

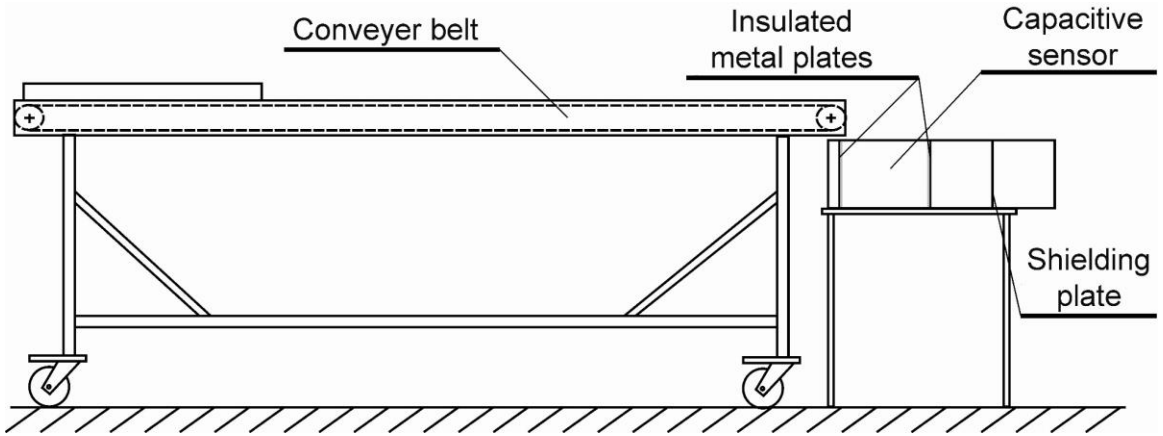
The function of capacitance sensors depends on the fact that the dielectric constant of an air/material mixture between two parallel plates increases with material volume concentration increasing.

Parallel plate capacitance sensor:

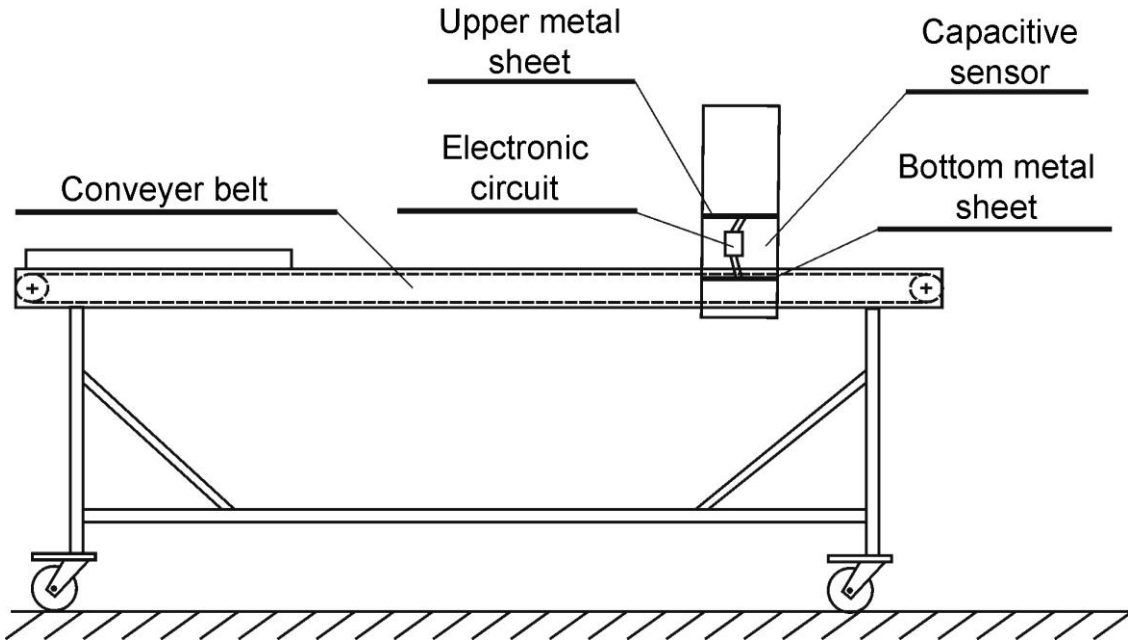
- two metal sheets 2 mm thick (830 x 260 mm)
- 180 mm distance
- sides - 10 mm thick acrylic glass
- sensor was driven at 27 MHz frequency.



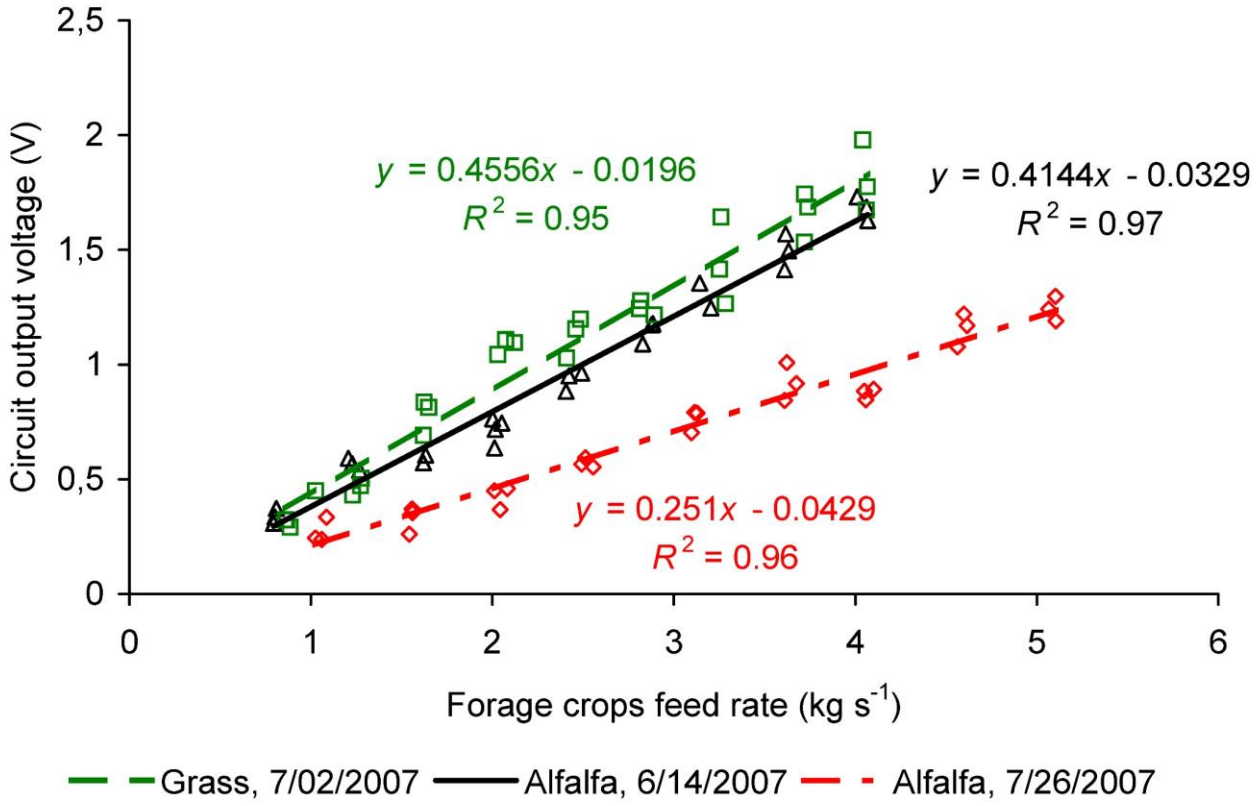
Block diagram of electronic apparatus arrangement for material feed rate measurement.



Initial arrangement of measurement device for laboratory tests. Conveyor belt carried weighted amount of material into the capacitive sensor between its plates. Shielding plate insulated capacitive sensor from surrounding influences.



Arrangement of measurement device for laboratory tests after improvement. Measurements with forage crops. Capacitor plates distance 300 mm.

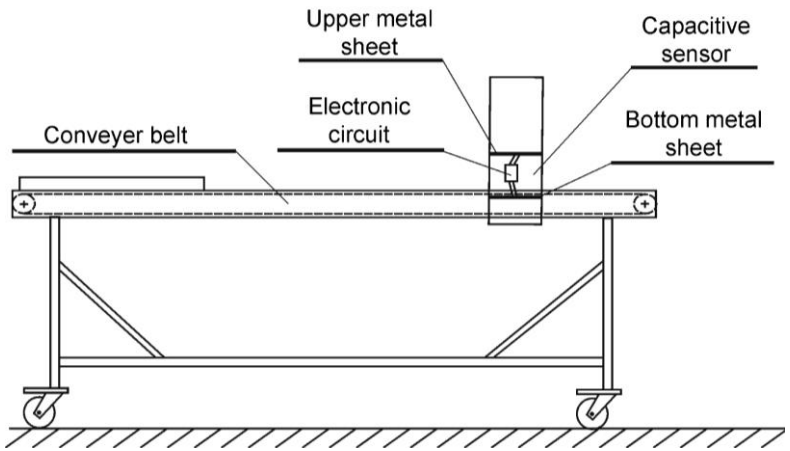


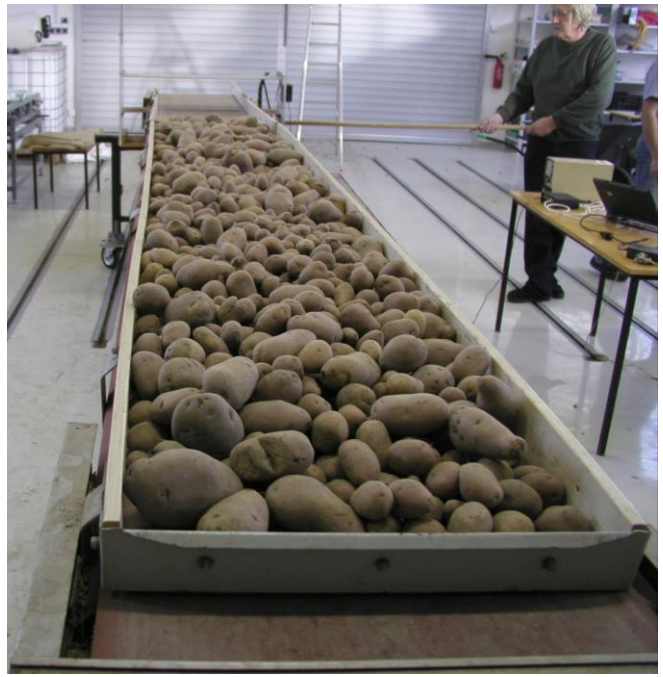
Dependence of the measuring circuit output voltage on forage crops feed rate. Grass 74.4 % of M.C. (green line), alfalfa 66.3 % of M.C. (black line), alfalfa 75.9 % of M.C. (red line, after laboratory set-up improvement).

Experiments with forages

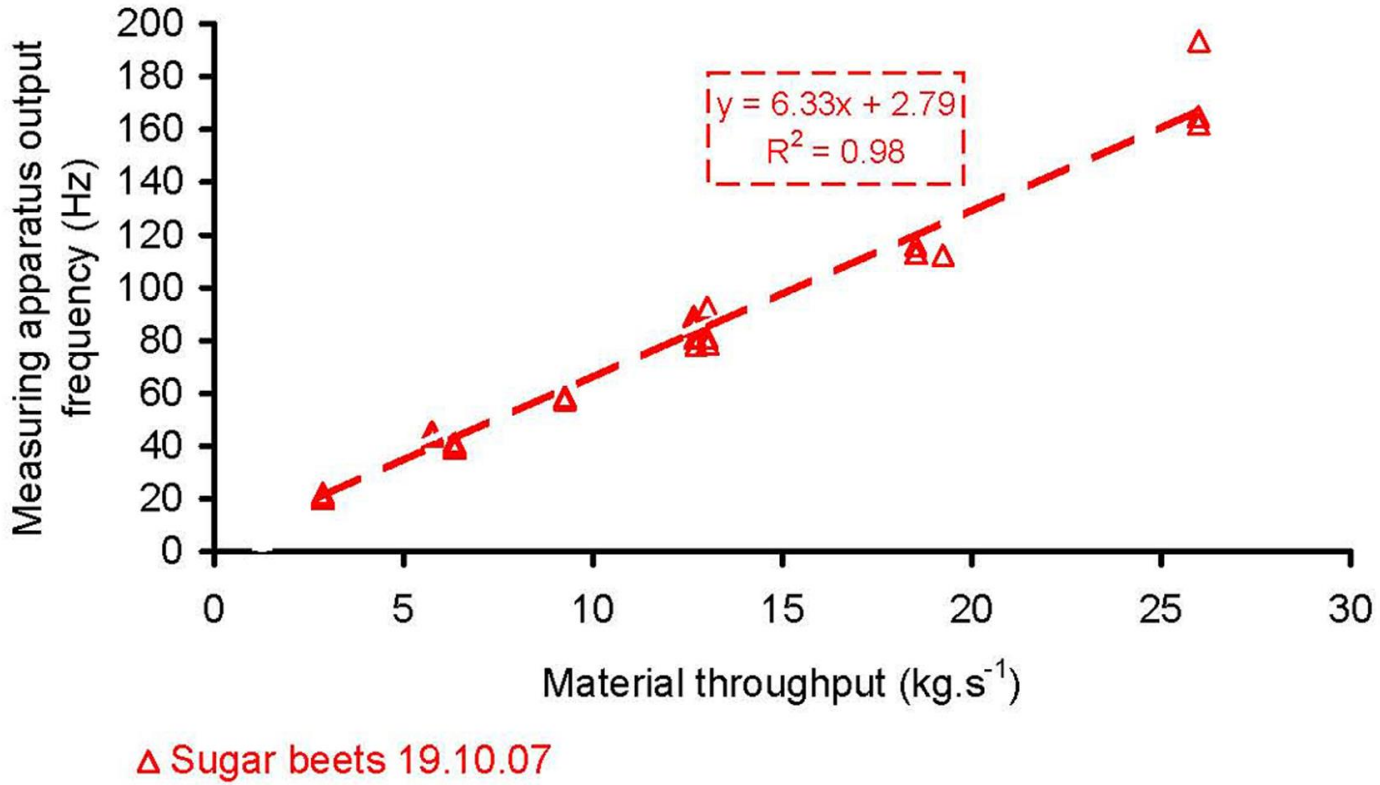
- Dependence of the circuit output voltage (directly proportional to sensor capacity) was linear in all cases in measured range of feed rates.
- Coefficients of determination ranged between 0.95 and 0.97.
- First two data sets obtained (green and black line) were very similar. Repeatability of the measurements was very good - the connection of electronic circuit was designed satisfactorily.
- Original laboratory set-up showed small problems to be improved. New arrangement also better reflected real situation on mowing machine.
- After the modification of laboratory set-up arrangement the dependence obtained was different from the previous ones.

Experiments with sugar beet and potatoes

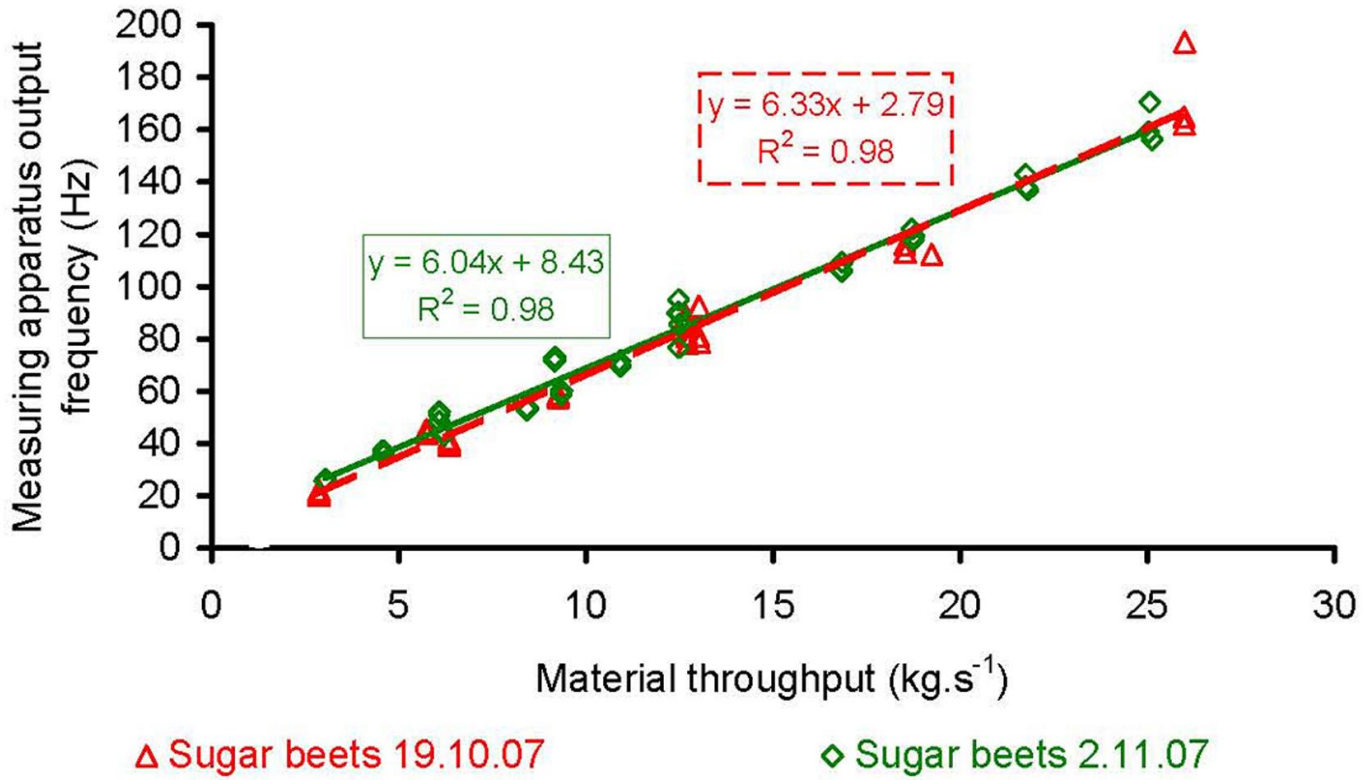




Arrangement of measurement device for laboratory tests after improvement was used. Capacitor plates distance 180 mm.



Dependence of measuring apparatus output frequency (directly proportional to voltage and sensor capacity) on sugar beets and potatoes throughput.



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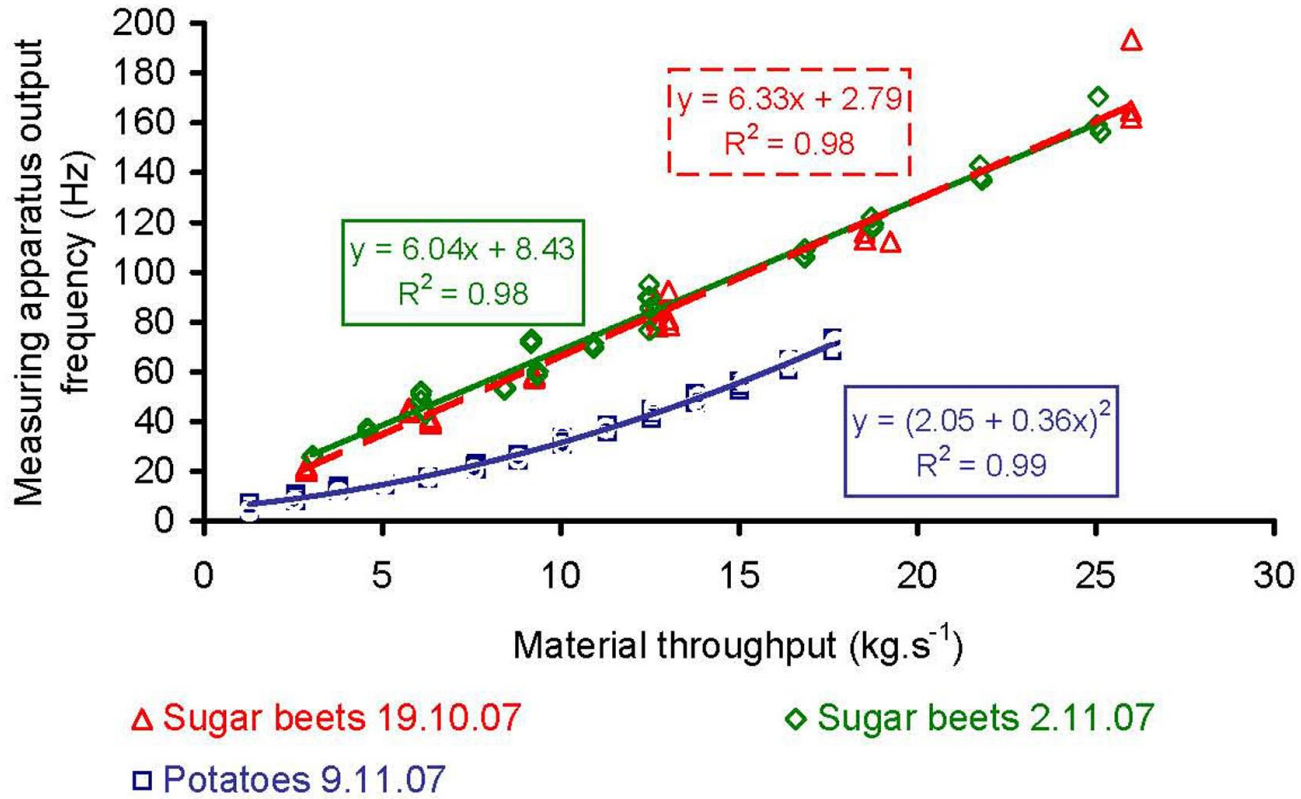

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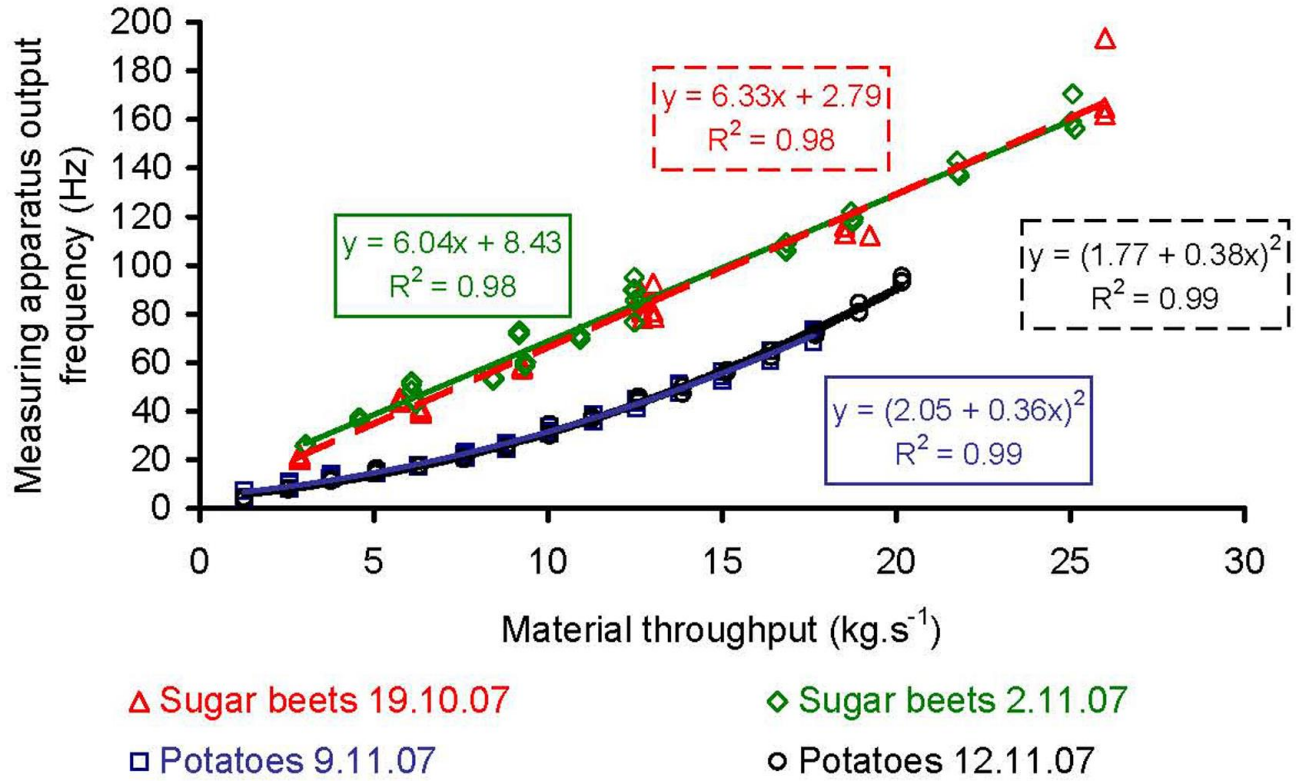


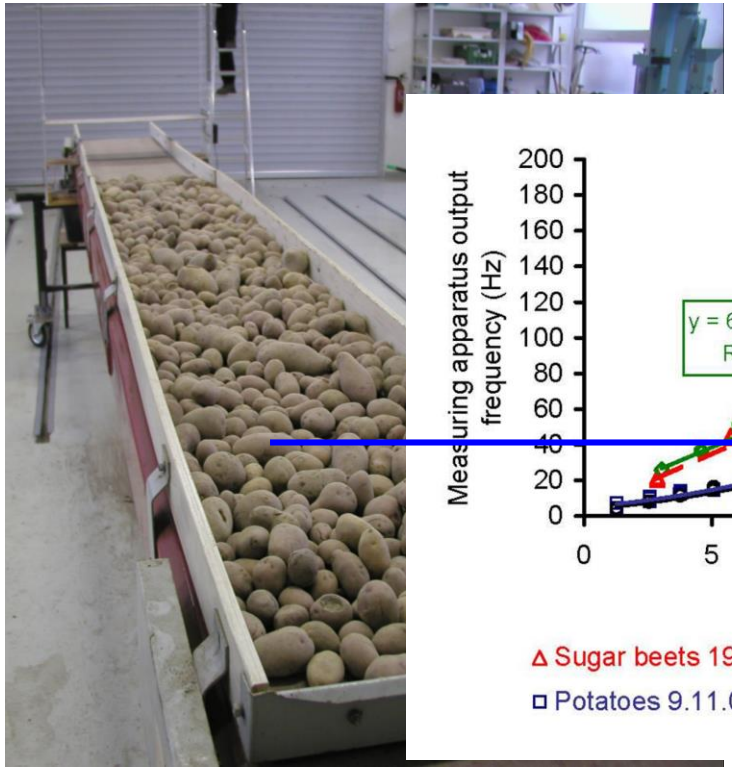
Dependence of measuring apparatus output frequency (directly proportional to voltage and sensor capacity) on sugar beets and potatoes throughput.

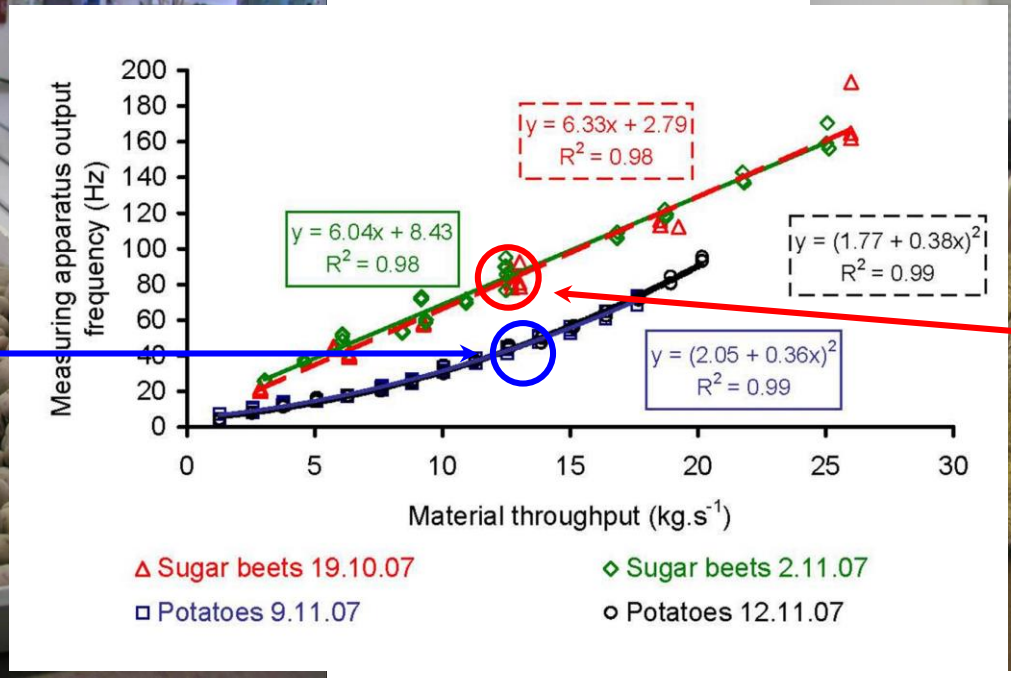
Sugar beets

- Measured output frequency depended linearly on throughput
- Coefficients of determination - $R^2 = 0.98$ in both cases
- Repeatability of the measurements was very good

Potatoes

- Surprisingly, measured output frequency of the same measuring device on potatoes depended nonlinearly and for the comparable throughputs smaller frequency values were measured
- Obtained dependence was power function $y=(a+bx)^2$
- Coefficients of determination - $R^2=0.99$
- Repeatability of the measurements was also very good





12.6 kg.s^{-1} with potatoes – 43 Hz output frequency

12.7 kg.s^{-1} with sugar beets – 85 Hz output frequency

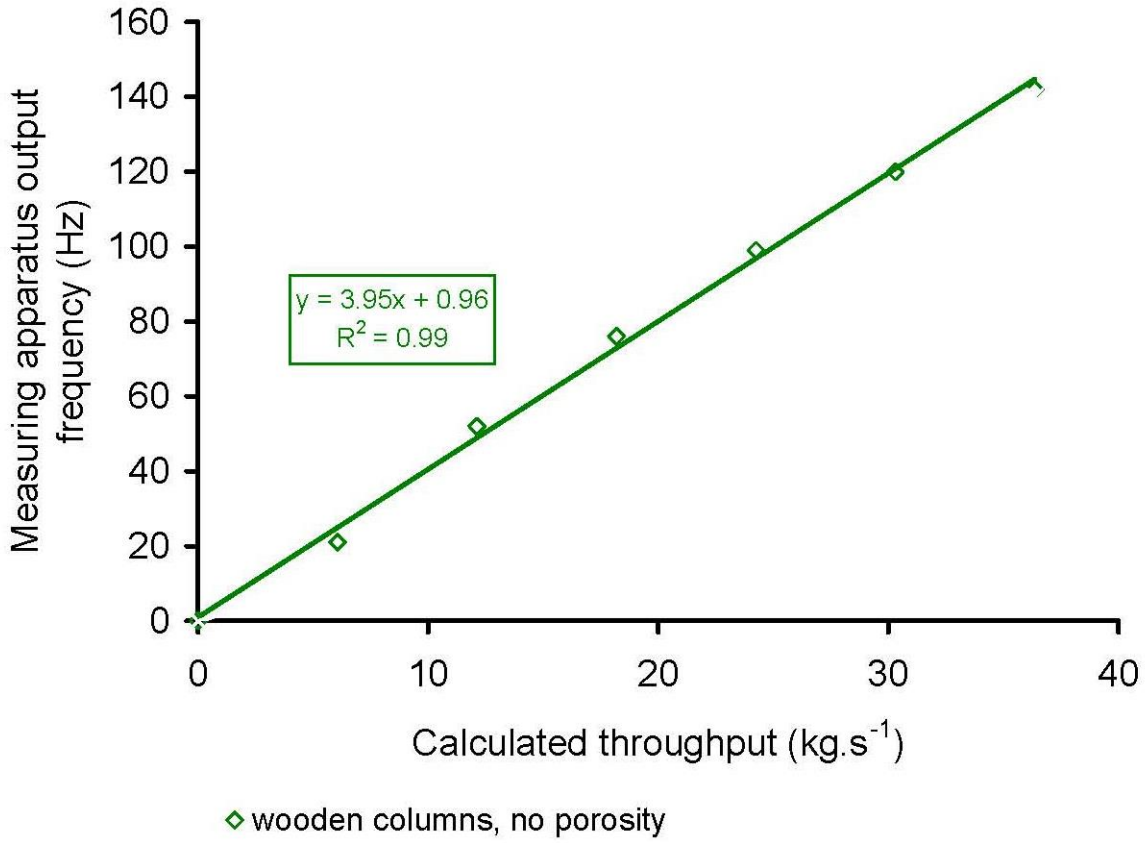
- Why we achieved so different output values for comparable material throughput?
- Why the trend is for sugar beets linear and for potatoes not?

Stationary experiments with wooden blocks

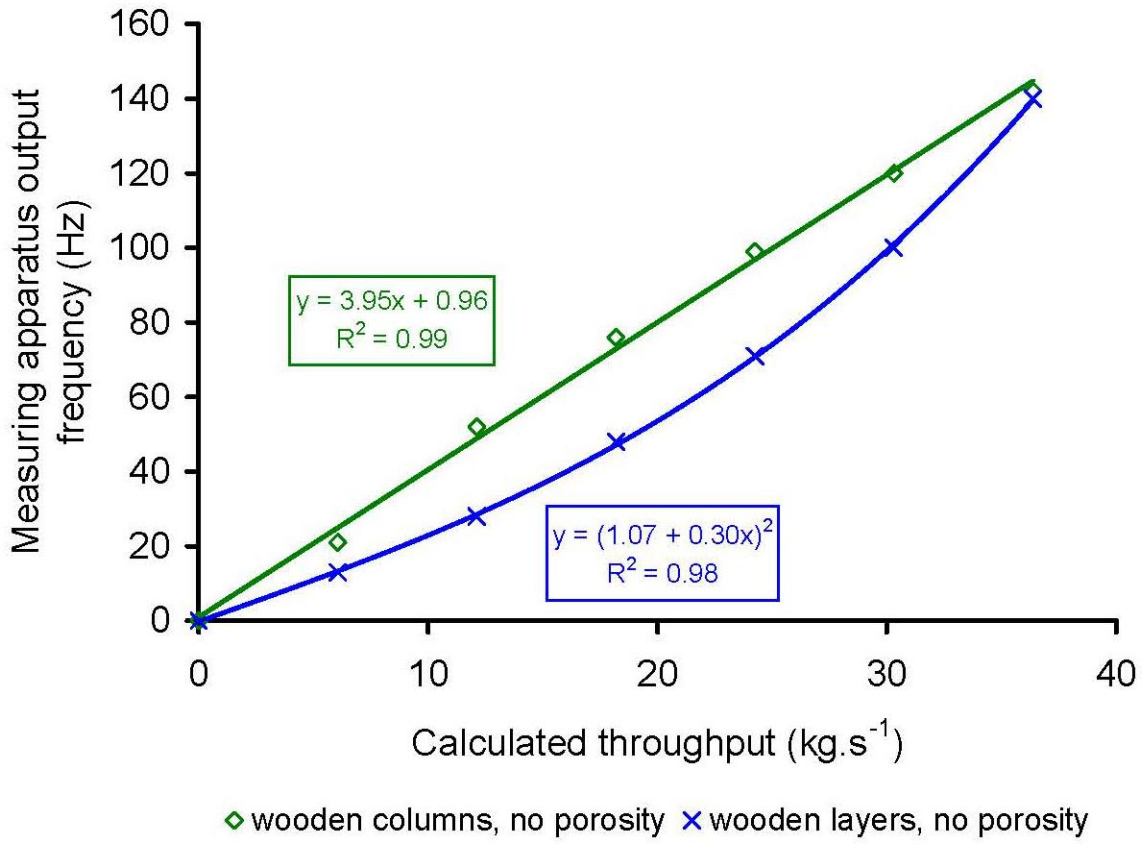
Two strategies of capacitive throughput sensor filling

By wooden columns

By wooden layers

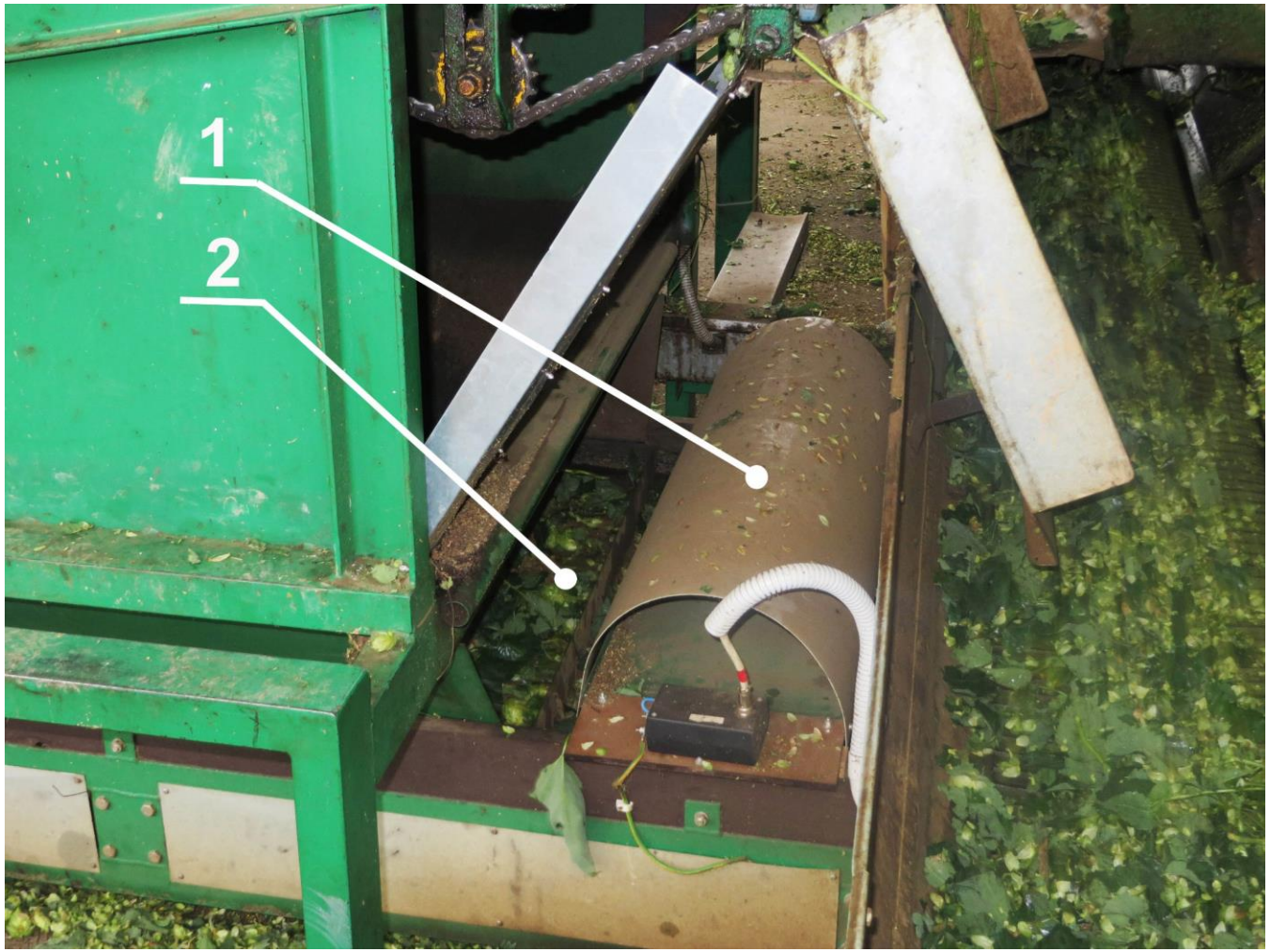


Dependence of measuring apparatus output frequency on the way of filling capacitive throughput sensor by wooden blocks.

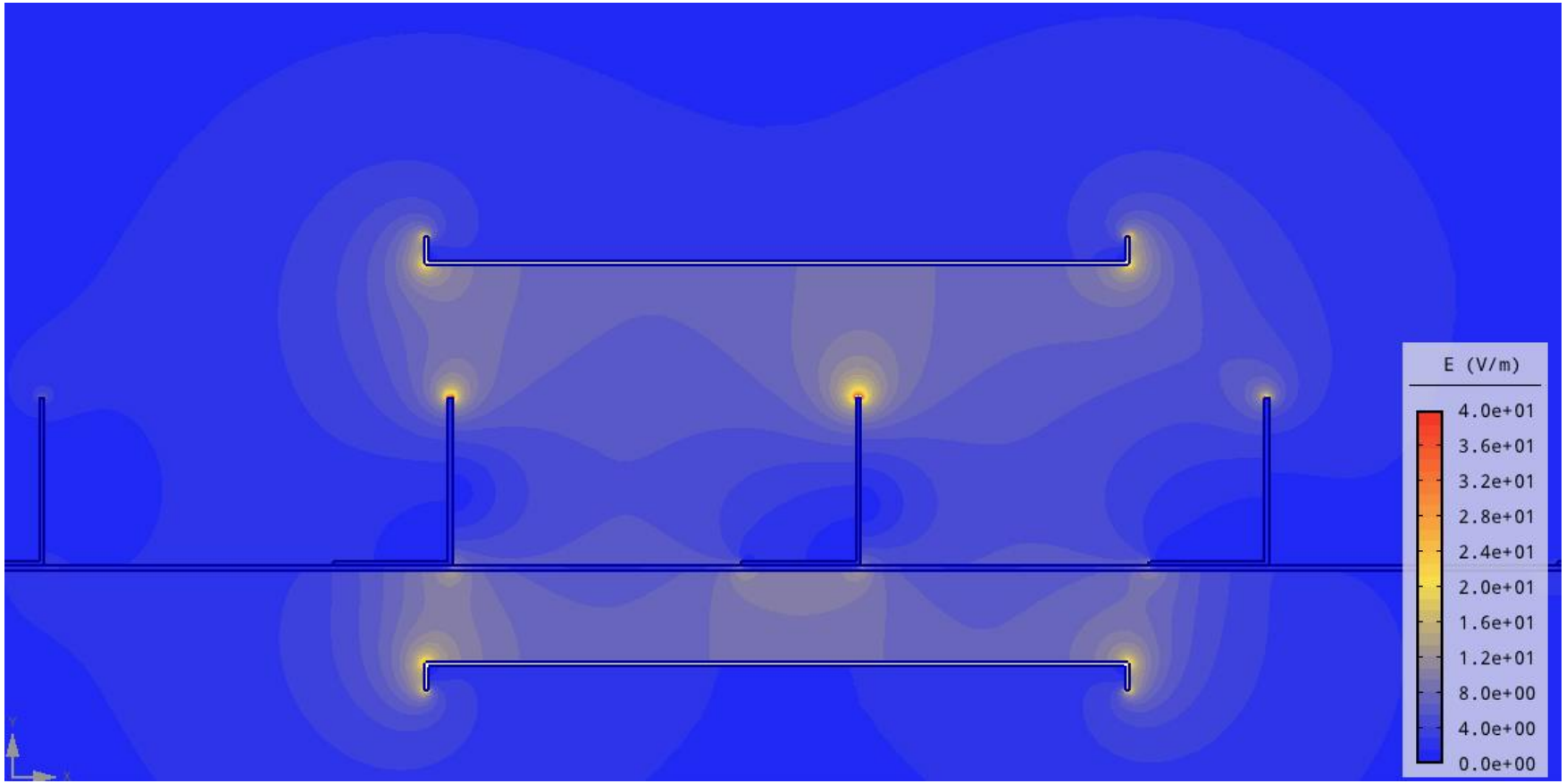


Dependence of measuring apparatus output frequency on the way of filling capacitive throughput sensor by wooden blocks.

It was proved that capacitance throughput sensor can be used as a tool for hop picking machine control.



Location of the capacitance throughput sensor on the pocket belt conveyor of the PT-30 stationary hop picking machine. 1 – capacitance throughput sensor, 2 – pocket belt conveyor with picked hop material.



Mathematical model of the capacitive sensor's electric field distribution when using the belt conveyor with metal pockets, calculated by Agros2D with higher-order accuracy. Blue colour – zero or small electric field intensity; red colour – high electric field intensity. Places with higher electric field intensity are located on the tops of metal pockets. 1 – upper, active plate, 2 – metal pockets, 3 – belt conveyor, 4 – bottom, grounding plate

Thank you very much for your attention!

František Kumhála