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Relationship between daily amplitude of air temperature and topography elements at vegetable field-scale

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Abstract:

The diurnal fluctuations of air temperature-humidity and soil temperature were estimated under Agryl covers and in an open field during the growing period of commercial early spring radish (*Raphanus sativus* L.var.radicula Pers) at field scale. We selected early spring radish, which is widely cultivated in the Czech Republic, and analysed the relationship of its growth with topographic and meteorological elements.

The study was conducted using experimental synchronic measurements of sensors distributed over a field with an area of 1.8 ha, and hourly meteorological datasets were collected for a period of 48 days (the vegetable growth period of spring radish). The selected field has a hilly terrain with an elevation difference of 10 m and well-evidenced aspect patterns. GIS-based methods allowed the distinction of microclimatic conditions that produce aspect-related patterns of the spatial-temporal distribution of basic meteorological inputs under Agryl and a comparison with environmental patterns.

The study aims:

One aim of this study is to develop a digital elevation model of a field that can be used to capture topographic effects on the spatial-temporal distribution of basic meteorological inputs inside covers.

Materials and methods:

Field data collection commenced in the spring of 2010 and is ongoing. The results presented here were recorded over a period of 48 days (the vegetable growth period of spring radish) in spring 2011. This methodology was applied on the Czech study area located in Polabí lowland, a region specialized on growing and marketing of vegetable crops (Fig. 1). For monitoring the meteorological parameters over field with 1.8 ha to early spring variety radish was selected. This crop requires high demands of uniformly distribution temperature-humidity conditions during growing period in especially largest of root (Table 1 and 2).

Data collected from mobile data loggers were used to model surface and soil temperatures and the relative humidity under the textile at each grid point. The data loggers were also grouped in areas of high and low altitudes to more effectively capture any topographic effect (Fig. 2a). This tool allowed the distinction of microclimatic conditions that produce altitude-slope-related patterns of the spatial-temporal distribution of the basic meteorological elements under the covers.

The terrain model of crop field is made by means of the Global Positioning System (GPS) and Geographical Information System (GIS) approaches. Latitude, longitude and altitude of 138 places from field were measured by hand-held RTK-GPS receiver (Fig. 2a).

The DEM of the radish crop field was developed at a 10 m x 10 m resolution by local spline interpolation based on elevation data collected in the field by GPS (Fig. 2a).

The resulting Splined DEM was used to derive a slope (angle degree) map (Fig. 2b.). The elevations and slopes at each data logger position were estimated from the DEM. The lowest and highest points in the field have an elevation of 186.5 and 196.5 m, respectively (Fig. 2a). The field area has a gentle slope (mean angle is 4 °) with a south-eastern exposure. The slope angle of the field varies between 0.5º and 7.5º, and the slope orientation ranges from 0º (north-facing slope) to 180º (south-facing slope) (Fig. 2b).

Table 1. Spring radish stages of development by the BBCH scales

Type of vegetables		10 BBCH	12 BBCH	14 BBCH
Raphanus sativus L.var.radicula Pers	Spring radish	*after emergence*	*≥3 leaves*	*start of harvest*

Table 2. Averages of the air temperature and relative humidity under the Agryl cover for the entire growing period of spring radish (48 days, March-April) in climatologic terms of measurement (7, 14, 21 hrs).

	air temperature (°C)						relative air humidity (%)					
	t_{max}	t_{min}	t_7	t_{14}	t_{21}	t_{mean}	RH_{max}	RH_{min}	RH_7	RH_{14}	RH_{21}	RH_{mean}
NE	39.1	3.2	4.5	26.3	12.7	15.5	100	20	87	46	76	72
NW	39.1	3.3	4.8	26.1	12.4	15.1	100	20	94	60	61	77
SE	40.1	3.4	5.8	28.1	14.3	15.6	100	20	97	45	75	73
SW	41.5	3.9	8.8	26.1	10.3	15.2	100	20	90	40	84	71
Central	42.0	3.1	7.9	28.1	9.8	15.3	100	21	98	44	90	76

Conclusion:

This paper examined the relationships between topographic attributes (e.g., angle slope) and microclimate (e.g., air and soil temperatures) at field scale. From this study it can concluded that:

(1) Temperature fluctuation under a cover is dependent on topographic elements as well as the temperature in the open field. However, the effect of slope on diurnal extreme temperatures outside the cover was more pronounced than that under the Agryl cover.

(2) The diurnal course of relative humidity (RH) both under and outside the Agryl cover demonstrated a pattern opposite that of the diurnal course of air temperature, i.e., a lower RH was found in the afternoon hours and a higher RH in the morning and evening hours.

(3) The highest critical fluctuations of RH values under the Agryl cover were observed at early afternoon and are lower by 15-25 % than the values observed in the open field. At the small field scale, the relative air humidity can be considered unaffected by slope and elevation during daytime hours.

(4) At at midday, the crop under the cover was under stress conditions (tmax≥25 °C and RH≤ 30 %) due to insufficient ventilation, leading to a significant increase in air temperature, while the relative humidity decreased to critical levels. In the middle part of the field, the air temperature increased up to 31.5 °C with a simultaneous reduction in relative air humidity to 20 %.

(5) The experiment results show that it would be effective to monitor the physiological responses of early spring vegetables in these conditions. In such conditions, the plant has closed stomata, and consequently, the photosynthetic activity dramatically decreases and speeds up the aging of the plants, accompanied by declining production quality.

(6) The air temperature differences between the crops grown under and without covers were small during the early hours of the day. With the advancement of the day, this difference amounted to approximately 5.0 ºC and 15.0 °C for the minimum and maximum temperatures at afternoon (15:00-16:00 hrs), respectively.

(7) Similar to the air temperature, the soil temperature also maintained a distinct diurnal course. The soil under the Agryl cover always maintained temperatures that were 4.0-5.0 ºC higher than those of the soil outside the cover.

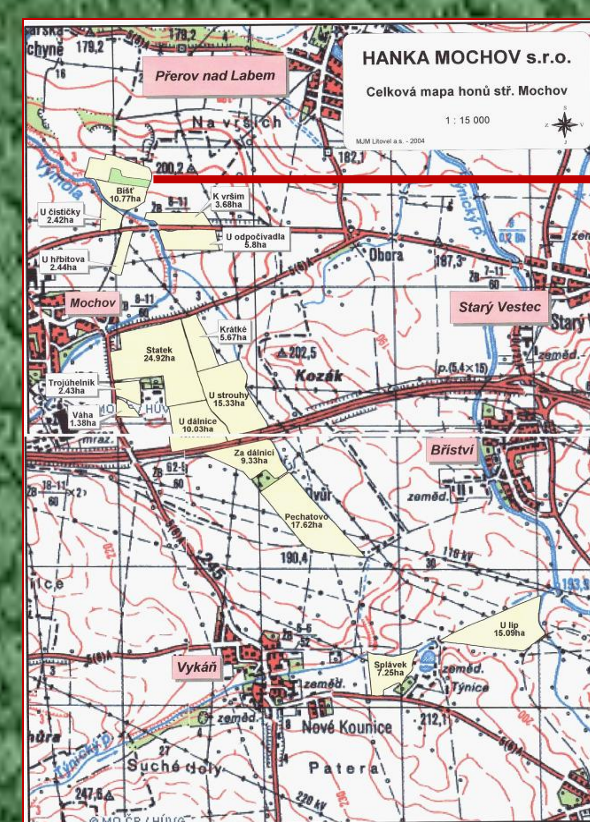
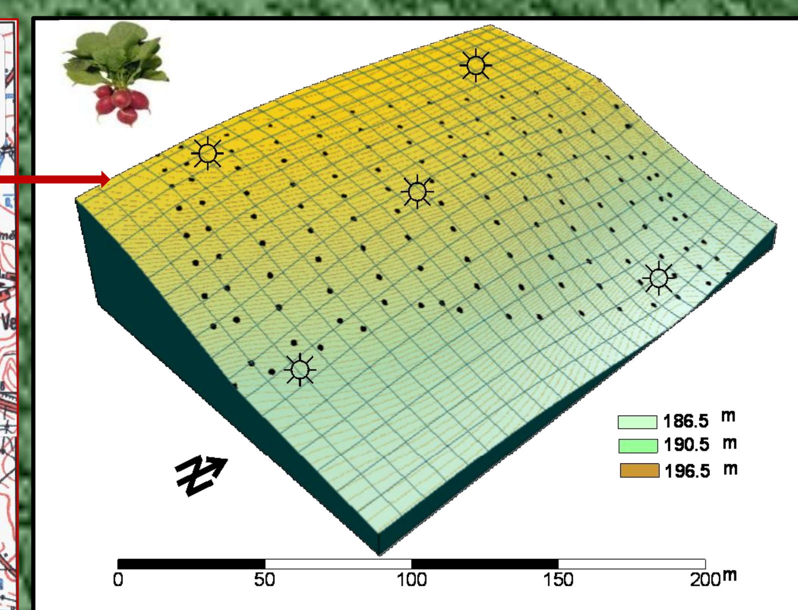


Fig. 1 Topographic map of location fields at the farm Hanka Mochov s.r.o.



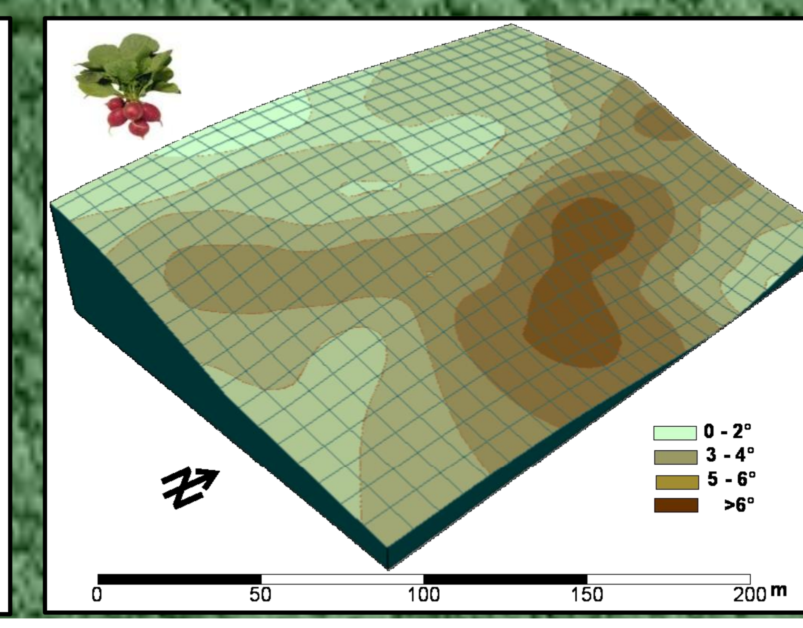
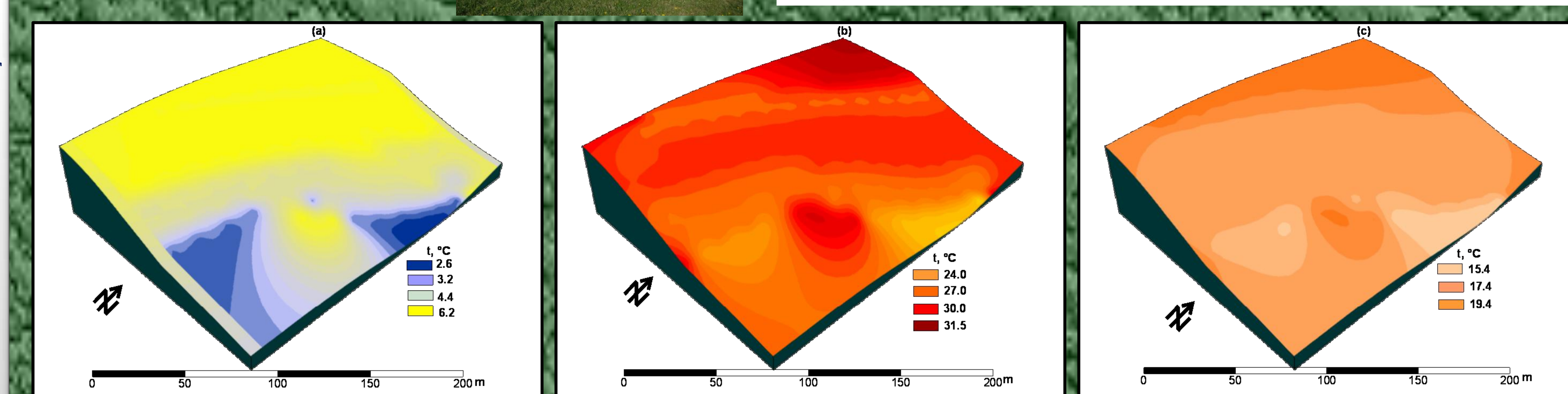
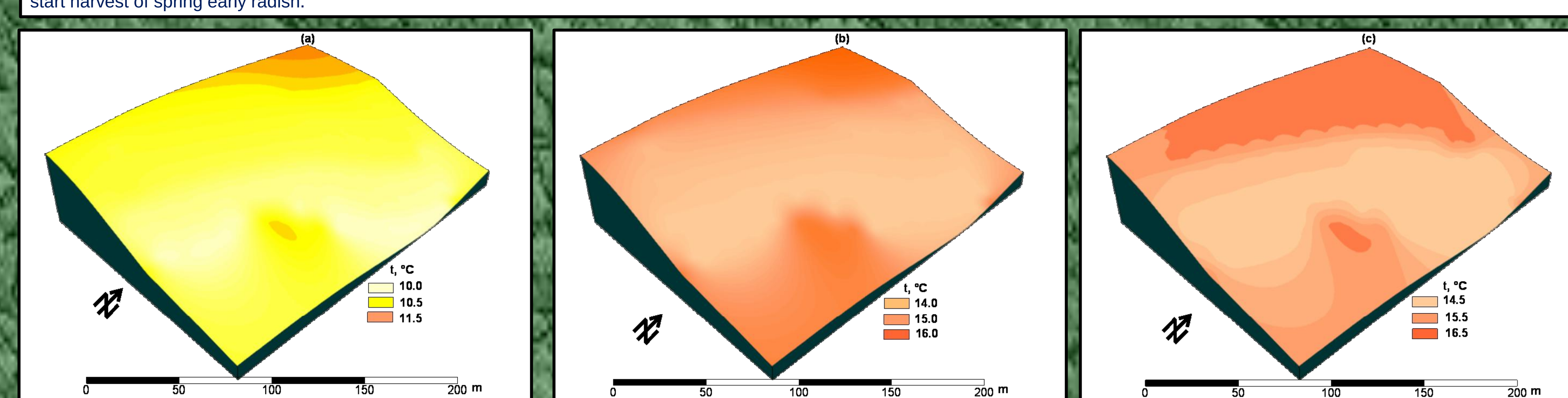


Fig. 2a)
Interpolation of the elevation data of selected field in the 3D surface plane: size of field: 1.8 ha, geographical position: φ=50.246 N, λ=14.606 E, h_{mean}=192 m. a. s. l.; Southeast orientation of field; the position of meteorological sensors across field (sun symbol); 138 grid points collected by GPS (black dots).
b) Interpolation of the slope angle of selected field in the 3D surface plane.

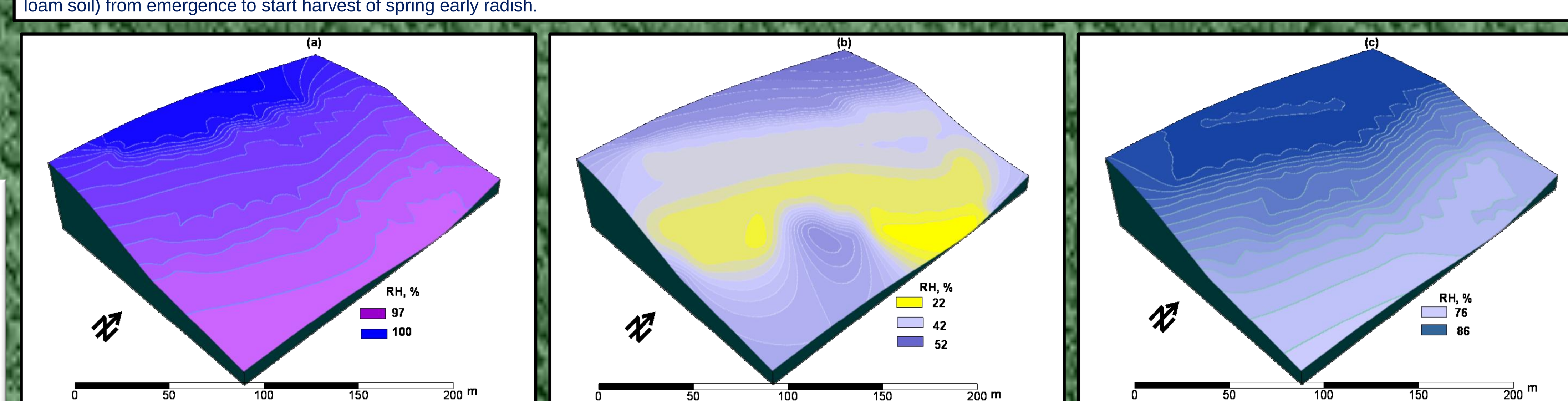
Seed was sown March 15. Immediately after sowing, field was covered with Agryl (polypropylene fibres) as a protective crop cover from minimize frost damage and enhancing early yields. The cover was kept on all covered field until harvest



Spatially distribution of interpolated average hourly air temperature field in climatologically term of measurement: (a) 7 a.m., (b) 14 p.m. and (c) 21 hrs at local time under Agryl from emergence to start harvest of spring early radish.



Spatially distribution of interpolated average hourly soil temperature of 5 cm depth in climatologically term of measurement: (a) 7 a.m., (b) 14 p.m. and (c) 21 hrs at local time under Agryl (sandy loam soil) from emergence to start harvest of spring early radish.



Spatially distribution of interpolated average hourly relative humidity in climatologically term of measurement: (a) 7 a.m., (b) 14 p.m. and (c) 21 hrs at local time under Agryl from emergence to start harvest of spring early radish.

Practical recommendations

(1) The negative effect of increasing the air and soil temperature amplitude under the Agryl cover can be compensated by an improved daily dose regime of irrigation. The use of this sort of crop protection is advisable in these environments to enhance the productivity and crop quality of vegetables at low cost. Growers benefit when they are able to produce higher quality and off-season spring radishes that fetch premium prices in the market.
(2) It is important to choose the optimal irrigation time. Generally, it is not appropriate to irrigate plants in a cloudless sky at noon hours. The sudden cooling due to irrigated water causes stress to the plants.
(3) However, under Agryl watering at midday, it is possible to reduce the negative effects of overheating and create the optimum temperature and humidity environment for plants
(4) As seen from Table 2 and maps, high air temperature with low humidity under the Agryl is already recorded in the early afternoon. Higher air temperatures, air humidity and soil temperatures with limited ventilation under the cover creates suitable conditions for the development of fungal diseases. Vegetables with a short growing season do not usually need fungicide products; however, for other vegetables, fungicide treatment is appropriate.
(5)The temperature analyses of experimental vegetable field show that in the southeast aspect soil temperature of 5 cm depth under cover had already recorded the highest soil temperature in the morning hours. For this part of the field is therefore advisable to choose an earlier variety, and together with environmental conditions as has expected an earlier harvest.

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