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CONNECTION BETWEEN PHENOLOGICAL PHASES AND URBAN HEAT ISLAND IN DEBRECEN AND SZEGED, HUNGARY

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Összefoglalás – A városi környezetben jelentősen eltérő a felszín anyaga, szerkezete és ezekből adódóan az energiamérlege a természetes felszínekhez képest. E tényezők lokális klímamódosulást okoznak, melynek egyik sokat vizsgált jelensége a városi hősziget. Feltételezzük, hogy e módosulások a városban élő növényzet fenológiai, fenometriai mutatóira is hatással vannak. Két magyarországi város (Debrecen és Szeged) esetén végeztünk hőmérsékleti méréseket és fenológiai megfigyeléseket 2003 tavaszán. A napi megfigyelésekhez az aranyvesszőt (*Forsythia suspensa*) választottuk, mivel elterjedése 60-70%-os lefedettséget mutat mindkét város esetén. Eredményeink szerint a fenológiai fázisok bekövetkezési időpontjának területi adatai szignifikáns kapcsolatot mutatnak a hősziget intenzitás területi eloszlásával. Legszorosabb kapcsolatot a 100%-os virágzás bekövetkezési időpontja között találtunk, Debrecenben (0,1%-os szinten szignifikáns).

Summary – A local climate with special spatial structure (e.g. heat island) is formed within the settlement compared to outside open spaces. We presume that these climatic modification affects the phenological and phenometrical properties of the urban vegetation. For this study we have chosen two medium-sized Hungarian cities (Szeged and Debrecen), with urban areas over 30 km^2 and with population between 160 and 200 thousand. The phenological and temperature observations have been taken in grid networks in spring of 2003. As a good observable plant, forsythia (*Forsythia suspensa*) was the object of our examination because this species occurs in the 60-70% of the areas of both cities. The time of the different phenological phases was monitored in a daily fashion. According to the results there is significant correlation between the spatial distributions of the timing of these phenological phases and of the intensity of the urban heat island. The strongest correlation occurs between the UHI intensity and the date of 100% flowering in Debrecen.

Key words: phenology, urban heat island, *Forsythia suspensa*, Debrecen, Szeged, Hungary

INTRODUCTION

Phenological observations were used as a bioindicative method by ecological research and the applied agricultural practice for a long time (*Fezer*, 1995; *Schwartz*, 1999). Impact of global climatic change on vegetation was widely investigated using long-term data and remote sensing (*Defila and Clot*, 2001; *Valentini et. al.*, 2001). Other researches studied the small scale modifying effect of urban climate on urban vegetation (e.g. *Roetzer et. al.*, 2000). The city itself represents a modified ecological environment for plants in many aspects (urban heat island phenomenon, high building density, air pollution, soil sealing and pollution, water balance) so pattern of phenological data represents mainly an ecological-microclimatical stuctures of urban area (*Karsten*, 1986). The results of these researches indicate that flowering of different plant species happened earlier in urbanised than in rural areas (*Roetzer et al.*, 2000). So shift of phenological phases is a result of a complex mechanism but it can be linked to the urban heat island (UHI) intensity.

The objective of this study is to analyse the eco-climatic effects in two Hungarian middle-sized cities, Debrecen and Szeged.

STUDY AREA AND METHODS

The investigated areas, Debrecen (47.5°N, 21.5°E) and Szeged (46°N, 20°E) are located in the north-eastern and in the south-eastern part of Hungary at 120 m and 79 m above sea level, respectively, on a flat plain. Administration districts of Debrecen (220,000 inhabitants) and Szeged (160,000 inhabitants) are about 300 km^2 (*Fig. 1*). Debrecen does not have any larger river, while River Tisza passes through Szeged. Szeged has a boulevard-avenue road system structure with a heavily built up centre region and housing estate zone in north-eastern part of the city. Debrecen has a less centre region at about the geometrical centre of the city than Szeged but there is a huge housing estate zone in the western part of the city. We used for the observation a 500 x 500 m grid network which was applied earlier for urban climate research (*Unger et al.*, 2001). Having averaged the phenological data the received mean values refer to the centre of each cell.

The investigated species was forsythia (*Forsythia suspensa*), because its distribution is well extended (60-70%) over both cities. The times of four selected phenological phases (beginning of the flowering, 25%, 50% and 100% blooming) of the plants (4-8 in one grid cell) were recorded. Blooming maps show the day's numbers starting from the 1st of January 2003 (year day – YD), similar to *Steinecke* (1999). In order to assess the extent of the relationships between the mean maximum UHI intensity and blooming events, correlation and regression analyses were applied in the statistical data processing.

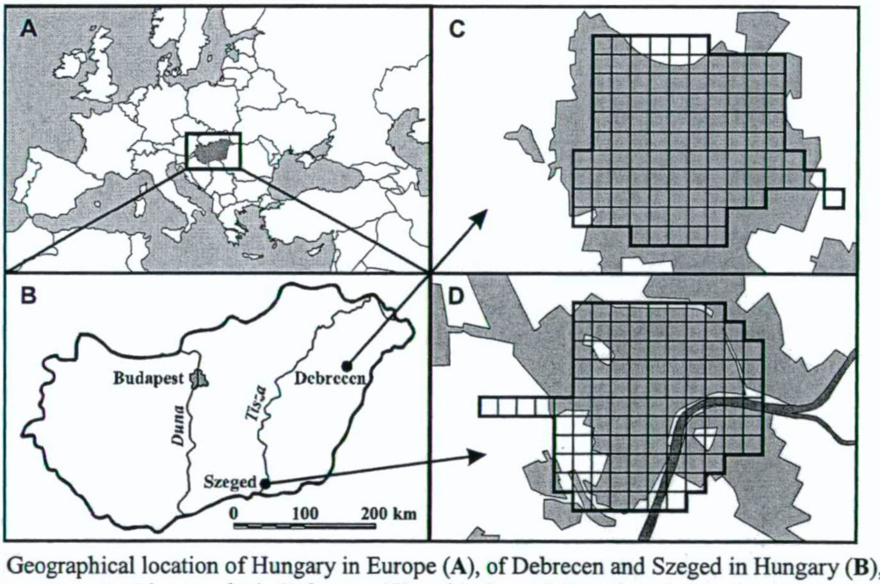

Fig. 1 Geographical location of Hungary in Europe (**A**), of Debrecen and Szeged in Hungary (**B**), and the measurement grid networks in Debrecen (**C**) and in Szeged (**D**). The urbanized areas are marked by grey on the parts of **C** and **D**.

RESULTS AND DISCUSSION

The urban climatological investigations in Szeged (UHI, humidity, human comfort) have a tradition of several years (e.g. *Unger*, 1992, 1999a, 1999b). Recent urban climate studies show maximum urban heat island intensities of 2.3°C in Debrecen (*Fig. 2A*) and 2.7°C in Szeged (*Fig. 2B*) as annual averages between April 2002 and March 2003. These values can extend up to 5.8°C and 6.8°C in Debrecen and in Szeged, respectively, at clear, anticyclonic weather conditions (*Szegedi and Kircsi,* 2003; *Sümeghy and Unger,* 2003). In our study the maximum UHI is the urban-rural temperature difference a few hours after sunset, when the UHI effect is most pronounced in its daily course.

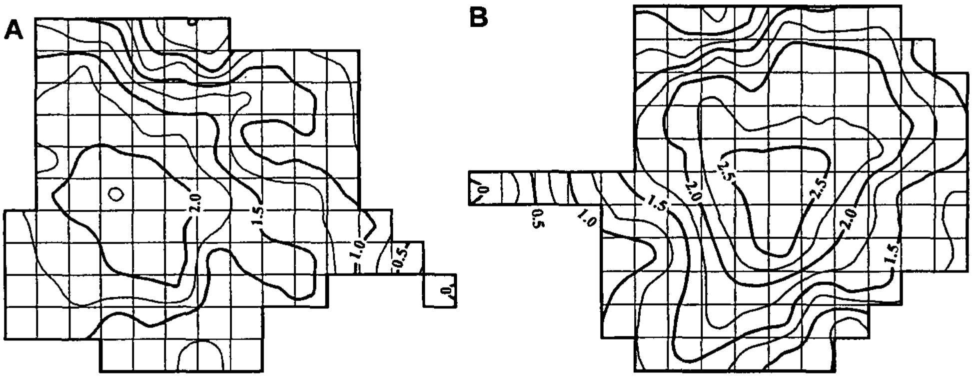

Fig. 2 Spatial distribution of the mean maximum UHI intensity (April 2002 – March 2003) in Debrecen (**A**) and Szeged (**B**)

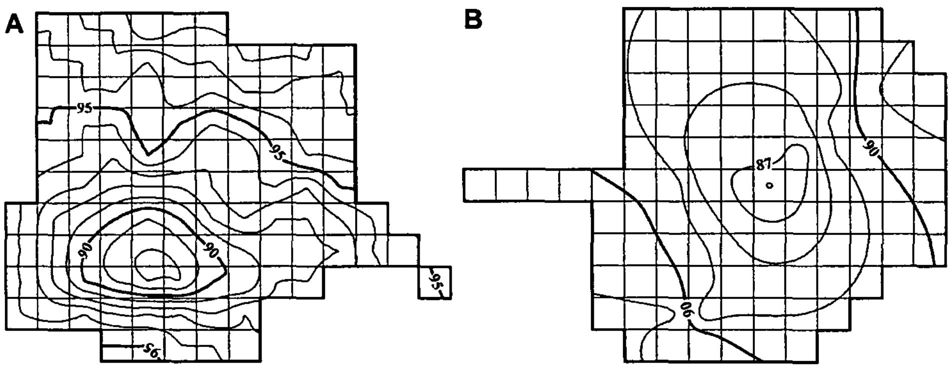

Fig. 3 Spatial distribution of the beginning (in YD) of the blooming *Forsythia suspensa* in Debrecen (**A**) and in Szeged (**B**) in spring 2003

Based on the received data, in both cities pheno-isochrone maps on spatial distribution of the different flowering dates were created. According to the results there is significant connection between the spatial distribution of the phenological data and of the heat island intensity. Two examples are presented to support this statement: *Fig. 3* and *Fig. 4* show the spatial distribution of the beginning of flowering and the full-flowering phenophases, respectively (**A** – Debrecen, **B** – Szeged). We have to mention, that the observation in

Debrecen covered more clusters, hence maps refer to Debrecen have higher resolution than those which regard to Szeged. As the figures show the investigated plants reached the given phase earliest time in the heavily built-up centre and housing estate region. These regions represent the highest UHI intensity, too (*Fig. 2*). Shapes of isolines are stretching out towards W in Debrecen and towards N-NE in Szeged due to the urban structure.

On account of macrosynoptical conditions and geographical location the flowering began in Debrecen 2-4 days after Szeged and the blooming process was drawling. The full-flowering phase occurred 10 days later than in Szeged.

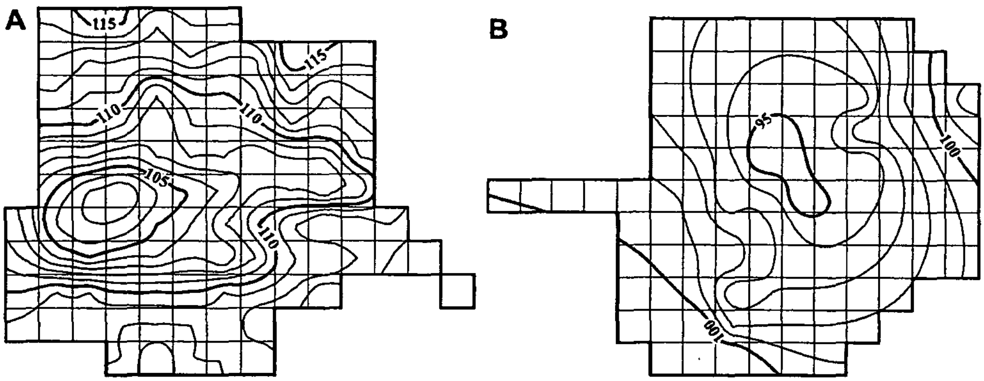

Fig. 4 Spatial distribution of the date (in YD) of the full-flowering phenophases of *Forsythia suspensa* in Debrecen (A) and Szeged (B) in spring of 2003

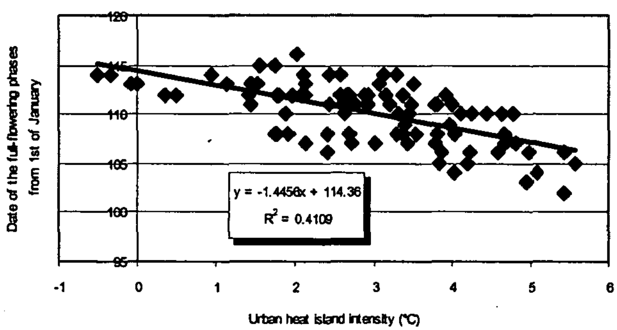

Fig. 5 Correlation between the urban heat island intensity and the date (in YD) of the full-flowering phenological phases in Debrecen in spring 2003

Fig. 5 shows the correlation between UHI intensity and date of 100% flowering in Debrecen in spring of 2003 by cells. The correlation coefficient is r = -0.6473 (r^2 = 0.4109) with a standard deviation of 2-3 days. It means that in such a complex modified process like blooming a strong relationship at a significance level of 0.1%. As the regression line presents the relationship between the two variables is negative, as it was expected.

CONCLUSIONS

The following conclusions are reached from the analysis presented:

(i) Pattern of phenological phases shows good correlation with microclimatological data.

(ii) Significant differences were experienced in the blooming date between city centres and suburbs in both cities.

(iii) Phenological phases can be shifted earlier by several days even one week (in our investigation 4-8 days) in heavily built city centre region and blocks-of-flats areas with high intensity heat island.

(iv) Time shifting of phenological phases can be attributed partly to the effect of urban heat island.

(v) The geographical location and the macrosynoptical conditions caused differences in blooming date between the two experienced cities.

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