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# The effect of day and night temperatures on apple skin colour formation

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***Summary***: The colour of fruits is considered to be an important quality indicator. Saleability greatly depends on how well covered the colour is of the specific type of fruits. It is a well-known phenomenon by growers that apples get nicer colours in one year while in other years the basically red and green colour cultivars can be differentiated only by morphological characteristic features. Cover colour is one of the phenometric variables and it is a well-known fact that significant differences can be experienced year by year. The experienced oscillation can be the cause of inappropriate water- and nutriment supply, however it can be the result of some kind of plant disease, extremely high or low temperature, setting rate above the average and outstanding fruit density. In the present examination it is postulated that the degree of cover colour is mostly influenced by day and night temperature. Therefore, our study aims to find out whether it is true or not. Cover colour belongs to those phenometric characteristic features, only the final value of which is taken into consideration; due to their nature of establishment or forming time it seems useless to follow closely the change in the time of vegetation. However, determining the start of colouring and knowing the dynamics of full colouring could carry very important information for growers. If it is possible to determine the curve describing the time change of colouring, we have a possibility to estimate it by means of enviroment variables. So it is also possible to model pigmentation in the future. Knowing this, colouring irrigation could be made more efficient in the future. For this, as a first step, it is inevitable to find out what the relationship is between the main meteorogical variables, namely day and night temperature and the difference between day and night temperature, and colour cover. In this study we summarize and show these interrelations.

***Key words***: apple, night and day temperatures, skin colour, summer ripening, autum ripening, winter ripening

## Introduction

In the '50s *Zerinvári* (1950), *Berényi & Justyák* (1956) started the survey in orchards as well as in mountanary vineyards. The first results of meteo phytoclimatic examinations on vineyards and orchards were published in the '60s due to the researches of *Bognár & Kozma* (1961). The analyses of macro and microclimatic impacts on the growth of fruits is linked with the name of *Szász* (1961). At the end of the sixties studies analysing the mutual effect of phenological, stage and meteorological parameters were published, *Csöbönyei &Stollár* (1969) mainly studied apple and grape cultures. These studies meant great help to develop orchard crop safety and in finding out about the productivity of different species. As a result of some really hard winters in the decade, the first studies on frost protection (*Pletser & Radnai*, 1964) seemed to come out. In the '70s, several research results were published revealing the relations between fruit growing, dry matter content and weather conditions. Similarly, during this period evapotranspirational researches came to light (*Füri & Kozma*, 1975), as well as studies about apple's water consumption (*Gergely & Stollár*, 1978), and results relating to Jonathan apple's ripening period estimated by weather variables (*Stollár*, 1977). In the '80s, greater and greater emphasies were laid choosing the production site by means of the description of meteorological background of different cultivars (*Stollár & Zárbok*, 1981; *Stollár*, 1984), temperature and radiation state of stands (*Dunkel* et al., 1981) and examinations of critical winter temperature on surviving winter, analysing mainly grapes (*Dunkel & Kozma*, 1981; *Csapó*, 1984).

## Material and method

The examination material used derives from the assortement of Újfehértói Gyümölcstermesztési Kutató és

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In the examination we recorded and measured 2 trees/cultivars in repetition system, the phenological phases and phenometric indicator of 586 kinds of apples, during the years of 1984–2001. Ripening period according to groups:

(1) Ripening in summer
(2) Ripening in autumn
(3) Ripening in winter

In the sample we separated the cultivars with good cover colour and later we analysed reciprocal effect with meteorological factors only in these cultivars. We made an examination on what reciprocal effect of average day and night temperature on the degree of cover colour has in different months of the vegetation period and 30 days before ripening. Among the cultivars, there were the so-called "old" cultivars, that were getting to be squeezed out of cultivation, popular and widespread cultivars as well as perspective, spreading cultivars. A total number of 1172 trees were examined. The different kinds of apples were planted by MM106 stock grafts on spindle shaped parent branched plantation in 1981–82. The difference between lines and stocks is 8 × 2 m.

Observation and surveying took place in the research area of Újfehértó. The position of the territory is plain, 115 metres above sea-level, 19 kms south of Nyíregyháza. Its soil evolved on sand soil-creating stone non-carbonate several layer humous sand, which has a strong, sour acidity (pH 5.74–5.79). Its organic matter content is low (<1%) in its genetic category.

In the examining period, from microclimatic date, air temperature was set hourly and on daily basis by means of a computer demodulation automatic meteorological measuring station.

In our calculations, we used the below-mentioned temperature variables:

– Night temperature ($T_{night}$),
– Day temperature ($T_{day}$),
– Difference between day and night temperature ($T_{diff}$),

During the records, cover colour degree was set in percentage (0–100%) in intervals.

The evaluation of data was fulfilled by means of Excel 97 for Windows programmes. We calculated average and standard deviation from the details. The correlation between phenometric indicators and meteorological elements were evaluated by linear regression and correlation analysis.

## Results

On the basis of frequency distribution of cover colour values it can be stated that almost half (49.7%) of the cultivars ripening in summer has a good cover colour, while 25.2% of this group can be counted to be a less well-colouring variety. Those kinds of apples represent the biggest subrate (32.1%-ot) in the sample, whose colouring rate reaches 64–81%. In the sample the cultivars with good cover colour appear in a significantly larger proportion than cultivars with weak cover colour.

The kinds of apples ripening in autumn show a fairly stable distribution in respect to colouring. 42.5% of these apples can be characterized with good cover colour, while 36,4% have weak cover colour.

In the sample, the number of cultivars with good cover colour and weak cover colour seems to be almost equal.

The frequency distribution of apples ripening in winter can be described by a U-shape function. This means that in the sample we can experience the predominance of well as well as weak colouring cultivars. We can notice the smallest proportion of cultivars with mid-range cover colour in this group.

If cover colour values are examined in the complete range of cultivars, as a whole, the following can be stated:

34.1% of the examined cultivars can be described with a colouring rate above 70%. Hereinafter, these apples will be considered well colourig cultivars (*Figure 1*). In case of 24.6% of the sample, colouring rate was between 10–39%. These apples belong to the weak-colouring category. The rate of cover colour in case of 41.2% of the assortement turned out to be between 40–70%; they can be regarded as mid-range colouring cultivars.

As a next step, in case of well colouring cultivars, we examined how day and night temperature and the difference of these temperatures influence the degree of the fruit's cover colour.

According to our hyphotesis, the degree of cover colour is mostly influenced by day and night temperature.

In the last 20 years the average night temperature of growing season has increased greatly in the examined habitat. Higher night temperature generally has an unfavourable result on production. Respiration becomes more intense and; therefore, daily weight growth becomes less.

In case of higher night temperature several quality indicators, e.g. sugar content also reaches a lower value, since the energy necessary because of the increased respiration is covered by the plant's own reserves.

Naturally it is also important to examine what changes characterize day temperature in time during the same period.

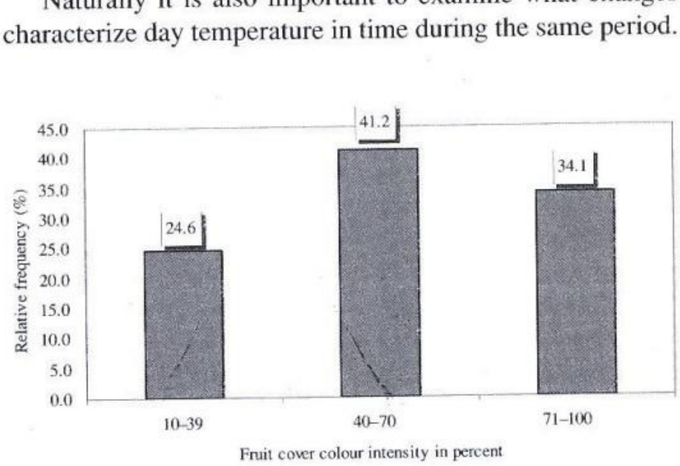


***Figure 1*** Distribution of apple cover colour at 586 apple cultivars

If day temperature increased more intensely, there is no need to worry, because all climatic conditions are given for growth. Even the same rate of growth in day and night temperature does not cause any problem. Problems can occur from the growers point of view if the two examined variables' rate of growth is different.

According to the results, the day temperature's rate of growth falls behind the same value of night temperature.

If we take the difference of day and night temperature and analyze what change the time series of this value shows in the examined period, the following statements can be done:

In the last 20 years the difference of average day and night temperature characteristic to the growing season has decreased, which can be considered significant in 5% rate (*Figure 2*). The decreasing trend proves that the increase rate of night temperature exceeds the change of day temperature. This means that if this tendency continues the same way, further decline in crop quality can be expected.

In the next parts of the study we show how the cover colour of apples is influenced by night and day temperatures characteristic to different months and their differences. Night temperature in August in p=5% level show a significant relation with the cover colour of apples ripening in summer (*Figure 3*). According to the results 5 degrees higher night temperature results in a 15–17% lesser degree of cover colour.

While high night temperature has an unfavourable effect on the establishment of cover colour, in case of higher day temperature a better cover colour can be expected. In case of apples ripening in autumn the relation between day temperature in October and the degree of cover colour is illustrated in *Figure 4*. The results show that in case of apples ripening in autumn, a 4 °C higher temperature results in 10–12% more favourable colouring rate.

In further parts of the study we demonstrate by different ripening groups which month's difference in day and night temperature has the greatest influence on the cover colour and what function can be used to show the interrelation.

## Cultivars ripening in summer

In case of apples ripening in summer the difference between average day and night temperature in August showed a significant relationship with cover colour degree in 1% rate (*Figure 5*). However, the character of the relation

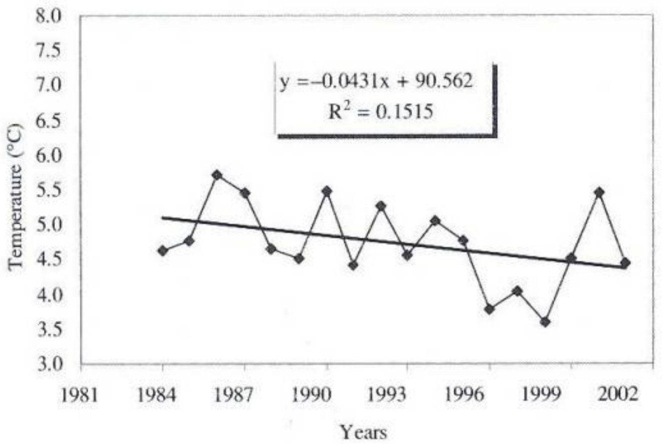


***Figure 2*** Time series of the average night and day temperature difference (Újfehértó, between1984–2001)

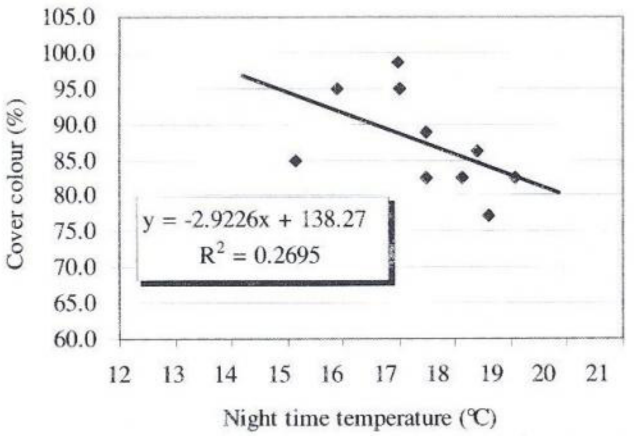


***Figure 3.*** Daily distribution of temperature in the crown area during the vegetation period (Derecske-2004)

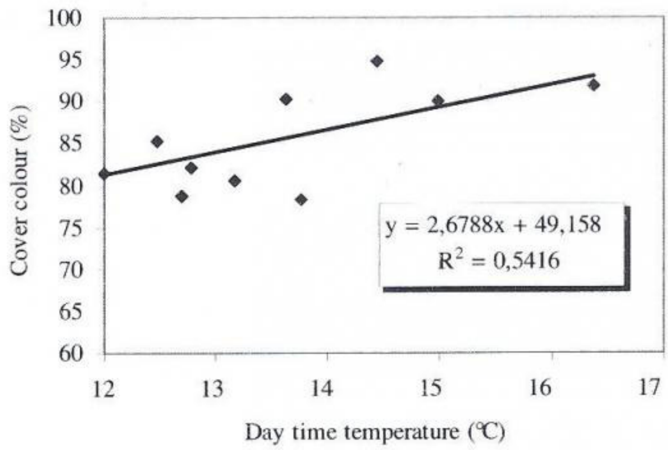


***Figure 4*** Relationship between day temperature and apple cover colour in October at outumnal ripening apple cultivars

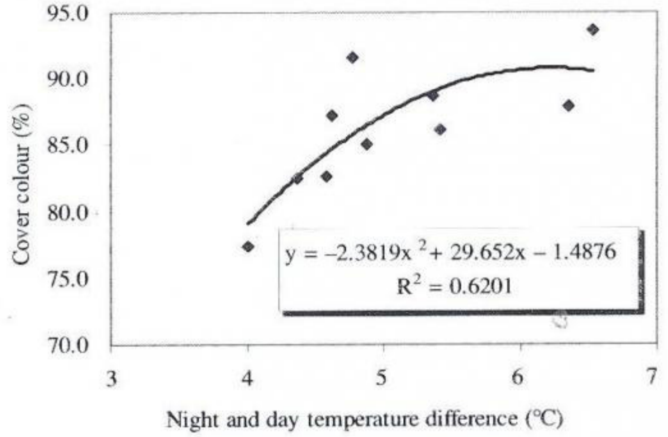


***Figure 5*** Relationship between day and night temperature difference and apple cover colour in August at summer ripening apple cultivars

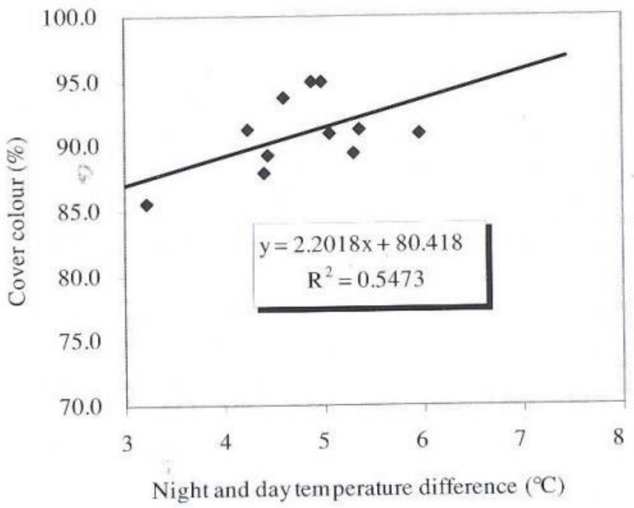


***Figure 6*** Relationship between day and night temperature difference and apple cover colour in September at autumnal ripening apple cultivars

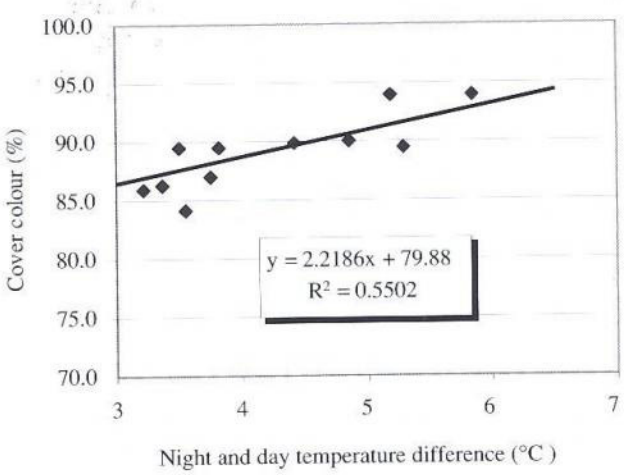


***Figure 7*** Relationship between day and night temperature difference and apple cover colour in October at winter ripening apple cultivars

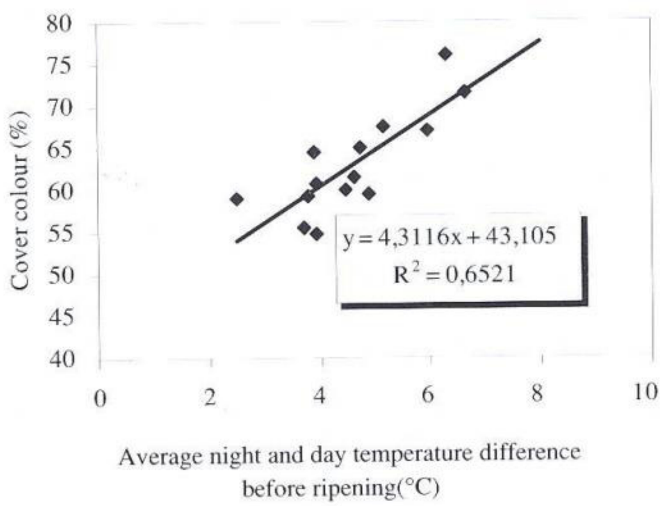


***Figure 8*** Relationship between apple cover color and average night and day temperature difference 1 month before ripening at summer ripening apple cultivars in apple gene bank plantation (Újfehértó, 1984–2001)

cannot be considered linear. That is, in case of big differences between day and night temperatures, a small extent in change does not result in significant change of cover colour. Furthermore, it can be stated that in case of a greater than 6,2 °C difference between day and night temperature the extent of cover colour of apples ripening in summer does not increase any more, but it starts decreasing (*Figure 5*).

**Cultivars ripening in autumn**

In case of cultivars ripening in autumn the difference between day and night temperatures in September showed a significant relationship with the cover colour degree in 1% rate (*Figure 6*). On the basis of the presented regression relationship it can be stated that if the difference of temperature is increased by 4 °C , as a result, we can reach a 10% higher cover colour degree. By colouring irrigation, this effect can be reached in the years when there is a small difference between day and night temperatures.

**Cultivars ripening in winter**

In case of apples ripening in winter the difference between average day and night temperature in October showed a significant relationship with cover colour degree in 1% (*Figure 7*). The cover colour change as a result of temperature difference could be observed in the smallest extent in case of this group. It can be stated that in case of a greater than 6,2 °C difference between day and night temperature the extent of cover colour of apples ripening in summer does not increase any more, but it starts decreasing (*Figure 7*).

If the exact dates of the examined cultivars' ripening and harvest are known, the relationship with the difference between day and night temperatures might be even closer. In *Figure 8* it is clearly seen that if the difference between the average day and night temperatures increases from 3 °C to 8 °C, in the meantime cover colour degree also increases from 54% to 78%.

## Conclusions

It is very important to know about day and night temperatures to estimate the extent of fruit cover colour. The presented regression relationships clearly proved that knowing the examined meteorological information the rate of colouring can be estimated

In case of cultivars ripening in winter genetical characteristics of the variety have a greater effect, while in case of apples ripening in summer or autumn the year plays a bigger role. „Spur" cultivars usually have a more intense cover colour, since because of the smaller tree size, they are influenced more by weather conditions. In the future it would be useful to analyse how cover colour changes in case of green and yellow cultivars, since their market value and saleability are greatly inflienced by these factors.

In the future it would also be practical to analyse the character of relationship and interrelation in other habitats with different soil and climatic characteristics. Since factor values received by regression procedures cannot be generalized to other areas without more thorough evaluation.

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