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COLD HARDINESS IN WINDMILL PALMS (*TRACHYCARPUS SP.)*

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Abstract
Palms are beneficial for urban ornamental horticulture, since they symbolize the tropics, but only few are adapted to temperate climates. Our objective was to monitor responses of the leaves to cold reflected by the changes in chlorophyll fluorescence of leaves of Trachycarpus geminisectus, T. nanus, T. takil, T. ukhrulensis, T. wagnerianus species with the use of a chlorophyll fluorometer during the fall of 2018. Our results indicate that there was a gradual decline of maximum quantum efficiency of photosystem II (PSII) represented by Fv/Fm values from the end of September till the end of November 2018. This change corresponds well with the change in air temperature. Some species like T. ukhrulensis seemed to be more sensitive to cold since the rate of decline was the greatest in this species, also in most cases the difference was significant compared to the other species. The smallest decline in Fv/Fm values could be observed in T. wagnerianus. However, the difference compared to the other species was only significant until the middle of October after which it was not significantly better than the other well performing species such as T. takil and T. geminisectus. T. nanus was intermediate in its values, since it had significantly lower values until the beginning of October compared to T. takil and T. geminisectus, but during the remaining measurement period was not significantly different from these species. T. geminisectus seemed to perform on average with the other species. We found that there was a correlation in some cases between the changes in minimum air temperature and that of the maximum quantum efficiency of photosystem II (PSII). The correlation was strongest in T. nanus, T. wagnerianus and T. ukhrulensis. It was weaker in T. geminisectus and none in T. takil.

1 Introduction

Ornamental horticulture represents a significant contribution to the economies of tropical, subtropical countries, since it primarily deals with landscaping of urban areas and enhances the beauty of natural scenery, thus supports the growth of tourism industry. The prominent tourist attractions include not only beach resorts and adjacent touristic complexes, but also consist of sights in towns, cities where landscaping with tropical, subtropical ornamental plants are a vital element of aesthetics [19]. Palms, which belong to the *Arecaceae/Palmae* family [7], are beneficial for urban

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ornamental horticulture since they symbolize the tropics and the lost Garden of Eden especially for tourists coming from colder climatic areas of the world. There are only a few genera and species in the palm family, which are adapted to colder regions of warm temperate climates considering that many inhabit mountainous areas in their natural habitats. These cold tolerant species even are able to tolerate subzero temperatures for short periods. In this way, one of the most popular and widely planted species, the Chinese windmill palm (*Trachycarpus fortunei*) has found its way into urban landscaping in the Mediterranean regions of Europe [9]. Therefore, we have chosen to evaluate the cold hardiness of some *Trachycarpus* species. Our objective was to monitor cold hardiness patterns of leaves of five *Trachycarpus* species by observing the changes in chlorophyll fluorescence of leaves in Szada, Hungary, during the fall of 2018.

Palms are one of the most common plants in tropical regions, where they usually dominate the rural landscape. The palm family is profoundly diverse and displays an astounding morphological variety. Their majesty of stature and gentility whenever seen, sets them apart from others, making them to be among the most sought after ornamental plants for horticulturists. Whenever a palm appears in any garden, it promptly transmits the aura of the tropics, and the feel of the jungle around them [10].

Trachycarpus is a genus of ten species of dwarf or moderate, solitary, dioecious, fan palms. Their remarkable cold tolerance has become one of the fundamental appeals to many growers and palm enthusiasts, along with their ease and speed of growth. *Trachycarpus* palms are used ornamentally across the globe, especially in regions where more tropical species will not be able to survive [14].

Light plays an essential role to plants and to life on earth because it drives the photosynthesis. Nevertheless, reduction in photosynthetic capacity called photoinhibition commonly occurs in nature when plants are exposed to solar radiation in excess of light energy necessary for photosynthetic or photorespiratory processes [16]. As the consequence of photoinhibition, midday decline of net CO_2 assimilation (A), stomatal conductance (S) as well as the decrease of maximum fluorescence (F_m) and that of the F_v/F_m ratio have been reported during the growing season for dicot trees [18] and shrubs [6] of both tropical and temperate origins. Based on the recovery kinetics, it has been suggested that the midday decrease in PS II efficiency involves at least two processes, one related to the xanthophyll cycle [5], the other to the D_1 protein inactivation [1].

The inhibitory effect of cold stress together with high irradiance has also been reported on photosynthesis and related physiological processes for both cold tolerant and chilling sensitive plants [12]. For example, during winter and early spring evergreens such as conifers are subject to increased photoinhibition termed “photochilling” in temperate climatic regions of the world [3]. Apparently the same is true in/from late autumn and/to early spring for a range of plants of subtropical origin like *Eucalyptus* [2] and sugar cane [4] grown under Mediterranean-type climates. Although, the key processes involved in the diurnal down regulation of photosynthesis have intensively been studied during the past decade, very little information is available on the high light induced alterations of physiological parameters in monocotyledon trees like the economically important palms (*Arecaceae)* [13].

2 Material and method

The experiment was carried out in Szada, Hungary. Measurements were made in the fall of 2018, depending on the weather, were conducted weekly and each measurement started at 10:00 a.m. A total of 12 measurements were recorded over 3 months, from the end of September to the end of November 2018. The examined taxa were the following: *Trachycarpus geminisectus, Trachycarpus nanus, Trachycarpus takil*, *Trachycarpus ukhrulensis*, *Trachycarpus wagnerianus*. Measurements were carried out with a PAM-2500 fluorometer manufactured by Heinz Walz GmbH. This is a portable chlorophyll fluorometer applying pulse-amplitude-modulated (PAM) measuring light to excite chlorophyll fluorescence [11]. One fully developed youngest leaf of each 4 individual plants from each species were measured, and 20 data were recorded on one occasion. Half an hour before measurement, the leaves were fitted with darkening clips for attachment with the PAM-2500 fluorometer. Results were expressed as the average plus/minus standard deviations. The data were analysed by two-factor analysis of variance (ANOVA) with repetitions and the means separated using the LSD test at p=0.05 and for the regression analysis with Microsoft ® Excel 2007 Analysis Toolpack (Microsoft Corporation., Redmond, Washington).

3 Results

Figure 1 shows the changes in the maximum quantum efficiency of photosystem II (PSII) given in F_v/F_m values for all five examined *Trachycarpus* species. It can be clearly seen on the graph that there is a gradual decline of F_v/F_m values from the end of September till the end of November 2018. This decline corresponds well with the decline in air temperature measured during the period of examination. The decrease of F_v/F_m values then change to rise (recovery) corresponding to the variations, decline or rise in daily minimum or maximum air temperature measured at the site.

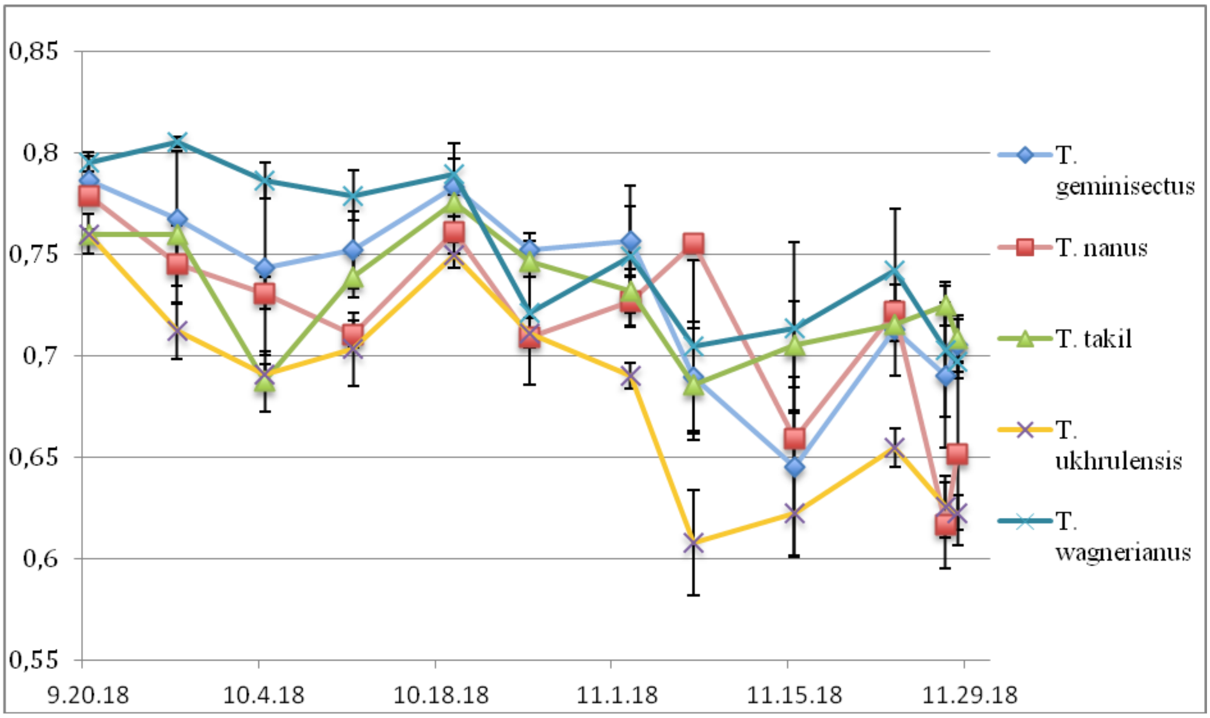

Figure 1. Changes in maximum quantum efficiency of photosystem II (PSII) during the course of the experiment in all examined Trachycarpus species.

When we examine the changes of the individual species there was a similar tendency for all taxa that corresponds well with the changes in minimum and maximum air temperature. As shown in the graph (*Fig. 1*), the first major decline in F_v/F_m values corresponds with the first occurrence of +5^{o}C minimum air temperature at the beginning of October, with a clear recovery until the middle of October related to again rising higher minimum and maximum air temperatures. The second decline in F_v/F_m values could be observed during the end of October when both minimum and maximum air temperatures dropped again, the later below +5^{o}C. End of October produced the first freezing minimum temperature after which a rapid decline in F_v/F_m values could be measured especially in *T. ukhrulensis*. After the middle of October, above freezing minimum air temperatures allowed for some recovery and rise in the F_v/F_m values. Then both maximum and minimum air temperatures dropped and the same was observed for the measured F_v/F_m values. Some species like *T. ukhrulensis* seemed to be more cold sensitive since the rate of decline was the greatest in this species and also the lowest values were measured in this species almost throughout the measurement period. From the beginning of November, *T. ukhrulensis* produced significantly the lowest F_v/F_m values thus proved to be the most sensitive to cold compared to all other species examined. The smallest decline in F_v/F_m values could be observed in the more widely cultivated and planted *T. wagnerianus*. Nevertheless, the difference compared to the other species was only considerable until the middle of October after which it was similar to the other well performing species such as *T. takil* and *T. geminisectus*. *T. nanus* was intermediate in its values, having notably lower values until the beginning of October compared to *T. takil* and *T. geminisectus*, but during the remaining measurement period was not significantly different from these species. *T. geminisectus* seemed to perform on average with the other species, meaning that in the given temperature range of the measurement period it was nor more cold sensitive nor more cold tolerant than the other taxa.

In *Fig. 2*, the relationship between the minimum air temperature and the maximum quantum efficiency of photosystem II (PSII) represented by F_v/F_m values was presented in all the examined *Trachycarpus* taxa.

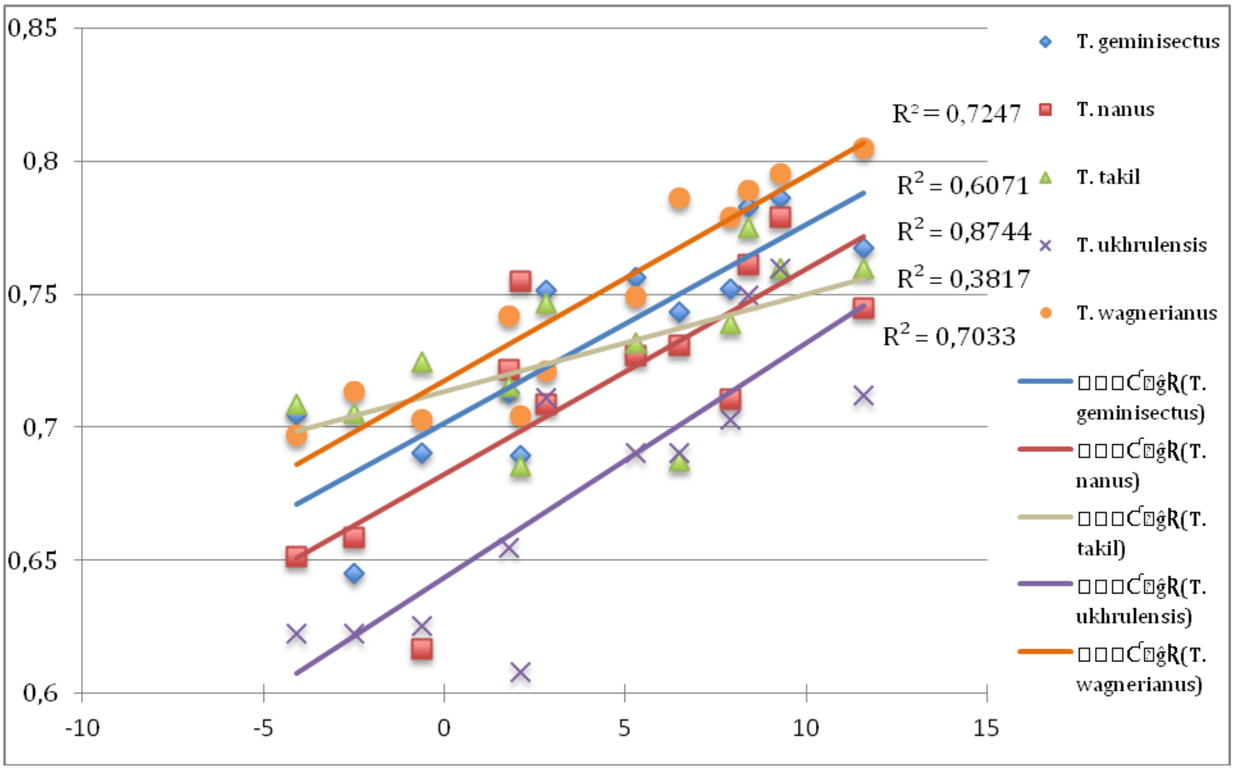

Figure 2. Relationship between minimum air temperature and maximum quantum efficiency of photosystem II (PSII) F_v/F_m values in the examined Trachycarpus taxa.

There was a correlation in some cases between the changes in minimum air temperature and that of the maximum quantum efficiency of PSII. The correlation was strongest in *T. nanus, T. wagnerianus* and *T. ukhrulensis*. It was weaker in *T. geminisectus* and very weak in *T. takil*.

Fig. 3 demonstrates the relationship between the maximum air temperature and the maximum quantum efficiency of photosystem II (PSII) represented by F_v/F_m values in all the examined *Trachycarpus* taxa can be seen.

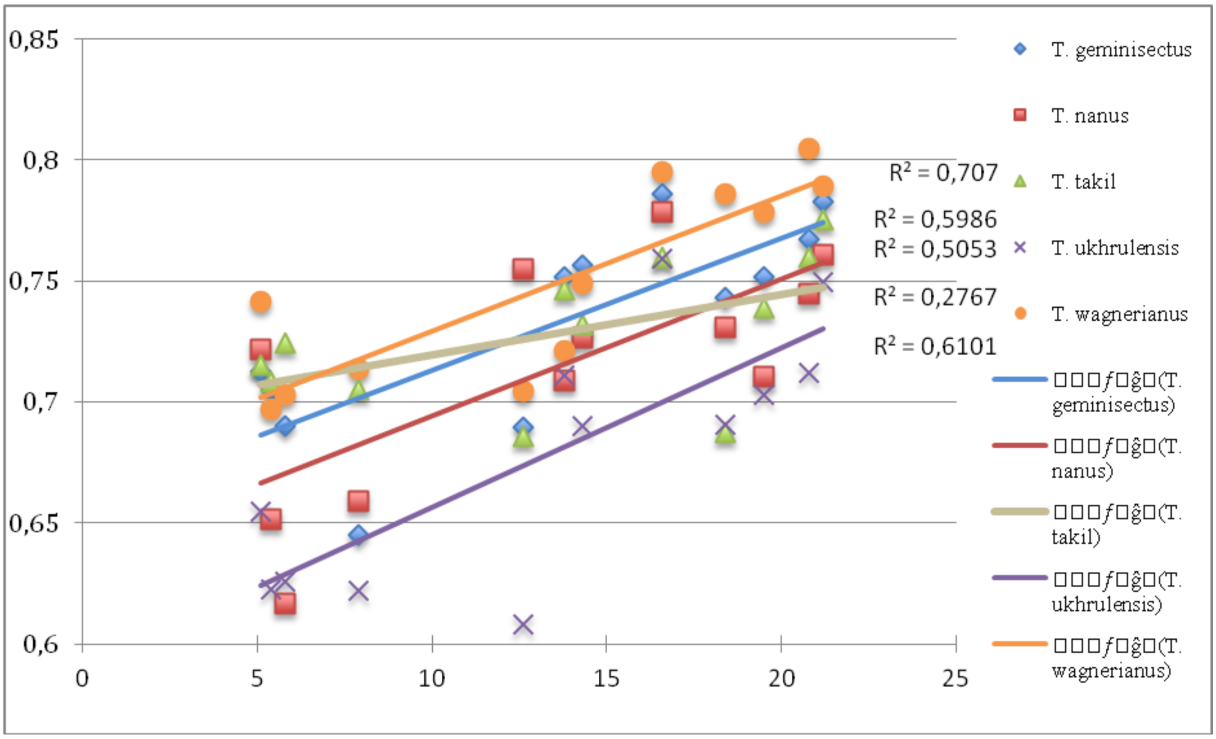

Figure 3. Relationship between maximum air temperature and maximum quantum efficiency of photosystem II (PSII) F_v/F_m values in the examined Trachycarpus taxa.

The chart (*Fig. 3*) shows that in some cases there was a correlation between the changes in maximum air temperature and that of the maximum quantum efficiency of PSII. The correlation was strongest in *T. wagnerianus*, and *T. ukhrulensis*, while it was weaker in *T. geminisectus* and *T. nanus*, and it was the weakest in *T. takil*.

4 Discussion and conclusions

Plants subjected to high irradiance at normal growth and low temperatures exhibit different photoinhibitory responses as a result of various concomitant and subsequent molecular events [12][16]. In early autumn, the decrease in the maximum quantum efficiency of photosystem II (PSII) represented by the F_v/F_m ratio could be resulted from the increase in xanthophyll cycle dependent energy dissipation in the antennae [5]. In late autumn to early winter, however, the maximum quantum efficiency of photosystem II (PSII) indicated by F_v/F_m ratio was markedly lower than in early autumn (*Fig 1*), which fitted well to earlier results [3] obtained by the seasonal variation of the maximum quantum efficiency of PSII (shown by F_v/F_m) and explained by low temperature induced partial inactivation of PS II activity [12]. Alteration of the maximum quantum efficiency of photosystem II (PSII) indicated by changes in the F_v/F_m ratio may also be indicative of PSII inactivation that parallel with the energy dissipation mechanism [15]. Since there is little information on the cold-freeze tolerance of palms other than the laboratory experiment of Equiza, M. A. & Francko, D. A. [8], performed on detached leaf segments, our non-invasive technique results will complement our earlier field experiment findings performed on intact whole palms [17]. Further research needs to be conducted to evaluate the freeze tolerance of palms that can be adapted to temperate climatic conditions, to establish the exact limit of winter hardiness in these species.

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