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PHENOLOGICAL DIFFERENCES OF *QUERCUS* TAXA

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Abstract
The vegetative and generative development of 14 Quercus taxa was examined over two vegetation period in our study. The BBCH (Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie) scale was used to describe the phenological phases, which was extended to ornamental trees. Based on our results, the bud breaking occurred in the second decade of April. Leaf development and shoot growth were finished in the following 20 days. The second shoot growing period was observed in 2018 in most of the studied plants, but not in 2019. The number or flowering trees was also higher in 2018, and the intensity of leaf discoloration was longer and more decorative. With and exception of Q. acutissima and Q. macrocarpa, all taxa had good marcescent ability.

1 Introduction

The genus of oaks is also important in forestry, horticulture and wood industry [7]. Their decorative value is mainly provided by the shape of their leaves [3], their autumn leaf discoloration [8], and their shape [1][11]. They can be used for park trees, or even urban afforestation because they have good adaptability [6]. Most of them are undemanding, heliophilous and thermophile species [10]. They have a good dust binding ability, so they can also be recommended as a protective forests. However, their salt tolerance is low [9]. A special feature that increases the ornamental value of *Quercus* taxa is that their leaves have different shape at the base and apex of the shoots, and different shaped leaves on spring and summer shoots formed during periodic stem development [5]. To determine these phenological differences, we applied the internationally accepted BBCH scale [12], which was extended to ornamental trees as well.

2 Method

Our experiments were performed in 2018-2019 in the Kecskemét Arborétum owned by KEFAG Kiskunsági Erdészeti és Faipari Zrt. 14 *Quercus* taxa were selected from the oak collection, which are follows:

Quercus acutissima (46.91584, 19.64775)
Quercus cerris (46.91915, 19.65346)
Quercus dentata (46.91431, 19.65266)
Quercus frainetto (46.91698, 19.65550)
Quercus ilex (46.91603, 19.65766)
Quercus imbricaria (46.91715, 19.65536)
Quercus libani (46.91610, 19.65696)
Quercus macrocarpa (46.91710, 19.65608)
Quercus petraea (46.91941, 19.65351)

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Quercus petraea ’Cochleata’ (46.91597, 19.65577)
Quercus pubescens (46.91940, 19.65361)
Quercus robur (46.91316, 19.65177)
Quercus robur ’Fastigiata’ (46.91651, 19.65553)
Quercus rubra (46.91227, 19.65238)

The methodology by [4] was used for the evaluation, which assings two-digit numerical codes to each phenophase as follows:

Table 1. Phenological phases of woody species and their associated BBCH identification keys

Code	*Description*
00-	Sprouting/bud development
00	Dormancy: buds closed and covered by scales
01	Beginning of bud swelling
03	End of bud swelling
07	Beginning of sprouting or bud breaking; shoot emergence
09	Buds show green tips
10-	Leaf development
10	Green leaf tips 10 mm above the bud scales
11	First leaves unfolded
15	More leaves unfolded, but not yet at full size. First leaves unfolded
17	Most leaves unfolded on majority of tree
19	Leaf expansion complete
30-	Stem elongation
30	Beginning of stem elongation
31	Stem about 10% of final length
39	Stem about 90% of final length; cessation of stem growth
50-	Inflorescence emergence
51	Inflorescence or flower buds visible
55	First individual flowers visible but still closed
59	First flower petals visible (in forms with petals)
60-	Flowering (main shoot)
60	First flowers open
61	Beginning of flowering, 10% flowers open
65	50% of flowers open, full flowering: first petals may be fallen
67	Flowering finishing; majority of petals fallen or dry
69	End of flowering: fruit set visible
70-	Fruit/cones development
72	Fruit/cones 20% of final size
75	Fruit/cones 50% of final size
78	Fruit/cones 80% of final size
79	Fruit/cones final size
80-	Fruit/cones ripening
89	Fruit/cones fully ripe

90-	Senescence, beginning of dormancy
91	Shoot growth completed; foliage still green and terminal buds developed
92	Beginning of leaf discoloration
93	Beginning of leaf fall
95	50% of leaves fallen
97	End of leaf fall

Source: [4]

Measurement of germination, flowering, shoot development (early April – early May); after the second stem development (early July); and during the fruit ripening, leaf discoloration and leaf fall (early October – early November) 1-2 times a week (depending on the intensity of the changes).

3 Results

3.1 2018 vegetation

Quercus acutissima, *Q. dentata* and *Q. ilex* were still in the bud swelling phase (BBCH 01-03) at the first measurement (13 April), but sprouting (BBCH 07-09) had already begun for the other taxa, moreover in case of *Q. libani*, *Q. robur* and *Q. rubra* leaf development has already begun. After that (on April 18) all the examined species and cultivars got over the bud development phase, only the *Q. ilex* was evaluated as BBCH 03 at this study time. At that time flower buds also appeared (BBCH 51-55) in several trees, only the anthers (catkins) of *Q. dentata* developed 6 days after, on April 24th. Leaf development (BBCH 10-19) and stem elongation (BBCH 30-39) also began at the most of the trees at this time.

Flowering (BBCH 60-69) began on April 24 in most specimens. However, the anthers of *Q. robur* 'Fastigiata' and *Q. rubra* were already observed on April 18. The latter species had the longest flowering period. The majority of the studied individuals bloomed between the last decade of April and the first decade of May. At the last date of the spring assessment period (11 May, the development of acorns (BBCH 70-79) also started for several taxa (*Q. cerris*, *Q. imbricaria*, *Q. macrocarpa*, *Q. petraea* 'Cochleata', *Q. robur*, *Q. robur* 'Fastigiata') (Figure 1).

During the summer assessment, we found that all of the studied taxa had a second shoot growth, and these shoots were fully mature (BBCH 39) in the most of the trees on 6 July. The second shoot growth period of *Q. libani*, a *Q. robur* and a *Q. robur* 'Fastigiata' has not been completed by this time. The acorns were fully developed (BBCH 89) for the mature trees at the first autumn assessment. In addition, the leaf discoloration (BBCH 92) also started in all examined plants. Leaf fall (BBCH 93) began first at *Q. macrocarpa* on October 11th. This tree was already found completely leafless (BBCH 97) on November 31th. By the time of the last assessment *Q. acutissima*, *Q. petraea* 'Cochleata', *Q. robur* 'Fastigiata' and *Q. rubra* had also fallen all their leaves (Figure 1).

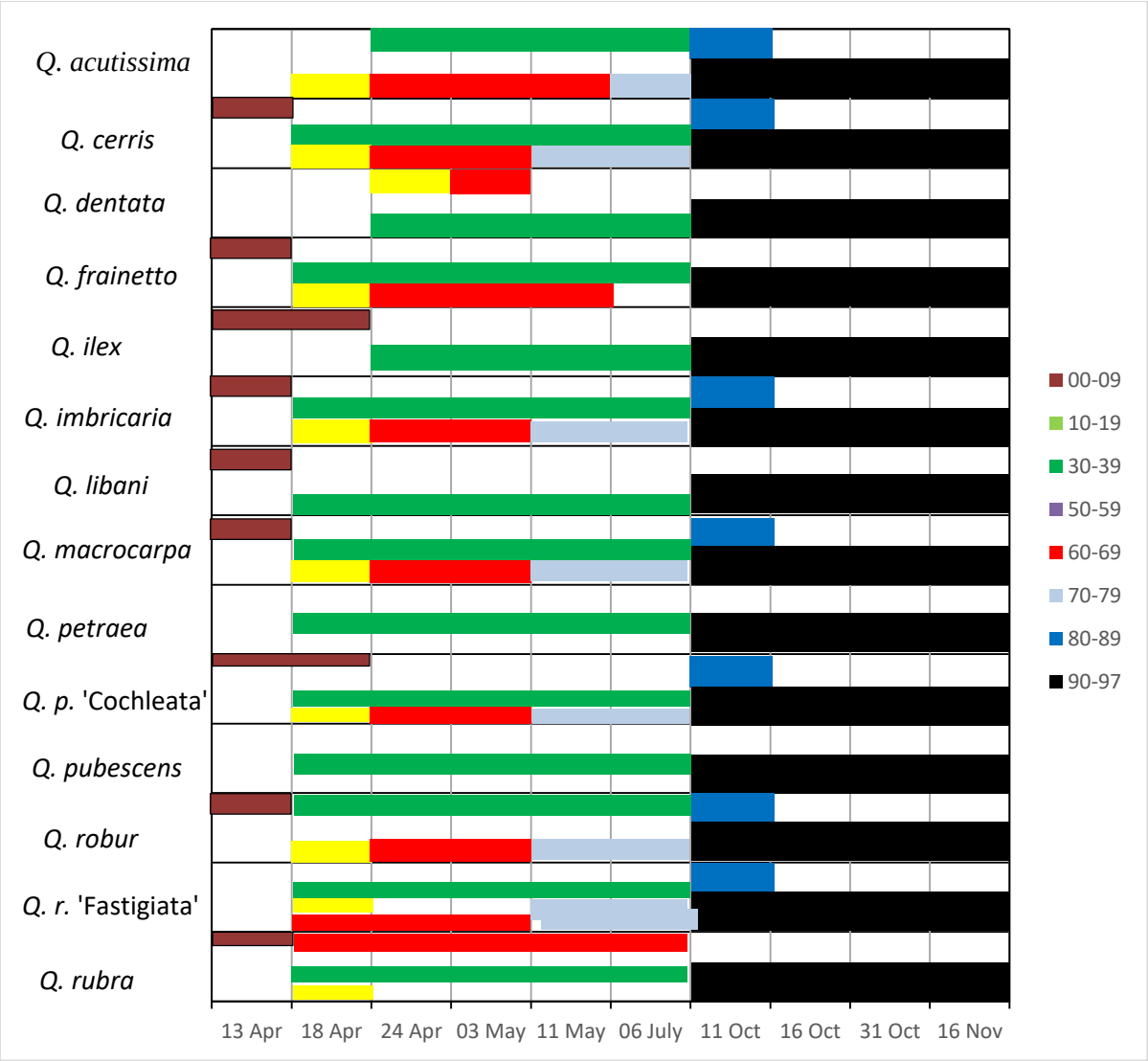

Figure 1. Phenogram of Quercus taxa in the 2018 vegetation (Kecskemét Arborétum)

3.2 2019 vegetation

At the first measurement time, most of the taxa were in the bud swelling phenophase (BBCH 03). However, the first green leaf tips (BBCH 10) and the beginning of leaves unfolding (BBCH 11) were already observed in the case of *Q. cerris*, *Q. dentata*, *Q. frainetto*, *Q. libani*, *Q. petraea*, *Q. robur* 'Fastigata' and a *Q. rubra*. Only in the case of sessile oak (*Q. petraea*) did vegetation begin before 12 April. Sprouting and leaves development also dominated a week later (19 April) most of the trees. Flower buds also began to appear (BBCH 51) in *Q. imbricaria*, *Q. macrocarpa* and a *Q. robur* 'Fastigiata' at this time. Stem elongation (BBCH 30-39) began uniformly on April 25 in the specimens. An exception was *Q. acutissima*, because separate internodes could only be observed for this tree firstly at the May 3 measurement. Flowering was also seen in this period (from late April to early May). In addition the above mentioned three taxa, *Q. frainetto* also had a generative stage in this year. It should be noted that the anthers of *Q. frainetto* and *Q. imbricaria* were on the trees on 4 July (Figure 2). The flowering time of *Q. petraea* 'Cochleata' could not be observed, but the formation of acorns (BBCH 70-79) were already observed during the last spring assessment (May 10). Similarly, flowering was not experienced by *Q. acutissima* in spring, but acorns were already observed on 4 July.

The second shoot growth was observed only in *Q. ilex*, *Q. libani*, a *Q. macrocarpa* and *Q. robur* 'Fastigiata', which had already been completed (BBCH 39) in the most of the plants at the summer evaluation time. An exception was *Q. robur* 'Fastigiata', because the spring formed buds of this taxon

did not begin to sprout (BBCH 07) until July 4. At the first autumn assessment (14 October), the development of acorns was completed in most of the plants, only *Q. petraea* 'Cochleata' had not yet reached the phenophase of full ripening (BBCH 89). The 14 individuals showed a uniform picture in term of leaves discoloration: all taxa received BBCH 92-93 value, so the leaf discoloration and beginning of leaf fall was visible on the plants. This statement is naturally not true in case of evergreen *Q. ilex*, which had already completed its vegetation period (BBCH 91) at this time. It was followed by *Q. acutissima* and *Q. macrocarpa* on 25 October which all the leaves fallen by this time. For the other taxa, the degree of leaf fall ranged from 1 to 50 % (BBCH 93-95) at the last two measurement times (Figure 2).

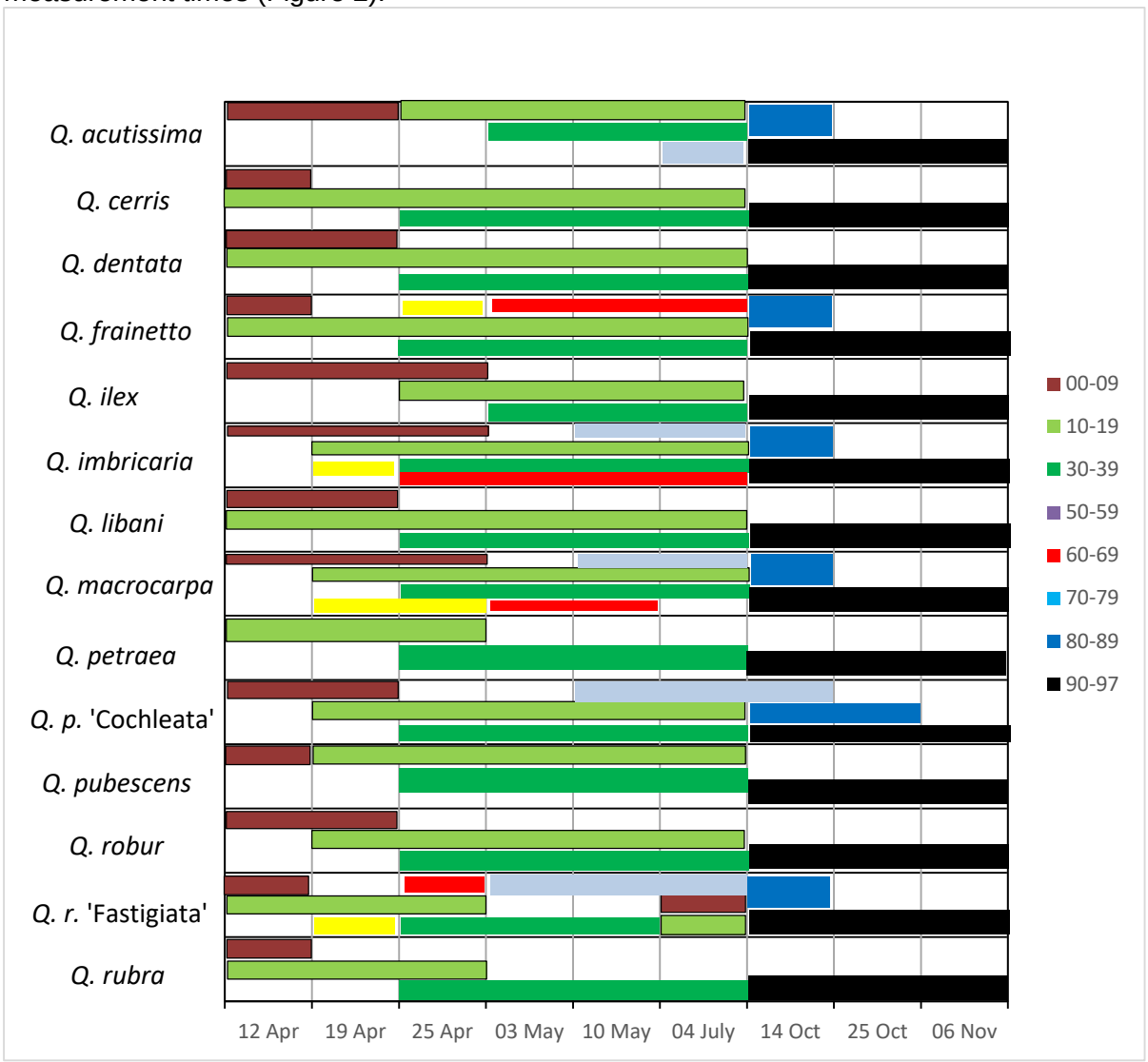

Figure 2. Phenogram of Quercus taxa in the 2019 vegetation (Kecskemét Arborétum)

4 Conclusions

Comparing the two years, it can be stated that the vegetation period started in the second decade of April in both years, however in 2019, leaf unfolding was also observed at the first assessment. This is presumably due to the mild winter weather. Acorns were produced in both years by *Q. acutissima*, *Q. imbricaria*, *Q. macrocarpa*, *Q. petraea* 'Cochleata' and *Q. robur* 'Fastigiata'. This phenomenon can be explained by poor production site (nutrient rich, lime-free soils is required) in the case of *Q. acutissima*, *Q. imbricaria* and *Q. macrocarpa* [11]. *Q. cerris*, *Q. dentata*, *Q. frainetto*, *Q. robur* and *Q. rubra* flowered in only one of the studied years, as reported in the literature [2]. No generative phase was observed by *Q. ilex*, *Q. libani*, *Q. petraea* and *Q. pubescens* that could be related to the young age of these trees. Leaf development and stem elongation were first completed

in native species, providing sufficient time for maturing of stems. *Q. acutissima* and *Q. macrocarpa* are the weakest in terms of leaf discoloration and leaf retention, which is also due to unfavorable environmental conditions.

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