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UDK 630*174+181.5+(4-015) (*Quercus* × *viridis* Trin.)

HERMAPHRODITIC, UNSEASONAL FLOWERING IN THE "GREEN OAK", GROWING IN NORTHERN DALMATIA, CROATIA

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Hermaphroditic flowering has been observed on a single tree, the "green oak", a supposed hybrid between *Quercus cerris* and *Q. ilex*. This tree has been systematically defined as *Quercus* × *viridis* Trinajstić, but it is unlikely that a hybrid of two species where acorns mature in the second year (*Q. cerris* L.) and in the first year (*Q. ilex* L.) could be found. For that reason, a new investigation of this tree was conducted. In late autumn, on 3 November 1998, during acorn collection from the crown, unseasonal flowering was discovered on two branches. Flowers appeared to be stiff, like female inflorescences, more elongated and with more flowers than normal. At first glance, the presence of numerous stamens in the inflorescence was evident. Under a hand lens, 4-6 stamens could be seen, surrounding a pistillate flower with well-developed stigmas. Inflorescences and individual flowers were photographed. Pollen from hermaphroditic flowers was photographed by a scanning microscope. In spring, on 26 April, abundant flowering of normal male and female flowers was observed, photographed and analysed. No aberrant morphology similar to the flowers discovered in November 1998 could be seen in the crown of the "green oak". Papers describing the occurrence of hermaphroditic flowering in some American oaks, especially the Gambel oak (*Q. gambelii* Nutt.), are discussed. Unseasonal flowering in "green oak" and the appearance of hermaphroditic flowers could not be explained by unusual climatic changes in the area. It could be speculated only that hermaphroditic flowering represents a primitive ancestral condition in the *Fagaceae*, as suggested by some of the authors discussed in the paper.

Key words: *Quercus* L., hermaphroditic flowering, unseasonal flowering

INTRODUCTION

In the village of Islam Latinski, Latitude 44° 12' N, Longitude 15° 26' E, 15 km NE from Zadar, Northern Dalmatia, Croatia, there grows a particular oak tree of impressive dimensions (Figure 1). This tree grows near the intersection of the main roads. Being so dominant in its size and habit, people used it as a focal point to measure distance and time to or from that tree. It is legendary because of its dimensions. It seemed that it has been part of this landscape from ancient time. Local inhabitants still claim that the tree is over 700 years old. The tree is different from other local oak species by its morphology, thicker bark, and its being covered with green leaves deep into the winter, hence people named it the "green oak". It is distinct in the environment of low growing degraded thermophilous, deciduous forests of the downy oak (*Q. pubescens* Willd.) and the Oriental hornbeam (*Carpinus orientalis* Mill.) where downy oak and Turkey oak (*Q. cerris* L.) are an integral part of that vegetation.



Figure 1. Older "green oak" near the village of Islam Latinski. Estimated age by use of the resistograph is 200 years. August 27th, 1995.

The evidence in literature, in which Trinajstić (1974) described the "green oak", prompted this research. He presumed that the "green oak" is a hybrid of "... = ? *Q. cerris* f. *austriaca* × *Q. ilex*". He gave a name to that tree *Quercus* × *viridis* Trinajstić, hibr. nov. Although hybrids between two oak species where acorns mature in the second year (*Q. cerris* L.) and in the first year (*Q. ilex* L.) are doubtful, in Trinajstić's paper the explanation or research which could support such a possibility is missing. That triggered our detailed biological and morphological investigation of the "green oak", supported by the local municipal organization "Nasadi" in Zadar (Siegert 1995; Vranković and Pernar 1995, Borzan *et al.* 1997, Borzan and Pfeifhofer 1998).

MATERIALS AND METHODS

The "green oak" tree was visited repeatedly several times a year. In autumn, on November 3rd, 1998, during the acorn collection from the crown, on two branches, freshly developed flowers were observed. The branches were cut off and examined the next day in the laboratory. The flowers were photographed and the pollen collected. Pollen grains from unseasonal flowering "green oak" inflorescences and from the regular flowering period next spring (April 26th, 1999) were collected from the "green oak", from *Q. cerris* and from *Q. ilex* trees. Pollen grains were photographed by means of a scanning electron microscope. In spring, on April 26th, 1999, abundant flowering of normal male and female flowers was observed, branches with flowers were cut off and details photographed and analysed in the laboratory. The same day, three km from the "green oak", another, but younger tree with similar morphological traits, was found (Figure 2). In autumn, on October 31st, 1999, both "green oak" trees were inspected again and searched for possible unseasonal flowers in the crown.

RESULTS

The "green oak" is approximately 200 years old, 20.2 m high and has a diameter of 1.6 m at breast height (Siegert 1995, Borzan *et al.* 1997). In late autumn, on November 3rd, 1998, during acorn collection from the crown of the "green oak", unseasonal flowering was discovered on two branches. Flowers were on 3-5 clustered inflorescences, arising on branches from the lowest spring shoot axils (Figure 3). Inflorescences were elongated, 2-5 cm long, stiff, much longer than normal female inflorescences, and shorter, but thicker than regular male inflorescences, densely covered with hairs (Figures 3-10). The presence of numerous stamens in the inflorescence was evident at first glance. Under a dissecting microscope, four to six stamens could be seen, surrounding a pistillate flower with well-developed stigmas. Opened anthers contained abundant well-developed pollen grains. Pistillate

flowers were surrounded along the rachis with more stamens present on the top of the inflorescence and fewer or none in the proximal part (Figure 4). Each inflorescence had abundant hermaphroditic flowers.

Pollen from the hermaphroditic flowers (Figure 13) and the normal spring pollen grains (Figures 14-16) collected in 1999 were photographed by a scanning electron microscope. No difference in the pollen size or shape was observed. Scanned pollen grains collected in spring 1999 were considerably smaller in the *Q. ilex* when compared to the pollen grains of the "green oak" and *Q. cerris*. The "green oak" and *Q. cerris* had pollen grains of the same size.

In spring of 26th April, 1999, abundant flowering of normal male and female flowers (Figures 7-10) was observed, photographed and analysed. No aberrant morphology similar to the flowers discovered in November 1998 could be seen in the crown of the "green oak".

In April 1999 another "green oak" tree, located three km from the original "green oak", was found (Figure 2). That tree is younger, and is approximately 80 years old.

In autumn, on October 31st, 1999, after a careful search within the crown of the "green oak" unseasonal flowering was not observed. In the crown of another, younger "green oak" tree, 6 branches with unseasonal flowers were observed. They were male catkins only (Figure 11), and no female or perfect flowers were found.

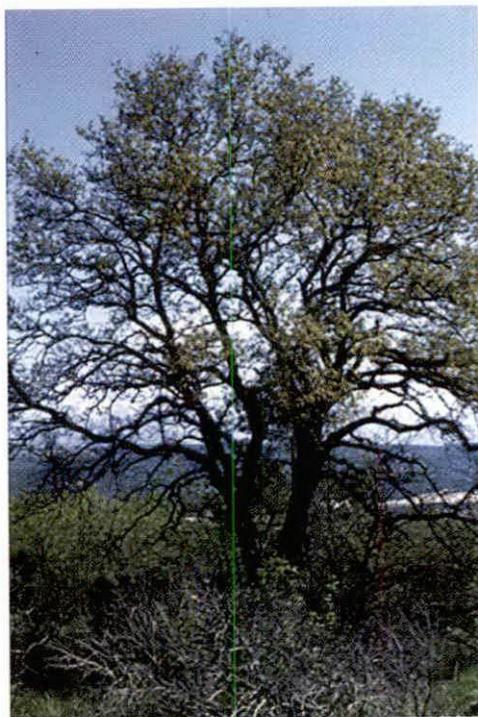


Figure 2. Younger "green oak" is approximately 70-80 years old. April 26th, 1999.

DISCUSSION

The morphology of the "green oak" has been described several times (Jedlowski 1955, Trinajstić 1974, Borzan et al. 1997). In each of those papers, additional traits were described. Jedlowski (1955) stated that the acorns fell before ripening. As a result of such an opinion he drew the scaly cup with a partially developed acorn. For that reason, in this paper the photograph of fully developed acorns of



Figure 3. Inflorescences with hermaphroditic flowers on branchlet of the "green oak". November 3rd, 1998.

the "green oak", collected on November 3rd, 1998, with scaly cup is shown. Acorns are 3-5 cm long and 1.5-2.3 cm thick (Figure 12).

The total number of fully developed acorns of the "green oak" tree in the last three years has not been more than 500 per year. That number is what we could



Figure 4. Female flowers are located on the rachis in the proximal part of the hermaphroditic inflorescence. Perfect flowers cover main part of the rachis, with more stamens in the distal region.



Figure 5. Part of the inflorescence with hermaphroditic flowers. Most of the anthers are open.



Figure 6. Part of the inflorescence with pistillate flowers. Pistills have 3-4 stigmas.

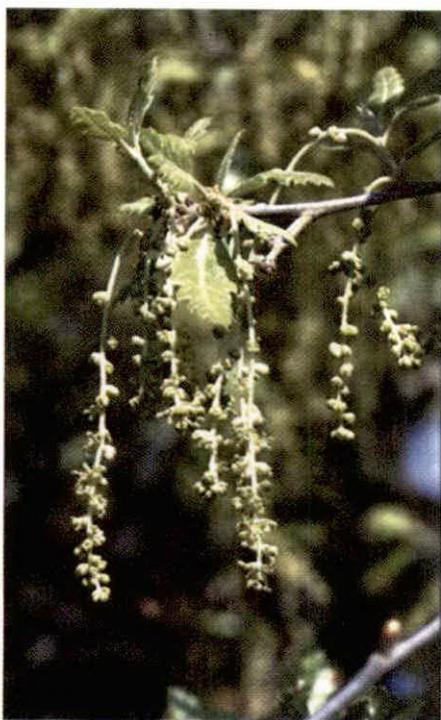


Figure 7. Normal, male aments in the crown of the "green oak". April 26th, 1999.



Figure 8. Close up of the normal, male ament of the "green oak". April 26th, 1999.

observe from the total number of collected acorns from the ground and from the crown. We collected them within a period of one month (between November 1st and 30th), once a month from the crown and once a week from the ground. It is believed that the total number of acorns is much greater, considering that local inhabitants and visitors who stop by that tree collect acorns too and take them away. Most of the acorna from the ground (ca 90 %) are infected by acorn weevils (*Curculio* L. spp.), with 2-5 larvae in each acorn.

Normal male and female flowers of the "green oak" have not been described yet. In Figure 7 normal male inflorescences are shown within the tree crown, and in Figure 8 one close up of the male inflorescence is presented. Figures 9 and 10 show normal spring female inflorescences born in the axils of the upper leaves on terminal shoots. Each inflorescence has 2-5 pistillate flowers; three on average.

The unseasonal flowering on November 3rd, 1998., showed aberrant flower morphology similar to that described by Tucker (1972), Tucker *et al.* (1980) and Scaramuzzi (1958). Tucker (1972) found hermaphroditic flowers on a specimen of *Q. turbinella* Greene ssp. *californica* Tucker on August 9th, 1941, and on one specimen of *Q. durata* Jeps. on August 31st, 1947, in California. In their paper, Tuc-



Figure 9. Normal female inflorescence of the "green oak" born in the axils of the upper leaves on young shoots of the current season. April 26th, 1999.



Figure 10. Typical, female inflorescence of the "green oak" with expressed stigmas. April 26th, 1999.

ker *et al.* (1980) describe another finding, this time on August 2nd and 3rd, 1978, on two plants of Gambel oak clones (*Q. gambelii* Nutt.) along a streamside in Utah. By the description, these hermaphroditic flowers resemble the hermaphroditic flowers of the "green oak". In the American oaks they appeared two to three months earlier than on the "green oak". Apart from the time variation in the formation of the hermaphroditic flowers, their location on the shoots differs in comparison to the American oaks too. Inflorescences with hermaphroditic flowers in the American oaks were born in positions where next year's catkins are normally initiated, i.e. around the base of the new emerging shoot. In the "green oak" they grew from axils of a spring woody shoot (Figure 3), so one could speak of a sort of cauliflorous occurrence. Fall male flowers were also found on the younger "green oak" on October 31st, 1999. They grew in the area of a shoot where next spring growth is normally expected, on the tip of the fall shoots (Figure 11).

It is worth mentioning an additional variation that exists between the American oaks and the "green oak". In the American species the acorns ripen in the first year, whereas in the "green oak" the acorns ripen in the second year. However, hermaphroditic flowers on *Q. coccifera* L. on which the acorns ripen in the second year were discovered during mid May 1954, and described by Scaramuzzi (1958).

Hermaphroditic flowers on the inflorescence are considerably longer than normal female spring inflorescences. Emphasising this fact, Tucker (1972) indicates that some oaks possess the potentiality for bearing a greater number of pistillate flowers, but the growth hormones most likely suppress their development in the upper part of the rachis. Thus, one to three female flowers ripen in the proximal part only. He continues: "If, then, the "normal" auxin regime were upset on rare occasions by a marked change in environmental conditions, perhaps this potential would be realized and ancestral gene combinations still in the code, but long suppressed, would be re-activated to produce not only elongated, multi-flowered inflorescences but hermaphroditic flowers as well. Tucker *et al.* (1980) suggest that "multi-flowered inflorescences containing hermaphroditic flowers represent a primitive ancestral condition in the *Fagaceae*, still present in the genome, but normally suppressed, which may be evoked by unusual environmental condition".

In the spring of 1999, in the crown of the "green oak", hermaphroditic flowers were not detected and that tree did not bloom in the fall of 1999. During May of 1999 severe attack of gypsy moth (*Lymantria dispar* L.) was detected. It caused defoliation on the "specimen" oak and even more drastic defoliation on the younger "green oak". Both trees recovered relatively quickly, hence by mid fall the effects of defoliation were not noticeable.

The formation of hermaphroditic flowers in oaks will most probably be researched for a duration of time before it can be defined with certainty. The "Green oak" will have to be visited, observed and studied continuously over several years. Only then will one be able to conclude if the out of the season and aberrational bloom is cyclical or if the aberrational bloom in fall of 1998 was an isolated case.



Figure 11. Male inflorescences from the crown of the younger "green oak" blooming in the fall. Flowers were found on October 31st, 1999, photographed 6 days later, after ripening in a container with water.

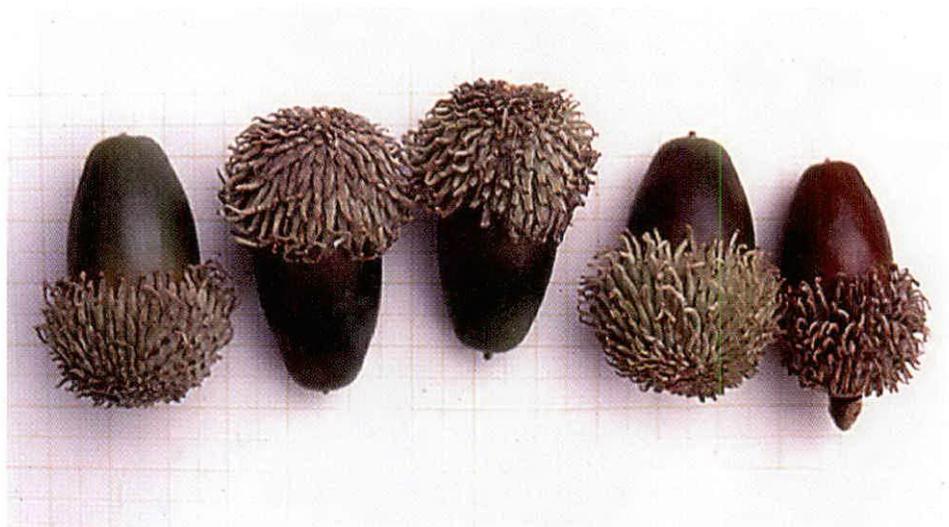


Figure 12. Acorns of the "green oak". November 3rd, 1998.

Taxonomical status of the "green oak" has not been completed. Trinajstić (1974) named it as hybrid of Turkey and holm oak, without the experimental pro-

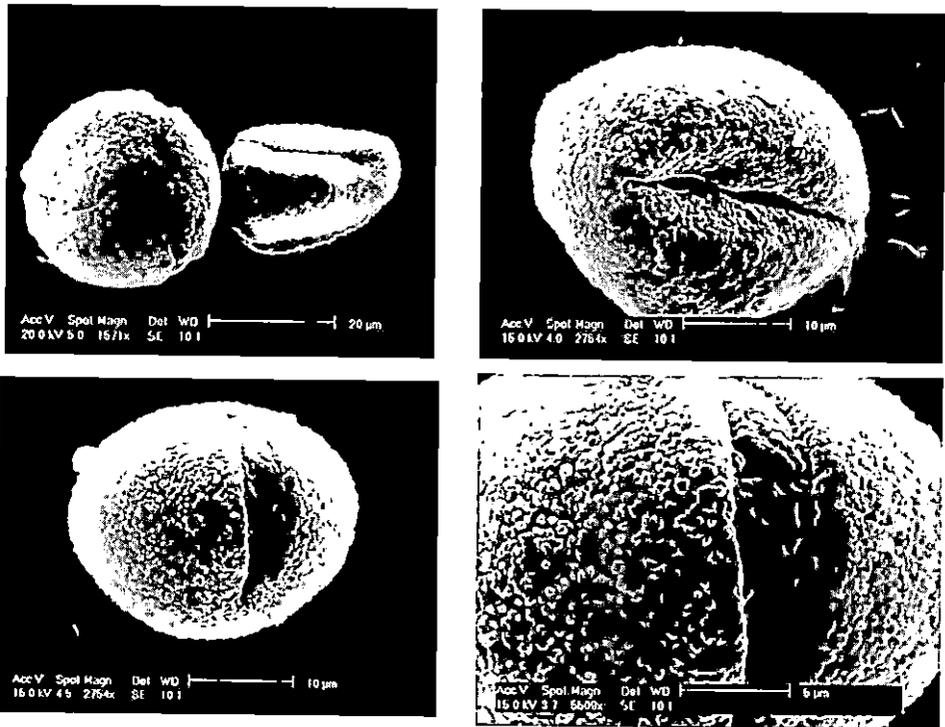


Figure 13. Pollen from hermaphroditic flowers of the "green oak" taken by scanning electron microscope.

of of hybridisation or the explanation of how these two species could be hybridised. Furthermore, he stated that the "green oak" is an evergreen. However, the "green oak" is not an evergreen tree. It does not bear foliage on biannual shoots. In the winters of 1994/1995 until 1999/2000 it was void of foliage. Lovrić (1981) also considers it as a "hybrid of holm and Turkey oaks (*Q. × ambrozyana* Simk.)", and states "that it appears in the eastern Adriatic coastal region in submediterranean forests of parental species as a sporadic and solitary specimen". However, in Krüssmann (1978) *Q. × ambrozyana* Simk. is mentioned as a synonym of cultivar *Q. cerris* 'Ambrozyana' and is believed to be a hybrid between Turkey oak and the cork oak (*Q. suber* L.). Jedlowski (1955) thinks that "according to its morphological traits, the "green oak" appears to be a hybrid of Turkey and cork oak". Borzan and Pfeifhofer (1998) analysed volatile compounds obtained by steam distillation of the "green oak", the Turkey oak and of the holm oak leaves. After gas chromatography and gas chromatography/mass spectrometry analysis, a cluster analysis of the patterns of the volatile substances in the leaves did not support the assumption that the green oak is a hybrid between the Turkey and holm oaks. Their opinion is "that the "green oak" could be a progeny of a back-crossed hybrid between *Q. cerris*

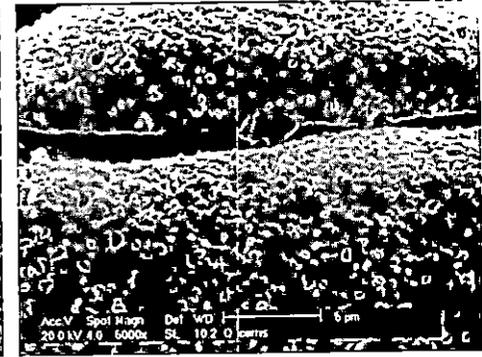
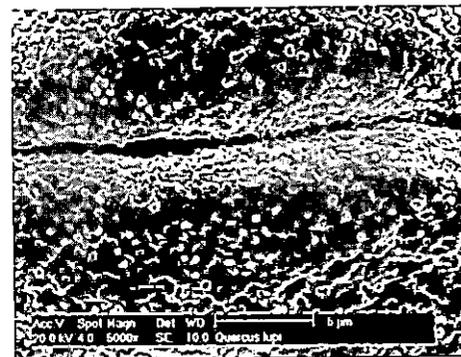
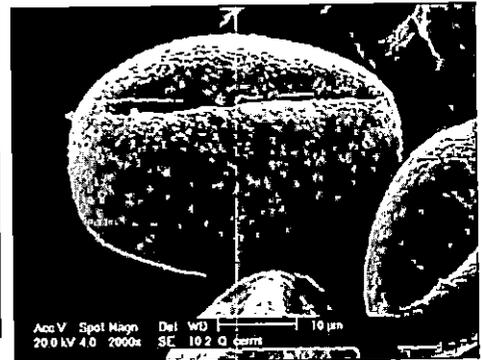
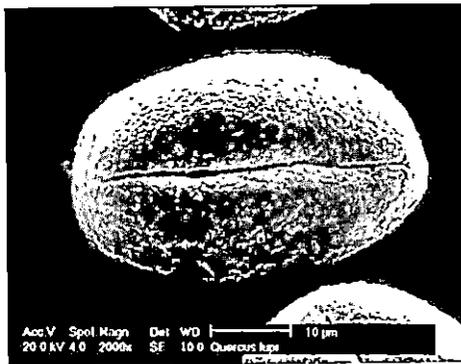
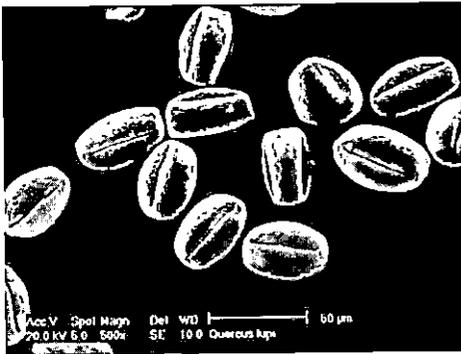


Figure 14. Pollen from typical, spring flowers of the "green oak" taken by scanning electron microscope.

Figure 15. Pollen from spring flowers of the Turkey oak (*Quercus cerris* L.) taken by scanning electron microscope.

and *Q. suber* or a variety of *Q. cerris* restricted to a small area of distribution in Ravni kotari, Croatia". Without cytological and molecular research, or without a

conducted hybridisation of the "green oak" and other submediterranean and Mediterranean oaks, it will be, difficult to define its taxonomical status.

Though it is difficult to believe that oak in which acorns mature in a single season could be hybridised with oaks whose acorns mature in two seasons, Cottam *et al.* (1982) cite the example of a successful by controlled hybridisation of three such crosses: *Q. turbinella* × *Q. cerris*, *Q. turbinella* × *Q. suber* and *Q. turbinella* × *Q. marilandica*. In those crosses the female parent was always *Q. turbinella*, whose acorns ripen during the first year. It is significant that for progenies from those crosses they gave a credible verification of their hybridity. Their morphological traits were intermediate to parental species and they have also been proved by the use of biochemical methods. Consequently they write: "Thus, whatever the genetic control may be of the timing of reproductive events, this difference in fruit maturation is not necessarily a major barrier to intercrossing". In the "green oak", however, if it is a hybrid, it is clear that the intermediary character toward *Q. ilex* is missing, since by its morphological traits it resembles Turkey oak but with smaller and more downy leaves, a thicker and corky bark red in furrows, and the ability to retain green foliage deep into winter.

The region of Ravni Kotari should be systematically explored to find all the samples of "green oak", to identify and protect them. Unfortunately, this region is covered with mines, as a residue of the 1991-1995 war, so at this time it is impossible to find and how frequent the "green oak" specimens appear in this area. Considering that in April of 1999 we found one more "green oak", one may assume that more could be found, as is also believed by local inhabitants.

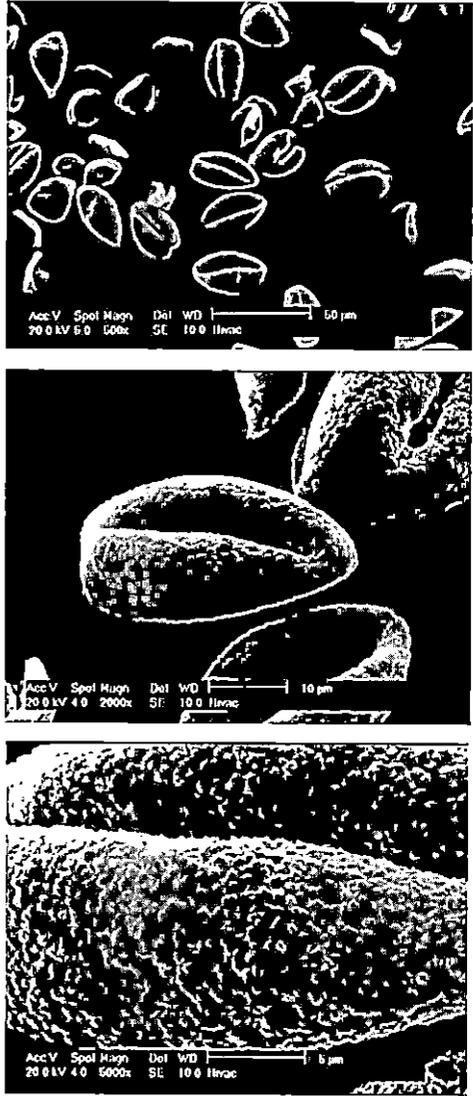


Figure 16. Pollen from spring flowers of the holm oak (*Quercus ilex* L.) taken by scanning electron microscope.

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HERMAFRODITSKO, IZVANSEZONSKO CVJETANJE "ZELENOGA HRASTA" KOJI RASTE U SJEVERNOJ DALMACIJI U HRVATSKOJ

Primijećeno je hermafroditsko cvjetanje na jednom stablu, "zelenom hrastu", pretpostavljenom hibridu između *Quercus cerris* i *Q. ilex*. To se stablo sustavno definiralo kao *Quercus x viridis* Trinajstić, ali je malo vjerojatno da postoji hibrid dviju vrsta u kojemu žirevi sazrijevaju u drugoj godini (*Q. cerris* L.) i u prvoj godini (*Q. ilex* L.). Iz toga su razloga poduzeta nova istraživanja toga stabla. Kasne jeseni, 3. studenoga 1998. godine, tijekom skupljanja žireva iz krošnje, na dvije je grane primijećeno izvansezonsko cvjetanje. Cjetovi su izgledali kruti kao ženski cvat, duži i s više cvjetova nego što je normalno. Na prvi se pogled u cvatu vidjela prisutnost brojnih stamena. Pod ručnim su se povećalom mogla vidjeti 4-6 stamena koji su okruživali muški cvijet s dobro razvijenim stigmama. Napravljene su fotografije cvata i pojedinih cvjetova. Pelud je iz hermafroditskih cvjetova fotografiran skenirajućim mikroskopom. U proljeće, 26. travnja, primijećeno je, fotografirano i analizirano bogato cvjetanje normalnih muških i ženskih cvjetova. U krošnji "zelenoga hrasta" nije zamijećena nikakva devijantna morfologija slična cvjetovima otkrivenim u studenome 1998. Razmatraju se radovi u kojima se opisuje pojava hermafroditskoga cvjetanja na nekim američkim hrastovima, posebno na gambelu (*Q. gambellii* Nutt.). Izvansezonsko cvjetanje "zelenoga hrasta" i pojava hermafroditskih cvjetova ne može se objasniti neobičnim klimatskim promjenama u ovom području. Može se samo pretpostaviti da hermafroditsko cvjetanje predstavlja primitivno naslijeđeno stanje u porodici *Fagaceae*, kao što sugeriraju neki autori o kojima se u ovom radu govori.

Ključne riječi: *Quercus* L., hermafroditsko cvjetanje, izvansezonsko cvjetanje