Shortened PhD thesis

Investigations on carpophagous insects of oaks in Hungary

Written by:
Anikó Hirka

Doctoral School of Forestry and Game Management
"Biological Basis of Forestry" (E2) programme

University of West Hungary
Sopron
2003

1. Importance of the subject

Oaks (including turkey oak, *Quercus cerris*) cover 32.4% (547,547 ha) of the Hungarian forested area. Their contribution to the total standing tree volume is 38% (124,764,000 m^3), even higher than their area ratio. According to modest estimates, an average of at least 1,000 tons of acorns are needed each year for artificial regeneration and compensatory planting. It is well known that the acorn crop has high year-by-year variation, and sometimes it is very difficult to obtain the necessary quantity of acorns. Therefore any new information leading to an increase in the acorn crop, decrease in damage to acorns, and improvement in the germination success of stored acorn crops has great significance with regard to forestry practice.

2. Scientific preliminaries

2. 1. Scientific preliminaries in Hungary

Both foresters and entomologists were already interested in oak carpophagous insects in the 2nd half of the 19th century. Works dealing mainly with gall wasps, written by **Adolf Erdődi**, **Vince Borbás**, **Nándor Illés** and **Adolf Rejtő** are known from this time. They dealt mainly with *Andricus quercuscalicis* as an organism producing galls valuable for industrial utilisation.

From the early 20th century attention turned to acorn weevils as important acorn pests. Studies from first half of the century included those of **Péter Matusovits**, **Pál Magyar** and **Gyula Roth**. They all focused on the influence of acorn weevil larvae on the germination ability of the damaged acorns.

From the 1950s studies dealing with acorns pests became more frequent. Beside the acorn weevils an increasing proportion of works dealt with acorn moths, and gall wasp studies became also more and more common. **Béla Újházy** published a detailed summary of the life history of acorn pests and gave information on possible methods of winter storage of acorns. **János Győrfi** published separate articles on acorn pests and included them in his summarising works as well. From the late 50s **Vilmos Mátyás** dealt in detail with both biotic and abiotic factors influencing the

acorn crop. He dealt with all three main groups of carpophagous insects. **Ernő Vicze** studied the life history of acorn weevils in detail.

György Bürgés, **Tibor Gál**, **István Eke** and **Ferenc Sifter** conducted an extensive research programme on pests of sweet chestnut including *Curculio elephas* and *Cydia splendana* also occurring on oaks. They published a considerable amount of information on the life history and importance of these species.

In the 80s **Wanda Balul** studied the fungus killing acorn germs. **Sándor Fodor** conducted control experiments against oak acorn pests, while **Katalin Leskó** studied their life histories.

2. 2. Scientific preliminaries in Europe

There are many articles dealing with oak insects in the North American literature, but mainly the European literature was studied in detail, because of the similarity of oak flora and their pests.

Hrašovec did a considerable amount of work mainly in connection with *Curculio* acorn weevils of pedunculate oak. In Romania **Scutareanu** studied insects feeding on reproductive organs of oaks, and in particular acorn pests.

Many articles were published in Czechslovakia (and later in Czech Republic and Slovakia) in connection with acorn pests. Of the authors, **Čermák**, **Červenák**, **Krístek** and **Kelbel** deserve special mention.

Detailed studies were conducted by **Debouzie**, **Desouhant** and **Menu** in France, on the insect pests (mainly *Curculio elephas*) of sweet chestnut and by **Delplanque** and **Rougon-Chassary** on acorn pests.

Andersson studied the relationships between damage caused by acorn weevils and the fungal infections of the acorns in South Sweden

Branco in Portugal and **Forrester** in Britain dealt with the influence of acorn insects on the germination ability of acorns.

3. Aims of the research

- Evaluation of the extent of damage caused by carpophagous insects in Hungary.
- Compilation of species lists of carpophagous insects and their food plants.
- Collection of information on carpophagous insects of exotic oaks.
- Experiments to study the process of acorn fall.
- Clarification of the role of carpophagous insects in the premature abscission of acorns.
- Studies on carpophagous insect/acorn fungi interactions, both via oviposition punctures and emergence holes.
- Planting experiments with intact and damaged acorns to study the survival and growth of seedlings.
- Collection of data regarding the life history and importance of previously neglected carpophagous species (i.e. *Neuroterus saliens, Callirhytis glandium*).
- Separation of acorns into individual rearing tubes in order to determine the emergence periods of carpophagous larvae, and to detect competition.

4. Methods

4. 1. Damage trends

Yearly damage data (1962-2002) for evaluation were taken from the database of the Hungarian Forest Research Institute Department of Forest Protection.

4. 2. Influence of altitude (a.s.l.) on damage rate of carpophagous insects

Six acorn samples of sessile oak were collected in autumn 2000 from different altitudes (200-700 m at 100 m intervals) in the territory of the Királyrét forest management unit in the Börzsöny Mountains. All acorns in the samples were classified in two categories (intact and damaged), and the damage ratios at different altitudes were compared.

4. 3. Field observations and rearing in laboratory

From 1995, particularly in 2000-2002, field observations were made to collect data on native and exotic host plants, life history and importance of oak carpophagous insects. Acorns collected in the field were taken to laboratory and insects were reared out either in mass or individual rearings. Repeated field observations from early summer to autumn were made at many different locations of Hungary such as Ásotthalom, Gödöllő, Gyula, Jászberény, Mátrafüred, Noszvaj, Püspökladány, Szárliget, Szentkút.

4. 4. Study the acorn fall process with collecting baskets

The aim of this experiment is to collect data on the process and main reasons of premature acorn abscission. Experiments were carried out in Mátrafüred in 2001-2002 with turkey oak (3 baskets under 1 tree) and in Püspökladány in 2000-2001 with pedunculate oak (2-2 baskets under 2 trees). Samples were collected with 1x1 m baskets with weekly removal. The acorns collected were individually dissected and their status and damaging agents were recorded.

4. 5. Individual rearing

Individual rearing were made over 3 years (2000-2002). One sample (oaks species/location) contained 500 acorns collected from the ground in late September/early October. The acorns (all without emergence holes) were put into plastic rearing tubes with ventilation lids. Length, diameter and weight of the acorns and the number of oviposition punctures were recorded. The samples were kept in a cold but frost-free place (simulating the usual storing conditions). Emergence-checking was carried out twice a

week. Species, number and individual weight of newly emerged larvae and number of new emergence holes were recorded each time.

4. 6. Planting experiments

60 undamaged and all of the damaged acorns (producing 1-3 larvae) of 4 samples (241 undamaged + 766 damaged acorns) were planted in 0,5 litre plastic containers in December 2001. The containers were kept in glasshouse at Gödöllő and were watered regularly. The emergence time of seedlings was recorded. Height and basal diameters of seedlings were measured at the end of the 2002 vegetation season.

4. 7. Field study to detect the relationship between oviposition punctures and fungal infections on premature acorns

In August 2000 and 2001 14 acorn samples (11 pedunculate oak, 2 turkey oak, 1 downy oak) containing an average of 91 acorns each (46-153) were examined. 9 samples from tree were taken in 30 minutes from reachable branches, 5 samples were taken from the ground in 15 minutes.

Each acorn was individually examined and dissected. Numbers and location of oviposition punctures and presence/absence of fungal infections were recorded.

4. 8. Study of germination success of stored acorns

Acorn samples of 5 oaks species (*Q. robur, Q. petraea, Q. pubescens, Q. cerris* and *Q. rubra*) from different locations in Hungary were taken in late February (2000-2002) after 4 months' storage (17 samples in 2000, 23 samples in 2001 and 20 samples in 2002). The average number of acorns in the samples was 554 in 2000, 535 in 2001 and 859 in 2002.

Acorns in the samples were sorted into two categories (with/without emergence hole). Then 100-100 acorns with and without emergence holes from each sample were taken randomly and dissected one by one. Status of germ, presence/absence of fungal infection were recorded.

5. Results

5. 1. Long term damage trend of acorn weevils

The area values of yearly damage by acorn weevils showed considerable fluctuations during the period 1962-2002. These fluctuations were closely related to the fluctuation in the quantity of the acorn crop. From 1989 onward a steep increase in the yearly damaged area could be observed. The main reason for this definite increase was probably related to the extremely long and strong drought period lasting from the late 80s until the mid 90s. These years with severe droughts together with the lack of temporary floods and excess surface waters resulted in much increased survivorship of acorn weevils leading to a much increased extent of damage.

5. 2. Influence of altitude on damage by acorn insects

There is no difference in the rate of insect damaged acorns in the samples collected at 200-300-400-500 m above sea level. A sudden drop could be observed between samples collected at 500 m and 600, 700 m. The reasons were probably due to climatic differences at different altitudes. This pattern should be studied in more detail.

5. 3. List of oak carpophagous insects

19 species of carpophagous insects (6 acorn weevils, 4 acorn moths and 9 gall wasps) develop in/on acorns of oaks in Hungary. 5 of them (*Curculio glandium, Cydia splendana, Andricus quercuscalicis, Callirhytis glandium, Neuroterus saliens*) have significant importance from the forest protection point of view. The other species usually occur sporadically and are less abundant.

5. 4. Host choice of carpophagous insects

The acorn weevils and acorn moths are more generalist and can develop in acorns of any native and exotic oak, even on the North

American red oaks (*Q. coccinea, Q. ilicifolia, Q. palustris, Q. rubra*). Most of them can live on trees other than oak (*Castanea, Fagus*).

Contrary to this, gall wasps are highly specialised, they accurately keep the to the intrageneric boundaries of the Eurasian oaks (i.e. *Quercus* and *Cerris* sections). There are two exceptions, *Callirhytis glandium* and *Neuroterus saliens* (according to literature), which can be found in acorns of oaks belonging to different sections (i.e. *Quercus cerris* and *Q. robur*).

The occurrence of *Andricus quercuscalicis* on *Quercus rubra* reported repeatedly in Central Europe cannot be supported.

5. 5. Process and main reasons of acorn fall

5. 5. 1. Pedunculate oak

In Püspökladány acorn insects were present in 59% (2000) and 48% (2001) of all acorns. Both in 2000 and 2001 acorn weevils were the dominant damage agents (49% and 19%), but the dominance of two gall wasp species (*Andricus quercuscalicis* and *Callirhytis glandium*) increased in 2001 (13% and 10%). Acorns attacked by *Callirhytis glandium* fell first (July-August). Most of the *Andricus quercuscalicis* infested acorns fell in August. Weevil infested acorns fell over a long period (from July to mid October). The percentages of full grown healthy acorns were low in both years, 4% in 2000 and 1% in 2001 (10,4 and 1,8 acorns/m^2).

5. 5. 2. Turkey oak

In Mátrafüred acorn insects were present in 46% (2001) and 38% (2002) of all acorns. Two species of gall wasps, *Callirhytis glandium* and *Neuroterus saliens* played a dominant role in 2001 (27% and 13%). Their prevalence dropped to 11% and 2% in 2002, and the prevalence of acorn weevils and acorn moths increased (18% and 6%). Small acorns infested by *Neuroterus* fell first, most of them by June-July. The fall of *Callirhytis* infested acorns started in August as half-size acorns and continued as fully grown acorns later in the season, until late October. Acorns damaged by acorn weevils and acorn moths fell in September-October. Percentages of

fully grown undamaged acorns were 3% (26,6 acorns/m^2) in 2001 and 5% (37,5 acorns/m^2) in 2002.

5. 6. Individual rearing

A total of 6,615 carpophagous larvae (5735 (86,7%) acorn weevils and 880 (13,3%) acorn moth) were reared out from 22 samples (each containing 500 acorns) of 4 oak species (*Q. robur, Q. petraea, Q. pubescens, Q. cerris*) in 3 years (2000-2002).

Contrary to earlier opinions the weevil larvae leave the acorns a long time (48-77 days) after collection of the acorns. The emergence period can last until late November, early December. It means that a considerable part of the damaged acorns appear undamaged even in the second half of November. So at the time of collection (i.e. mid October) the ratio of damaged acorns can be correctly evaluated only by dissecting the acorns.

No size differences have been found between undamaged and damaged acorns collected in autumn. 38% more oviposition punctures were found on damaged acorn than on the undamaged ones (1.32 and 0.96 punctures/acorns). The explanation for the punctures on undamaged acorns can be either the egg, or early larva mortality, or the probing punctures of females, without eggs laid in them.

The number of larvae that developed in an acorn cannot be estimated by counting emergence holes, because no correlation between these two numbers has been found. In extreme cases even 11 larvae leave the acorn through a single emergence hole.

The average number of larvae reared out from acorns of different oak species is ca. proportional to the average size of the acorn of the given species (2.61 larva/acorn for *Q. cerris*, 1.92 larvae/acorn for *Q. robur*, 1.32 larvae/acorn for *Q. petraea*, 1.47 larvae/acorn for *Q. pubescens*). In the case of species with larger acorns (particularly *Q. cerris*) the frequency of multi-larval acorns is higher and the frequency of single-larval acorns is lower. The pattern is opposite in case of *Q. robur, Q. petraea* and *Q. pubescens*.

The average larval weight decreases with increasing number of larva developed in the same acorn. This decreasing trend is least steep for *Q. cerris* and more definite for the other 3 species (*Q. robur, Q. petraea* and

Q. pubescens). It means that while *Q. cerris* can provide enough food for even 4-5 larvae, the other species cannot.

5. 7. Planting experiment

According to the planting experiments with more than 1000 acorns, it can be concluded that even damaged acorns can germinate and produce viable seedlings if the larvae have not killed the germ itself. The oak species with large acorns (*Q. cerris, Q. robur*) can tolerate the presence of a few larvae relatively well. The percentage of acorns producing viable seedlings by the end of the first growing season is only 17% lower for damaged acorns (1-3 larvae) than for undamaged acorns. This difference is considerably larger for *Q. robur*.

In case of *Q. cerris* the germination rate and the survivorship in the first season are in most cases independent from the number of larvae in the acorn. For *Q. robur* there is strong negative correlation between the survival rate and the number of larvae.

The size parameters (height and diameter) of seedlings developing from damaged acorns were smaller than those of undamaged acorns, but this difference becomes considerable only at three larvae for *Q. cerris* and *Q. robur*. A turkey oak acorn has the chance to produce a viable (but small) seedling even after development of 6 acorn weevil larvae in it.

5. 8. Influence of oviposition punctures on fungal infections

After studying 14 samples (ca. 1,300 acorns) of 3 oak species before the ripening of acorns (August) it has become evident that the punctures made by the ovipositing weevils play a vital role in fungal infections and premature fall of acorns.

While the relative frequency of fungal infection on intact acorns on the tree is less than 5 % on average, this value is an order of magnitude higher on punctured acorns. The probability of fungal infection is fivefold higher through a hole in the acorn shell than through a hole in the acorn cup.

The percentage of unpunctured healthy acorns on the ground at the same time is 0-6%. In some samples 60% of the punctured acorns on the

ground already showed the signs of fungal infection. The chance of fungal attack is even higher in the case of acorns punctured through the acorn shell.

5. 9. Germinating success of stored acorns

The relative frequency of acorns without fungal infection among the acorns undamaged by insects ranges from 40% to 70%, so after 4 months of storage the prevalence of fungal infection in undamaged acorns was 30-60%. A considerable part of these acorns had lost their germinating ability by February.

The relative frequency of fungal infection in insect damaged acorns ranges from 92 to 96%. Only 20-22% of these acorns (insect damaged acorns with fungal infection) keep their germination ability. In 16-39% of the acorns damaged by insects the germ is killed by the fungal infection protruding through the emergence hole rather than by the insects themselves.

There is a significant positive correlation between the ratio of insect damaged acorns (as explanatory variable) and the prevalence of fungus killed germs among acorns undamaged by insects (as dependent variable). The explanation for this phenomenon is that the fungi reaching the cotyledons proliferate very efficiently and this can lead to a much increased infection pressure able to penetrate even the shell of undamaged acorns. So the germination success of any acorn store in spring is strongly influenced by the prevalence of insect damaged acorns (with emergence holes) in the same store.

6. Recommendations for utilisation of the results

The results in connection with the life history and importance of carpophagous can be used in education (forestry and special courses for plant protection experts).

Many results included in the thesis can directly or indirectly be used in forestry practice. They are listed below:

The gall wasp *Andricus quercuscalicis* needs presence of both turkey oak (*Quercus cerris*) and pedunculate oak (*Quercus robur*) to complete its life cycle. Therefore the presence of large flowering turkey oaks in close vicinity of seed orchards and seed-crop stand can considerably increase the risk that acorns will be damaged by this species. Removing the large flowering turkey oaks from the vicinity of these pedunculate stands will likely decrease the damage rate of *Andricus quercuscalicis*.

Acorn weevil larvae spend a long time (1-3 years) in the soil, therefore temporary spring floods and the excess water in spring can decrease their abundance significantly. This fact should be considered when seed orchards and seed crop stands are being selected.

Where technically and financially possible reconstructing a natural-like water regime providing temporary surface waters (flood or excess water) is recommended (mainly in lowland pedunculate oak forests). This can have a significant positive effect on the growth and general health conditions of the stands and can effectively decrease the abundance of acorn weevils and several other insect pests.

Although there is no consequent difference between the falling time of the fully-grown damaged and healthy acorns, delayed acorn collecting is recommended. At the time of the later collection more larvae will have left the acorns and therefore more damaged acorns can be distinguished from the healthy ones.

At the time of acorn collection only dissecting representative acorn samples can give reliable information on the damage rate. Because of the long emergence period, the majority of damaged acorns seem healthy even a month after collection. On top of this the number of emergence holes on an acorn does not give useful information about the number of larvae developing in the acorn nor the status of the germ.

At the time of collection as many damaged acorns as possible should be removed from storage, because the presence of acorns with emergence holes increases the fungus caused germ mortality in otherwise intact acorns.

A late November or early December removal of damaged acorns is recommended. In the case of expensive acorns in a shortage (i.e.

pedunculate oak in some years) it is certainly profitable even considering the high labour costs.

A fungicide seed dressing can help considerably to save the spring germination ability of acorn storage. The technology is still to be worked out.

7. Presentations and publications related to the subject of thesis

7. 1. Oral presentations

Csóka Gy., Hirka A. 2001: Colonization of native herbivores on exotic oaks in Central Europe. RES-IUFRO Conference, 10-13 September 2001, Aberdeen, Scotland

Csóka Gy., Hirka A. Csiky Zs. 2003: Az erdővédelem magyarországi szakirodalma (1792-2000). A Magyar Rovartani Társaság előadóülése: Budapest 2003. február 21.

Hirka A. 2001: A magyarországi tölgyek karpofág rovaregyüttese – néhány újabb eredmény. Emlékülés Tallós Pál születésének 70. évfordulója alkalmából. Budapest, 2001. dec. 12.

Hirka A., Csóka Gy. 2000: Indirect effects of carpophagous insects on germination succes of stored oak acorns. International Symposium on Forest Protection and Forest pathology. Zvolen-Sielnica, 4-6. August, 2000.

Hirka A., Csóka Gy. 2001: Egyes karpofág rovarok közvetett negatív hatása tárolt tölgymakk csíraképességére. Növényvédelmi Tudományos Napok, 2001. febr. 27-28.

Hirka A., Csóka Gy. 2001: Interakciók tölgyek és karpofág rovaraik között. Magyar Biológiai Társaság, Ökológia Szakosztály, Magökológiai Szimpóziuma, Budapest, 2001. november 27.

7. 2. Posters

Csóka Gy., Hirka A. 1997: A kocsányos tölgy (*Quercus robur* L.) egyedspecifikus rügyfakadási ideje, és ennek hatása egyes herbivor rovarok denzitására. IV. Magyar Ökológus Kongresszus, Pécs, 1997. június

Csóka Gy., Hirka A. Csiky Zs. 2003: Az erdővédelem magyarországi szakirodalma (1792-2000). 49. Növényvédelmi Tudományos Napok: Budapest, 2003. február 25-26.

Hirka A., Csóka Gy. 2001: Direct and indirect effects of carpophagous insects on fecundity of Central European oaks. RES-IUFRO Conference, 10-13 September 2001, Aberdeen, Scotland

7. 3. Abstracts

Csóka Gy., Hirka A. 1997: A kocsányos tölgy (*Quercus robur* L.) egyed-specifikus rügyfakadási ideje, és ennek hatása egyes herbivor rovarok denzitására. IV. Magyar Ökológus Kongresszus előadásainak és posztereinek összefoglalói, 48.

Csóka Gy., Hirka A. Csiky Zs. 2003: Az erdővédem magyarországi szakirodalma (1792-2000). 49. Növényvédelmi Tudományos Napok (Budapest, 2003. február 25-26.) előadásainak összefoglalói, 42. oldal

Hirka A., Csóka Gy. 2001: Egyes karpofág rovarok közvetett negatív hatása tárolt tölgymakk csíraképességére. Növényvédelmi Tudományos Napok Összefoglalói, 50.

7. 4. Conference proceedings:

Hirka A., Csóka Gy. 2000: Indirect effects of carpophagous insects on germination success of stored acorns. **Hlavac P.; Reinprecht L; Gáper J.** (eds) 2000: Proceedings of the conference on "Ochrana lesa a Lesnicka fytopatologia 2000" pp- 51-56.

Hirka A., Csóka Gy. (2001): Új szempont a tölgymakk téli tárolásának eredményességére vonatkozóan. in: **Mátyás Cs., Führer E., Tóth J.** (2001): Gondolatok az erdővédelemről az ezredfordulón. Az MTA Erdészeti Bizottsága és az Erdészeti Tudományos Intézet jubileumi ülése Pagony Hubert és Szontagh Pál 75. születésnapja alkalmából. Az ERTI kiadványai 15. 81-86.

7. 5. Journal articles

Csóka Gy., Hirka A. 2002: Adatok a Magyarországon nem őshonos tölgyeken megtelepedő herbivor rovarok ismeretéhez. Erdészeti Kutatások, 90 (2000-2001). 195-204.

Csóka Gy., Hirka A., Kmetty L., Kis L-né 1998: Vizsgálatok kocsányos tölgyek rügy-fakadásával kapcsolatban. Erdészeti Kutatások, 88. 305-309.p.

Hirka A. 2000: A tölgymakk dézsmálói. Élet és Tudomány, LV. évf. 22. sz. 684-686.

Hirka A. 2001: A tölgymakk károsítói. Erdőgazda, 3. évf. 1. sz. 10.

Hirka A., Csóka Gy. 2002: Egyes karpofág rovarok közvetett negatív hatása tárolt tölgymakk csíraképességére. Növényvédelem, 38 (4), 157-161.

Hirka A., Csóka Gy. 2002: Adalékok a tölgy karpofág rovarok jelentőségének megítéléséhez. Mag kutatás, fejlesztés és környezet. XVI. (1.), december, 22-24.

7. 6. Book (CD-ROM)

Csóka Gy., Hirka A., Csiky Zs. 2002: Az erdővédelem magyarországi szakirodalma. Agroinform, Bp.