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Leaf Longevity of *Quercus glauca* Thunb., with Reference to the Influence of Gall Formation by *Contarinia* sp. (Diptera: Cecidomyiidae) on the Early Mortality of Fresh Leaves

Junichi YUKAWA and Kiyoshi TSUDA*

(*Entomological Laboratory*)

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Introduction

Quercus glauca Thunb., an evergreen oak, called "Arakashi" in Japanese, is commonly distributed in southwestern Japan, south coast of Korea and southern China. On the fresh leaves of the plant, there can be seen subglobular galls produced by an unidentified cecidomyiid species of the genus *Contarinia*[7]. Frequently, 2 or more galls arise continuously along the midrib, and the galled leaves remain folded upward. This infestation has been suspected to cause earlier fall of fresh leaves.

To evaluate the survival rates of leaves, it is necessary to trace the fall of marked leaves for successive seasons. Kikuzawa[3,4], who presented leaf longevities and survival curves for several deciduous trees, pointed out the necessity to obtain the data not only for calculation of leaf longevity but also for understanding the mode of life of the tree species concerned. Additionally, in recent years the interrelations between phytophagous insects and their host plants have increasingly been paid attention by biologists in terms of coevolution theory[1]. In association with the ecological field studies on the gall midges by the senior author (JY) and his collaborators, some autoecological and phenological aspects of their host plants have also been surveyed since 1970 to obtain a better understanding of ecological interrelations between them.

The present paper is primarily intended to describe the infuluence of gall formation by *Contarinia* sp. on the early mortality of fresh leaves. Survival curves and leaf longevities of *Q. glauca* are also presented to add something to the autoecological knowledge of the tree species. Further, the mean leaf longevities are compared with those of other broad-leaved evergreen trees[6,8].

Materials and Methods

Field studies were conducted at Mt. Shiroyama (100 m high) in Kagoshima City during the period from 1976 to 1985. Ten plants (150–260 cm high) of *Q. glauca* were selected as census trees. Four (tree nos. B1–B4) of them were surveyed to compare the early mortality of galled leaves with that of ungalled ones. The mean number of new leaves emerged per twig was surveyed on the remaining 4–6 trees (tree nos. A1–A6). Sixty to 82 newly extended twigs were randomly selected on the 6 trees every year from 1976 to 1978. They were marked with coloured plastic tape to

* Present address: Tahara Agricultural Center, Cyanamid (Japan), Ltd., Tahara-cho, Aichi 441–34.

distinguish 3 different cohorts (=leaves belonging to different year-classes of emergence). The long term survival curves of ungalled leaves were obtained by recording the numbers of surviving leaves on the twigs once a year from spring to summer until July 1985 when the last leaf produced in 1978 was shed. The mean leaf longevities were calculated from the survival curves. The developmental stages of *Contarinia* sp. were examined in the laboratory by dissecting both the galls and leaf buds collected from the census field April 1977 and 1978.

Table 1. Relative abundance of galls with and without mature larvae of *Contarinia* sp., indicating the time of their escape from the galls

	Galls exam.	Galls with larvae		Empty galls	
		no.	(%)	no.	(%)
15. Apr. 1977	147	130	(88.4)	17	(11.6)
16. Apr. 1977	182	118	(64.8)	64	(35.2)
18. Apr. 1977	163	55	(33.7)	108	(66.3)
6. May 1977	84	2	(2.4)	82	(97.6)

Table 2. Mean number of *Quercus glauca* leaves emerged per twig

Tree no.	1976 Twigs exam.	1976 Mean	1976 s.d.	1977 Twigs exam.	1977 Mean	1977 s.d.	1978 Twigs exam.	1978 Mean	1978 s.d.
A1	14	5.79	1.58	—	—	—	18	5.00	1.41
A2	22	6.91	2.47	26	5.00	2.06	29	6.41	1.64
A3	27	6.48	2.49	10	6.40	2.12	12	6.67	1.50
A4	4	5.50	1.92	1	7.00	—	—	—	—
A5	6	7.83	1.94	6	5.83	1.60	—	—	—
A6	9	6.22	1.56	17	5.47	1.94	1	3.00	—
Total	82	6.50	2.20	60	5.48	1.99	60	5.98	1.69

Results

In 1977, overwintered leaf buds started to open in late March at the census field. Swarming males and ovipositing females of *Contarinia* sp. were sometimes observed early in and the middle of April. Eggs of the gall midge were found to be oviposited on undersurface of the newly emerged leaves. Hatched first instars developed rapidly to second, and then third (final). Galls became prominent at the later larval stadia. Around the middle of April, mature larvae began to escape from their galls (Table 1), and fell down to the ground to pass through the summer, autumn and winter in the soil.

The mean number of new leaves emerged per bud varied with tree and year from 3.00 to 7.83 (Table 2). After emergence, many galled leaves fell during a short period from April to May, following the escape of mature larvae from the galls (Fig. 1). Only 30% of the galled leaves survived until August, and almost all of the survivals were shed before winter. In addition, the ungalled leaves (category ULWG) which were attached to the twigs with galled leaves were also shed earlier. Their survival rate during this period was 76.9%, which was significantly ($X^2=3.50>$

$X^2_{0.10}$) lower than 89.8% of the ungalled leaves (category ULNG) which were attached to the twigs without galled leaves (Fig. 1).

Fig. 2 shows the long term survival curves for the ungalled leaves (ULNG) which were not shed during the early period (first 2 months) of their life. The curve for the leaves emerged in 1976 was similar in shape to that for 1977's. Fifty to 70% of the 1976 and 1977 leaves survived for at least 24 months after emegence. The curve for the leaves of 1978 was somewhat different from those for

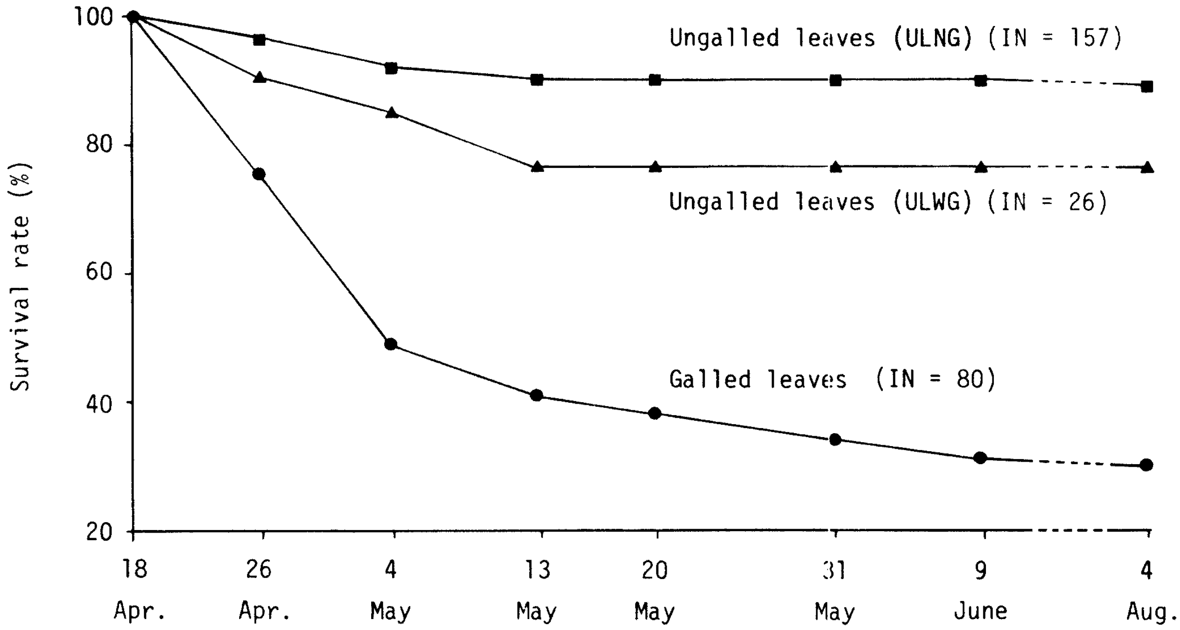

Fig. 1. Survival curves from April to August 1977 for the galled and ungalled new leaves of *Quercus glauca*. ULNG: Ungalled leaves attached to the twigs without galled leaves; ULWG: Ungalled leaves attached to the twigs with galled leaves. IN: Initial number of leaves.

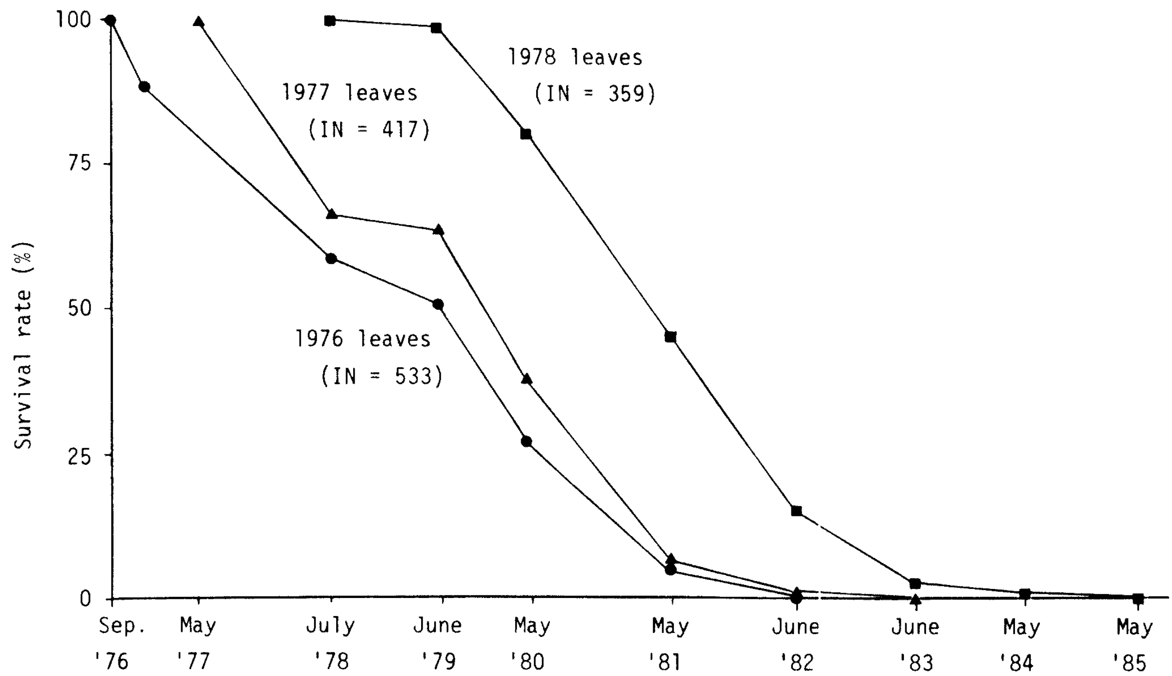

Fig. 2. Survival curves of *Quercus glauca* leaves emerged in 1976, 1977 and 1978. IN: Initial number of leaves.

the preceding 2 years. In particular, the survival rate of the 1-year old leaves was extremely high (97.2%). Thereafter, the number of leaves was reduced lineally until June 1983. A few leaves survived for at least 72 months. As a result, the mean leaf longevity appeared to be longest in the 1978 leaves, and followed by 1976 and 1977 (Table 3).

Discussion

There are many reports on foliage loss caused by a wide variety of defoliators[5], but only a few examples have been presented as for gall-forming organisms. The Japanese pine leaf gall midge, *Thecodiplosis japonensis* Uchida & Inouye is known to produce subglobular galls at the basal portion of needles of *Pinus* spp. Inouye[2] mentioned that the galled needles became shorter in length and fell earlier (during the first winter) than normal needles. The gall formation by the euonymus gall midge, *Masakimyia pustulae* Yukawa & Sunose, is also responsible for the earlier fall of the heavily galled leaves of *Euonymus japonicus* Thunb.[6].

The present study revealed that the gall formation by *Contarinia* sp. caused the earlier fall of the galled leaves of *Q. glauca* (Fig. 1). In addition, the ungalled leaves (ULWG) which were attached to the twigs with the galled leaves were shed distinctly earlier than others (ULNG). This means that even the ungalled leaves (ULWG) were affected by the gall formation on neighbouring leaves attached to the same twig. Such a phenomenon has not hitherto been reported. Thus, the gall formation should be regarded as an important mortality factor which operates not only directly but also indirectly on the survival of the host leaves.

In the interrelation between the euonymus gall midge and its host plant, the earlier fall of the heavily galled leaves which carry many midge larvae, in turn, acts as a density-dependent mortality factor upon the midge larvae, since the gall midge lives inside the leaf galls throughout the larval and pupal stages[6]. However, in the relation between *Contarinia* sp. and *Q. glauca*, the earlier fall of galled leaves dose not seem to cause the high mortality on the midge larvae, because most of them escape from their galls before defoliation (Table 1). The interrelation in this case is, therefore, one-sided rather than mutual. This may be extended to other gall midges, including the Japanese pine leaf gall midge, whose larvae escape from the galls after maturation.

Table 3. Mean longevity of ungalled *Quercus glauca* leaves attached to the twigs without galled leaves

Cohort	Leaves exam.	Longetivity (month)	s.d.
1976	533	32.61	18.71
1977	417	26.55	15.45
1978	359	34.25	14.29

The survival rates and longevities of the ungalled leaves (ULNG) varied with cohort (Fig. 2; Table 3). Among 3 different cohorts, the leaf longevity was longest in the 1978 leaves. This was probably related to the tendency that the survival rates during the period from July 1978 to June 1979 were relatively high for all the leaves of different cohorts (Fig. 2). In particular, more than 97% of the 1978 leaves survived for the first 1 year, and this advantage was maintained thereafter. Thus, if the early mortality rate is minimized the longevity naturally becomes longer. The mean number of newly emerged leaves per twig was not related to the leaf longevity.

Leaf longevities have been given for only 2 species of broad-leaved evergreen trees in Japan. The present data (Table 3) is apparently shorter than 51.5 months for *Actinodaphne longifolia* (Blume) Nakai[8], and longer than 23.9 for *Euonymus japonicus* Thunb.[6]. Unpublished data of the senior author (JY) indicates that a majority of species belonging to the family Lauraceae have longer leaf longevities than *Q. glauca*. A further accumulation of data on other trees might enable to compare adaptive strategies among tree species in relation to their systematic position.

Summary

Along the midrib of fresh leaves of *Q. glauca*, there can be seen subglobular galls produced by a cecidomyiid species of the genus *Contarinia*. The gall formation by the midge larvae caused earlier fall of galled leaves during a short period from April to May, following the escape of the midge larvae from their galls. Only 30% of galled leaves could survive until August, and almost all of them were shed before winter. In addition, some of the ungalled leaves which attached to the twigs with the galled leaves were also shed earlier than other ungalled leaves.

The long term survival curves were presented for the ungalled leaves of 3 different cohorts. A few leaves survived for at least 72 months after emergence. The mean leaf longevity varied with cohort, being 32.6 months for the 1976, 26.6 for the 1977, and 34.3 for the 1978 leaves.

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