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Populus galls induced by *Pemphigus* aphids in Sinai

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ABSTRACT

In St Katherine (Sinai, Egypt), *Pemphigus populi* (Homoptera, Pemphigidae) induces a gall in early spring on the base of the leaves of the black poplar, *Populus nigra* L. By late April, the wingless fundatrix aphid has produced several hundred offspring parthenogenetically within the gall. The two trees examined differed in leaf size, infestation rate and gall size. Gall size and complexity influenced insect weight. Galled leaves were smaller and had shorter petioles, probably because galls disrupted leaf growth: galled leaf petioles has the cortex, phloem and xylem disorganized and destroyed in the region close to the origin of the gall, and the first vascular bundle was collapsed. Leaf phenol concentrations were much lower in the highly infested old tree in comparison with the lightly infested young tree.

KEYWORDS: *Populus*, *Pemphigus*, interaction, gall, phenol, St Katherine, Sinai, Egypt

INTRODUCTION

Populus nigra (Family: Salicaceae) is a plant native to Europe and Asia with many hybrids; the variety commonly cultivated in Egypt is European one, "Lombardy poplar". The plant rarely produces flowers in Egypt and is propagated by cuttings (El-Hadidi & Boulos 1988). In St Katherine (Sinai, Egypt), the gall-forming aphid *Pemphigus populi.* (Homoptera: Aphidoidea) attacks the leaf of most *Populus nigra* trees in late April causing heavy infestations of large conspicuous galls on the base of the leaves. Inducers are usually very specific in selecting their host species, organ and tissue, controlling the size, shape, structure, colour and physiology of the gall (Dreger- Jauffret & Shorthouse 1992). Previous work on European *Pemphigus* aphids on *Populus* showed that gall formation is mainly located on the leaf petiole (Foster 1990).

Morphological symptoms either in colour or deviation from the normal shape brought about by any pathological organism in plants are always associated with biochemical changes in the plant tissues (Chakrabarti & Chakrabarti 1984); galls certainly do this, causing, for example, changes in phenol metabolism (Purohit *et al.* 1980).

In this work, morphological, anatomical and physiological studies were performed on galled and ungalled leaves of *Populus* plants infected by *Pemphigus populi.*

MATERIALS AND METHODS

As variation in host suitability can be large both within and between trees, two adjacent trees with different galling intensity (tree A with low infestation rate, and tree B with high infestation rate) were selected at the town of St Katherine, Sinai, Egypt. Whole shoots were randomly sampled from trees without distinction as to branch height or orientation. In order to distinguish unambiguously among different leaves on a shoot, leaves were numbered sequentially, starting with the leaf whose petiole was lowest on the shoot axis. Sampling

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occurred during the gall formation in late April and early May. Various parameters were measured: petiole length (in mm), leaf area (in mm^2) and gall size (length x width in mm), gall weight (in mg, using a Cahn electrobalance), number of chambers per gall (1-5), and gall colour (green or pinkish). The gall was dissected, and the number of immature nymphs and adults counted. Microscopic sections were done on the base of the leaf (galled and ungalled) according to the method of Corgan & Widmayer (1971). Phenol concentration was determined in the laboratory (Ain Shams University, Egypt) in the galled and ungalled leaves, and in the gall itself for both trees using the method of Swain & Hillis (1959).

RESULTS AND DISCUSSION

In St Katherine, *Pemphigus populi* induces a gall on the base of the leaves of introduced black poplar, and there were no galls on the leaf petiole as on many European *Populus*. The wingless stem-mother aphids (fundatrix) are highly mobile in selecting a suitable leaf, and forming a large fleshy irregular-gall on the base of the blade of the leaf (Fig. 1). Successful stem mothers were full of embryos within her body and became enclosed within the gall. By late April, the fundatrix produced more than three hundred offspring parthenogenetically and these develop within the gall. By late May, the gall dehisced and winged adults (Fig. 2), emerged to fly out of the *Populus* gall, searching for the secondary host to complete the life cycle. The second host is as yet unknown.

Figure 1: A typical single-chambered gall on the base of the *Populus* leaf.

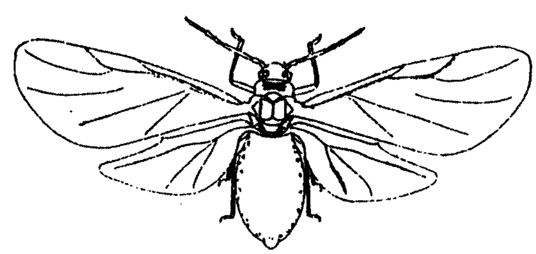

Figure 2: The winged adult of *Pemphigus populi*

A total of 284 galled leaves were examined. Virtually all galls concentrated at the base of the leaf, at the junction between leaf blade and leaf petiole. The position of the gall is a crucial determinant of potential fitness of individual stem mothers, since a poor galling site can result in the production of no progeny, while a female at a good site may produce hundred of offspring (Whithan 1980). Vascular feeders often prefer the base of the leaf blade for gall formation, because everything translocated into or out of the leaf must flow through that point (Whithan 1978), and the concentration of noxious phenolics is lowest (Zucker 1982).

There was a significant difference between trees in gall size and both galled and ungalled leaf area (Table 1). There were no significant differences between both trees for the ungalled and galled petiole length, gall weight and the insect weight.

Within the same tree, there was no correlation between the number of gall chambers and leaf area. Furthermore, there was no correlation between gall colour (green & reddish) and insect stage (nymph & mature). There was a highly significant correlation between the number of gall chambers and aphid weight ($r= 0.96$, $p<<0.001$), and between gall size and weight ($r=0.98$, $p<<0.001$). Ungalled leaves were much larger than galled leaves ($t=6.65$, $df=28$, $p<<0.001$), and had longer petiole ($t=2.03$, $df=18$, $p<<0.05$).

Table 1: Measurements of mean leaf area, petiole length, gall size, gall weight and insect weight in samples from two black popular trees in St Katherine, Sinai (± S.E.)

	Tree A (Low infestation rate)	Tree B (High infestation rate)	Significance
Ungalled leaf area (mm)	13.7 ± 0.38	18.33 ± 0.912	$T_{18}= 4.1$, $p<< 0.001$
galled leaf area (mm)	7.6 ± 0.48	15.56 ± 0.91	$T_{18}= 6.8$, $p<< 0.001$
Ungalled petiole length (mm)	3.4 ± 0.17	3.8 ± 0.19	$T_{18}= 0.03$, $p> 0.1$
galled petiole length (mm)	2.18 ± 0.19	2.3 ± 0.14	$T_{18}= 0.21$, $p> 0.1$
gall size (mm)	9.13 ± 0.63	7.0 ± 0.51	$T_{18}= 1.99$, $p< 0.05$
gall weight (mg)	1.55 ± 0.11	1.39 ± 0.11	$T_{18}= 0.34$, $p> 0.1$
Aphid weight (mg)	0.21 ± 0.014	0.26 ± 0.021	$T_{18}= 0.26$, $p> 0.1$

The microscopic sections showed that the normal leaf petiole was composed mainly of the epidermis, cortex of parenchyma and three superposed concentric vascular bundles, while the petiole of galled leaves had disorganised cortex, phloem and xylem, completely destroyed in the region close to the origin of the gall. Galls caused a collapse of the first vascular bundle, while the other two remained intact (Fig. 3). These data indicate that the insect's needs are apparently gained from the vascular bundle nearest the larval chamber, so the gall receives most of its nutrient by simply intercepting some of the passing nutrients and assimilates.

Figure 3: Cross section of the petiole at the base of the galled leaf showing its junction with the gall. (VB= vascular bundle; GC= gall cavity; J= junction between the gall cavity and the petiole of the galled leaf).

Determination of overall concentrations of phenols in both trees showed that the phenol concentration is much lower in the highly infested tree, in both leaves and galls (Table 2). These data indicate that the stem mother does not select leaves at random, and agree with the findings of Zucker (1982), where preference was negatively correlated with the concentration of phenolics.

Table 2: Analysis of the total phenol (mg/gm fresh weight) of the leaf gall tissue of two trees with different infestation rate (Tree A and B).

	Tree A (Low infestation rate)	Tree B (High infestation rate)
Ungalled leaf	11.1 ± 0.05	9.0 ± 0.03
Galled leaf	7.0 ± 0.02	5.5 ± 0.06
Gall tissue	15.3 ± 0.08	13.4 ± 0.09

All calculations: Mean ± SE

Within the same tree, the total phenol concentration was much higher in galls than in leaves (galled or ungalled), and higher in galled than ungalled leaves. The higher phenolic content in galled tissues has been reported in many plants, interpreted as the plant increasing the concentration as a defence mechanism against the herbivore (Wegen & Glase 1981; Tandon & Arya 1982). An alternative explanation is that phenols may be involved in protecting of the gall-maker from pathogens such as fungi or other natural enemies (e.g. parasitoids). Thus gall insects may manipulate the expression of phenolic compounds for their own protection (Abrahamson *et al.* 1991). Another possible explanation for the increase in total phenol content in gall tissue is that *o*-and *p*-dihydroxy phenols and polyphenols act as IAA-oxidase inhibitors (Shekhawat *et al.* 1978). Shekhawat *et al.* (1978) concluded that there is a direct correlation between increased phenols (total and *o*-dihydroxy) and decreased IAA-oxidase activities. This inhibition of IAA-oxidase activity by phenolic inhibitors or protectors leads to hyperauxinity in the tissues, resulting in gall formation .

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الملخص العربى

الأورام النباتية على شجر الحور والتى تسببها حشرة المَن "*بيمفيجوبياس*" فى سيناء

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تعتبر الدراسة واحدة من سلسلة الدراسات عن علاقة الحشرات بالنبات فى النظام البيئى المتميز لمنطقة الجبال بمحمية سانت كاترين بسيناء. فى هذا البحث وجد أن حشرة المن (*بيمفيجوس بوبيلارى*) من فصيلة بيمفيجيدى تسبب أورام نباتية على قواعد الأوراق لنبات الحور الأسود (*بوبيليس نيجرا*) وذلك خلال فصل الربيع. ففى نهاية شهر أبريل وجد أن حشرة المن الناضجة والغير مجنحة تنتج مُئات من الحوريات وذلك بالتكاثر البكرى وذلك داخل الورم النباتى الذى تسببه الحشرة فى أطوارها الاولى.

تم فحص عدد ٢ شجرة حور ذات أعمار مختلفة وقد وجد أن الشجرتين بعد الإصابة تختلفان فى حجم الأوراق ومعدل الإصابة وحجم الأورام على قواعد الأوراق. وجد أيضا أن حجم الورم على النبات يتحكم بشكل كبير فى عدد الحشرات الموجودة بداخل الورم. كما أثبتت الدراسة أن حجم الأوراق المصابة كانت صغيرة وذات عروق وسطية قصيرة إذا ما قورنت بالأوراق السليمة وربما يرجع هذا إلى أن الورم يسبب تدمير خلايا النمو فى الأوراق، حيث وجد أن خلايا الخشب واللحاء لعنق الأوراق المصابة قد تم تدميرها بصورة كبيرة بالإضافة إلى تدمير بعض الحزم الوعائية. أيضا أثبتت الدراسة الفسيولوجية أن تركيز مادة الفينول فى الأوراق المصابة كانت أقل بكثير من الأوراق السليمة كما أختلف تركيز الفينول بين أوراق الشجرتين.