Pakistan J. Zool., vol. 47(3), pp. 685-690, 2015.

Edge Effects on Gall-Inducing Insect *Mikiola fagi* (Diptera: Cecidomyiidae) in the Oriental Beach Forests

Erol Akkuzu,[1]* Eda Dıngıloğlu[2] and Sabri Unal[1]
[1]*Faculty of Forestry, Kastamonu University, Kastamonu-37150, Turkey*
[2]*Institute of Science, Kastamonu University, Kastamonu-37150, Turkey*

Abstract.- This study investigated the influence of forest edges on the leaf galls induced by *Mikiola fagi* (Hartig) on oriental beech (*Fagus orientalis* Lipsky). Two main objectives of this study were a) to compare the effects of forest edges on the number of leaf galls, and b) to compare the forest edges and forest interiors concerning the length and weight of the galls. Investigations on this subject were conducted in 2013-2014 in the Forest Enterprise Chief of Tezcan in Kastamonu located in Western Blacksea region of Turkey. The results showed that 1) the number of leaf galls was greater along the forest edges than in the forest interiors, 2) the length and the weight of the galls did not differ significantly between forest edges and forest interiors.

Key Words: Gall midges, *Mikiola fagi*, *Fagus orientalis*, Turkey.

INTRODUCTION

Oriental beech (*Fagus orientalis* Lipsky) is one of first-class forest trees which can reach 40-50 m in height with large diameters. Being among deciduous forest trees, beech trees are exposed to numerous adverse effects of many biotic and abiotic factors. One of the biotic factors causing damage on beech leaves is gall midges belonging to family Cecidomyiidae (Diptera). The family Cecidomyiidae, with over 4600 currently recognized species all over the world, is one of the biggest of the order Diptera (Gagne, 2004).

Gall midges damage many parts of the plant including the bark, shoots, leaves, pre and post flowering shoot buds, inflorescence buds, axillaries, flowers, newly formed fruit and twigs (Rehman *et al.*, 2013).

Plant galls induced by foreign organisms (*e.g.* gall midges) are cells, tissues or organs of abnormal growth formed due to an increase in cell volume and/or cell number (Rohfritsch and Shorthouse, 1982; Dreger-Jauffret and Shorthouse, 1992; Raman *et al.*, 2005; Carneiro *et al.*, 2009). Galling insects produce galls by inducing cellular hypertrophy and hyperplasia on plant meristematic tissues (Mani, 1964). Although species of family Cecidomyiidae are quite small insects morphologically, they play very important roles in ecosystem. Most of gall midge larvae cause abnormal formations on plants by feeding on plant tissues. Larvae of gall midges essentially feed on host plants in order to complete their life cycle. Kampichler and Teschner (2002) emphasized that *Mikiola fagi* (Hartig) is one of the most common gall-inducing cecidia of beech trees in Europe.

Gall-forming insects may affect host plant photosynthetic rates in a more complex way than leaf-chewing insects (Fay *et al.*, 1993; Crawley, 1997; Larson, 1998; Fay and Throop, 2005), since gall-makers do not remove photosynthetic tissue (Constantino *et al.*, 2009). Galled leaves, even when reaching maturity, may behave as a sink organ rather than as a source of nutrients for the plant (Constantino *et al.*, 2009).

Many studies show that insects lay eggs on plants where there are the appropriate resources for the development of their larvae to optimize the survival and future success of offspring (Vuorisalo *et al.*, 1989; Thompson and Pellmyr, 1991; Réale and Roff, 1992; Awmack and Leather, 2002; Fox and Czesak, 2002; Obermaier *et al.*, 2008; Fry *et al.*, 2009; Morrison and Quiring, 2009; Trager *et al.*, 2009; Beguinot, 2011). Stone and Schönrogge (2003) also indicated that galls on plants are believed to supply the inducer with enhanced nutrition, a favorable microclimate and, in some cases, protection from natural enemies. Gall-forming *M. fagi* are under attack by many species of

* Corresponding author: eakkuzu@kastamonu.edu.tr
0030-9923/2015/0003-0685 $ 8.00/0

parasitoids (Dziurznski, 1961; Fernandes *et al*., 2003). The morphology of the galls (*e.g*. size, shape, structure) may change in response to biological and evolutionary responses of gall-making insects towards parasitoids and predators (Cornell, 1983; Weis and Abrahamson, 1986; Price *et al*., 1987; Zwölfer and Arnold-Rinehart, 1994; Stone and Cook, 1998; Tabuchi and Amano, 2004).

Habitat modifications (*e.g.* habitat edges, fragmentations) effect density and distribution of insect populations. Didham *et al*. (2007) indicated that habitat fragmentation deeply influence the plant communities, primarily regarding changes in the number of species, and the structure and nutritional quality of the plants. This has obvious effects on herbaceous insects (Tscharntke *et al*., 2002).

Many studies have been conducted concerning the effects of habitat modifications on the structure of insect communities (Hines *et al*., 2005; White and Andow, 2006; Didham *et al*., 2007; Tylianakis *et al*., 2007; Almeida-Neto *et al*., 2011; Kaartinen and Roslin, 2011; Perre *et al*., 2011; Araujo and Espirito-Santo Filho, 2012). However, there are few studies that have investigated the effects of forest edges on *M. fagi*. The objectives of this study were to investigate the effects of forest edges on the abundance of gall-inducing *M. fagi* and length and weight of the galls.

MATERIALS AND METHODS

Study area

The experiment was conducted between the years of 2013-2014. To address our research questions, oriental beach stands were selected from the Forest Enterprise Chief of Tezcan, Kastamonu (41°50’N and 34°04’E) which is located in Western Blacksea Region of Turkey.

The study area is mostly dominated by oriental beech, but with small quantities of oak and other species such as chestnut, and other deciduous species. The height of trees varies greatly from 20 m to 30 m, and the diameter of trees at breast height (dbh) from 25 cm to 40 cm in the field.

Climate data from 1930 to 2000 taken from the Inebolu Meteorology Station (64 m a.s.l.) show that the region is characterized by mild winters with January daily temperatures ranging from -8.5°C (minimum) to 24.4°C (maximum) and warm summers with July temperatures ranging from 10.4°C (minimum) to 35.2°C (maximum). Mean annual precipitation is 1024.6 mm in the area. Climate for the study area was cooler and wetter than the weather station (64 m asl) data due to higher altitudes (ranging from 680 to 810 m).

Field and laboratory experiments

Field experiments in the study area were conducted in September, 2013 and September, 2014 that leaf galls induced by *M. fagi* were fully growth. Randomly selected lower crown branches (40 cm in length and 1.50 m above the ground) were cut from the beech trees located in the forest interiors and forest edges. The extent of the edge ranges from 50 to 500 meters (Laurence, 2000). Current consensus holds that edge effects typically extend 150 meters into a fragment (Bierregaard *et al*., 1992; Murcia, 1995). In this study, branch samples were taken from 150 m into the forest.

The number of branches cut from the forest interiors and forest edges was given in Table I brought to the laboratory. Then, the galls were counted to assess the density of *M. fagi* (Tables I, II) and measured for length and weight (Table I). The lengths of the galls per branch were assessed by a trinocular stereozoom microscope with a computer image analyzer program (ImPA®), and the weights by a digital weight scale.

Table I.- Effect of forest edges on the density, length, and weight of galls (Mean±SEM) induced by *M. fagi* on *F. orientalis.*

	Forest interior	Forest edge
Density of gall	0.50±0.06 (n=323)	1.95±0.19 (n=232)
Length of gall	9.33±0.18 (n=102)	9.34±0.25 (n=91)
Weight of gall	0.22±0.01 (n=102)	0.22±0.01 (n=91)

Statistical analysis

Data were tested for normality by the Levene’s test. If necessary, they were log-transformed prior to analysis to meet the assumptions of normality. After that, independent

Table II.- Resulting *independent samples t-test* for the influence of forest edges on the density, length and weights of galls induced by *M. fagi* on *F. orientalis.*

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Density									
Equal variances assumed	70.709	.000	-8.067	553	.000	-3.20804	.39767	-3.9891	-2.4269
Equal variances not assumed			-7.851	445.343	.000	-3.20804	.40860	-4.0111	2.4050
Length									
Equal variances assumed	4.310	.039	-.025	191	.980	-.00788	.31234	-.62395	.60819
Equal variances not assumed			-.025	168.393	.980	-.00788	.31695	-.63358	.61782
Weight									
Equal variances assumed	3.694	.056	-.110	191	.913	-.00196	.01778	-.03703	.03312
Equal variances not assumed			-.109	180.223	.913	-.00196	.01791	-.03731	.03339

samples t-tests were used to test for differences in variables at two sites (forest edges vs forest interior). All the statistical analyses were performed with the significance level of $\alpha=0.05$ using SPSS® 21.0 for Windows® software.

RESULTS

An independent samples t-test was employed to test for the determination of statistical differences between the two data sets obtained from the forest edge and forest interior. *M. fagi*-induced gall density varied significantly ($p<0.05$) between the two experimental sites (forest interior and forest edge) (Tables I, II). The number of galls was significantly higher along the forest edges than in forest interiors (Table II).

We investigated the effects of forest edges on the length of *M. fagi*-induced galls. It was found that the length of the *M. fagi*-induced galls collected from the forest edges and forest interiors did not differ significantly ($p>0.05$) (Tables I, II).

M. fagi-induced galls collected from the forest edges and forest interiors were weighted to examine the difference between the two sites (Table I). Table II showed that there was no significant difference in the mean weight of the galls.

DISCUSSION

During the last decades, researches on plant-herbivore interactions increased considerably (Faria and Fernandes, 2001). Lebel *et al*. (2008) pointed out that host plant selection can be made by the galling female so as to maximize the nutrition of the larvae during its development (Mani, 1964; Rohfritsh, 1992) or to minimize microclimatic conditions stress (Edward and Wratten, 1980). Some other factors could also influence host selection, such as chemical defence (Bryant *et al*., 1983; Coley *et al*., 1985), vigour of the plant module (Price, 1991), biotic and abiotic conditions of forests.

Edges may affect the organisms in a forest fragment by causing changes in the biotic and abiotic conditions (Lovejoy *et al*., 1986; Laurance and Yensen, 1991; Saunders *et al*., 1991; Murcia, 1995). Our data provide strong evidence that forest edges positively affect the abundance of gall midges induced by *M. fagi*. The results of this study show that trees along the forest edges attract the gall midge *M. fagi* probably due to diffrences in the forest structure and microclimate conditions between the trees along the forest edges and in the forest interiors. Our findings were in agreement with other studies. Araujo *et al*. (2011) emphasized that host plants along the edges are more prone to galling insect attack possibly because they are under some level of stress due to edge effect. Plants inhabiting the edges of fragmented habitats may experience high levels of stress, and comparisons of physical and chemical traits of plants found along the edge with those of plants in the interior should provide an indication of the degree of environmental stress caused by the edge effect (Ishino *et al*., 2012).

There was no significant difference in the size and weight of the *M. fagi*-induced galls collected from the forest edges and forest interiors. We also found that there was only one larva in each *M. fagi*-induced galls. Fernandes *et al*. (2003) described the gall inducer *M. fagi* as that are conical, glabrous, yellowish, and one-chambered with only one larva of the galling insect inside.

Skuhravý and Skuhravá (1993, 1996) classified the gall midges into four groups. According to this classification, *M. fagi* occurs abundantly in the study area, but not causing important damage to their host plant *F. orientalis.*

ACKNOWLEDGMENTS

This study is funded by the Scientific Research Projects Committee of Kastamonu University with the project number KUBAP-01/2013-50.

REFERENCES

ALMEIDA-NETO, M., PRADO, P.I. AND LEWINSOHN, T.M., 2011. Phytophagous insect fauna tracks host plant responses to exotic grass invasion. *Oecologia,* **165:** 1051-1062.

ARAUJO, W.S. AND ESPIRITO-SANTO FILHO, K., 2012. Edge effect benefits galling insects in the Brazilian Amazon. *Biodivers. Conserv*., **21**: 2991-2997.

ARAUJO, W.S., JULIAO, G.R., RIBEIRO, B.A., SILVA I.P.A. AND SANTOS, B.B., 2011. Diversity of galling insects in *Styrax pohlii* (Styracaceae): edge effects and use as bioindicators. *Rev. Biol. Trop*., **59**: 1589–1597.

AWMACK, C.S. AND LEATHER, S.R., 2002. Host-plant quality and fecundity in herbivorous insects. *Annu. Rev. Ent.,* **47**: 817–844.

BEGUINOT, J., 2011. Comparison of the severity of selection among beech leaves prior to egg-laying between a leaf-mining and two gall-inducing insects. *Eur. J. Ent.*, **108**: 71–78.

BIERREGAARD Jr. R.O., LOVEJOY, T.E., KAPOS, V., DOS SANTOS, A.A. AND HUTCHINGS, R.W., 1992. The biological dynamics of tropical rain-forest fragments. *Bioscience,* **42:** 859-866.

BRYANT, J.P., CHAPIN, F.S. AND KLEIN, D.R. 1983. Carbon/nutrient balance in boreal plants in relation to vertebrate herbivory. *Oikos,* **40:** 357-368.

CARNEIRO, M.A.A., BRANCO, C.S.A., BRAGA, C.E.D., ALMADA, E.D., COSTA, M.B.M., MAIA, V.C. AND FERNANDES, G.W., 2009. Are gall midge species (Diptera: Cecidomyiidae) host-plant specialist? *Rev. Bras. Ent*., **53**: 365–378.

CONSTANTINO, P.A.L., MONTEIRO, R.F. AND WILSON, M.D., 2009. Gall midge attack intensity and host-plant response in a Neotropical coastal ecosystem. *Rev. Bras. Ent.*, **53**: 391–397.

COLEY, P.D., BRYANT, J.P. AND CHAPIN III, F.S., 1985. Resource availability and plant antiherbivore defence. *Science,* **230**: 895-899.

CORNELL, H.V., 1983. The secondary chemistry and complex morphology of galls formed by the Cynipinae (Hymenoptera): why and how? *Am. Midl. Nat*., **110**: 225–234.

CRAWLEY, M.J., 1997. Plant-herbivore dynamics. In: Plant ecology (ed. M.J. Crawley), 2nd ed., Oxford, Blackwell Scientific Publications. Oxford, U.K. pp. 401–474.

DIDHAM, R.K., TYLIANAKIS, J.M., GEMMELL, N.J., RAND, T.A. AND EWERS, R.M., 2007. Interactive effects of habitat modification and species invasion on native species decline. *Trends. Ecol. Evol.,* **22**: 489–496.

DREGER-JAUFFRET, F. AND SHORTHOUSE, J.D., 1992. Diversity of gall-inducing insects and their galls. In: *Biology of insect-induced galls* (eds. J.D. Shorthouse and O. Rohfritsch), Oxford University Press. Oxford, U.K. pp. 8–33.

DZIURZNSKI, A., 1961. The inhabitants of the galls of *Mikiola fagi* HTG. I. Materials for the morphology and development of *Mikiola fagi* HTG. (Itonididae), as well as of its endophagous primary parasite *Secondes coactus* RATZB. (Chalcididae). *Acta Zool. Cracov.*, **2**: 9–49.

EDWARD, P.J. AND WRATTEN, S.D., 1980. *Ecology of insect-plant interactions.* The Camelot Press., Southampton, UK. 60 pp.

FARIA, M.L. AND FERNANDES, G.W., 2001. Vigour of adioecious shrub and attack by a galling herbivore. *Ecol. Ent.,* **26:** 37-45.

FAY, P.A., HARTNETT, D.C. AND KNAPP, A.K., 1993. Increased photosynthesis and water potentials in *Silphium integrifolium* galled by cynipid wasps. *Oecologia*, **93**: 114-120.

FAY, P.A. AND THROOP, H.L., 2005. Branching responses in *Silphium integrifolium* following mechanical or gall damage to apical meristems and neighbor removal. *Am. J. Bot*., **92**: 954–959.

FERNANDES, G.W., DUARTE, H. AND LÜTTGE, U., 2003. Hypersensitivity of *Fagus sylvatica* L. against leaf galling insects. *Trees*, **17**: 407–411.

FOX, C.W. AND CZESAK, M.E., 2002. Evolutionary ecology of progeny size in arthropods. *Annu. Rev. Ent.*, **45**: 341–369.

FRY, H.R.C., QUIRING, D.T., RYALL, K.L. AND DIXON, P.L. 2009. Influence of intra-tree variation in phenology and oviposition site on the distribution and performance of *Ennomos subsignaria* on mature sycamore maple. *Ecol. Ent.*, **34**: 394–405.

GAGNÉ, R.J., 2004. A catalog of the Cecidomyiidae (Diptera) of the World. *Ent. Soc. Wash.*, **25**: 1-408.

HINES, J., LYNCH, M.E. AND DENNO, R.F., 2005. Sap-feeding insect communities as indicators of habitat fragmentation and nutrient subsidies. *J. Insect Conserv.*, **9**: 261–280.

ISHINO, M.N., DE SIBIO, P.R. AND ROSSI, M.N., 2012. Edge effect and phenology in *Erythroxylum tortuosum* (Erythroxylaceae), a typical plant of the Brazilian Cerrado. *Braz. J. Biol.*, **72**: 587-594.

KAARTINEN, R. AND ROSLIN, T., 2011. Shrinking by numbers: landscape context affects the species composition but not the quantitative structure of local food webs. *J. Anim. Ecol.*, **80**: 622–631.

KAMPICHLER, C. AND TESCHNER, M., 2002. The spatial distribution of leaf galls of *Mikiola fagi* (Diptera: Cecidomyiidae) and *Neuroterus quercusbaccarum* (Hymenoptera: Cynipidae) in the canopy of a Central European mixed forest. *Eur. J. Ent.*, **99**: 79-84.

LARSON, K.C., 1998. The impact of two gall-forming arthropods on the photosynthetic rates of their hosts. *Oecologia***, 115**: 161–166.

LAURANCE, W.F., 2000. Do edge effects occur over large spatial scales? Trends. *Ecol. Evol.*, **15**: 134–135.

LAURANCE, W.F. AND YENSEN, E., 1991. Predicting the impacts of edge effects in fragmented habitats. *Biol. Conserv.*, **55**: 77-92.

LEBEL, P., SILVA, S.C.L. AND CORTEZ, J.A., 2008. Galling insect distribution on *Psychotria barbiflora* (Rubiaceae) in a fragment of Atlantic Forest. *Ecotrópicos*, **21**: 46-53.

LOVEJOY, T.E., BIERREGAARD JR., R.O., RYLANDS, A.B., MALCOLM, J.R., QUINTELA, C.E., HARPER, L.H., BROWN, K.S., POWELL, A.H., POWELL, G.V.N., SCHUBART, H.O.R AND HAYS, M.B., 1986. Edge and other effects of isolation on Amazon forest fragments. In: *Conservation biology: The science of scarcity and diversity* (ed. M.E. Soule), Sinauer Associates, Sunderland, Massachusetts. pp. 257-285.

MANI, M.S., 1964. *Ecology of plant galls.* Junk, The Hague, the Netherlands. 434 pp.

MORRISON, A. AND QUIRING, D., 2009. Intra-plant heterogeneity influences the preference and performance of juveniles and adults of a gall midge. *Ecol. Ent.*, **34**: 287–295.

MURCIA, C., 1995. Edge effects in fragmented forests: implications for conservation. *Tree,* **10**: 58-62.

OBERMAIER, E., HEISSWOLF, A., POETHKE, H.J., RANDLKOFER, B. AND MEINERS, T., 2008. Plant architecture and vegetation structure: two ways for insect herbivores to escape parasitism. *Eur. J. Ent.*, **105**: 233–240.

PERRE, P., LOYOLA, R.D., LEWINSOHN, T.M. AND ALMEIDA-NETO, M., 2011. Insects on urban plants: contrasting the flowers head feeding assemblages on native and exotics hosts. *Urban Ecosyst*., **14**: 711–722.

PRICE, P.W., 1991. The plant vigour hypothesis and herbivore attack. *Oikos,* **62**: 244-251.

PRICE, P.W., FERNANDES, G.W. AND WARING, G.L., 1987. Adaptive nature of insect galls. *Environ. Ent*., **16**: 15–24.

RAMAN, A., SCHAEFER, C.W. AND WITHERS, T.M., 2005. *Biology, ecology, and evolution of gall-inducing arthropods.* Volume 1 and 2, Science Publishers Inc., New Hampshire, pp. 817.

REALE, D. AND ROFF, D.A., 1992. Quantitative genetics of oviposition behaviour and interactions among oviposition traits in the sand cricket. *Anim. Behav*., **64**: 397–406.

REHMAN, H.M., MAHMOOD, R. AND RAZAQ, M., 2013. Phenology, population dynamics and within tree distribution of *Dasineura amaramanjarae* Grover, 1965 (Diptera: Cecidomyiidae) in Punjab, Pakistan. *Pakistan J. Zool*., **45**: 1563-1572.

ROHFRITSH, O., 1992. Patterns in gall development. In: *Biology of insect induced galls* (eds. J.D. Shorthouse and O. Rohfritsh), Oxford University Press. pp. 60-87.

ROHFRITSCH, O. AND SHORTHOUSE, J.D., 1982. Insect galls. In: *Molecular biology of plant tumors* (eds. G. Kahl and J.S. Schell), Academic Press, New York. pp. 131-152.

SAUNDERS, D.A., HOBBS, R.J. AND MARGULES, C.R., 1991. Biological consequences of ecosystem fragmentation: A review. *Conserv. Biol.,* **5**: 18-32.

SKUHRAVÝ, V. AND SKUHRAVÁ, M., 1993. Zur verbreitung und schädlichkeit der gallmücken (Cecidomyiidae, Diptera) an waldbäumen in mitteleuropa. *Anz. Schädlingskd. Pfl.*, **66**: 134–140.

SKUHRAVÝ, V. AND SKUHRAVÁ, M., 1996. Betrachtung der gallmücken (Diptera, Cecidomyiidae) an dominanten forstgehölzen Eurasiens nach ihrem schädlichkeitsgrad mit anführung einiger taxonomischer probleme. *Anz. Schädlingskd. Pfl.*, **69**: 56-58.

STONE, G.N. AND COOK, J.M., 1998. The structure of cynipid oak galls: patterns in the evolution of an extended phenotype. *Proc. R. Soc. Lond. B.*, **265**: 979–988.

STONE, G.N. AND SCHÖNROGGE, K., 2003. The adaptive significance of insect gall morphology. *Trends Ecol. Evol.*, **18**: 512–522.

TABUCHI, K. AND AMANO, H., 2004. Impact of differential parasitoid attack on the number of chambers in multilocular galls of two closely related gall midges (Diptera: Cecidomyiidae). *Evol. Ecol. Res.*, **6**: 695–707.

THOMPSON, J.N. AND PELLMYR, O., 1991: Evolution of oviposition behaviour and host preference in Lepidoptera. *Annu. Rev. Ent.*, **36**: 65–89.

TRAGER, M.D., BOYD, B.M., DANIELS, J.C. AND PENCE, J.A., 2009. Host plant selection, larval survival and reproductive phenology in *Megathymus yuccae* (Lepidoptera: Hesperiidae). *Environ. Ent.*, **38**: 1211–1218.

TSCHARNTKE, T., STEFFAN-DEWENTER, I., KRUESS, A. AND THIES, C., 2002. Characteristics of insect populations on habitat fragments: a mini review. *Ecol. Res.*, **17**: 229–239.

TYLIANAKIS, J.M., TSCHARNTKE, T. AND LEWIS, O.T., 2007. Habitat modification alters the structure of tropical host–parasitoid food webs. *Nature*, **445**: 202–205.

VUORISALO, T., WALLS, M., NIEMELA, P. AND KUITUNENE, H., 1989. Factors affecting mosaic distribution of galls of an eriophyid mite, *Eriophyes laevis*, in alder, *Alnus glutinosa. Oikos*, **55**: 370–374.

WEIS, A.E. AND ABRAHAMSON, W.G., 1986. Evolution of host-plant manipulation by gall makers: ecological and genetic factors in the Solidago–Eurostasystem. *Am. Nat*., **127**: 681–695.

WHITE, J.A. AND ANDOW, D.A., 2006. Habitat modification contributes to associational resistance between herbivores. *Oecologia*, **148**: 482–490.

ZWÖLFER, H. AND ARNOLD-RINEHART, J., 1994. Parasitoids as a driving force in the evolution of the gall size of Urophoraon on Cardueae hosts. In: *Plant galls* (ed. M.A.J. William), Oxford University Press, New York. pp. 245–257.

(Received 30 January 2015, revised 7 March 2015)