





Article

# The Impact of *Cameraria ohridella* (Lepidoptera, Gracillariidae) on the State of *Aesculus hippocastanum* Photosynthetic Apparatus in the Urban Environment

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**Abstract:** The paper presents the results on resistance of *Aesculus hippocastanum* Linnaeus, 1753 trees to *Cameraria ohridella* Deschka & Dimić, 1986 (Lepidoptera, Gracillariidae) impact under conditions of a modern urban environment on the example of Dnipro city as the largest industrial city in Ukraine. Field experiments were conducted in all park areas of the city, which allowed covering the full gradient of the existing urban environment and considered the different degrees of the tree settlement by the invasive insect species. The research of the impact of *C. ohridella* caterpillars' vital activity on the photosynthetic apparatus state was carried out by applying a chlorophyll fluorescence induction technique. Diagnosis of photosynthetic dysfunction of fresh *Ae. hippocastanum* leaves was conducted using a portable "Floratest" fluorometer manufactured in Ukraine. Interpretation of the obtained Kautsky curves showed that significant changes in their critical parameters associated with the degree of leaf damage by *C. ohridella* caterpillars were not detected. The influence of tree growth site conditions on the following 4 main indicators of chlorophyll fluorescence induction was established: the initial value of fluorescence induction after irradiation; the value of "plateau" fluorescence induction; the maximum value of fluorescence induction; the stationary value of fluorescence induction after light adaptation of the plant leaf. It was found that the efficiency coefficients of photochemical processes in *Ae. hippocastanum* trees growing in low terrain levels differed significantly, which can probably be interpreted as their response to the specific characteristics of the urban environment.

**Keywords:** urban environment; invasive insects; biology of invaders; the vital activity of invasive miner moths; resistance of urban dendroflora; adaptation of introducents; photosynthetic apparatus of trees; the Kautsky curve

## 1. Introduction

The environment of an industrial city encompasses a large number of stressors for plants that inhibit their development and vital activity [1–3]. Among the dominant stress

factors that affect living organisms in urban conditions, effects of climate changes associated with rising air temperatures and drought occurrence [4], pesticide contamination from surrounding agrocenoses [5,6], motor transport and industrial enterprises emissions are of particular interest [7–10]. Harmful effects of pollutants can manifest themselves in various functional changes in trees, including their interactions with lepidopteran phytophages [11] and predators that feed on these phytophages [12–14]. In an urban environment, disruption of biochemical reactions, physiological functions, morphostructure, and reduction of resistance to pests and diseases are observed in woody plants depending on concentration of the toxic substances and duration of their exposure.

In the last two decades, horse chestnut (*Aesculus hippocastanum* L.) introduced to the Steppe zone of Ukraine has suffered greatly from the invasive miner *Cameraria ohridella* Deschka & Dimić, 1986, which is manifested in damage of assimilating organs, premature defoliation and resulted in a significant reduction of reserve materials necessary for the normal plant life [15,16]. It worsens the condition and sometimes causes premature death of the trees [17,18].

Diagnostics of the influence of environmental factors for the purpose of rapid assessment of plant functional state requires the use of express and informative techniques that would allow conducting analysis both in the laboratory and in the field conditions with minimal violation of the studied object integrity. Such techniques include the method of chlorophyll fluorescence induction widely applied in modern studies of photosynthetic processes [19–23].

Photosynthesis is one of the processes most vulnerable to stressors, so valuable information on the state of the photosynthetic apparatus in a plant under the impact of phytophage feeding can be obtained by fluorescence analysis [24,25]. The influence of many different urbanized factors on the functional state of woody plant leaves resulted in adaptive changes of plants accompanied by certain morphological changes in the assimilation apparatus, as well as a shift in seasonal developmental rhythms [26,27].

It is known that certain sections of the chlorophyll fluorescence induction curve may be used as indicators of the corresponding physiological processes in the photosynthetic chain. Violations of its particular components caused by exo- and endogenous factors show themselves in specific changes in the corresponding sections of the curve. The photosynthetic apparatus in plants was characterized using the method in many woody plants growing in an urban environment due to its close relationship with chlorophyll fluorescence intensity [28–30]. White oak (*Quercus alba* L.) compared to red maple (*Acer rubrum* L.) shows more significant differences in chlorophyll fluorescence parameters under megalopolis conditions compared to these species growing in native forest conditions [31]. The results of Uhrin & Supuka [32] confirmed that the  $F_v/F_m$  (maximum efficiency of primary photosynthesis processes) parameter proved to be an effective tool for measuring the growth response of roadside sycamore maple (*Acer pseudoplatanus* L.) in the transformed urban environment. Analysis of the  $F_v/F_m$ , Frd (fluorescence reduction coefficient, which characterizes the quantum efficiency of photosynthesis or the viability index), and PCII (stability of light-harvesting complexes photosystem II to the influence of different strains of pathogens) parameters allowed assessing the adaptation potential of wild pear (*Pyrus pyraeaster* L.) and European mountain ash (*Sorbus domestica* L.) trees to water deficiency [33]. Results obtained demonstrate the possibility to use changes in certain sections of the chlorophyll fluorescence induction curve to detect deterioration in the life state of Moreton Bay fig (*Ficus macrophylla* Pers.), london plane (*Platanus × acerifolia* (Aiton) Willd.), Chinese elm (*Ulmus parvifolia* Jacq.) in drought conditions [34], and to assess the resistance of horse chestnut (*Aesculus hippocastanum* L.), small-leaved lime (*Tilia cordata* Mill.), and European white birch (*Betula pendula* Roth.) trees to soil salinization due to the use of salt as deicing agent [35]. It was found that the chlorophyll fluorescence  $F_v/F_m$  parameter of eucalyptus (*Eucalyptus saligna* Sm.) leaves have statistically significant association with wood density and the amount of wood decomposition in summer period [36]. The effect of heavy

trimming of roadside small-leaved lime trees (*Tilia cordata* Mill.) on the photosynthesis process was investigated compared to neighboring non-trimmed trees [37].

Changes in chlorophyll fluorescence parameters may indicate the effect of phytophagous insects on the plant photosynthetic apparatus [38–40]. For example, it has been demonstrated a close relationship between the level of damage of cork oak (*Quercus suber* L.) and holm oak (*Quercus ilex* L.) trees by the great capricorn beetle and chlorophyll content in leaves depending on the age of the phytophage [41]. The effect of different residential densities of *Coccus hesperidum* L. (Hemiptera, Coccidae) per leaf on the plant pigments concentration (chlorophyll a, chlorophyll b, and carotenoids) and chlorophyll fluorescence parameters (maximum quantum yield of photosystem II  $F_v/F_m$ , the effectiveness of “open” reaction centers (RC) in the light  $F_v/F_m$ , and coefficient of non-photochemical quenching of chlorophyll QN and coefficient of photochemical quenching of chlorophyll QP) was studied in lemon plants (*Citrus limon* var. *ponderosa* L.) and ferns (*Nephrolepis biserrata* (Swartz) Schott.). The effect of the degree of infestation with *C. hesperidum* on the pigments loss in plants and changes in the photosynthetic productivity of host plants was characterized [42].

The goal of our study was to establish the effect of *C. ohridella* feeding on the critical parameters of the Kautsky curve of *A. hippocastanum* in different conditions of the urban environment.

## 2. Material and Methods

The research was conducted during the 2019 growing season in Dnipro city (Ukrainian North Steppe subzone). The city is situated in temperate zone with a relatively active atmospheric circulation (the atmospheric circulation is predominantly from east to west). The climate is temperate continental [15,43,44]. One of the climate features in the territory is the wide fluctuations in weather conditions from year to year. Moderately wet years alternate with sharply dry ones, and hot dry winds occurs fairly common. In general, the climate is characterized by rather cool winters and hot summers.

Within Dnipro city territory, we selected eight park ecosystems (Figure 1, Table 1) that have different conditions of horse chestnut growth (Table 2). Four trees of *Ae. hippocastanum* were selected on the territory of each park area with similar morphological and taxational characteristics (trunk diameter 132–151 cm; height 17–21 m).



**Figure 1.** Map of the sampling units within the territory of Dnipro city (Ukraine).

**Table 1.** Characteristics of research areas.

No.	Name	Park Coordinates	Altitude Above Sea Level, m
1	Botanical Garden of DNU	48°26'14" N, 35°02'35" E	127
2	Novokodatskyi Park	48°29'08" N, 34°56'42" E	82
3	Taras G. Shevchenko Park	48°27'48" N, 35°04'23" E	83
4	Pridneprovsky Park	48°23'59" N, 35°07'59" E	75
5	Metallurgists Square	48°28'26" N, 34°59'31" E	65
6	Lazaria Hloby Park	48°28'11" N, 35°01'48" E	56
7	Druzhby narodiv Forest Park	48°32'02" N, 35°05'42" E	65
8	Park Sahaydak	48°29'13" N, 35°03'41" E	50

**Table 2.** Characteristics of the location of parks within the gradient of landscape and soil-climatic conditions.

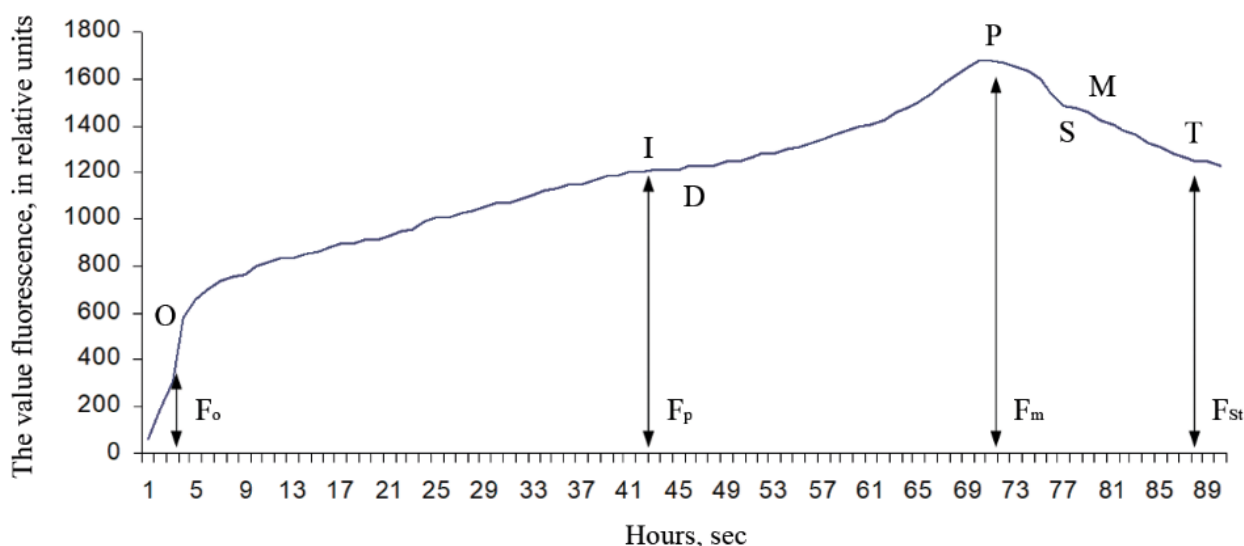
No.	Name	Relief Part (Floodplain, Sandy Terrace, Third Terrace, Ravine, Watershed)	Mechanical Composition of Soil (Sand, Sandy Loam, Loam, Clay)	Soil Humus Content, %	Slope Exposure and Steepness (for Example, 3% Northwest-Facing Slope)	Park Area, ha	Degree and Predominant Type of Anthropogenic Impact (for Example, Moderate Recreation, Heavy Aerogenic Pollution)	Share of a Target Tree of all the Trees in the Park, %
1	Botanical Garden of DNU	Watershed, upper third of ravine	loam	2.3–5.7	7° northeast-facing slope	46	moderate recreation, moderate aerogenic motor vehicle pollution	<1
2	Novokodatskyi Park	floodplane	loam	3.1–3.8	various-exposed slopes, 2–7°	35	moderate recreation, moderate aerogenic motor vehicle pollution, heavy aerogenic industrial pollution,	1.4
3	Taras G. Shevchenko Park	upland with access to watershed	loam	3.2–4.8	15° northwest-facing,	57	moderate recreation, moderate aerogenic industrial pollution	16
4	Pridneprovsky Park	sandy terrace	sandy loam	0.9–1.4	-	7	moderate recreation, heavy aerogenic industrial pollution,	12
5	Metallurgists Square	watershed	loam	2.8–3.4	-	3.8	moderate recreation, moderate aerogenic motor vehicle pollution, moderate aerogenic industrial pollution,	8
6	Lazaria Hloby Park	floodplane	loam	3.3–4.7	-	26	moderate recreation, moderate aerogenic motor vehicle pollution, mild aerogenic industrial pollution	<1
7	Druzhby narodiv Forest Park	third terrace	loam	2.2–4.6	-	90	moderate recreation, moderate aerogenic motor vehicle pollution	<1
8	Park Sahaydak	floodplane	Sandy loam (filling artificial soils)	0.7–1.6	-	34	moderate recreation, moderate aerogenic motor vehicle pollution, moderate aerogenic industrial pollution	<1

To study the effect of *C. ohridella* caterpillars feeding on the photosynthesis processes in *Ae. hippocastanum* plants, leaves of medium formation were selected at 5 pcs. from the illuminated crown exposition (which was mostly infected by a miner). Model leaves were selected on annual vegetative growth from the lower third in dry weather. Each examined leaf was marked individually.

The research was conducted on 14 June 2019, which corresponded to the development of the 5th-age caterpillars of *C. ohridella* second generation, which begins to give an irruption in this generation in the conditions of Dnipro city. The age of the caterpillars was determined with the visual parameters of the mines made by their. The damage degree of the horse chestnut leaf blades by *C. ohridella* was assessed visually with a previously self-developed scale [15]. Light intensity measurements were conducted with RCE-174 luxometer (PCE Instruments, Meschede, Germany, 2018). Temperature and relative humidity measurements were conducted with HE-173 thermohygrometer (Huato Electronic Co.LTD, Shenzhen, China, 2018).

Portable fluorometer “Floratest” was used for the diagnosis of native chlorophyll disorders in fresh *Ae. hippocastanum* leaves. Portable fluorometer “Floratest” comprises a base unit with a graphic liquid crystal display, control buttons, a remote optoelectronic sensor, connecting cable to the USB port of a personal computer, and a network adapter. The remote optoelectronic sensor includes an LED that has a maximum radiation intensity of  $\lambda = 470 \pm 20$  nm. Irradiation indicators in the sensor were the following: irradiation wavelength  $470 \pm 15$  nm; irradiated spot area not less than  $15 \text{ mm}^2$ ; light intensity within the spot at least  $2.4 \text{ W/m}^2$ . Signal reception indicators in an optoelectronic sensor: the spectral range of fluorescence intensity measurement was 670–800 nm; receiving window area  $9 \text{ mm}^2$ ; photodetector sensitivity at  $\lambda = 650$  nm was  $0.45 \text{ A/W}$ .

Observations were made using fresh *Ae. hippocastanum* leaves. After the start of light exposure, the intensity of chlorophyll fluorescence (fluorescence induction or fluorescence induced (caused) by light) begins to change significantly over time. The time dependence of the chlorophyll fluorescence intensity has the characteristic form of a curve having one or more maximum, and it is called the chlorophyll fluorescence induction curve (the Kautsky curve) (Figure 2).



**Figure 2.** Typical chlorophyll fluorescence induction curve [45]:  $F_0$  is the initial value of fluorescence induction after irradiation is turned on;  $F_p$  is the “plateau” fluorescence induction value;  $F_m$  is the maximum value of fluorescence induction;  $F_{St}$  is the stationary value of fluorescence induction after light adaptation of a plant leaf.

The shape of this curve is quite sensitive to changes that occurred in the photosynthetic apparatus in plants when adapting to different environmental conditions, which has become the basis for the widespread use of the Kautsky effect in the study of photosynthesis. To interpretation the Kautsky curve [45], we used its known critical parameters:  $F_0$  means the initial value of fluorescence induction after irradiation is turned on;  $F_p$  means the value of “plateau” fluorescence induction;  $F_m$  means the maximum value of fluorescence induction;  $F_{St}$  means the stationary value of fluorescence induction after light adaptation of a plant leaf. In addition to the critical parameters of the Kautsky curve, we used calculated parameters as variable chlorophyll fluorescence ( $F_v = F_m - F_0$ ); maximum efficiency of primary photosynthesis processes ( $E_f = F_v / F_m$ ), and coefficient of photochemical processes efficiency ( $E = (F_m - F_{St}) / F_{St}$ ).

The data were analyzed using Statistica 8.0 program (StatSoft Inc., USA). The Table 1 demonstrate the results as  $\bar{x} \pm SD$  (mean  $\pm$  standard deviation). The experimental groups were determined using ANOVA and the Tukey test, where the differences were considered significant at  $p < 0.05$ . In the Figures small square is median, the upper and lower line of

the rectangle is 75% and 25% quartiles, the upper line is minimum and maximum values, circles and asterisks is outliers. The empirical correlation coefficient ( $r$ ) and its error ( $Sr$ ) were calculated to assess the association between the Kautsky curve parameters and the degree of leaf blade damage; the  $r/Sr$  ratio was compared with the threshold value of Student's  $t$ -test for a given sample size.

### 3. Results

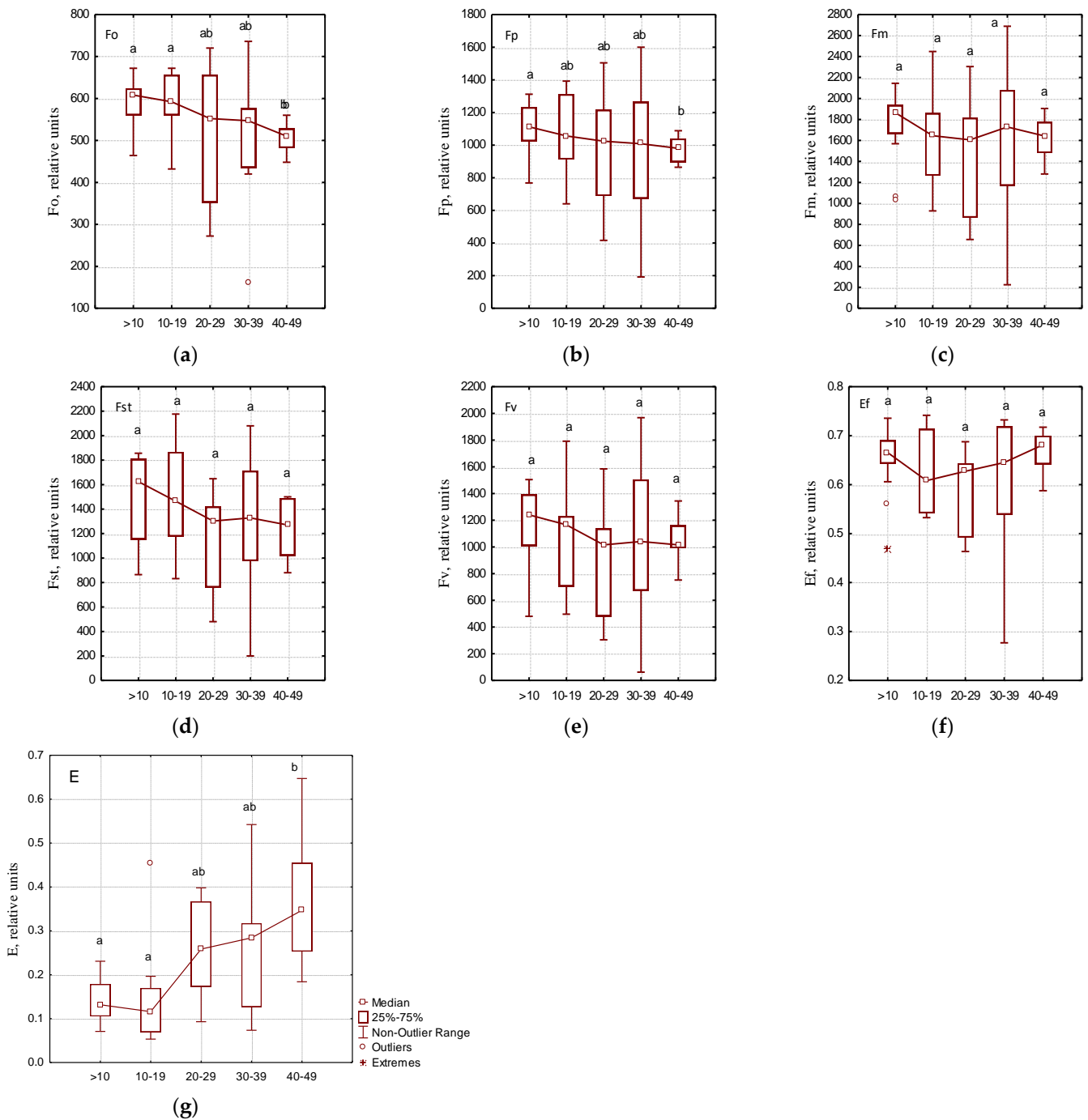
As a result of the phytosanitary monitoring of park areas in Dnipro city, it was found that the trees of *Ae. hippocastanum* were not equally infected with *C. ohridella* (Table 3). The analysis of chlorophyll fluorescence induction variability showed specific patterns of changes in a number of physiological parameters of photosynthesis. Significant changes in the critical parameters of the Kautsky curve depending on the degree of leaf blade damage by *C. ohridella* caterpillars were not detected (Figure 3).

**Table 3.** Average damage level of *Ae. hippocastanum* leaf blades by *C. ohridella* miner ( $\bar{x} \pm SD$ ,  $n = 40$ ).

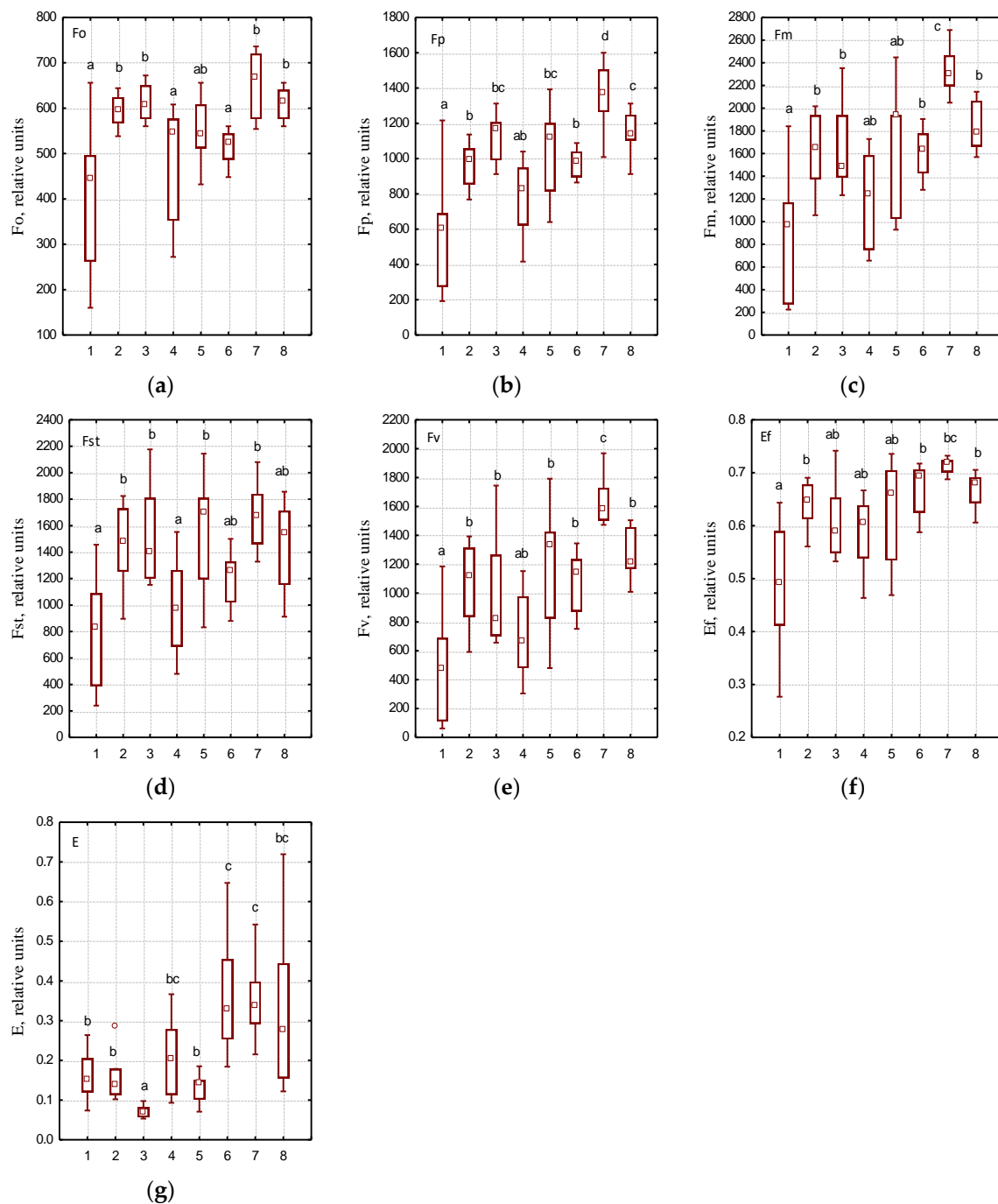
No.	Name	Average Damage Level
1	Botanical Garden of DNU	$0.36 \pm 0.008$
2	Novokodatskyi Park	$0.06 \pm 0.003$
3	Taras G. Shevchenko Park	$0.16 \pm 0.007$
4	Pridneprovsky Park	$0.36 \pm 0.006$
5	Metallurgists Square	$0.12 \pm 0.004$
6	Lazaria Hloby Park	$0.47 \pm 0.017$
7	Druzhby narodiv Forest Park	$0.35 \pm 0.011$
8	Park Sahaydak	$0.08 \pm 0.009$

The use of the fluorescence analysis method allowed the determination the effect of growing site conditions on individual indicators of chlorophyll fluorescence induction in the leaves of the studied *Ae. hippocastanum* trees (Figure 3). High plasticity was established in the structure of chloroplasts in horse chestnut leaves which was characterized with  $F_0$ ,  $F_v$ ,  $F_p$ , and  $F_{St}$  parameters. We found significant differences in the above parameters in *Ae. hippocastanum* leaves sampled from Botanical Garden of DNU compared to the leaves of the studied plant species sampled from different parks in Dnipro city. It was noted that the efficiency coefficients of photochemical processes ( $E$ ) in *Ae. hippocastanum* trees in the parks located at low terrain levels were grouped separately (Figure 4c). The lowest  $E$  values were recorded in horse chestnut trees in Botanical Garden of DNU, Novokodatskyi Park, Taras G. Shevchenko Park, and Metallurgists Square; this may indicate a decrease in the intensity of photochemical reactions.

Of all the parameters of the Kautsky curve (Table 4), only  $E$  values correlated with the degree of leaf blade damage by phytophages ( $p < 0.05$ ). At the same time, a very high degree of correlation was found between the remaining parameters of the Kautsky curve:  $F_p$ ,  $F_m$ ,  $F_{st}$ ,  $F_v$ , and  $E_f$  ( $p < 0.001$ ).



**Figure 3.** Measurements of physiological parameters of photosynthesis depending on the leaf damage degree: (a)— $F_0$ —the initial value of fluorescence induction after switching on irradiation, (b)— $F_p$ —the value of fluorescence induction “plateau”, (c)— $F_m$ —the maximum value of fluorescence induction, (d)— $F_{st}$ —the steady value of fluorescence induction after light adaptation of the leaf of the plant, (e)— $F_v$ —variable chlorophyll fluorescence, (f)— $E_f$ —the maximum efficiency of primary photosynthesis processes, (g)— $E$ —efficiency coefficients of photochemical processes; different letters within each figure indicate significant differences between the groups ( $p < 0.05$ ) according to the results of Tukey test,  $n = 7$ .



**Figure 4.** Variability of photosynthesis characteristics in various urban parks of Dnipro city: (a)— $F_0$ —the initial value of fluorescence induction after switching on irradiation, (b)— $F_p$ —the value of fluorescence induction “plateau”, (c)— $F_m$ —the maximum value of fluorescence induction, (d)— $F_{st}$ —the steady value of fluorescence induction after light adaptation of the leaf of the plant, (e)— $F_v$ —variable chlorophyll fluorescence, (f)— $E_f$ —the maximum efficiency of primary photosynthesis processes, (g)— $E$ —efficiency coefficients of photochemical processes; at the x-axis: 1—Botanical Garden of DNU, 2—Novokodatskyi Park, 3—Taras G. Shevchenko Park, 4—Pridneprovsky Park, 5—Metallurgists Square, 6—Lazaria Hloby Park, 7—Druzhby narodiv Forest Park, 8—Park Sahaydak; at the y-axis: the values of parameters indicated in Table 1; please see Figure 3 for an explanation of statistical processing.



**Table 4.** Correlations between the Kautsky curve parameters and the degree of leaf damage by phytophages ( $n = 40$ ).

Characteristic	Leaf Damage Degree, %	F <sub>0</sub>	F <sub>p</sub>	F <sub>m</sub>	F <sub>st</sub>	F <sub>v</sub>	E <sub>f</sub>	E
Leaf damage degree, %	1	–	–	–	–	–	–	–
F <sub>0</sub>	–0.276 ± 0.156	1	–	–	–	–	–	–
F <sub>p</sub>	–0.201 ± 0.159	0.933 ± 0.058 ***	1	–	–	–	–	–
F <sub>m</sub>	–0.127 ± 0.161	0.853 ± 0.085 ***	0.952 ± 0.050 ***	1	–	–	–	–
F <sub>st</sub>	–0.263 ± 0.157	0.812 ± 0.095 ***	0.890 ± 0.074 ***	0.945 ± 0.053 ***	1	–	–	–
F <sub>v</sub>	–0.079 ± 0.162	0.768 ± 0.104 ***	0.909 ± 0.068 ***	0.990 ± 0.023 ***	0.933 ± 0.058 ***	1	–	–
E <sub>f</sub>	–0.053 ± 0.162	0.659 ± 0.122 ***	0.774 ± 0.103 ***	0.889 ± 0.074 ***	0.837 ± 0.089 ***	0.907 ± 0.068 ***	1	–
E	0.320 ± 0.154 *	0.108 ± 0.161	0.143 ± 0.161	0.128 ± 0.161	–0.191 ± 0.159	0.127 ± 0.161	0.148 ± 0.160	1

Notes: \*— $p < 0.05$ , \*\*\*— $p < 0.001$ .

#### 4. Discussion

The analysis of chlorophyll fluorescence induction variability allowed determining specific patterns of changes in series of photosynthesis physiological parameters. The background fluorescence level ( $F_0$ ) depends on the loss of excitation energy during migration along pigment matrix, as well as on the content of chlorophyll molecules that do not functionally associated with reaction centers [46,47]. The maximum values of  $F_0$  parameter were recorded in the *Ae. hippocastanum* leaves sampled from Park Sahaydak and Novokodatskyi Park, and the lowest values were observed in leaves sampled from Lazaria Hloby Park. This is due to the fact that a structural change in the pigment complex associated with the loss of green leaf tissues under the phytophage influence. As the number of antenna chlorophylls decreases, the initial level of fluorescence decreases, and vice versa.

The  $F_p$  parameter characterizes the highest level of fluorescence, i.e., it means the maximum value on the induction curve. It has the most variable pattern characterized by adaptive changes [48]. In the structure of the pigment complex in the studied *Ae. hippocastanum* plants, the lowest  $F_p$  values were found in trees having the highest degree of leaf damage by *C. ohridella* larvae (Botanical Garden of DNU, Lazaria Hloby Park, and Pridneprovsky Park). It was caused by a decrease in the number of both light-harvesting and antenna chlorophylls. The obtained data are supported by the tendency to decrease the variable fluorescence of chlorophyll ( $F_v$ ) with an increase in the damage degree of horse chestnut leaves by mining moth larvae. The calculated  $F_v$  parameter is expressed as the difference between the highest level of fluorescence and background fluorescence indicating the amplitude value of changes in the Kautsky curve [49,50].

The value of the steady-state fluorescence level ( $F_{st}$ ) also decreased with an increasing degree of damage of *Ae. hippocastanum* leaves. This parameter is characterized by a dynamic equilibrium between the processes that cause an increase in fluorescence and the processes that lead to its decrease [51]. As shown in Figure 3, there is a significant difference in the values of all key parameters of chlorophyll fluorescence induction. We have shown that an increase in the number of *C. ohridella* mines reduces the values of all major indicators ( $F_0$ ,  $F_v$ ,  $F_p$  and  $F_{st}$ ), which affects the overall physiological state of *Ae. hippocastanum* leaves. In general, plant defense responses to insect attacks are very often associated with a decrease in the rate of photosynthesis [52]. Genotypes that are capable to maintain the rate of photosynthesis under these conditions probably show greater resistance, i.e., the plant's ability to grow, develop, and bear fruit satisfactorily even at a certain level of herbivorous insect infestation [53].

Another important indicator to assess the functional state of the leaves is the efficiency of dark photochemical reactions, E. This parameter reflects the relative number of electrons transported along the electron transport chain. Increasing the efficiency of dark photochemical reactions in the leaves of *Ae. hippocastanum* sampled in Lazaria Hloby Park, Druzhby narodiv Forest Park, Park Sahaydak shows that electronic transport on FSII and FSI is more efficient, while some decrease in E parameter may indicate inhibition of dark photochemical reactions. In addition, the reduction of E coefficient in the leaves *Ae. hippocastanum* sampled in Botanical Garden of DNU, Novokodatskyi Park, Taras G. Shevchenko Park and Metallurgists Square (especially against the background of  $F_0$  increasing), may indicate not

only a decrease in the intensity of photochemical reactions, but also destructive changes in the photosynthetic apparatus [54,55].

The value of the efficiency coefficient of dark photochemical processes (E) reflects the activity of ribulose biphosphate carboxylase as the main enzyme in the Calvin cycle. Apparently, ribulose biphosphate carboxylase has not only carboxylase activity, but also oxygenase activity; thereby, an increase in this enzyme activity can be associated with an increase in the process competitive to photosynthesis, photorespiration. The photorespiration can account for up to 50% of the enzyme activity. Our correlation analysis confirmed the current data of numerous researchers [56,57] about the fact that photorespiration process has a protective effect on the photosynthetic apparatus in plants, and its intensity significantly increases under the action of stress factors.

## 5. Conclusions

Effect of *C. ohridella* caterpillars on the photosynthetic apparatus in *Ae. hippocastanum* allowed determining specific patterns of changes in critical parameters of chlorophyll fluorescence induction. Significant changes in the critical parameters of the Kautsky curve depending on the degree of leaf blade damage by *C. ohridella* caterpillars were not identified. The use of the fluorescence analysis method allowed determining the effect of growing site conditions on individual indicators of chlorophyll fluorescence induction in the leaves of the studied *Ae. hippocastanum* trees. High plasticity was established in the structure of chloroplasts in horse chestnut leaves which was characterized with  $F_o$ ,  $F_v$ ,  $F_p$ , and  $F_{St}$  parameters. We found significant differences in the above parameters in *Ae. hippocastanum* leaves sampled from Botanical Garden of DNU compared to the leaves of the studied plant species sampled from different parks in Dnipro city. It was noted that the efficiency coefficients of photochemical processes (E) in *Ae. hippocastanum* trees in parks located at low terrain levels were differed markedly. The lowest efficiency coefficients of dark photochemical reactions were recorded in horse chestnut trees from the Botanical Garden of DNU, Novokodatskyi Park, Taras G. Shevchenko Park, and Metallurgists Square, which can probably be associated with the urban environment characteristics.

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