Plant & Fungal Research (2026) 9 (1): 90-95
https://doi.org/10.30546/2664-5297.2026.9.01.095
ISSN 2617-8001 (print), ISSN 2664-5297 (online)

Effects of imidacloprid-based pesticides on *Cladophora glomerata* (L.) Kütz. collected from Zangilan district

Shafiga S. Umudova[1], Shakar J. Mukhtarova

Institute of Botany Public Legal Entity, Ministry of Science and Education of the Republic of Azerbaijan, A. Abbaszade str., entr. 99, Az1073, Baku, Azerbaijan

[1]Corresponding author (e-mail: *ushafiga@gmail.com*)

Abstract: Pesticides transported from agricultural land into freshwater ecosystems may adversely affect aquatic organisms and disrupt ecological balance. This study investigated the effects of two imidacloprid-based pesticides (Kingprid and Kingema) on *Cladophora glomerata* collected from Zangilan district. This filamentous green alga was selected as a model organism due to its sensitivity to environmental changes and its ecological role as a primary producer in freshwater habitats. Chlorophyll content, cell viability, and structural alterations were evaluated as indicators of stress. The results showed that both pesticide formulations led to a marked decline in chlorophyll content and cellular viability, with the intensity of effects increasing under higher exposure levels. At lower exposure, only slight pigment fading and minor structural modifications were observed, whereas higher exposure resulted in pronounced discoloration, membrane damage, cytoplasmic shrinkage, and fragmentation of algal filaments. Comparative analysis indicated that Kingprid exerted a stronger toxic effect than Kingema across all observed parameters. One-way ANOVA confirmed statistically significant differences among the treatments ($p < 0.001$), demonstrating a clear relationship between pesticide exposure and algal response. These findings suggest that imidacloprid-based pesticides can negatively impact freshwater algal communities, potentially reducing primary productivity and altering ecosystem stability. The study highlights the importance of incorporating algal bioassays and bioindicator species into ecological risk assessment and environmental monitoring programs, particularly in regions with increasing agricultural activity, such as the Zangilan district.

Keywords: *aquatic pollution, bioindicators, cell viability, chlorophyll degradation, ecological stress, filamentous algae, Kingema, Kingprid, pesticide toxicity*

INTRODUCTION

With the intensification of agriculture, the possibility of agrochemicals entering natural water bodies is also increasing. As a result of rainfall, irrigation and drainage processes, these substances can be transported from agricultural fields to nearby rivers and other aquatic ecosystems. This leads to prolonged exposure of organisms living in the aquatic environment to chemicals at a low concentration [Lozano et al., 2025; Onyango et al., 2024]. Since aquatic ecosystems are mainly based on primary production processes, any change affecting photosynthetic organisms can spread along the trophic chain and affect the overall balance of the ecosystem.

Neonicotinoid insecticides are considered to be agrochemicals that have attracted particular attention from an environmental perspective in recent years. Imidacloprid, one of the widely used representatives of this group, is widely used against pests in agriculture and various studies have reported that its traces have been detected in surface waters near agricultural fields [Nagai et al., 2011; Shoaib, 2019]. Although these substances are mainly designed to affect the nervous system of insects, they can also cause indirect stress effects on photosynthetic organisms living in the aquatic environment [Nugnes et al., 2022]. Algae are considered one of the main components of primary production in aquatic ecosystems and are very sensitive to changes in the environment. Under the influence of chemicals, algal cells usually do not immediately die, but rather their metabolism tries to adapt to new conditions. This process can be accompanied by physiological changes such as weakening of photosynthesis, changes in pigment balance and increased oxidative stress [Muniz, 1990; Brown, Lean, 1995]. Observation of such early reactions commonly pollution processes occurring in aquatic ecosystems at an earlier stage.

The filamentous green algae *Cladophora glomerata* (L.) Kütz. is widely distributed in the shallow zones of rivers and streams. These algae can develop in areas with sufficient light and solid substrates, forming a dense filamentous cover. Due to their morphological

Received: 08.01.2026; Received in revised form: 06.02.2026; Accepted: 29.05.2026
Citation: Umudova, Sh. S., Mukhtarova, Sh. J. (2026). Effects of imidacloprid-based pesticides on *Cladophora glomerata* (L.) Kütz. collected from the Zangilan district. *Plant & Fungal Research*, *9*(1), 90-95.

structure, they are sensitive to chemical changes in the aquatic environment, since they are in direct and constant contact with water, and therefore are often used to determine ecological stress in aquatic ecosystems [Vonk, Kraak, 2020].

The research took place in Zangilan district in southwestern Azerbaijan, which is part of the Araz River basin. The River Okhchuchay and a number of its tributaries flow through the district, forming diverse freshwater ecosystems. In these areas, shallow areas, water flow variability, and rocky substrates create favorable conditions for the development of filamentous algae [Müseyibov, 1998].

As a result of many years of war and anthropogenic impacts, pollution has been observed in some water bodies of the district. In the post-war period, along with the restoration of territories and the gradual development of agriculture, the use of agrochemicals is expected to increase. This may increase the likelihood of pesticides entering aquatic ecosystems in the future and intensify their impact on organisms living in the aquatic environment [Huang et al., 2025; Nadudvari et al., 2025].

In this regard, studying the impact of pesticides on aquatic ecosystems is considered particularly relevant. In districts where agricultural activities are expanding, pesticide residues can enter rivers and other water bodies and cause various physiological and structural changes in algal communities and other aquatic organisms.

The aim of this study is to investigate the physiological and structural changes that occur when *Cladophora glomerata* (L.) Kütz. algae collected from freshwater bodies of Zangilan district are exposed to imidacloprid-containing pesticide (Kingprid and Kingema). The results obtained are expected to contribute to a better understanding of pesticide-induced stress mechanisms in freshwater ecosystems and to future ecological monitoring studies in the district.

MATERIAL AND METHODS

Study material and preparation. The study was conducted using samples of filamentous *Cladophora glomerata* (L.) Kütz. collected from freshwater habitats along the Okhchuchay River within Zangilan district (Jahangirbarli area, southwestern Azerbaijan; 39°03′09″ N, 46°44′20″ E). The samples were obtained from shallow zones with rocky substrates. During collection, care was taken not to disturb the natural structure of the filaments. The material was then transferred to the laboratory using cooled containers to limit possible stress effects. After preparation, the samples were placed in Petri dishes and left in the laboratory for a short time before the experiment [APHA, 2005; Thomas et al., 2020].

Pesticide exposure. The collected algal material was subjected to imidacloprid-containing pesticides (Kingprid and Kingema). Kingprid and Kingema (King Wing, China) were purchased from local agricultural suppliers. Both formulations are commercial products of King Wing and were comparatively evaluated in order to assess their neonicotinoid-like stress effects on freshwater algal cells under laboratory conditions. Four experimental conditions were established: control (untreated), 0.01%, 0.05%, and 0.1% pesticide concentrations. Individual filaments were distributed into separate Petri dishes, with four samples used for each condition. To reduce random variation, the entire procedure was carried out in three independent runs.

Experimental conditions. All samples were kept under the same environmental conditions throughout the experiment. Light exposure and temperature remained unchanged for all treatments. Handling was kept minimal, and particular attention was given to avoiding physical disturbance or contamination of the filaments [Thomas et al., 2020].

Methodological remarks. The general approach followed commonly applied laboratory practices used in in vitro studies of filamentous algae. Rather than relying on a rigid protocol description, the procedure was carried out step by step under controlled conditions, ensuring consistency during observations and measurements.

Statistical analysis. The experimental data obtained from control and pesticide-treated samples were statistically evaluated to determine the significance of the observed changes under different exposure levels. Comparative analysis for each pesticide treatment was performed separately using one-way analysis of variance (one-way ANOVA). The analysis included the calculation of sum of squares (SS), degrees of freedom (df), mean squares (MS), F-statistic (F), p-values, and critical F values (F crit). Differences among treatments were considered statistically significant at $p < 0.001$. All statistical calculations were performed using JASP.

RESULTS AND DISCUSSION

Effects of Kingprid and Kingema on green algae: Chlorophyll degradation. No visible changes were recorded in the control samples throughout the experiment. The algae maintained their normal green coloration, and both visual inspection and spectrophotometric data confirmed that chlorophyll levels remained stable. A different pattern emerged in the treated groups. With Kingprid exposure, the earliest response was a slight loss of green intensity, which became more noticeable as exposure increased. At a low concentration, the change was minimal and limited to mild fading. An increase in concentration caused a clear decrease in green pigmentation. At the highest concentration, the amount of chlorophyll decreased sharply, and some samples became almost completely colorless. Kingema produced a similar overall response, although the effects were less pronounced compared with Kingprid. Even at the lowest concentration, a reduction in pigment intensity was already visible. At moderate and high concentrations, the filaments shifted strongly away from their normal green state, often showing yellowish or brownish coloration, which suggests a stronger disruption of the photosynthetic pigments.

Algal vitality. No changes were observed in the control samples, and the cells maintained their integrity with a well-preserved filamentous organization. In contrast, the changes in the cells exposed to Kingprid occurred gradually. At a low concentration, most cells still looked normal, with minimal structural effects. With higher exposure levels, cellular damage became more evident, particularly cytoplasmic shrinkage and distortion of cell walls. At elevated concentrations, damage became more severe, with membrane breakdown and leakage of cellular material. In the 0.05% solution, the frequency of plasmolysis and cytoplasmic changes increased. In the 0.1% solution, disruption of the cell membrane, cytoplasmic leakage, and disintegration of the filament structure were widely observed. The results of the ANOVA analysis are presented in Table 1 and Table 2.

Comparative evaluation. Both pesticides accelerated chlorophyll degradation and decreased cell viability in *Cladophora glomerata* (L.) Kütz. algae in a concentration-dependent manner. However, the effect of Kingprid pesticide was more aggressive, causing faster physiological and structural changes even at lower concentrations. Kingema had a relatively weaker effect, and the changes were mainly observed more clearly at higher concentrations. (Fig. 1) shows chlorophyll and filament changes under increasing pesticide concentrations.

A one-way ANOVA analysis showed that pesticide concentration had a statistically significant effect on the viability of *Cladophora glomerata* algae ($p < 0.001$). For the Kingprid pesticide, the results indicated that changes in concentration were associated with a very strong effect on algal viability ($F = 820.5$, $p < 0.001$). The high F value indicates that the differences between the tested concentrations are highly significant. As the concentration of Kingprid increased, a noticeable decrease in the viability of *Cladophora glomerata* algae became evident, which points to a strong toxic effect of the pesticide on algal cells. In a similar way, the Kingema pesticide was also associated with a statistically significant effect on the viability of *Cladophora glomerata* algae ($F = 597.2$, $p < 0.001$).

The ANOVA results indicate that increasing pesticide concentration leads to a significant reduction in algal viability (disruption of the cell membrane, cytoplasmic leakage, and disintegration of the filament structure) compared to the control group. When the effects of both pesticides were compared, it was determined that Kingprid exhibited a stronger inhibitory effect than Kingema. This is explained by its higher F value and the greater decrease in viability with increasing concentration. Taken together, the results show that increasing pesticide concentration is linked to a significant reduction in algal viability and this points to a potential ecological impact

Table 1. One-way ANOVA analysis showing the effect of different concentrations of Kingprid pesticide on the viability of *Cladophora glomerata* (L.) Kütz.

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	6540.2	3	2180.07	820.5	<0.001	4.07
Within groups	21.3	8	2.66			
Total	6561.5	11				

Note: SS – Sum of Squares; df – degrees of freedom; MS – Mean Square; F – F-statistic; P-value – significance level; F crit – critical F value.

Table 2. One-way ANOVA analysis of the effect of different concentrations of Kingema pesticide on the viability of *Cladophora glomerata* (L.) Kütz.

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	4675.6	3	1535.33	597.2	<0.001	4.07
Within groups	20.9	8	2.61			
Total	4696.5	11				

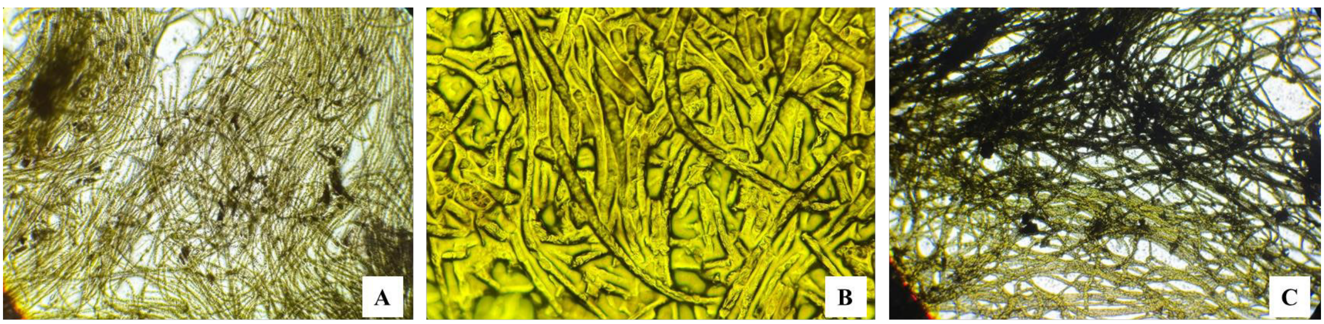

Figure 1. Changes in chlorophyll content and filament structure under increasing pesticide concentrations. A- control, B- Kingema, C- Kingprid

of agricultural pesticides on algal communities in freshwater ecosystems.

CONCLUSION

This study investigated how the imidacloprid-containing pesticides Kingprid and Kingema affect the filamentous alga *Cladophora glomerata* (L.) Kütz. The findings indicate that both substances promote chlorophyll breakdown and decrease cell viability. These effects intensified as the concentration increased. Notably, even at lower concentrations, early signs of physiological stress were detected in the algal filaments. Comparative analysis revealed that the Kingprid pesticide had a stronger impact on algal cells compared to Kingema. At higher concentrations, the cell structure was disrupted and the filaments began to break apart. The obtained results indicate that pesticides can have negative effects on primary producers in aquatic ecosystems. Therefore, monitoring the ecological impact of pesticides in aquatic environments is of great importance.

REFERENCE

APHA: American Public Health Association. (2005). Standard methods for the examination of water and wastewater. American Water Works Association/ Water Environment Federation, Washington DC.

Brown, L. S., & Lean, D. R. S. (1995). Toxicity of selected pesticides to lake phytoplankton measured using photosynthetic inhibition. *Environmental Toxicology and Chemistry 14*(1), 93-98. https://doi.org/10.1002/etc.5620140111

Huang, J., Piao, X., Zhou, Y., & Li, S. (2025). Toxicity assessment of 36 herbicides to green algae: Effects of mode of action and chemical family. *Agrochemicals*, *3*(2), 164-180 https://doi.org/10.3390/agrochemicals3020012

Lozano, V. L., Alvarez Dalinger, F. S., & Moraña, L. B. (2025). The insecticide imidacloprid promotes algal growth in absence of zooplankton. *Journal of Xenobiotics*, *15*(3), 90. https://doi.org/10.3390/jox15030090

Muniz, I. P. (1990). Freshwater acidification: Its effects on species and communities of freshwater microbes, plants and animals. Proceedings of the Royal Society of Edinburgh Section B: *Biological Sciences*, *97*, 227-254. https://doi.org/10.1017/S0269727000005364

Museyibov, M. A. (1998). Physical geography of Azerbaijan. Baku. pp. 156-195 [Müseyibov M.A. (1998). Azərbaycanın fiziki coğrafiyası. Bakı, s.156-195.]

Nadudvari, A., Schagerl, M., & Ancheta, S. M. (2025). Possible effects of pesticide washout on microalgae growth. *Water*, *17*(18), 2716. https://doi.org/10.3390/w17182716

Nagai, T., Ishihara, S., Yokoyama, A., & Iwafune, T.

(2011). Effects of four rice paddy herbicides on algal cell viability and the relationship with population recovery. *Environmental Toxicology and Chemistry*., *30*(8), 1898-1905. https://doi.org/10.1002/etc.582

Nugnes, R., Russo, C., Orlo, E., Lavorgna, M., & Isidori, M. (2022). Imidacloprid: Comparative toxicity, DNA damage, ROS production and risk assessment for aquatic non-target organisms. *Environmental Pollution*, *316*(2), 120682. https://doi.org/10.1016/j.envpol.2022.120682

Onyango, J., van Bruggen, J. J. A., Kitaka, N., Simaika, J., & Irvine, K. (2024). Effects of combined nutrient and pesticide exposure on algal biomass and *Daphnia magna* abundance. *Environmental Systems Research 13*(1), 1. DOI: 10.1186/s40068-023-00321-0

Shoaib, N., & Ikram, N. (2019). Effects of pesticides on photosynthesis of marine phytoplankton. *Bangladesh Journal of Botany*, *47*(4): 401-408.

Thomas, M. C., Flores, F., Kaserzon, S., Fisher, R., & Negri, A. P. (2020). Toxicity of ten herbicides to the tropical marine microalgae *Rhodomonas salina*. *Scientific Reports*, *10*, 7612. https://doi.org/10.1038/s41598-020-64116-y

Vonk, J. A., & Kraak, M. H. S. (2020). Herbicide exposure and toxicity to aquatic primary producers. *Reviews of Environmental Contamination and Toxicology 250*, 119-171. https://doi.org/10.1007/398_2020_48

Zəngilan rayonundan toplanmış *Cladophora glomerata* (L.) Kütz. yosununa imidakloprid tərkibli pestisidlərin təsirinin qiymətləndirilməsi

Şəfiqə S. Umudova, Şəkər C. Muxtarova
Botanika İnstitutu Publik Hüquqi Şəxs, Azərbaycan Respublikası Elm və Təhsil Nazirliyi, A. Abbaszadə küç., giriş 99, AZ1073, Azərbaycan

Kənd təsərrüfatı sahələrindən şirin su ekosistemlərinə daxil olan pestisidlər su orqanizmlərinə mənfi təsir göstərə və ekoloji tarazlığı poza bilər. Bu tədqiqatda Zəngilan rayonundan toplanmış *Cladophora glomerata* yosununa imidakloprid tərkibli iki pestisidin (Kingprid və Kingema) təsiri araşdırılmışdır. Bu filamentli yaşıl yosun ətraf mühit dəyişikliklərinə həssaslığı və şirin su ekosistemlərində ilkin istehsalçı kimi mühüm rolu baxımından model orqanizm kimi seçilmişdir. Stress göstəriciləri kimi xlorofilin miqdarı, hüceyrə canlılığı və struktur dəyişiklikləri qiymətləndirilmişdir. Nəticələr göstərmişdir ki, hər iki pestisid xlorofil miqdarının və hüceyrə canlılığının əhəmiyyətli dərəcədə azalmasına səbəb olmuş, bu təsir yüksək səviyyələrində daha intensiv olmuşdur. Aşağı təsir səviyyələrində yalnız zəif piqment solması və cüzi struktur dəyişiklikləri müşahidə olunmuşdur və yüksək təsir zamanı ciddi rəngsizləşmə, hüceyrə membranının zədələnməsi, sitoplazmanın yığılması və filamentlərin parçalanması qeydə alınmışdır. Müqayisəli analiz göstərmişdir ki, Kingprid preparatı Kingema ilə müqayisədə daha güclü toksik təsir göstərmişdir. Bir faktorlu dispersiya analizi (ANOVA) variantlar arasında statistik cəhətdən əhəmiyyətli fərqlərin olduğunu təsdiq etmişdir ($p < 0.001$) və pestisid təsiri ilə yosun reaksiyası arasında aydın əlaqə olduğunu göstərmişdir. Əldə olunan nəticələr imidakloprid tərkibli pestisidlərin şirin su yosun birliklərinə mənfi təsir göstərir, ilkin məhsuldarlığı azaldır və ekosistem sabitliyini pozur. Tədqiqat, xüsusilə kənd təsərrüfatı fəaliyyəti artan bölgələrdə, o cümlədən Zəngilan rayonunda, ekoloji risklərin qiymətləndirilməsi və monitorinq proqramlarında yosun bioindikatorlarının istifadəsinin vacibliyini vurğulayır.

Açar sözlər: *su çirklənməsi, bioindikatorlar, hüceyrə canlılığı, xlorofilin parçalanması, ekoloji stress, sapşəkilli yosunlar, Kingema, Kingprid, pestisid toksikliyi*

Оценка воздействия имидаклопридсодержащих пестицидов на водоросль *Cladophora glomerata* (L.) Kütz., собранную в Зангиланском районе

Шафига С. Умудова, Шакар Дж. Мухтарова
Институт ботаники Публичное Юридическое Лицо, Министерство Науки и Образования Азербайджанской Республики, ул. А. Аббасзаде, подезд 99, AZ1073, Баку, Азербайджан

Пестициды, поступающие из сельскохозяйственных территорий в пресноводные экосистемы, могут оказывать неблагоприятное воздействие на водные организмы и нарушать экологическое равновесие. В данном исследовании изучено влияние двух имидаклопридсодержащих пестицидов (Kingprid и Kingema) на водоросль *Cladophora glomerata*, собранную в Зангиланском районе. Данная нитчатая зелёная водоросль была выбрана в качестве модельного организма, благодаря своей чувствительности к изменениям окружающей среды и важной роли первичного продуцента в пресноводных экосистемах. В качестве показателей стрессового воздействия оценивались содержание хлорофилла, жизнеспособность клеток и структурные изменения. Результаты показали, что оба пестицида вызывали значительное снижение содержания хлорофилла и жизнеспособности клеток, причём эффект усиливался при увеличении уровня воздействия. При низком уровне воздействия наблюдались лишь незначительное обесцвечивание пигмента и слабые структурные изменения, тогда как при более высоком уровне отмечались выраженная потеря окраски, повреждение клеточных мембран, сжатие цитоплазмы и фрагментация нитчатой структуры. Сравнительный анализ показал, что препарат Kingprid оказывал более сильное токсическое воздействие по сравнению с Kingema. Однофакторный дисперсионный анализ (ANOVA) подтвердил статистически значимые различия между вариантами ($p < 0.001$), что указывает на чёткую зависимость между уровнем воздействия пестицидов и реакцией водорослей. Полученные результаты свидетельствуют о том, что имидаклопридсодержащие пестициды могут негативно влиять на сообщества пресноводных водорослей, снижать первичную продуктивность и нарушать устойчивость экосистем. Исследование подчёркивает важность использования водорослей в качестве биоиндикаторов при оценке экологических рисков и проведении экологического мониторинга, особенно в регионах с развивающейся сельскохозяйственной деятельностью, таких как Зангиланский район.

Ключевые слова: *загрязнение воды, биоиндикаторы, жизнеспособность клеток, деградация хлорофилла, экологический стресс, нитчатые водоросли, Kingema, Kingprid, токсичность пестицидов*