

Relationship of soil salinization in Apsheron with chlorophyll content

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Abstract. The effect of saline ions (Cl^- , SO_4^{2-} , and CO_3^{2-}) on the accumulation of chlorophylls in the leaves of new decorative tree-shrub plants introduced on salted Apsheron soils, their degree of salinity resistance, and the dependence of chlorophyll content on the types of saline ions are studied. A direct correlative relationship was established between the type of salinization and the accumulation of green pigments. It was revealed that toxic ions of chloride, sulfate and carbonate entering the root system and through it into the leaves of the studied species have a negative effect on the structure of chloroplasts, promote hydrolysis of protein compounds, breakdown of the protein-chlorophyll bond, accumulation of intermediate products of amides, cadoverin, putrescine and ammonia. The latter lead to tissue and their death.

1 Introduction

The purpose of this article is to identify the degree of salt tolerance of some new ornamental tree and shrub species introduced in various types of soil salinity in Apsheron and their relationship with the synthesis of chlorophyll “a” and “b” and the influence of toxic ions, the accumulation and decay of chlorophylls that contribute to damage to the photosynthetic apparatus [1, 2]. The Apsheron peninsula, located in Azerbaijan, is no exception to this global concern, facing challenges associated with salinization of soils due to natural processes and anthropogenic activities [2, 3]. Understanding the relationship between soil salinity and chlorophyll content in different plant species is fundamental for devising effective strategies to enhance plant tolerance to saline conditions. Therefore, this study aims to investigate the effect of soil salinity on chlorophyll content in selected tree and shrub species native to various ecological regions worldwide. By characterizing the response of different plant species to varying soil salinity levels, this research seeks to elucidate the adaptive strategies employed by plants to cope with salinity stress [4 - 6].

2 Materials and methods

2.1 Study area and plant selection

The study was conducted on the Apsheron peninsula, an area characterized by arid climatic conditions and diverse ecological regions. Various tree and shrub species from different parts of the world were carefully selected for the study to represent a wide range of ecological adaptations. Species were chosen from a wide range of countries across Europe, Asia, and Africa.

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2.2 Experimental design

The primary objective of the experiment was to investigate the effect of soil salinity on chlorophyll content in the leaves of selected tree and shrub species. Soil samples were collected from multiple locations across the Apsheron peninsula to capture the variability in soil salinity levels. The chemical composition of the soil samples was analyzed using a "Palintest" soil testing kit to determine key parameters such as pH, electrical conductivity, and concentrations of major ions.

2.3 Data collection

Quantitative composition analysis of chlorophyll was conducted using a semi-automatic photometer AP-120, enabling the measurement of chlorophyll "a" and "b" concentrations. Measurements were taken at specific wavelengths (420-460 nm) to ensure accurate determination of chlorophyll levels.

2.4 Experimental conditions

The experiment was conducted over multiple seasons, with particular emphasis on spring and summer, which are crucial periods for plant growth and development. Environmental parameters such as temperature, humidity, and soil moisture were monitored throughout the experiment to assess their influence on chlorophyll content and accumulation. Special attention was paid to variations in environmental conditions across different sampling sites to capture the full spectrum of ecological factors affecting plant responses to soil salinity.

2.5 Data analysis

Data on chlorophyll content obtained from the measurements were subjected to rigorous statistical analysis to identify patterns and correlations among different plant species and soil salinity levels. The relationships between soil salinity types (chloride-sulphate, sulphate-chloride, chloride-carbonate) and chlorophyll content in the selected species were analyzed using appropriate statistical methods, allowing for the identification of significant trends and associations.¹

3 Results and discussion

Imported trees and shrubs from various regions (Europe, Asia, Africa, and Mediterranean) and climate zones (temperate, tropical) were studied [6]. The study examined over 40 species of imported trees and shrubs, including large-flowered magnolia, cypress, and *Japanese sophora*. The chemical composition of the soil, irrigation water and plant pigments were analyzed using specialized instruments (Palintest and AP-120 photometer) [3]. Salinity ions (Cl^- , SO_4^{2-} and CO_3^{2-}), depending on their concentration, determine the degree of salinity. However, these salting ingredients are in a complex relationship. In this regard, under the conditions of the Apsheron peninsula, it is important to understand the specific effects of each ion on plant physiology and chlorophyll content.

The Apsheron peninsula belongs to arid regions; hot summers and lack of humidity contribute to a significant increase in the toxic effect of salinizing ions in the soil. A significant increase in temperature in summer (35° - 39° C) increases the double effect of salts on vegetation, on trees and shrubs in particular. Imported species struggle with Apsheron's dry climate and soil salinity, leading to reduced appearance and adaptive ability.

Table 1. Chlorophyll content (mg/g fresh weight) of imported tree and shrub species in Apsheron (chloride-sulfate salinity).

N	Plant species	Chlorophyll "a", mg/g	Chlorophyll "b", mg/g	a+b, mg/g	a/b, mg/g
1	<i>Magnolia grandiflora</i> L.	1,40±0,2	0,59±0,09	2,99±0,29	2,37±0,1
2	<i>Photinia serrulata</i> L.	3,64±0,6	1,02±0,1	4,66±0,7	3,56±0,3
3	<i>Laurocerasus vulgaris</i> C.	3,30±0,5	1,00±0,1	4,30±0,6	3,30±0,3
4	<i>Euonymus japonica</i> L.	5,94±0,9	1,90±0,9	7,8±1,2	3,1±0,1
5	<i>Chamaerops humilis</i> L.	4,05±0,6	2,00±0,3	6,05±0,9	2,02±0,6
6	<i>Eriobotrya japonica</i> L.	8,89±1,2	3,19±0,5	12,08±1,2	2,78±0,6
7	<i>Arbutus unedo</i> L.	3,28±0,5	1,42±0,2	4,70±0,7	2,30±0,5
8	<i>Sophora japonica</i> L.	4,02±0,6	1,59±0,2	5,61±0,8	2,52±0,4
9	<i>Pyracantha coccinea</i> R.	4,71±0,7	1,18±0,5	5,89±1,2	3,99±0,7
10	<i>Tecoma Campsis radicans</i> L.	3,45±0,5	1,12±0,1	4,57±0,6	3,08±0,5
11	<i>Nandina domestica</i> T.	4,59±0,7	1,87±0,3	6,46±1,0	3,00±0,6

This study monitored their stability, growth, and pigment levels under these conditions (Table 1). *Eriobotrya japonica* L. is played the highest chlorophyll levels (8.89 mg/g for "a" and 3.19 mg/g for "b"). Other species showed lower levels, with *Magnolia grandiflora* L. having the lowest (1.40 mg/g for "a" and 0.59 mg/g for "b") (Table 1). Therefore, the noted species is an unacceptable species for landscaping chloride-sulfate soils, however, the ratio of chlorophyll "a" and "b" is the most acceptable indicator for those species in which the synthesis and accumulation of chlorophyll is significantly high.

Table 2. Chlorophyll content (mg/g) in new tree and shrub species introduced from global flora, measured per gram of fresh leaf weight (sulphate-chloride salinity).

N	Plant species	Chlorophyll "a", mg/g	Chlorophyll "b", mg/g	a+b, mg/g	a/b, mg/g
1	<i>Maclura pomifera</i> S.	3,64±0,6	0,74±0,1	4,38±0,7	4,91±0,6
2	<i>Albizia julibrissin</i> D.	3,38±0,5	0,61±0,1	3,99±0,6	5,54±0,1
3	<i>Vitex agnus-castus</i> L.	3,74±0,6	1,02±0,1	4,76±0,7	3,66±0,5
4	<i>Cercis siliquastrum</i> L.	2,94±0,4	1,00±0,1	3,9±0,5	2,94±0,3
5	<i>Mirtus communis</i> L.	4,26±0,7	1,34±0,2	5,60±0,7	3,17±0,5
6	<i>Cydonia oblonga</i> M.	3,48±0,5	1,40±0,2	4,88±0,7	2,48±0,3
7	<i>Pistacia vera</i> L.	3,60±0,6	1,61±0,2	5,21±0,8	2,23±0,3
8	<i>Hibiscus syriacus</i> L.	3,80±0,6	1,52±0,2	5,32±0,8	2,50±0,4
9	<i>Eucalyptus rostrata</i> S.	8,89±0,6	2,14±0,3	11,03±0,9	4,15±0,4
10	<i>Sophora japonica</i> L.	4,02±0,6	1,17±0,1	5,19±0,7	3,43±0,4
11	<i>Pyracantha coccinea</i> R.	4,74±0,7	1,35±0,2	7,09±0,9	3,50±0,4

Our experiments conducted in the arid and hot conditions of the Apsheron peninsula did not observe the previously reported interaction between toxic ions and protein compounds in plant cells, which is known to enhance adaptation mechanisms and increase their stability [3, 6]. Salting ions

(chloride-sulfate) disrupt chloroplast structure at high concentrations, leading to protein degradation, toxic compound buildup, and ultimately, leaf litter and photosynthetic dysfunction [4-6].

Table 2 presents data on the content of chlorophyll "a" and "b", as well as their ratio in the leaves of various ornamental tree and shrub species introduced in the sulfate-chloride soil type of the Apsheron peninsula. As can be seen from the table, the studied species were delivered from different ecological and climatic regions. The largest amount of chlorophyll "a" was observed in eucalyptus beak-shaped (*Eucalyptus rostrata* Schlecht.) - 8.89 mg/g. Due to the normal course of growth and development by the summer period in resistant species in the ratio of chlorophyll "a" and "b", no sharp deviations were observed during the sulfate-chloride type of salinity. Slow growth of leaves and shoots, flowering and fruit formation were noted.

Determination of the content of green pigments in experimental plants to some extent confirms our assumptions about the deeper toxic effect of chloride-carbonate ions on physiological processes, namely the growth and development, adaptation of new ornamental species on Apsheron (Table 3). The effects of drought and chloride-carbonate ions affect plants on a wider scale, flowers fall off, growth slows down, and in some species, morphometric changes and burns on the leaf blade are observed.

The manifestation of strong toxicity during the sulfate-chloride type of salinity did not appear in comparison with the chloride-sulfate type, and the presented species showed an adaptive function [4, 7]. This research studied the ability of various trees and shrubs to tolerate chloride-carbonate salinity, a common problem in the Absheron region. The study identified three groups: limited tolerance: species like *Vitex agnus-castus* L. and *Olea europaea* L. can manage some chlorine and sulfate, but experience slower growth.

Table 3. Chlorophyll content (mg/g fresh weight) in new tree and shrub species in Apsheron (summer)

N	Plant species	Chlorophyll "a", mg/g	Chlorophyll "b", mg/g	a+b, mg/g	a/e, mg/g
Chloride-carbonate					
1	<i>Magnolia grandiflora</i> L.	2,23± 0,3	0,80± 0,1	3,03± 0,4	2,78± 0,2
2	<i>Photinia serrulata</i> Lindl.	2,03± 0,3	1,41± 0,2	3,44± 0,5	1,43± 0,2
3	<i>Acer platanoides</i> L.	1,73± 0,2	0,94± 0,1	2,67± 0,3	1,84± 0,2
4	<i>Laurocerasus vulgaris</i> Carr	2,81± 0,4	0,06± 0,1	2,87± 0,3	1,88± 0,1
5	<i>Cercis siliguastrum</i> L.	2,31± 0,3	1,12± 0,1	3,43± 0,4	2,06± 0,3
6	<i>Eleagnus umbellata</i> Thunb.	3,34± 0,5	1,32± 0,2	4,66± 0,7	2,50± 0,3
7	<i>Ligustrum ovalifolium</i> Hassk.	3,95± 0,6	1,24± 0,2	4,29± 0,7	3,18± 0,3
9	<i>Robinia pseudoasasia</i> L.	4,40± 0,7	1,27± 0,2	5,67± 0,8	3,46± 0,3
10	<i>Ulmus crassifolia</i> Nutt.	3,99± 0,6	1,06± 0,1	4,05± 0,7	3,76± 0,3
11	<i>Buxus microphylla</i> (Siebold)	3,04± 0,5	1,07± 0,1	4,1± 0,7	2,84± 0,3
12	<i>Juniperus sabina</i> L.	0,88± 0,1	0,51± 0,1	1,39± 0,2	1,72± 0,1
13	<i>Cupressus macrocarpa</i> L.	1,42± 0,1	3,94± 0,2	5,36± 0,5	0,36± 0,1
14	<i>Cupressocyparis Leylandr</i>	1,85± 0,1	0,48± 0,1	2,33± 0,2	3,85± 0,2

Moderate tolerance: plants like *Calligonum bakuensa* Litw. and *Robinia pseudoacacia* L. exhibit resistance to drought and some salinity. High tolerance: Species like *Sophora japonica* L. and *Pistacia terebinthus* L. can withstand the toxicity of chloride-carbonate salinity effectively (Table 4).

Table 4. Resistance of new species introduced on the Absheron peninsula to various types of salinity

Chloride-sulphate	Sulphate-chloride	Chloride-carbonate
<i>Vitex agnus-castus</i> L.	<i>Calligonum bakuense</i> L.	<i>Sophora japonica</i> L.
<i>Euonymus japonica</i> L.	<i>Juniperus shinensis</i> L.	<i>Pyracantha coccinea</i> R.
<i>Ulmus densa</i> Litv.	<i>Tamarix ramosissima</i> L.	<i>Eleagnus angustifolia</i> L.
<i>Ulmus parvifolia</i> Jacq.	<i>Magnolia grandiflora</i> L.	<i>Eleagnus caspica</i> (Sosn).
<i>Juniperus chinensis</i> L.	<i>Anabasis aphylla</i> L.	<i>Ulmus caprinifolia</i> R.
<i>Olea europae</i> L.	<i>Pyracantha angustifolia</i>	<i>Photinia serrulata</i> L.
<i>Laurocerasus vulgaris</i> C.	<i>Pinus eldarica</i> Medw.	<i>Nandina domestica</i> T.
<i>Ligustrum japonicum</i> T.	<i>Pinus pinea</i> L.	<i>Pistacia terebinthus</i> L.
<i>Ligustrum lucidum</i> .	<i>Cupressus sempervirens</i> L.	<i>Caesalpinia gilliesii</i> Walt.
<i>Punica granatum</i> L.	<i>Robinia pseudoacacia</i> L.	<i>Amygdalus communis</i> L.

Fig. 1. and Fig. 2. show the dynamic progression of the accumulation of chlorophyll “a” and “b” during the growing season in evergreen species - *Laurus nobilis* L., *Vinca minor* L. and *Lisium chinensis* Mill. As can be seen from the curves, the increase in the amount of pigments increases dynamically until the end of summer and is at a fairly high level. However, at the end of summer and in autumn, the accumulation of chlorophyll in *Vinca minor* L. is the highest. It is noteworthy that in saline conditions with the onset of autumn, the amount of chlorophyll “a” decreases slowly, and chlorophyll “b” relatively sharply. It should also be noted that in new introduced species there is a decrease, and in the “local” *Laurus nobilis* L. there is a tendency to increase chlorophyll content.

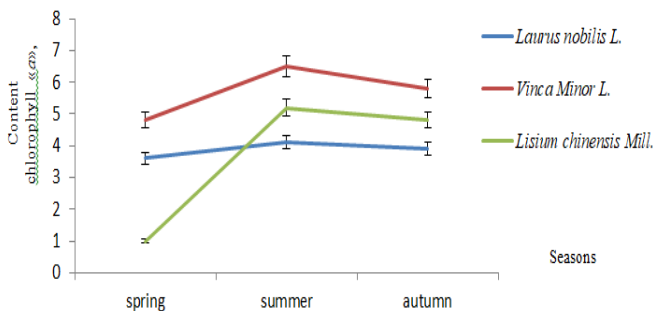


Fig.1. Dynamics of chlorophyll “a” accumulation during the growing season, mg/g.

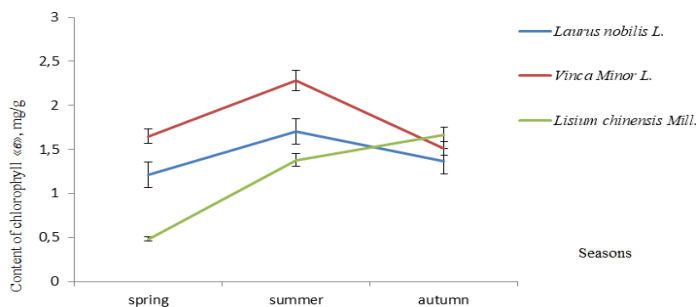


Fig.2. Dynamics of chlorophyll “b” accumulation during the growing season, mg/g.

It should be noted that salinity ions Cl^- , SO_4^{2-} and CO_3^{2-} are characteristic in the soils of Apsheron and they have a certain impact on the adaptation mechanisms of new introduced species of trees and shrubs. As a result of the research, it was revealed that with the chloride-sulfate type of salinity, plants have halo succulent characteristics, and with the chloride-carbonate type of salinity, halo xerophytic characteristics are noted. Chloride and carbonate ions have a more profound toxic effect than sulfate ions.

In this regard, chloride type of salinity, toxic ions entering the leaf blade primarily break protein-chlorophyll bonds, the structure of chloroplasts and promote the hydrolysis of protein molecules, and subsequently the accumulation of intermediate products, namely amides, cadaverine, putrescine and molecular ammonia [6, 7]. Accumulated toxic substances contribute to a decrease in photosynthesis, growth and development, the formation of burns and leaf drying and early leaf litter [5 - 7].

As a result of the above, introduced species undergo profound changes, and sometimes complete destruction. Biological indication to salinity is weak and is expressed to varying degrees in different species. Despite profound physiological and biochemical changes, some species exhibit partial resistance to the salinity of Apsheron soils. It was revealed that in saline soils of the Apsheron peninsula, the degree of influence of salinity ions (Cl^- , SO_4^{2-} and CO_3^{2-}) on the accumulation of chlorophylls in the leaves of new introduced species has a direct correlation with the presence of toxicant concentrations. Toxic ions primarily affect the protein-chlorophyll bond, destroy chloroplasts, reduce photosynthesis, resulting in the formation of chlorophyllide and phytolic acid, which contribute to the formation of burns on the leaf blade of various sizes and a decrease in the photosynthetic productivity of species.

The study revealed a direct correlation between soil salinity types and the accumulation of chlorophyll in the leaves of the studied tree and shrub species. Saline ions, particularly chloride, sulfate, and carbonate, were found to have a negative impact on chlorophyll content and the overall health of the plants [4, 6]. These ions can disrupt the structure of chloroplasts, leading to the breakdown of protein-chlorophyll bonds and the accumulation of harmful compounds such as amides, cadaverine, putrescine, and ammonia. Consequently, leaf tissues become poisoned, resulting in tissue damage, leaf necrosis, and premature leaf abscission [1]. The introduction of exotic tree and shrub species from various regions of the world into the Apsheron peninsula for landscaping purposes requires careful consideration of their salt tolerance levels. While some species may exhibit higher tolerance to specific ions or soil salinity types, others may be more susceptible to salt-induced stress [2, 4].

4 Conclusion

In conclusion, this study provides valuable insights into the response of selected tree and shrub species to soil salinity stress, focusing on the regulation of chlorophyll content as a key physiological mechanism. Through comprehensive analyses, we have demonstrated that soil salinity significantly influences chlorophyll content and photosynthetic efficiency in different plant species, with varying degrees of tolerance observed among the studied taxa. Our findings underscore the importance of understanding the complex interactions between environmental stressors and plant physiological responses to develop effective strategies for mitigating the adverse effects of soil salinity on vegetation. The differential responses of plant species to salinity stress highlight the need for tailored approaches in plant breeding and land management to enhance salt tolerance and promote ecosystem resilience in saline environments. Furthermore, the identification of plant species exhibiting high salt tolerance and chlorophyll retention under salinity stress provides valuable insights for selecting suitable candidates for afforestation and ecological restoration efforts in salinized areas such as the Apsheron peninsula. By harnessing the adaptive traits of salt-tolerant species, we can contribute to the establishment of biodiverse and resilient ecosystems capable of sustaining ecosystem services and supporting local livelihoods in saline-prone regions.

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