SESQUITERPENE LACTONES AS STIMULATORS OF PHOTODYNAMICALLY ACTIVE PORPHYRINS

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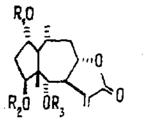
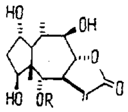
The photosensitizing properties of sesquiterpene lactones have been considered by means of a study of their influence on the pigmentary system of plants. An investigation of the action of germacranolides, eudesmanolides, guaianolides, and pseudoguaianolides on the fluorescence spectra of leaves in the presence of exogenous 5-aminolevulinic acid (5-ALA) has permitted the conclusion that these compounds are capable of inhibiting the transformation of 5-ALA in the chain of the biosynthesis of chlorophyll.

Among secondary metabolites of plant origin, particular interest is presented by the sesquiterpene γ-lactones that are widely distributed in nature and possess a diverse spectrum of biological activity, including the property of regulating growth [1, 2]. Some authors [3] connect the growth-regulating activity of compounds of this series with their capacity for interacting with enzymes participating in the biosynthesis of new proteins and nucleic acids, and also with the possibility of the inhibition of bound enzymes (amylase and protease). Other investigators [4] suggest that the action of sesquiterpene lactones is directed to cell division and not to a change in the dimensions of cells and their life period.

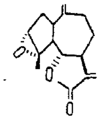
In this connection, interest is presented by a study of the influence of sesquiterpene lactones onthe state of the pigmentary system of plants, since the action of many herbicides and natural phytotoxins is mediated by the appearance of endogenous porphyrins not energetically connected with the photosystems. Such porphyrins are active photosensitizers of the peroxide oxidation of lipids, which leads to damage of plant tissues in the light.



(I) $R_1=R_2=Ac$; $R_3=H$
(V) $R_1=R_2=R_3=H$
(XI) $R_1=R_3=Ac$; $R_2=H$



(II) R=Ac
(VII) R=H



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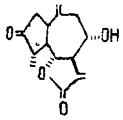

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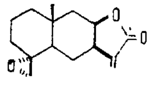

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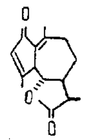
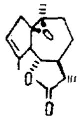
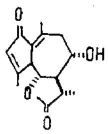


(VIII)



(IX)



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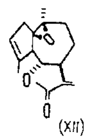

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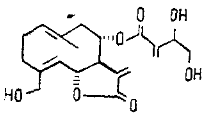

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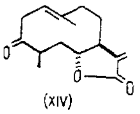

(XIV)

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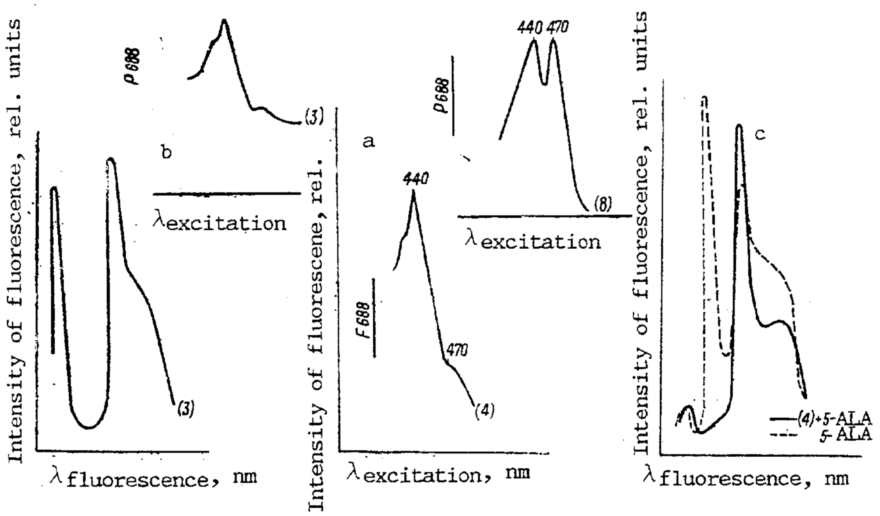

Fig. 1. Spectra: a) of chlorophyll fluorescence excitation under the action of solutions of grosshemin (4) and schillin (8); b) of chlorophyll excitation and fluorescence under the action of a solution of estafiatin; c) of the chlorophyll fluorescence of leaves treated with solutions of grosshemin (4) and of 5-aminolevulinic acid (5-ALA).

We have studied the photosensitizing activity of sesquiterpene lactones isolated from plants growing in Kazakhstan. It was found that practically all the compounds studied affected the state of the pigmentary apparatus of plants, as was shown by a change in the structure of the fluorescence excitation spectra in the leaves. The most considerable changes in the spectra were observed in specimens that had been treated with inuchinenolide-C (I)), gaigranin (II),* estafiatin (III), grosshemin (IV), dideacylinuchinenolide-C (V), epoxyisoalantolactone (VI), deacylgaigranin (VII), achillin (VIII), arborescin (IX)), and austricin (X). Thus, in the chlorophyll fluorescence excitation spectra the intensity of the band at 440 nm increased and it became either the main band, as in the case of (IX), (X), (VII), (III), (IV), britannin (XI), arglabin (XII), and cnicin (XIII), or comparable with the 470 nm band (Fig. 1a), as in the case of (V), (VI), and (VIII), which shows a redistribution of energy over channels not typical for the normal functioning of the photosynthetic apparatus of plants. Under these conditions the fluorescence spectrum of the chlorophyll of green leaves did not change. Estafiatin (III) was an exception to this. When leaves were treated with (III), in addition to changes in the chlorophyll excitation spectra, a new well-defined band appeared in the fluorescence spectra with a maximum at 597 nm, which is characteristic for Mg^{2+}-protoporphyrin (Fig. 1b). In this case, the nature of the observed changes was analogous to the changes in the fluorescence of leaves on their treatment with a chelator of bivalent metals possessing photoherbicidal activity [5, 6]. These effects can be explained both by an increase in the level of chlorophyll precursors and also by a change in the parameters of the migration of energy in the pigmentary complex as a result of a change in its spatial organization. The latter may be a consequence of the membranotropic action of the substance tested.

To investigate the influence of sesquiterpene lactones on the synthesis of porphyrins, we studied their action on the fluorescence spectra of leaves in the presence of exogenous 5-aminolevulinic acid. It is known that, on treatment with 5-aminolevulinic acid (5-ALA), bands with maxima at 567 nm and 636 nm with excitation at 410 and 440 nm are observed in the chlorophyll fluorescence spectra of green leaves, which is connected with an accumulation of biosynthetic precursors of chlorophyll: Mg^{2+}-protoporphyrin and protochlorophyll, respectively [5].

We have found that the treatment of plants with solutions of (XIII), argolide (XIV), (XI), (I), (II), (V), (VI), (VII), (VIII), (IX), and (IV) suppresses the capacity of exogenous 5-ALA for inducing the accumulation of protoporphyrins (Fig. 1c). This was shown by the absence of bands characteristic for chlorophyll precursors in the fluorescence spectra of leaves that had been treated with 5-ALA. The results obtained indicate a capacity of the

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*Direct transliteration of the Russian name (other forms are conceivable); not identified — Translator.

series of compounds under consideration for inhibiting the transformation of 5-ALA in the chain of the biosynthesis of chlorophyll. This once again confirms the conclusion given above that the changes in the structure of the excitation spectra of leaves caused by treatment with the substances under investigation are not the consequence of an increase in the amount of chlorophyll precursors in the pigmentary system but are caused by a change in the parameters of the migration of energy in the pigmentary complex.

An exception is estafiatin (III). In the presence of this compound, the capacity of 5-ALA for causing an accumulation of biosynthetic precursors of chlorophyll was not suppressed, which again indicates a similarity of the mechanism of the action of this lactone to that of chelators of bivalent metals [5]. This permits a conclusion of the promising nature of such substances in connection with the search for new photosensitizers for green plants.

EXPERIMENTAL

The sesquiterpene lactones inuchinenolids-C, gaigranin, estafiatin, grosshemin, achillin, arborescin, austricin, britanin, arglabin, cnicin, and argolide were isolated and prepared from plants of the natural flora of Kazakhstan by methods described previously [7]. The derivatives dideacylinuchinenolide-C, epoxyisoalantolactone, and deacylgaigranin were obtained from the corresponding initial lactones by known methods of hydrolysis and epoxidation [8].

The influence of the sesquiterpene lactones on the state of the pigmentary apparatus of plants was determined by a procedure developed for studying the mechanisms of the action of photodynamic herbicides [9]. As the test object we used cotyledonous leaves of cucumbers of the Libella variety. The leaves were treated by the infiltration method in the vacuum of a RN 15/11 oil pump with solutions of the sesquiterpene lactones in concentrations of $5 \cdot 10^{-3}$; 10^{-3}; and 10^{-4} M. Control samples were infiltrated with distilled water. Incubation was carried out in the dark at 25°C for 16 h. The influence of the substances on the state of the pigmentary apparatus was studied by spectrofluorometry. Fluorescence spectra were recorded on an Elyumin-2M fluorimeter.

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