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Action dichroism in the chloroplasts rearrangements in various plant species

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INTRODUCTION

It has been recently found that for some plant objects ligth depended displacements of chloroplasts show characteristic features in polarized light. The behaviour of chloroplasts in the cells illuminated with linear polarized light shows that absorption of radiant energy in various cells areas depends on the direction of polarization. Consequently, assuming the dichroic properties of the photoreceptor, a conclusion may be drawn that photoreceptor molecules are oriented in the cell structures. (Haupt 1960; Haupt, Bock 1962; Mayer 1964; Zurzycki 1967 b).

In a great majority of plant species displacements of chloroplasts are controlled by short wave lengh range of light (Senn 1908) and action spectra of this phenomenon, so far studied, suggest the flavin pigment as an active photoreceptor (Haupt 1963; Zurzycki 1967 a). Among plant species belonging to the above mentioned group specific reaction of chloroplasts to polarized light was found in *Selaginella martensii* (Mayer 1964) and *Funaria hygromatrica* (Zurzycki 1967 b) — in both cases for low and high light arrangements — and in *Vallisneria spiralis* (Seitz 1967) for strong light rearrangements and for the ability of chloroplasts to be centrifuged. Thus, up till now, the phenomenon of action dichroism in chloroplasts rearrangements was stated for few objects, which are most frequently used for studies on chloroplasts movements due to their suitable anatomical structure which makes microscopical observation in vivo easy.

The problem arrises if the phenomenon in question is of the more general character and can be found in other objects. This problem is especially actual because Haupt and Weisenseel (1967) have recently stated that chloroplasts in *Lemna trisulca* do not react to polarized light in the way which should be expected. An arrangement specific for this kind of light was obtained only when directing the light bean in the plane of the leaf and not when illuminating it perpendicularly to its surface.

The aim of the present study was to check if action dichroism in rearrangements of chloroplasts can be found in various plant material belonging to different taxonomical and ecological groups.

MATERIAL

Following plant species were used for experiments:

Algae: *Voucheria sessilis*,
Mosses: *Mnium cuspidatum*,
Mnium medium
Cirriphyllum piliferum

Submerse angiosperms: *Potamogeton crispus*
Lemna trisulca
Utricularia vulgaris
Hottonia palustris

Leaves of terrestial plants: *Symphytum cordatum*
Sambucus nigra
Asparagus Sprengeri
Polygonatum odoratum
Sedum maximum

The material was collected from natural conditions and kept in the laboratory no longer than one week (usually 2—3 days).

METHODS

Actually the method consisted in illuminating the objects with unpolarized or linearly polarized monochromatic light and microscopic examination of its effects. Objects were mounted on slides and illuminated on the microscopic table. Details concerning preparation of particular materials will be described below.

For ilumination blue light (λ = 454 nm) isolated by Zeiss interference filter was used. A Zeiss „Bernotar" polaroid plate served as polarizer (Zurzycki 1967 b). Intensity of illumination was measured in the plane of the objects with a microthermoelement (Zurzycki 1961). Control experiments with unpolarized light were always done in the same light energy as experiments with polarized light. Intensity of radiation was regulated by changing the voltage supply of the lamp.

RESULTS

Vaucheria sessilis. The rearrangements of chloroplasts taking place in this filamentous algae in high light intensity consist in displacements of chloroplasts, which formerly covered the whole circumference of the cell (dark position), to those parts of the cell which are more or less parallel to the light rays. A chloroplast free zone running along the filament is formed (S e n n 1908). Preparation of material was performed according to the procedure described by F i s c h e r - A r n o l d (1963). Filaments were placed in a drop of water and covered with a cover glass suported on a vaseline ring. After 2 hours pretreatment in darkness the cells were illuminated.

The reaction of chloroplasts to light was not in every case reproducible and often whimsical as it was just mentioned by F i s c h e r - A r n o l d (1963). Fig. 1 presents the commonest and most typical reactions. It shows that when the electrical vector of light is directed perpendicularly to the filaments axis — the dislocation of chloroplasts is very clear and a broad chloroplasts free zone on both (upper and lower) cell sides is formed. On the other hand by a parallel orientation of the E-vector, displacements are much weaker, the curvatures of the cell wall are covered with chloroplasts and a much narrower and irregular chloroplast free zone is formed.

Mnium medium. The leaf lamina of this moss is composed of one layer of large cells. High light displacements take place rather slowly. The cells shown in fig. 2 were illuminated during 2,5 hours. Rearrangements, although not completed, show clearly that the side walls parallel to the E-vector of polarization are free of chloroplasts.

Mnium cuspidatum. The cells composing leaf lamina are small in size. Movement of chloroplasts is extremely slow. After 5 hours of strong illumination only about a half of chloroplasts were displaced to the side walls. In this case too, side walls parallel to the E-vector are not covered with chloroplasts.

Cirriphyllum piliferum. The cells of leaf lamina are spindle shaped in outlines and very narrow. After 1,5—2 hours of irradiation rearrangement of chloroplasts takes its final state. It is striking that the percentage of chloroplasts remaining in flat position is highly dependent on the direction of polarization (fig. 3). When the E-vector is directed perpendicularly to the cell axis a „normal" relation between chloroplasts arrangement and light intensity was obtained, wheras, by parallel directions the decrease of the number of chloroplasts remaining in flat position is nearly none even in high light intensity.

Potamogeton crispus. The leaf lamina is composed of two layers of cells, both containing many chloroplasts. The cells of the upper layer are bigger and nearly isodiametric in outlines, these of the lower layer

smaller and elongated. Along the inner edges of the cells there are small and narrow intercellulars. A rather poorly developed intercellular system makes the leaves highly transparent.

For experiments a segment of leaf of 5—6 mm lengh was cut out from the central leaf region. Illumination of the cells with strong unpolarized light brings the chloroplasts in 1—1,5 hours from the initial flat

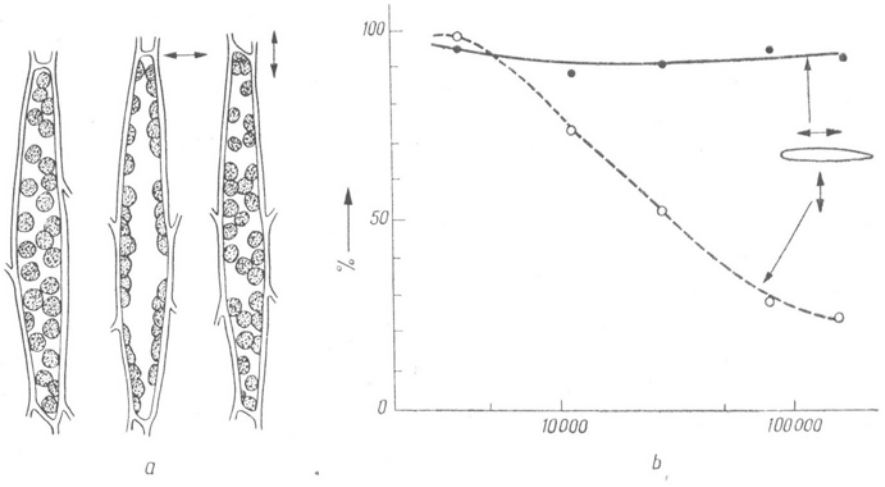


Fig. 3. *Cirriphyllum piliferum*. *a* — Position of chloroplasts before illumination (left) and after 2 hours illumination with polarized blue light of the E-vector directed perpendicularly (middle) and paralelly (right) to the cells axis. Intensity of light 160 000 erg/cm²sec.; *b* — dependence of the percentage of chloroplasts in a flat position (Y-axis) on the intensity of polarized light (X-axis) for two directions of polarization.

position to the side walls, so that, all side walls are occupied by them (fig. 4a). By using polarized light of the same intensity the displaced chloroplasts occupy only these side walls which are perpendicular to the E-vector of polarization (fig. 4b). In both cases illumination was performed from the upper leaf surface and the cell layer turned towards light was examined. The lower leaf layer (turned against light and illuminated through the upper layer of the cells) shows after illumination with polarized light also some rearrangements of chloroplasts but their final position is not so regular as in the previous case (fig. 4c). The chloroplasts show a tendency to gather on the side walls perpendicular to the E-vector but parallel walls are also to some extent occupied by them. This reaction of chloroplasts is due to the modification of the light passing through the first layer of the cells (local screening and depolarization) and is not connected with any other reaction pattern of the cells. Illumination of the same tissue directly with polarized light induces very

Plate I

Fig. 1. *Vaucheria sessilis*. *a* — position of chloroplasts before illumination; *b* and *c* — arrangement obtained after 1. hour illumination with polarized blue light of 130 000 erg/cm² sec. intensity. The E-vector directed perpendicularly (*b*) or parallel (*c*) to the filament axis.

Fig. 2. *Mnium medium*. Result of 2.5 hours illumination with polarized blue light of 80 000 erg/cm²sec. intensity. Direction if the E-vector of polarized light is marked by arrows.

Fig. 4. *Potamogeton crispus*. *a*, *b* — strong light position of chloroplasts in the upper cell layer of the leaf illuminated directly. Light intensity 50 000 erg/cm²sec., time of illumination 90 min. *a* not polarized, *b* polarized light. *c*, *d* — strong light position of chloroplasts in the lower cell layer illuminated with polarized light from the other leaf side (*c*), or directly (*d*).

Plate II

Fig. 5. *Elodea canadensis*. Upper cell layer illuminated directly for 45 min with polarized light of 27 000 erg/cm²sec. intensity.

Fig. 6. *Utricularia vulgaris*. Fragments of the stem after 50 min illumination with polarized light of 46.000 erg/cm²sec. intensity.

Fig. 7. *Lemna trisulca*. *a* and *b* — the same fragment of the leaf after 45 min illumination with polarized light of 38 000 erg/cm²sec. intensity.

Fig. 8. *Lemna trisulca*. Position of chloroplasts obtained after 90 min illumination with polarized light of about 80 erg/cm²sec. intensity.

Fig. 9. *Lemna trisulca*. Leaf showing no specific reaction to polarized light. Illumination 60 min, light intensity 30 000 erg/cm²sec.

Plate III

Fig. 10. *Symphytum officinale*. Position of chloroplasts in the palisade parenchyma after 70 min illumination with blue light of 140 000 erg/cm²sec. intensity a) unpolarized, b) polarized light.

Fig. 11. *Symphytum officinale*. Position of chloroplasts in the spongy parenchyma in leaves adapted to weak ligth and after 70 min illumination with 140 000 erg/cm²sec. intensity of unpolarized (*b*) and polarized (*c*) light.

Fig. 12. *Sambucus nigra*. Palisade parenchyma after 60 min illumination with polarized light of 63 000 erg/cm²sec. intensity.

Fig. 13. *Sambucus nigra*. Spongy parenchyma, details as in fig. 12.

Fig. 14. *Sambucus nigra*. Air remaining in some intercellulars after water infiltration. These places are not transparent (dark) in ordinary microscope illumination (*a*) and show bright luminescence in crossed nicols (*b*).

Plate IV

Fig. 16. *Polygonatum odoratum.* Position of chloroplasts in the palisade parenchyma in weak light (*a*) and after 70 min illumination with polarized light of 96 000 erg/cm²sec. intensity (*b* and *c*).

Fig. 17. *Hottonia palustris.* Palisade parenchyma (*a*) and spongy parenchyma (*b*) after 1 hour illumination with polarized light (40 000 erg/cm²sec.)

Fig. 19. *Sedum maximum.* Position of chloroplasts in palisade parenchyma in weak light (*a*) and after 1 hour illumination with polarized light (96 000 erg/cm²sec.).

Plate V

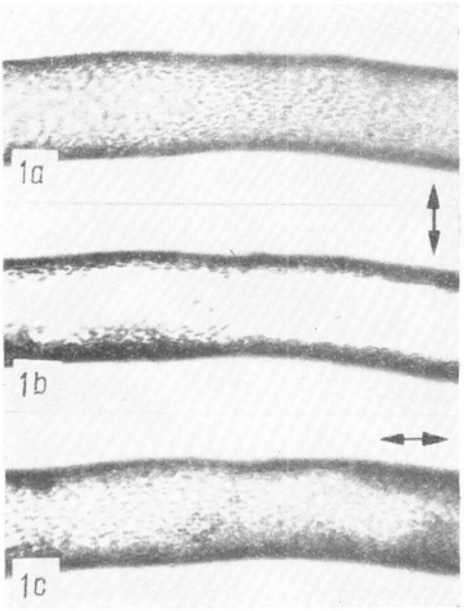
Fig. 20. *Sedum maximum.* Position of chloroplasts in spongy parenchyma cells in weak light (*a*) and after 1 hour illumination with polarized light of 42 000 erg/cm²sec. intensity (*b*).

Fig. 21. *Sedum maximum.* Cells of palisade parenchyma. Treatment as in fig. 19 b.

Fig. 22. *Sedum maximum.* Cells of spongy parenchyma. Treatment as in fig. 20 b.

Fig. 23. *Sedum maximum.* Cells of palisade parenchyma after 1 hour illumination with polarized light of about 80 erg/cm²sec. intensity.

Fig. 24. *Sedum maximum.* Cells of spongy parenchyma. Treatment as in fig. 23.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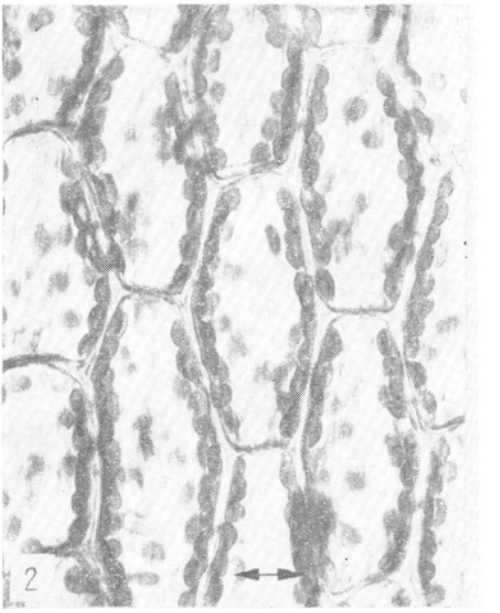
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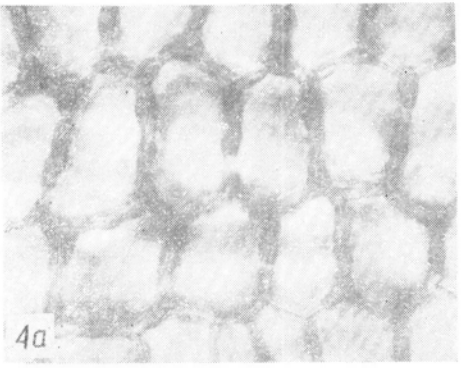
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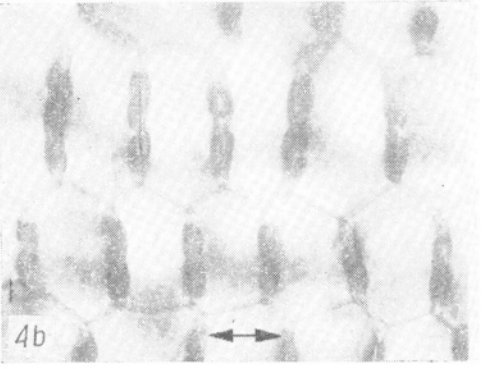
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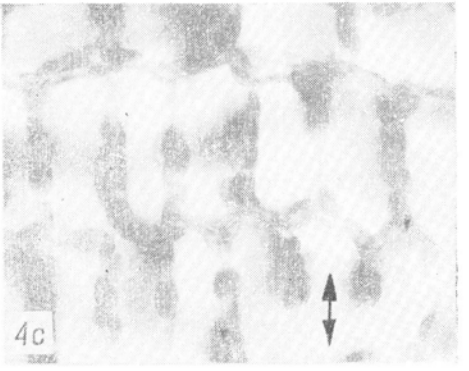
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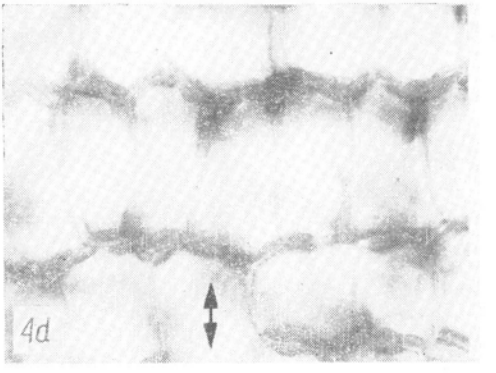
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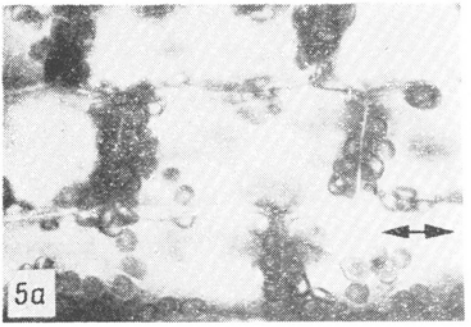
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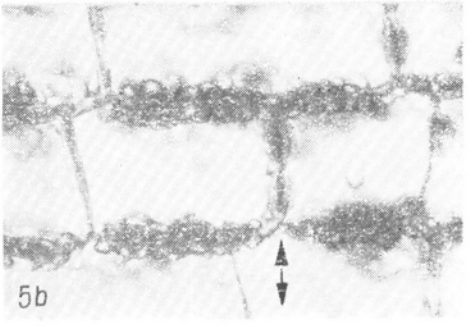
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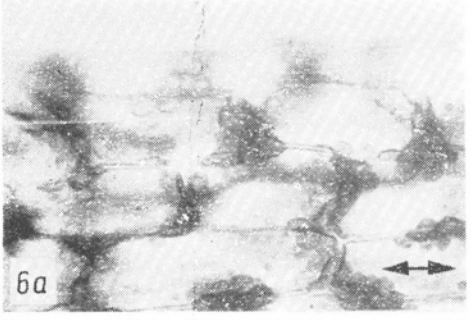
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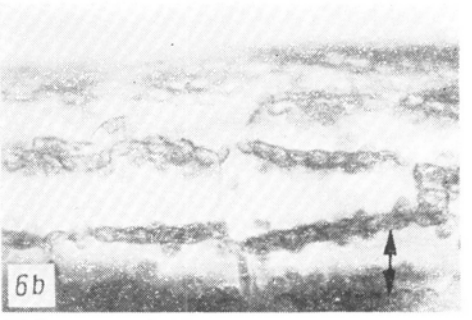
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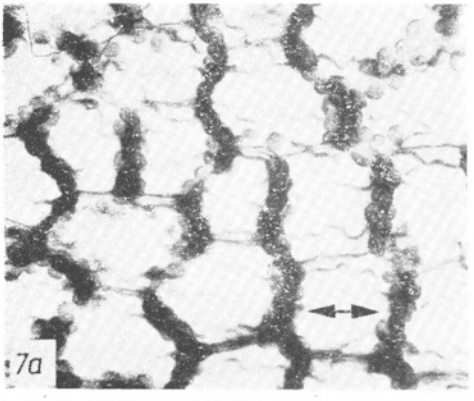
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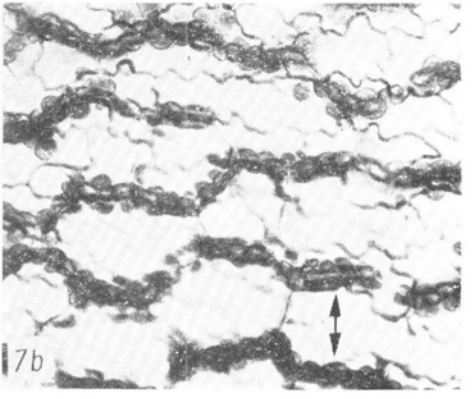
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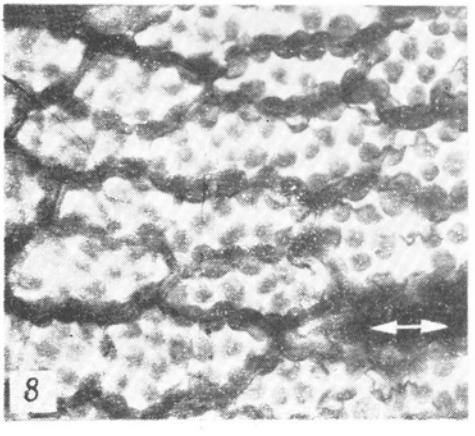
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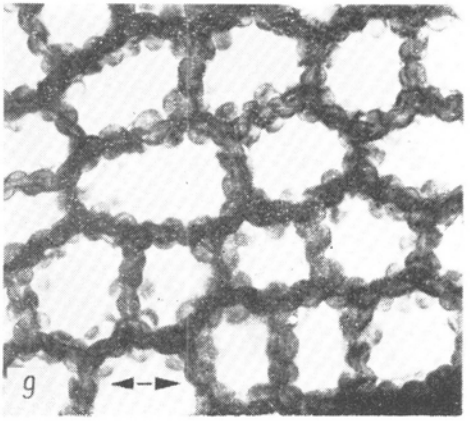
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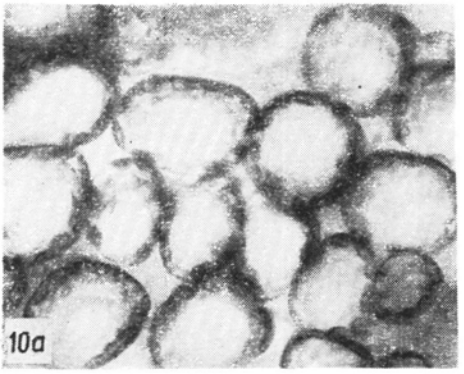
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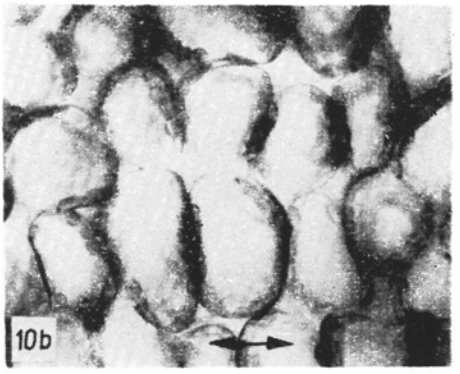
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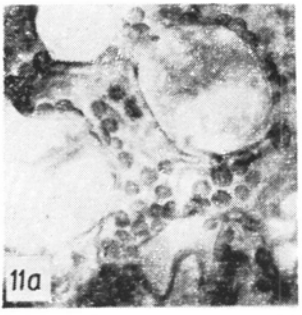
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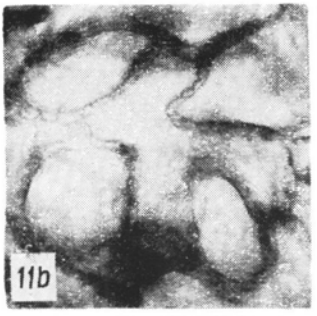
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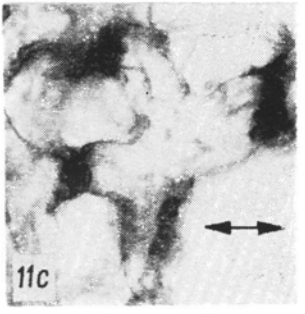
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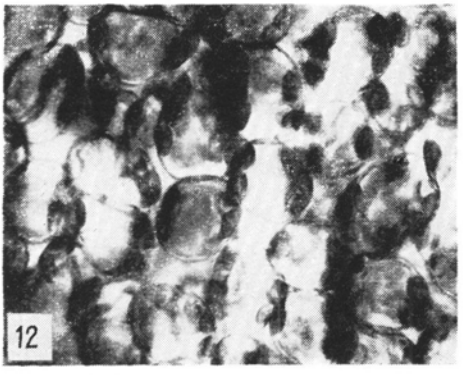
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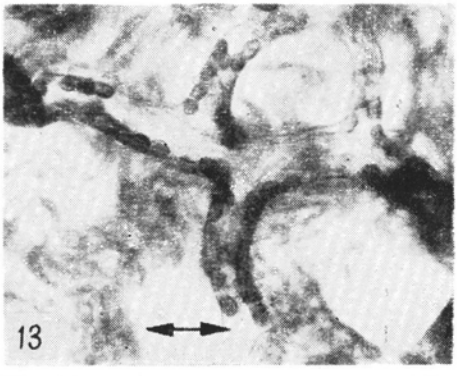
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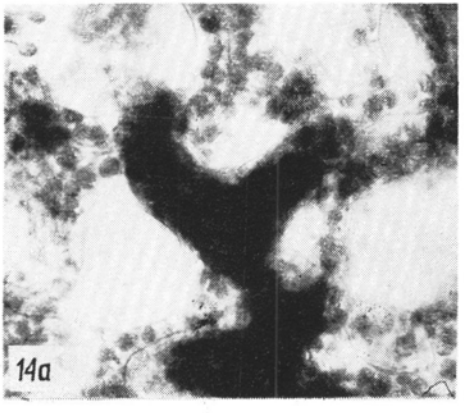
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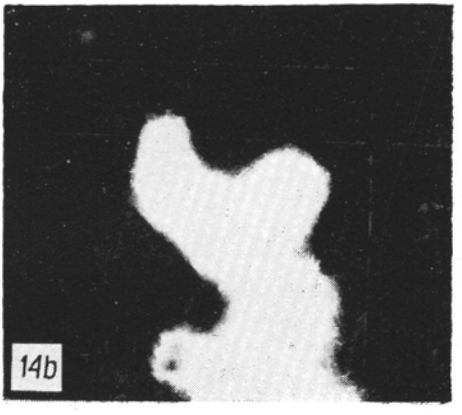
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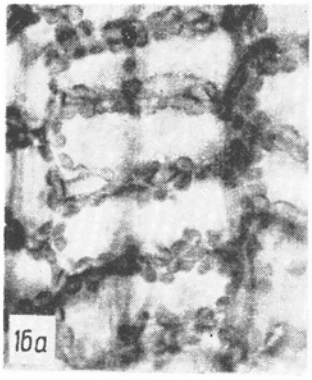
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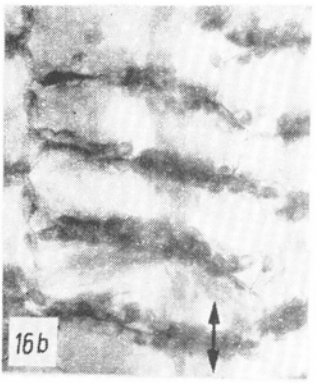
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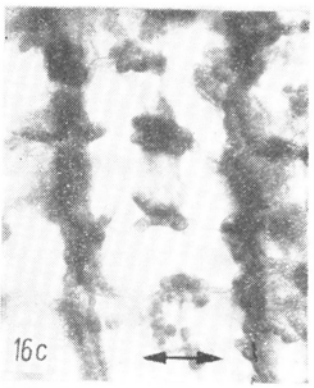
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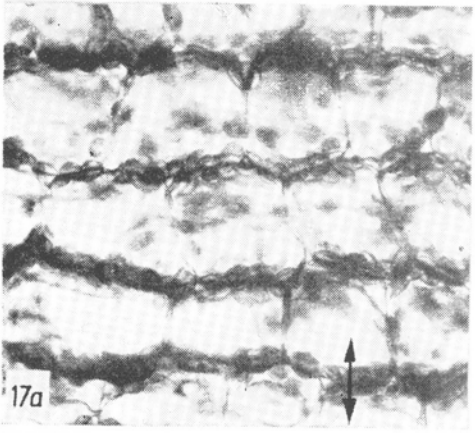
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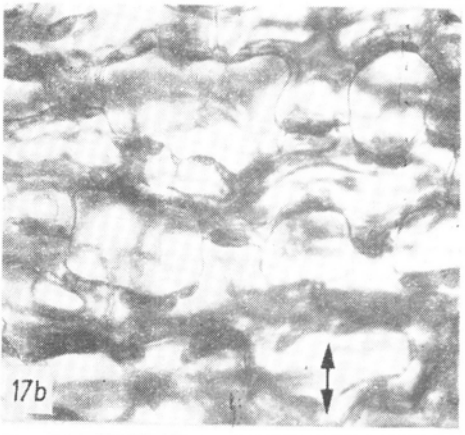
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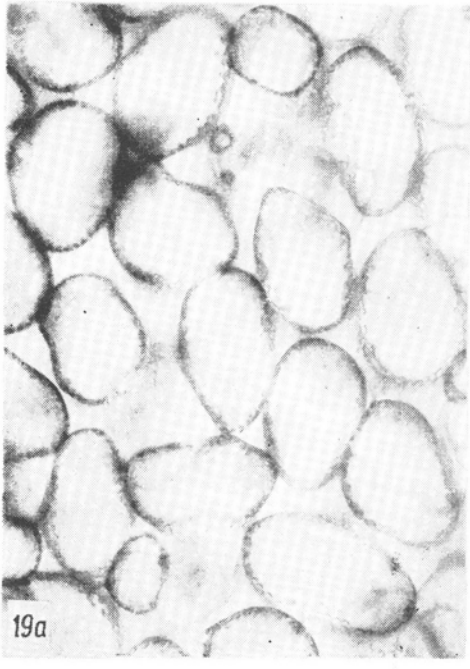
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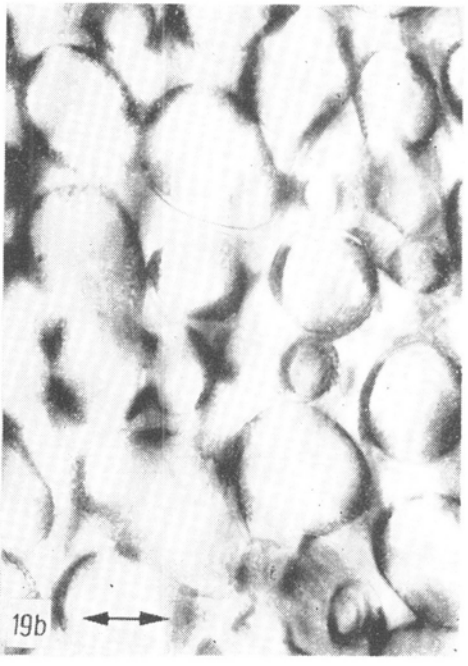
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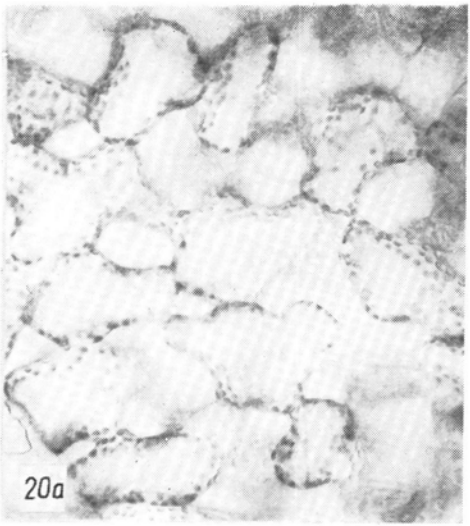
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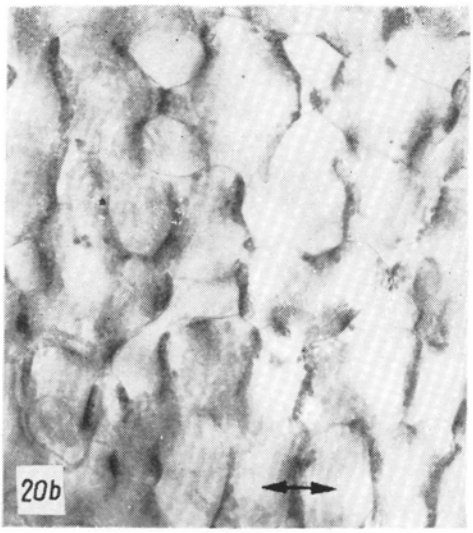
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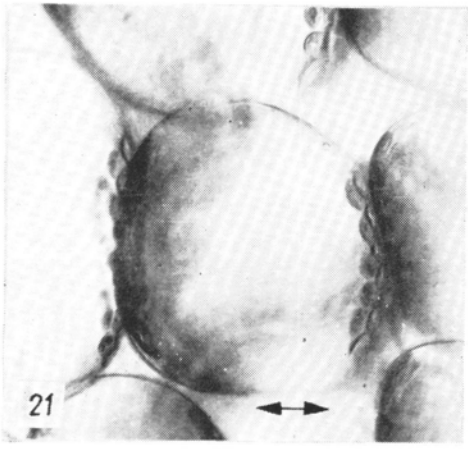
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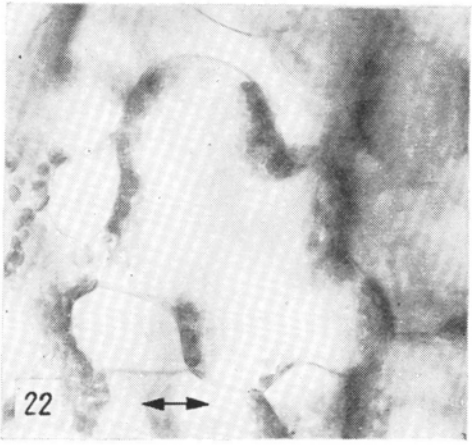
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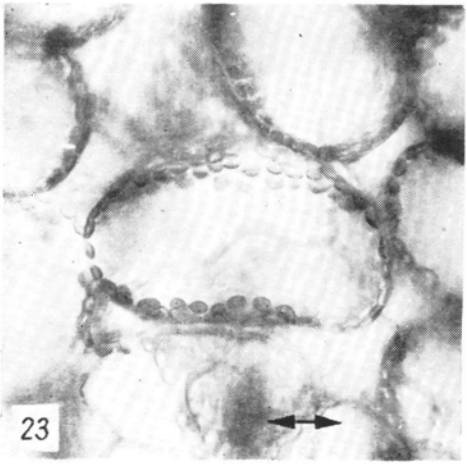
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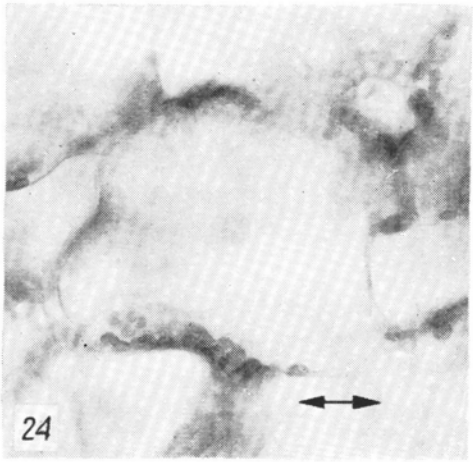
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regular arrangements of chloroplasts which in this case strictly avoid the side walls parallel to the E-vector of light (fig. 4d).

Elodea canadensis. Typical orientation of chloroplasts in strong light rearrangements induced by polarized light is easy obtainable in those parts of the leaf where no bigger intercellulars exist (fig. 5 a, b). The final distribution of chloroplasts is quite similar to those reported by Seitz (1967) for *Vallisnaria.*

Utricularia vulgaris. Younger stems, in which the intercellular system is not greatly developed, were taken for investigation. In this material the cells situated near the stem surface are well visible in vivo. Fig. 6 shows the arrangement of chloroplasts obtained after illumination with polarized light. In this case too a regular position depending on the direction of polarization is to be found.

Lemna trisulca. Two different types of reaction to polarized light have been found in this species. In most cases polarized light directed perpendicularly to the leaf surface induces typical rearrangements i.e. in strong light chloroplasts avoid side walls more or less parallel to the E-vector. Fig. 7 shows the example of such a behaviour where in the same cells a strong light rearrangement was induced two times with a different orientation of polarization. When illuminated with very low intensity of polarized light some chloroplasts situate on the cell walls parallel to the E-vector (fig. 8). Among a large material of *Lemna* another reaction pattern was found in some cases. In these cases arrangement of chloroplasts after illumination with polarized light falling perpendicularly to the leaf surface is typical for high light intensity of unpolarized light; all side walls of the cells being occupied by chloroplasts independent of their direction to the plane of polarization (fig. 9). This type of reaction was also found by Haupt and Weisenseel (1967).

Symphytum officinale. From the middle parts of the leaf lamina a fragment of dimentions about 5×10 mm without bigger veins was cut out. This fragment was placed in a drop of water and illuminated under microscope. After illumination the fragment was infiltrated with water in a vacuum. To prevent dislocation of chloroplasts during infiltration (the procedure lasted 5—10 mins.) cold water of temperature 3—5°C was used as infiltrating medium. Immediately after infiltration the leaf fragment was mounted on a slide and examined from the side of the former illumination.

In the leaves adapted to weak light the upper cell walls of the palisade parenchyma are not covered with chloroplasts. Chloroplasts are situated on the side walls and at the upper curvatures of the cells forming a crown around the cell outline examined from above. Strong illumination from the upper side of the leaf induces not very distinct dislocations. The chloroplasts seemed only to leave the upper cell curvatures (fig. 10a). After illumination with polarized light the rearrangements are more

pronounced. The chloroplasts leave those parts of the side walls which are more or less parallel to the E-vector and locate on the other, perpendicularly situated ones (fig. 10 b). It must be stressed that this reaction of chloroplasts is not always quite clear and reproducible.

In the spongy parenchyma chloroplasts may be found in weak light on all cell walls, most of them beeing situated on the upper and lower (in respect to the leaf geometry) walls (fig. 11a). After illumination from the lower side of the leaf with strong unpolarized light chloroplasts displace to the side walls (fig. 11b) and in polarized light to those parts of the side walls only, which are perpendicular to the E-vector of polarization (fig. 11c). Like in the former tissue this behaviour of chloroplasts could be found not in every case and not for every cell.

Sambucus nigra. Shade leaves were used for experiments. In contrast to the above described procedure, in this case, fragments of the leaf blade were water infiltrated before illumination. This procedure does not prevent displacements of chloroplasts and assures a more equalized light penetration.

Arrangements obtained after irradiation with polarized light are similar to those described for *Symphytum* but the polar situation of chloroplasts is much more clear and reproducible (fig. 12, 13). These differences did not seem to be connected with the character of investigated species but with the pretreatment procedure. Infiltration makes the leaf more transparent, light rays do not undergo so many reflections and refractions in the intercellulars and therefore the degree of depolarization of light in the leaf tissues is much lower. Examining an infiltrated leaf one can easily find that places where some air remained in the intercellulars (fig. 14 a black areas) show bright luminescence when examined in crossed nicols, suggesting that in those places strong depolarization takes place (fig. 14 b).

Small and not numerous plastids appearing in the lower epidermis of *Sambucus* leaves are green and able for light controlled displacements. In dispersed weak light they are distributed at random near all cell walls. After illumination with high light intensity they may be found only on the side walls (fig. 15a). In polarized light chloroplasts take a position on those parts of the side cell walls which are exactly perpendicular to the E-vector of polarization (fig. 15 b). Due to a small number and dimentions of chloroplasts and rich curvatures of the side walls the situation of chloroplasts in proper places is expecially well visible. For this reason epidermis could constitute a suitable material for study of the dynamic of chloroplast displacements. Unfortunately a continuous observation during illumination of the whole leaf is impossible and the efforts of obtaining normal displacements in isolated epidermis have been as yet unsuccesfull. After isolation chloroplasts either do not change

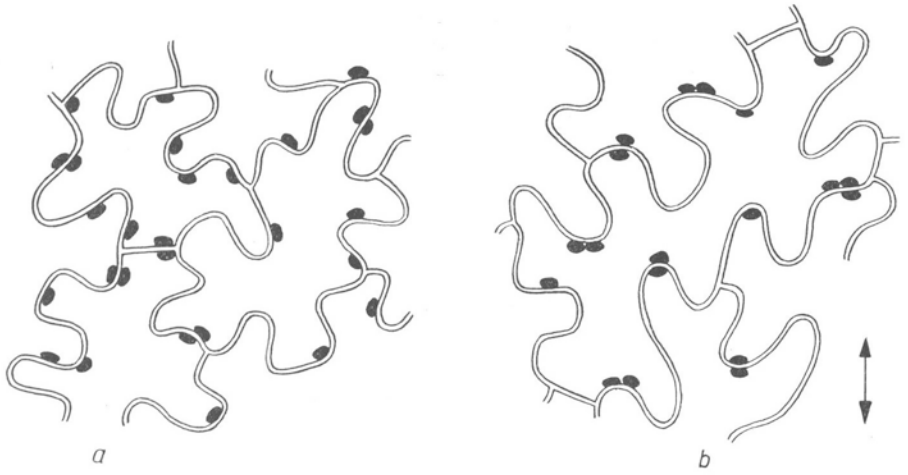

Fig. 15. *Sambucus nigra*. Position of chloroplasts in lower epidermis cells after 1 hour irradiation with blue light of 63 000 erg/cm²sec. intensity *a* — unpolarized, *b* — polarized light. Drawings made according to microphotographs.

their position or show caryostrophic accumulation around the cell nucleus.

Polygonatum odoratum. The outlines of the palisade parenchyma cells are in this species not round but rectangular, their longer side oriented perpendicularly to the leaf axis. Fragments of leaf were illuminated after water infiltration. In weak light chloroplasts cover all side walls and make a crown near the upper cell edges (fig. 16 a). Afer illumination with polarized strong light the side walls parallel to the E-vector become more or less free of chloroplasts. When the E-vector of light is directed parallel to the shorter side walls they become nearly quite free (fig. 16 b) in the case of parallelism with longer cell walls usualy some chloroplasts remain in the middle of their lengh where very often a small curvature of the cell wall exists (fig. 16 c).

Hottonia palustris. Water infiltrated leaves are irradiated. In the cells of spongy parenchyma as well as in palisade parenchyma the same phenomena as the above described ones take place. In both tissues the side walls parallel to the E-vector are forbidden for chloroplasts in strong light rearrangements (fig. 17 a, b). In some cases peculiar positions of chloroplasts were observed, for instance chloroplast „sitting" on the top of a narrow cell wall curvature (fig. 18). In this case only a part of the chloroplast remains in direct contact with the layer of protoplasm but the place of contact corresponds directly with the point where the curvature becomes perpendicular to the E-vector of polarization.

Sedum maximum. Fragments of leaves were water infiltrated before illumination. Big dimentions of cells as well as a very distinct reaction

of chloroplasts make this material especially suitable for demonstration of the effects of polarized light.

In the palisade parenchyma the low ligth intensity position of chloroplasts is, as usually in these tissues, on the side walls and by their upper curvatures (fig. 19 a). Illumination with strong light does not change this

Fig. 18. *Hottonia palustris.* Position of chloroplast at the curvature of the side cell wall after illumination with polarized light.

picture very distinctly, only the marginal crown of chloroplasts becomes smaller. By illumination with polarized light distinct dislocation of chloroplasts is obtained consisting in chloroplasts gathering on either of the oposite side parts of the cell perpendicular to the E-vector of light (fig. 19 b, 21). In the spongy parenchyma the chloroplasts distributed in diffused weak light randomly at all cell walls (fig. 20 a) are after strong illumination with unpolarized light directed to the side walls. By using polarized light only those fragments of the side walls which are perpen-

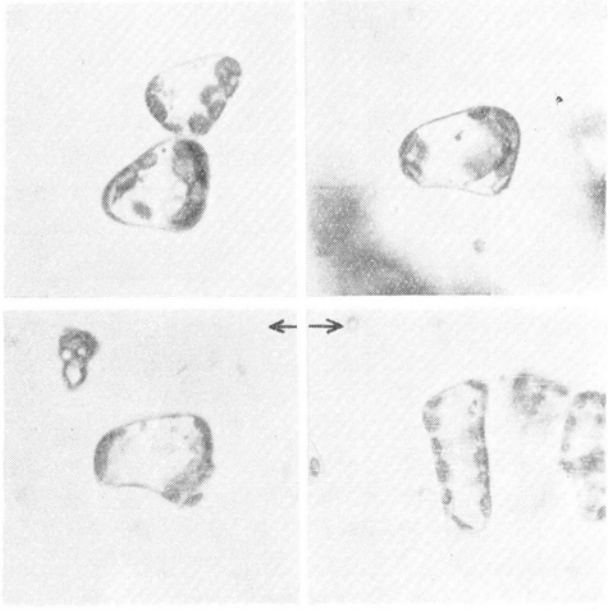

Fig. 25. *Asparagus Sprengeri.* Isolated leaf cells after 90 min illumination with polarized blue light of 96 000 erg/cm²sec. intensity.

dicular to the E-vector are covered with chloroplasts (fig. 20 b, 22). In both tissues it was possible to demonstrate the opposite action of polarized weak light. In the palisade parenchyma the effect of such radiation is not visible very clearly, but one can find that the upper crown of chloroplasts is larger by those curvatures of the cells which are running parallel to the E-vector of light (fig. 23). In the spongy parenchyma weak polarized light induces distinct arrangement of chloroplasts on those side walls which are in this case parallel to the E-vector of polarization (fig. 24).

Asparagus Sprengeri. Displacements of chloroplasts were studied on isolated cells. Leaves were homogenized 2—5 min. in a micro-homogenizer in 0.3 M/l sucrose as a medium and some drops of the cell suspension was closed with vaseline under cover glass. In a great percentage of cells (90—95%) no chloroplast dislocations were found independent of the light conditions, but some cells maintained the ability to chloroplast rearrangement at least for another hour. In such cells illumination with polarized blue light induces dislocation of chloroplasts to those walls which are parallel to the direction of light rays and perpendicular to the electrical vector of polarization. Fig. 25 presents some examples of such a reaction.

DISCUSSION

Orientation of chloroplasts depending not only on the intensity but also on the direction of polarization of light (action dichroism) has been found up till now in few objects i.e. in *Selaginella* (Mayer 1964), *Vallisneria* (Seitz 1967), *Funaria* (Zurzycki 1967) and *Lemna* (Haupt and Weisenseel 1968). The present study escales the list of species showing the action dichroism over other species. Specific reaction to polarized light was found for filamentous alga *Vaucheria*, three other species of mosses (*Mnium* and *Cirriphyllum*), leaves of water angiosperms (*Potamogeton, Hottonia*), stem of carnivorous plant (*Utricularia*) and leaves of land plants (*Symphytum, Sambucus, Polygonatum, Asparágus* and *Sedum*). In the composed anatomical structure of the leaves of the last group the specific reaction is shown both by spongy and palisade parenchyma as well as epidermis cells if they only contain chloroplasts capable to reorientation.

It is worth to stress that action dichroism of polarized ligth was found in all objects taken for investigations if they fulfilled two conditions: 1) they are able for light controlled rearrangements of chloroplasts and 2) light may reach the cells in polarized form. One may suppose that the phenomenon of action dichroism is general feature of a green plant cell.

In every case the behaviour of chloroplasts is in accordance with the assumption of orientation of the photoreceptor molecules in the way that

their absorption vector is parallel to the cell surface. In that case in strong light chloroplasts avoid such places which are situated parallel to the E-vector of light and in weak light they orientate reversely. A low intensity action dichroism was found for *Potamogeton, Lemna* and *Sedum*.

All the investigated species belong to plants in which the position of chloroplasts is controlled by the blue range of radiation (Senn 1908). Action spectra of the chloroplast rearrangements were studied for some species only i.e. *Vaucheria* (Fischer-Arnold 1963), *Lemna* (Zurzycki 1962), *Selaginella* (Mayer 1964), *Vallisneria* (Seitz 1967) and *Funaria* (Zurzycki 1967 a) and some discrepances between species were stated. The general appearance of action dichroism may suggest that the chemical nature of the active photoreceptor is in every case the same or very similar, because it is difficult to assume that pigments of quite different chemical nature were in the same way oriented in cell structures. Recently Schönbohm (1968) reported that for *Mougeotia*, where the movement of chloroplasts is actually controlled by a phytochrome system, the activity of blue light shows also action dichroism.

The consequence of the characteristic reaction of chloroplasts to polarized light is that using this type of radiation the general effect of illumination depends on the geometry of the cell. It was found for *Funaria* (Zurzycki 1967 b) that when the plane of polarization makes the longer cell walls forbidden for chloroplasts more plastids remain in a flat position even in high light intensity. In the above discussed case for *Cirriphyllum*, where the cells are extremely long, the influence of the cell geometry is especially well expressed (fig. 3). On the other hand, in the palisade parenchyma cells strong unpolarized light induces not very distinct displacements. By using polarized light much better visible rearrangements may be induced in the case of *Sedum* (fig. 21).

The orientation of the cell surface to the plane of polarization is the decissive parameter which determines the end position of chloroplasts in polarized light. This was especially well visible in two cases: 1) in *Sambucus* epidermis, where a lot of place in the cells (small number and dimensions of chloroplasts) makes that the plastids may chose those points on the curved side walls, which are situated exactly perpendicularly to the E-vector of light and 2) in *Hottonia* mesophyll, where a chloroplast "sitting" on the narrow cell curvature was found. In the last case the attracting force of the proper fragment of the cell surface was so great that the chloroplasts lost their whole surface contact with the protoplasmic layer and remained connected with the cell surface only in limitted, but situated in the proper place area.

To exert its influence, the polarized light must reach the cell surface. It seems that the depolarization which may take place in the cell walls due to the birefridigence of these structures plays no important role. In the side walls of *Potamogeton. Mnium, Funaria, Lemna* sometimes

strong birefridigence can be stated in crossed nicols, but the reaction of chloroplasts shows in these cases a typical action dichroism. On the other hand in the intercellulars filled with air very strong depolarization takes place (fig. 14). This is the reason why it is sometimes difficult to find a typical action dichroism in not infiltrated leaves. It must be supposed that, in the natural conditions, action dichroism may have some significane for water plants, but nearly none for land plants with their leaves rich in intercellular system.

The results obtained for *Lemna* need further explanations. The reaction reported by Haupt and Weisenseel (1967) has been confirmed by us, but for some strains of *Lemna* only. The other ones demonstrated a typical behaviour which should be forseen from the orientation of photoreceptor molecules. The attempt of explaining this exeptional case will be reported elsewhere (Zurzycki 1969).

SUMMARY

1. Green assimilating cells of different species were investigated in polarized blue light. The behaviour of chloroplast rearrangements in that condition was studied.

2. The existence of action dichroism was stated for following species: *Vaucheria* (filament alga), *Mnium cuspidatum, M. medium,* and *Cirriphyllum piliferum* (Mosses), *Potamogeton crispus, Lemna trisulca, Elodea canadensis, Utricularia vulgaris, Hottonia palustris* (water angiosperms), *Symphytum cordatum, Sambucus nigra Asparagus Sprengeri, Polygonatum odoratum, Sedum maximum* (terrestial plants). In each case the reaction of chloroplasts suggest the same orientation of the photoreceptor molecules. One may state that action dichroism is a general phenomenon among green plants.

3. Only in one exeptional case (*Lemna trisulca*) two types of chloroplasts reaction was found, suggesting orientation of photoreceptor in one case and disorientation in the other.

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Dichroizm działania światła w przemieszczeniach chloroplastów u różnych gatunków roślin

Streszczenie

1. Jak wykazano uprzednio dichroizm działania światła polegający na uzależnieniu orientacji chloroplastów nie tylko od intensywności i długości fali światła, ale i od kierunku polaryzacji jest cechą charakteryzującą przemieszczenia chloroplastów u kilku gatunków. W niniejszej pracy studiowano zachowanie się chloroplastów w komórkach naświetlanych spolaryzowanym światłem niebieskim u szeregu gatunków należących do różnych grup systematycznych i ekologicznych.

2. Występowanie dichroizmu działania stwierdzono u następujących gatunków: *Vaucheria* sp., *Mnium cuspidatum, M. medium, Cirriphyllum piliferum, Potamogeton crispus, Lemna trisulca, Elodea canadensis, Utricularia vulgaris, Hottonia palustris, Symphytum cordatum, Sambucus nigra, Asparagus Sprengeri, Polygonatum odoratum* i *Sedum maximum*. We wszystkich wypadkach reakcja chloroplastów wskazuje na podobną orientację drobin fotoreceptora. Wyniki pozwalają na stwierdzenie, że dichroizm działania jest zjawiskiem ogólnym wśród roślin zielonych.

3. Tylko w jednym wypadku (*Lemna trisulca*) stwierdzono dwa możliwe typy reakcji chloroplastów na światło spolaryzowane, sugerujące w jednym wypadku orientację cząsteczek fotoreceptora, w drugim wypadku brak takiego zorientowania.