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Photochromic relocation *quality of Adiantum capillus-veneris L.*

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ABSTRACT

Adiantum capillus-veneris, is a species of ferns in the genus *Adiantum* with a subcosmopolitan worldwide distribution. It is cultivated as a popular garden fern and houseplant. *Adiantum capillus-veneris* is native to the United States. The aim of this study was to overview its therapeutic effects than its nutritive and industrial effects. This review article was carried out by searching studies in PubMed, Medline, Web of Science, and IranMedex databases. The initial search strategy identified about 107 references. In this study, 36 studies was accepted for further screening and met all our inclusion criteria [in English, full text, therapeutic effects of *Cynara scolymus L.* and dated mainly from the year 1981 to 2016. The search terms were “*Adiantum capillus-veneris*”, “light spectrum quality”, “pharmacological effects”. Photochromic relocation to the nuclear region in phytochrome-dependent *Adiantum capillus-veneris* spore germination by partial spore-irradiation experiments was shown. The light wavelength dependence of stomatal opening matched that of photosynthesis.

Keywords: *Adiantum capillus-veneris L.*, Phytochemicals, light spectrum quality, Pharmacognosy, Alternative and complementary medicine.

INTRODUCTION

Adiantum capillus-veneris, the Southern maidenhair fern [1], black maidenhair fern, maidenhair fern, and venus hair fern [2], is a species of ferns in the genus *Adiantum* with a subcosmopolitan worldwide distribution. It is cultivated as a popular garden fern and houseplant. *Adiantum capillus-veneris* is native to the United States [3]. It is also native to Eurasia, the Levant in Western Asia[4]. The warm microclimate created by hot mineral springs permits the growth of the plant far north of its normal range[5, 6].

It is found in temperate climates from warm-temperate to tropical, where the moisture content is high but not saturating, in the moist, well-drained sand, loam or limestone many habitats, including rainforests, shrub and woodlands, broadleaf and coniferous forests, and desert cliff seeps, and springs[7]. It often may be seen growing on moist, sheltered and shaded sandstone or limestone formations, generally south-facing in the southern hemisphere, north-facing in the north, or in gorges [8]. It occurs throughout Africa in moist places by streams. On moist sandstone cliffs it grows in full or partial shade, even when unprotected. *Adiantum capillus-veneris* grows from 6 to 12 in [15 to 30 cm) in height [9-11]; the frond rachis is black and wiry. *Adiantum capillus-veneris* is cultivated and widely available around the world for planting in natural landscapenative plants[12-15] and traditional shade gardens, for outdoor container gardens, and commonly as an indoor houseplant. The fern is listed as an endangered

species in North Carolina (as southern maidenhair-fern) and threatened species in Kentucky (as venus hair fern), due to loss of Appalachian habitat [8, 16]. This plant is used medicinally by Native Americans. The Mahuna people use the plant internally for rheumatism, and the Navajo people of Kayenta, AZ use an infusion of the plant as a lotion for bumblebee and centipede stings. The Navajo people also smoke it or take it internally to treat mental illness [17, 18].

Photochromic activity

Light spectrum quality

Photochromic in etiolated seedlings of wild-type *Arabidopsis* and its transgenic lines L15 and L20 was investigated. Results revealed that phy1 has Pr' and Pr'', designated phy1' and phy1'', akin to phyA, which comprises both Pr photochemical types (phyA' and phyA''), and in contrast to phyB that possesses only Pr''. The proportion of phy1' and phy1'' depends on pre-illumination for induction of germination. The pigment most likely accumulated in the seeds and was active in promoting *Arabidopsis* seed germination [19].

The isolation of two blue light photoreceptor genes, designated cryptochrome genes 4 and 5 (CRY4 and CRY5), from the fern *Adiantum capillus-veneris* was reported. The intracellular distribution of reporter beta-glucuronidase (GUS)-CRY fusion proteins indicates that GUS-CRY3 and GUS-CRY4 localize in fern gametophyte nuclei. The nuclear localization of GUS-CRY3 is regulated in a light-dependent manner. Together with our physiological knowledge, these results suggest that CRY3, CRY4, or both might be the photoreceptor that mediates inhibition of spore germination by blue light [14].

Photochromic relocation to the nuclear region in phytochrome-dependent *Adiantum capillus-veneris* spore germination by partial spore-irradiation experiments was shown. Intracellular distribution of PHY-GUS fusion proteins expressed in germinated spores by particle bombardment showed the migration of Acphy2, but not Acphy1, into nucleus in a red light-dependent manner, suggesting that Acphy2 is the photoreceptor for fern spore germination [20].

The behavior of actin filaments under various light conditions was observed in *Adiantum capillus-veneris* gametophytes. In chloroplasts staying in one place under a weak light condition and not moving, circular structures composed of actin filaments were observed around the chloroplast periphery. In contrast, short actin filaments were observed at the leading edge of moving chloroplasts induced by partial cell irradiation. In the dark, the circular structures found under the weak light condition disappeared and then reappeared around the moving chloroplasts. Mutant analyses revealed that the disappearance of the circular actin structure was mediated by the blue light photoreceptor, phototropin [21].

Chloroplasts in *neo1* mutants still become relocated from the dark position to the light position under red light. Four *neo1* mutant alleles were tested and all of them showed the red-light-induced chloroplast relocation. The same light positioning was evident for nuclei under red light in the *neo1* mutant. The nuclear light positioning was also induced in darkness with the addition of Suc or glucose. These results indicate that photosynthesis-dependent nondirectional movement contributes to the light positioning of these organelles in addition to the *neo1*-dependent directional movement toward light [22].

Blue light response of *Adiantum* stomata was investigated and it was found that the light wavelength dependence of stomatal opening matched that of photosynthesis. The results indicate that *Adiantum* stomata lack sensitivity to CO₂ in the dark and that stomatal opening is driven by photosynthetic electron transport in guard cell chloroplasts, probably via K⁺ uptake [23].

Red light-induced nuclear movement is mediated by neochrome1 (*neo1*), blue light-induced movement is redundantly mediated by *neo1*, phototropin2 (*phot2*) and possibly *phot1*, and dark positioning of both nuclei and chloroplasts is mediated by *phot2*. Thus, both the nuclear and chloroplast photorelocation movements share common photoreceptor systems [24].

Phototropic responses in land plants are induced by blue light and mediated by blue light receptor phototropins. Mutants for *phy3* were also partially deficient in rhizoid blue light-induced negative phototropism, suggesting that *phy3*, in conjunction with phototropins, redundantly mediates the blue light response [25].

The responses of stomata to light in the fern *Adiantum capillus-veneris* was investigated. The results were confirmed in the isolated *Adiantum* epidermis. The red light-induced stomatal response was not affected by the mutation of phy3, a chimeric protein of phytochrome and phototropin in this fern. The results suggest that ferns of *Leptosporangiopsida* lack a blue light-specific stomatal response, although the functional phototropin and plasma membrane H (+)-ATPase are present in this species [26].

The analysis of expressed sequences from a diverse set of plant species has fueled the increase in understanding of the complex molecular mechanisms underlying plant growth regulation. This plant contribute significantly to the understanding of plant growth regulation, particularly for pteridophytes[27].

The real, biologically active conformation of the LOV domain within the whole phototropin is different from the crystal structure of the isolated LOV domains. The MD simulations do offer, however, insight into details of the dynamics of the dark and illuminated LOV domains, which are discussed in the light of recent experiments [28].

The isolation of two blue light photoreceptor genes, designated cryptochrome genes 4 and 5 (CRY4 and CRY5), from the fern *Adiantum capillus-veneris* was reported. The results suggest that CRY3, CRY4, or both might be the photoreceptor that mediates inhibition of spore germination by blue light [29].

Chloroplast movement was induced by partial cell illumination using a high-fluence blue microbeam in light-grown and dark-adapted prothallial cells of the fern *Adiantum capillus-veneris*. The data indicate that the signal transduction pathways of the HFR and the LFR must be distinct [30].

Large-scale screening for genes whose expression was regulated by phytochrome and antagonistically by a blue light receptor in the spores of the fern *Adiantum capillus-veneris* L. was reported. The expression of this cDNA was induced 8 h after a red light treatment and the red light induction was photoreversibly prevented by far-red light and photo irreversibly by blue light. The mRNA of this gene was detectable 4 h after red light irradiation and gradually increased in germinating spores [31].

Genomic clones encoding sequences similar to those encoding blue-light photoreceptors (cryptochromes) isolated in higher plants. These structural features indicate that the genes indeed encode *Adiantum* cryptochromes and represent a small gene family having at least three members [32].

The phytochrome gene (PHY1) cDNA from the fern *Adiantum capillus-veneris* encodes an amino acid sequence that shows equal similarity (50-60%) to all five *Arabidopsis* phytochromes (PHYA-E). it suggest that the phy1 phytochrome molecule is too diverged from those of *Arabidopsis* to be fully functional[33].

Perception of polarized light inducing phytochrome-mediated polarotropism in protonemata of the fern *Adiantum capillus-veneris* L. was analyzed .the difference in amount (or percent) of the far-redabsorbing form of phytochrome (Pfr) between the extreme tip and the subapical region appears to be crucial in regulating the direction of apical growth; the difference in Pfr level between the two sides of the protonemal apex may occur mainly at the apical dome. Furthermore, the transition moments of the red-absorbing form of phytochrome (Pr) and Pfr seem to be aligned parallel and normal, respectively, to the cell surface at the periphery of the apical hemisphere [34].

The morphology of the plasma membrane and the cell wall of single-celled protonemal filaments of the fern *Adiantum capillus-veneris* grown under continuous red light was examined. Measurements of the size and the density of the randomly distributed plasma membrane particles indicate that the tip region must be specialized with respect to other plasma-membrane activities as well. Thus the tip region contains not only the highest density of randomly destributed intramembrane particles, but also particles of different sizes than those found elsewhere in the plasma membrane [35].

The structure and distribution of cell organelles were observed in the gametophytes of *Adiantum capillus-veneris* L. . During cell division, mitochondria aggregated at the poles of the spindle and at the equatorial plane of the spindle margin. After cytokinesis the vacuole system becomes fragmented and is redistributed uniformly throughout the tip cell, the daughter nucleus rounds up and becomes surrounded by oil droplets [36].

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