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Research Article

Interlocked Molecules of Rotaxane and Catenane: A Valuable Tool in the Sustainable Management of Crop Protection Against Damage by UV Radiation

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In this critical review article or emerging field of molecular machines of converting energy into movement and forces for energy conversion at a molecular level, based on literature data and own results on supramolecular structures. We focus mainly on investigations regarding rotaxanes and catenanes which exhibit novel photochemical and photophysical properties. These supramolecular photochemical complexes may have applications in areas such as protection against ultraviolet (UV) radiation, necessary to minimize the expected negative impacts of climate change on agro-ecosystems

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Climate change will affect the agricultural sectors in many ways, and these impacts will vary from region to region, however effects of regional climate change on agriculture have been limited. This change in the pattern of weather has been predicted to have significant impacts on agricultural productivity at global level [1,2].

The increase in global average global surface temperature combined with the increased ultraviolet (UV) radiation, due to depletion of the stratospheric ozone layer may negatively affect in agricultural crops. Consequently, the direct negative effects of exposure to intense UV radiation on plant growth, photosynthesis, and productivity are generally significant [3,4]. UV radiation is primary environmental factor affecting the growth and development of plants. High levels of UV radiation can cause photo-oxidative stress in plants affecting the development of plants and decreased photosynthesis as well as reduced biomass.

When plants are exposed to intense ultraviolet radiation, significant and irreversible damage to important metabolic processes including damage to photosystems in which photosynthesis takes place [5]. Moreover, the photochemical efficiency of chloroplast photosystems can be inhibited by broadband UV radiation.

Agricultural technologies for climate change mitigation requires, among other things, optimizing photosynthesis process efficiency, particularly in arid and semi-arid regions. Since in these regions UV radiation can damage plants, significantly decreasing growth and productivity.

Photosynthetic processes one of the most important processes that supplies the energy required for the survival of all living organism on earth. The initial process is the absorption energy from sunlight by a specialized supramolecular organization called a light-harvesting antenna converting the energy of sunlight to a usable form of potential chemical energy [6]. This natural process energy-conversion have inspired researchers to produce artificial counterparts.

In this regard, supramolecular chemistry is an interdisciplinary field of research that rapidly expanding at the frontiers of molecular science which focuses on the study of on the chemical systems made up of a discrete number of assembled molecular subunits or components. Due to its importance and potential applications in a wide range of fields, currently the supramolecular systems are used in the creation of numerous functional biomaterials and therapeutics [7].

Key applications of this field are the construction of supramolecular photochemical useful for the conversion, storage and optimization the efficiency of solar energy, since this would have important practical applications, including mitigate the effect of increased exposure to the UV radiation on the productivity of the crops [8]. For this purpose, numerous mechanically interlocked molecular structures have been synthesized. Researches have been trying to develop highly complex light–harvesting systems to utilize the full solar spectrum. These complexes can be implemented as functional supramolecular structures and can be used molecular redox switches to generate and control molecular motion [9].

Recently structures of rotaxane and catenane have emerged as one of the important classes of supramolecular photochemistry systems capable of multi-electron transfer. Theses supramolecular systems in which reversible changes in the positions their structural components can be controlled by means of external stimuli such as photons and electrons, since they usually contain electron donor macrocycles and electron acceptor wires ideal for the design of simple molecular machines [10]. One of the most attractive features of these interlocked systems is their ability to induce controlled photon collection and subsequent energy transfer.

These complexes behave as a kinetically controlled molecular switch and emerged as an excellent photoactive material, due to its extraordinary properties to accepting properties and low reorganization energy, which are capable of absorbing light and undergoing a transfer cascade of energy [11,12].

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Studies on the interlocked model systems have allowed organic chemists to develop novel donor-acceptor structures to tailor the charge separation and storage characteristics for specific application including artificial photosynthetic.

Researchers have designed and sensitized components that are efficient for incorporation into a supramolecular system for capturing and storing solar energy in chemical bonds on a large scale as does natural photosynthesis [13-15]. In the field of artificial photosynthesis, the use of interlocked structures composed of electron-donor groups mechanically linked to rotaxane and catenanes are very small compared to many other types of electron acceptors biomolecules that are able to mimic the charge-separation process upon exposure to light.

Among the many supramolecular systems reported to date, the well-studied interlocked systems are catenanes and rotaxanes.

We are interested in researching and developing UV-protective approaches based on supramolecular systems, focusing particularly on complex supramolecular photoconversion systems with synergist functionality capable of protecting plants from damage caused by intense ultraviolet radiation.

An artificial molecular machine, also called molecular motors, refers to any discrete number of synthetic molecular components (supramolecular system) that produce quasi-mechanical movements as a result of some external stimulus. Most of the synthetic molecular machines so far are based on rotaxanes and catenanes because motions of their molecular components can be easily predicted [] (Langton and Beer, 2014). Important features of these supramolecular systems derive of cooperativity effects from noncovalent interactions (i.e. Van der Waals interactions, coulombic forces, electrostatic interactions, hydrophobic interactions, hydrogen bonds, and π–π stacking) between the molecular components that contain complementary recognition sites. The noncovalent interactions between molecules control many biological functions, for this reason, these types of interactions are now exploited for the synthesis of artificial molecular machines.

Actually, an innovative technology has developed in plant nutrition that consists on clusters of selenium, nickel, titanium and polyoxomolybdates, which constitute the molecular structures of rotaxane and catenane structures, these compounds are reversibly converted between a high energy and a low energy isomer, thus making it a possible candidate for molecular solar thermal energy storage (Lightbourn et al., 2016). The rotaxane-catenane structures induced the construction of a supramolecular dendrimer involving orthogonal binding motifs that are enables to optimize the photosynthetic light capture, storing and maintaining more available power provided by the monochromatic beam of light of wavelength 563 nm. Therefore, these compounds improve photosynthetic efficiency and serve as a reserve material that can be used to allow plants to survive starvation induced by darkness.

References

1. Altieri M, Nicholls C (2013) The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change* 140: 33-45.
2. Koluman Darcan N, Silanikove N (2018) The advantages of goats for future adaptation to Climate Change: A conceptual overview. *Small Ruminant Research* 163: 34-38.
3. Häder D, Williamson C, Wängberg S, Rautio M, Rose K, et al. (2015) Effects of UV radiation on aquatic ecosystems and interactions with other environmental factors. *Photochemical & Photobiological Sciences* 14: 108-126.
4. Zandalinas S, Mittler R, Balfagón D, Arbona V, Gómez-Cadenas A, et al. (2017) Plant adaptations to the combination of drought and high temperatures. *Physiologia Plantarum* 162: 2-12.
5. Zhang Z, Jin L, Li Y, Tikkanen M, Li Q, et al. (2016) Ultraviolet-B Radiation (UV-B) Relieves Chilling-light-induced PSI photoinhibition and accelerates the recovery of CO2 assimilation in cucumber (Cucumis sativus L.) leaves. *Scientific Reports* 6.
6. Basso S, Simionato D, Gerotto C, Segalla A, Giacometti G, et al. (2014) Characterization of the photosynthetic apparatus of the Eustigmatophycean Nannochloropsis gaditana: Evidence of convergent evolution in the supramolecular organization of photosystem I. Biochimica et Biophysica Acta (BBA) - *Bioenergetics* 1837: 306-314.
7. You L, Zha D, Anslyn E (2015) Recent advances in supramolecular analytical chemistry using optical sensing. *Chemical Reviews* 115: 7840-7892.
8. Zeng Y, Chen J, Yu T, Yang G, Li Y, et al. (2017) Molecular–supramolecular light harvesting for photochemical energy conversion: making every photon count. *ACS Energy Letters* 2: 357-363.
9. Abendroth JM, Bushuyev OS, Weiss PS, Barrett CJ, et al. (2015) Controlling Motion at the Nanoscale: Rise of the Molecular Machines. *ACS Nano* 9: 7746-7768. [crossref]
10. Mattia E, Otto S (2015) Supramolecular systems chemistry. *Nature Nanotechnology* 10: 111-119.
11. Barin G, Frasconi M, Dyar S, Iehl J, Buyukcakir O, et al. (2013) Redox-controlled selective docking in a [2] catenane host. *Journal of the American Chemical Society* 135: 2466-2469.
12. Stoddart J (2017) Mechanically Interlocked Molecules (MIMs)-Molecular Shuttles, Switches, and Machines (Nobel Lecture). *Angewandte Chemie International Edition* 56: 11094-11125.
13. Das S, Song B, Mahler A, Nesterov V, Wilson A, et al. (2014) Electron transfer studies of high potential zinc porphyrin–fullerene supramolecular dyads. *The Journal of Physical Chemistry C* 118: 3994-4006.
14. Langton M, Beer P (2014) Rotaxane and catenane host structures for sensing charged guest species. *Accounts of Chemical Research* 47: 1935-1949.
15. Lightbourn L, Amarillas L, León R (2016) Rotaxanes, fulvalenes and catenanes: optimization of photosynthesis by nanocomposites. *Polymat Contributions* 136.