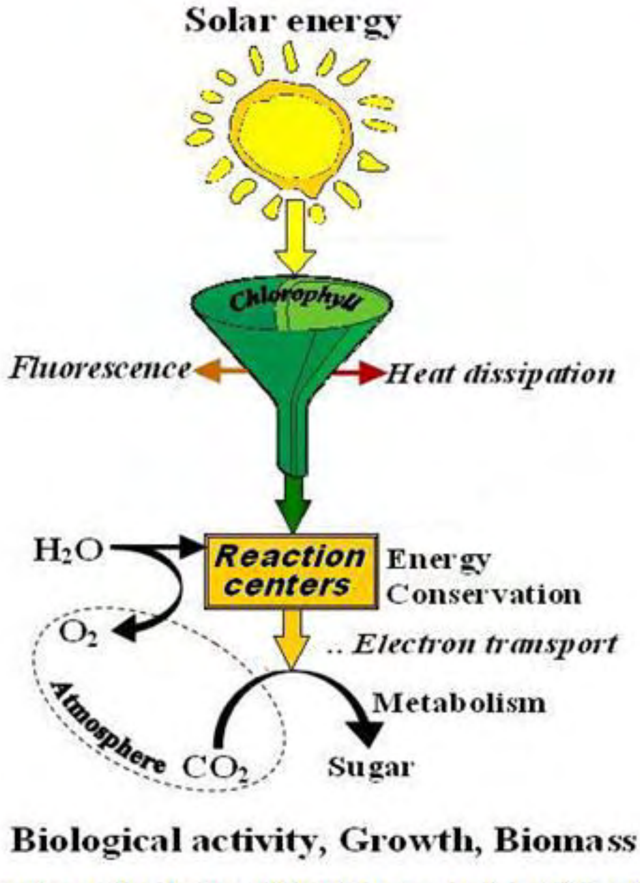
National Symposium on

Photosynthesis

& felicitation function for

Prof. Dr. Govindjee



Energy cascade in photosynthesis (modified from a poster of Prof. Reto J. Strasser)

Plant Bioenergetics & Biotechnology Laboratory
Department of Botany, Mohanlal Sukhadia University
Udaipur (Rajasthan) India

National Symposium on Photosynthesis

08-09 December 2017

& Felicitation function of Prof. Govindjee

Keynote Speaker

Prof. Dr. Govindjee
Professor Emeritus
University of Illinois, USA

Venue

New University Guest House
Mohanlal Sukhadia University Udaipur, INDIA

Plenary Speakers

Prof. Ashwani Kumar	Humboldt Fellow (Germany), Professor Emeritus of Botany, University of Rajasthan, Jaipur, INDIA
Prof. Arvind K. Purohit	Professor Emeritus of Plant Physiology, Bikaner Agriculture University, Bikaner
Prof. Ashwani Pareek-	School of Life Science, Jawaharlal Nehru University, New Delhi
Prof. Sneh L. Singla-Pareek	International Centre for Genetic Engineering and Biotechnology, New Delhi

$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{12H_2O} \xrightarrow[\text{Chlorophyll}]{\text{Light}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Water}}{6H_2O} + \underset{\text{Oxygen}}{6O_2}$$

Organizing Committee

Patron	**Prof. J.P. Sharma** Honorable Vice Chancellor Mohanlal Sukhadia University Udaipur, India
Co-Patron	**Prof . B.L. Ahuja** Dean & Chairman, Faculty of Science, MLSU, Udaipur, INDIA
Convener	**Prof. Kanika Sharma** Head, Department of Botany, MLSU, Udaipur, India
Organizing Secretary	**Dr. Vineet Soni** Department of Botany, MLSU, Udaipur, India

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Dr. Vineet Soni, Organizing Secretary
Plant Bioenergetics & Biotechnology Laboratory, Department of Botany,
Mohanlal Sukhadia University, Udaipur-313001, INDIA

National Symposium on Photosynthesis

Department of Botany, MLSU, Udaipur, India

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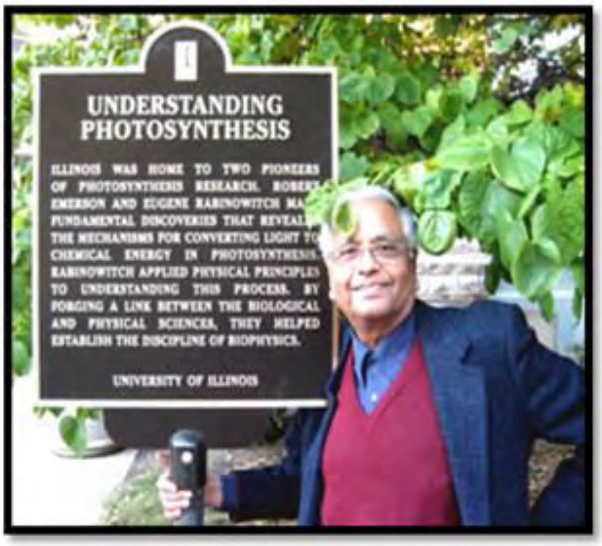
Felicitation function of

Prof. Dr. Govindjee

Professor Emeritus,
University of Illinois, USA



Plenary Speakers

Prof. Arvind K. Purohit

Prof. Ashwani Kumar

Prof. Ashwani Pareek

Dr. S. L. Singla Pareek

Organized by

Bioenergetics & Biotechnology Laboratory
Department of Botany, MLSU, Udaipur, India

CITY OF LAKES-UDAIPUR

Known as 'City of Lakes' Udaipur is a beautiful city in the state of Rajasthan in the western part of India. It was founded by Maharana Udai Singh II in 1559 as the capital of the Mewar kingdom. Located in the Arawali Ranges, Udaipur is one of the most well-known tourist destinations of the country and beautifully exemplifies the Rajasthani culture. Known for its heritage, history, culture, scenic locations and the Rajput-era palaces, Udaipur was also voted as the best city in the world in 2009 by *Travel +Leisure* magazine.

The climate of the district is moderate without significant seasonal variation. January is coldest month while May and June are the hottest months. The mean temperature is 22 degrees Celsius. Average rainfall at the city headquarter is 85.80cms. With numerous hotels to serve visiting tourists, Udaipur is home to some of the world's most renowned and the country's best luxury hotels and resorts. The lakes, temples, huge forts and palaces boast about the rich legacy of this city. The city has kept a balance between preserving the rituals and traditions of the past while keeping up with the modern advancements and changes in lifestyle.

Udaipur is famous around the world as 'City of Lakes' or 'Venice of the East'. It surprises everyone with its glassy lakes in the midst of desert Rajasthan. The Pichola Lake, FetahSagar, Udai Sagar and Swaroop Sagar are considered some of the most beautiful lakes of in the state. Fetah Sagar contains two small islands, one of which contains Udaipur Solar Observatory, and other one has a beautiful garden called Nehru Garden. Other tourist places to visit in Udaipur are Jagdish temple, City place, Bhartiya Lok Kala Mandal, Sahelion Ki Bari, Pratap Memorial, Sajjangarh Biological Park, Sukhadia circle, Jag Mandir, Lake Palace , Biodiversity Park, Gulab Bagh, Dudh Talai, Shilp Gram, Gangaur Ghat , Moti Magri. Best tourist places near Udaipur are Chittorghar, Kumbhalghar, Haldigathi, temples of Ranakpur, Nathdwara, Eklingji and Mount Abu. The city is well connected to the major cities of India by road, rail and air. The city lies 403 kilometers south west of the state capital, Jaipur and 250 km northeast from Ahmedabad.

MOHANLAL SUKHADIA UNIVERSITY, UDAIPUR

Mohanlal Sukhadia University at Udaipur is a state University established by an Act in the year 1962 to cater the needs of higher education in Southern Rajasthan with more than 2.25 lakh students. Earlier, known as 'University of Udaipur', it was renamed as Mohanlal Sukhadia University in 1982 as a mark of respect to the memory of Late Shri Mohanlal Sukhadia, the architect of Modern Rajasthan.

The university is **NAAC Accredited 'A' Grade University** and is located in Aravali Hill area largely dominated by tribal populations. Even since its inception, university has been striving to maintain excellence in teaching, research and community service. Great emphasis has been laid in creating scientific temper, maintaining high ethical values and in keeping pace with emerging areas of higher learning. University has ensured overall and inclusive approach making it most preferred institution for higher education, learning and research.

Regular review of existing courses and introduction of new courses of current national and international relevance have been a major activity of the university to produce human resources which is more skilled and employable. Emphasis has been laid on inter-disciplinary and emerging, technologies. To maintain high quality, the teaching and learning processes have been made more rigorous and effective. Evaluation process has been made more transparent and credible. Creation of new knowledge through research is one of the major objectives of higher education. Realizing its role in creation of new knowledge, the university has not only made visible impact on national and international levels but has also attracted interest of other institutions for collaborative research. Recognition of the Department of Botany, Geology, Physics and Zoology by UGC for its 'Special Assistance Programme' and support received from DST under FIST programme to various science departments is the testimony of scientific advances made by the faculty members.

DEPARTMENT OF BOTANY

The department of Botany was established in 1964, for imparting UG and PG courses as well as Ph.D. degree. Since its inception, the department has shown a steady growth and over a period of four decades, the department has emerged as a strong center of higher learning under the dynamic leadership of the doyens of botany like Prof. H.D. Kumar, Prof. C.P. Malik. Prof. H.N. Singh, Prof. Y.D. Tyagi, Prof. L. N. Vyas, Prof. B.L. Chaudhary. The department was sponsored by various finding schemes like DRS (UGC), FIST (DST), SAP (UGC).It has following well equipped research laboratories which are engaged in researches of international repute in the field of plant Biotechnology, microbiology, bioenergetics, abiotic stress physiology, molecular Ecology, plant pathogen interaction and secondary metabolites.

PLANT BIOENERGETICS & BIOTECH LABORATORY

Plant Bioenergetics & Biotechnology Laboratory works on various aspects of photosynthesis, *in vitro* morphogenesis and abiotic stress tolerance in plants. The laboratory has strong scientific collaborations with many esteemed research laboratories of France, Germany, Switzerland, Spain and Austria. Presently, the lab members are working to understand the physiological basis of drought tolerance in succulent plants and lichens.

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NAAC ACCREDITED 'A' GRADE STATE UNIVERSITY

Prof. J.P. Sharma
Vice-Chancellor

Message

I am delighted to know that National Symposium on Photosynthesis is being organized at Mohanlal Sukhadia University, Udaipur, on 8th-9thDecember, 2017. I am also glad that several eminent scientists from ICGEB (New Delhi), JNU (New Delhi), University of Rajasthan (Jaipur) and Agriculture Universities, will be participating in this symposium to discuss broad themes pertaining to photosynthesis research.

It's a matter of great pride that a great personality and distinguished plant biologist Prof. Govindjee, University of Illinois, USA will deliver key note lecture. His presence will add credit to this symposium. It's an immense honor for our university. It would encourage the young brains to choose their career in research and contribute to the society in the years to come.
I am sure that several important recommendations would emerge out of the deliberations during the two days symposium.

I wish the symposium to be highly interesting, informative, thought provoking and invigorating. I congratulate the organizing secretary Dr. Vineet Soni and his team for making such kind of academic event happens at MLSU, Udaipur.

(Prof. J.P. Sharma)

Prof. B.L. Ahuja
Dean & Chairman- Faculty of Science

UNIVERSITY COLLEGE OF SCIENCE
MOHANLAL SUKHADIA UNIVERSITY
UDAIPUR-313039, RAJASTHAN, INDIA

Message

I am very delighted to know that Plant Bioenergetics and Biotechnology Laboratory, Department of Botany, MLSU, Udaipur is going to organize a National Symposium on Photosynthesis on 8^{th}-9^{th} December, 2017. It is a matter of great pleasure that several eminent scientists from various reputed institutions throughout the India will be participating in this symposium.
It is a matter of great pleasure that renowned plant scientist and a prominent figure in photosynthesis research Prof. Govindjee, University of Illinois, USA is the keynote speaker of the symposium. I am sure that his lecture will inspire students to pursue their research work in this field.

I hope that lectures delivered by eminent invited speakers would provide an opportunity to augment research activities in MLSU. I wish the organizer my best wishes for the grand success of this symposium.

(Prof. B.L. Ahuja)

Prof. Kanika Sharma
Head
DEPARTMENT OF BOTANY
MOHANLAL SUKHADIA UNIVERSITY
UDAIPUR-313039, RAJASTHAN, INDIA

Message

It is a matter of great honor and pride for the Department of Botany that a two day National Symposium on photosynthesis being organized in honor of an eminent scientist Prof. Govindjee on 8th & 9th Dec. 2017.

All life on this planet is supported by plants which produce food and oxygen by the process of photosynthesis. In this changing scenario where the world is facing problems like food crisis, depletion of oxygen, environmental pollution, a two day national symposium on photosynthesis is in line with the demand of the day. The symposium will focus on recent research and developmental activities in this area and will provide a platform for young scientists to interact with renowned scientists like Prof. Govindjee, Prof. Rajni Govindjee, Prof. Arvind Kumar Purohit, Prof. Ashwani Kumar and Prof. Sheh Lata Singla-Pareek, and motivate them to take up research in this very important field of Botany.

I wish the organizing secretary Dr. Vineet Soni and his team very best and congratulate them for organizing such an event.

(Prof. Kanika Sharma)

Dr. Vineet Soni
Organizing Secretary

PLANT BIOENERGETICS & BIOTECH LAB.
DEPARTMENT OF BOTANY
MOHANLAL SUKHADIA UNIVERSITY
UDAIPUR-313039, RAJASTHAN, INDIA

Message

On behalf of the Organizing Committee, I would like to cordially welcome you all to National Symposium on Photosynthesis and felicitation function in honor of eminent plant biologist Prof. Govindjee. It is indeed an honor to be the host of the **FIRST NATIONAL SYMPOSIUM ON PHOTOSYNTHESIS IN RAJASTHAN** and shall make all honest and sincere efforts to make it a success in all ways. The symposium mainly focuses on recent research and developmental activities in photosynthesis research. I hope that the symposium proceedings will serve as a comprehensive compilation of the present knowledge and experience and will be used widely.

I would like to thank to Honorable Vice Chancellor Professor J.P. Sharma, Dean and Chairman- Faculty of Science Professor B.L. Ahuja and Head of the Botany Department Professor Kanika Sharma to support and motivation for the success of this symposium. I am also thankful to Dr. Preetpal Kaur, Sunita Parihar, Manisha Rathore, Hanwant Singh, Deepak Kumar, Upma Bhatt, Suresh Chand Mali, Bhanupriya, Shani Raj and Sanjay Parihar for their hard work and dedication to make the symposium successful.

I hope, that this symposium is intellectually stimulating, enjoyable, and memorable for all the attendees and professionally satisfying them at the historical, cultural city Udaipur. As the Organizing Secretary, let me assure you that every effort will be made to make your visit and stay a memorable one.

Thanking you

(Vineet Soni)

About keynote speaker

Prof. Govindjee: Mister Photosynthesis

*Govindjee has been entrenched in the basic research in the area of photosynthesis for 60 years! He has been rightfully called Mr.Photosynthesis; and he is an institution in himself. Since 1999, Govindjee has been professor emeritus of biochemistry, biophysics and plant biology at the University of Illinois at Urbana-Champaign (UIUC), Illinois, USA, after serving on the faculty of the UIUC for ~40 years. He learned his plant physiology from Shri Ranjan, who was a student of Felix Frost Blackmann (of Cambridge, UK). Then, Govindjee studied photosynthesis at the UIUC, under two giants in the field, **Robert Emerson** (a student of 1931 Nobel laureate Otto Warburg) and **Eugene Rabinowitch** (who had worked with James Franck, a 1926 Nobel laureate in physics), obtaining his Ph.D., in biophysics (with minors in physics and in chemistry), in 1960!*

Govindjee is best known for his extensive research on excitation energy transfer, light emission (prompt and delayed fluorescence and thermoluminescence), primary photochemistry, and electron transfer in photosystem II (PS II, water-plastoquinone oxidoreductase). His research, with many others, includes the discovery of a short-wavelength form of chlorophyll a functioning in PS II; the two-light effect in Chl a fluorescence; and, with his wife, Rajni Govindjee, the two-light effect (Emerson enhancement) in NADP+ reduction in chloroplasts. His major achievements, together with several others, include an understanding of the basic relationship between Chl a fluorescence and photosynthetic reactions; a unique role of bicarbonate/carbonate on the electron acceptor side of PS II, particularly in the protonation events involving the Q_B binding region; the theory of thermoluminescence in plants; the first picosecond measurements on the primary photochemistry of PS II; and the use of fluorescence lifetime imaging microscopy (FLIM) of Chl a fluorescence in understanding photoprotection by plants against excess light. His current focus is on the history of photosynthesis research and in photosynthesis education.

Professor Govindjee has received a large number of honours including ***Fellow of the American Association for the Advancement of Science (AAAS); Distinguished lecturer of the School of Life Sciences, UIUC; Fellow and lifetime member of the National Academy of Sciences (India); Past president of the American Society for Photobiology (1980–1981); Fulbright scholar*** *(1956),* ***Fulbright senior lecturer*** *(1997), and* ***Fulbright specialist*** *(2012);* ***Honorary President of the 2004 International Photosynthesis Congress*** *(Montréal, Canada); the first recipient of the* ***Lifetime Achievement Award of the Rebeiz Foundation for Basic Biology*** *(2006); and recipient of the* ***Communication Award of the International Society of Photosynthesis Research*** *(2007) and the* ***Liberal Arts and Sciences Lifetime Achievement Award of the UIUC*** *(2008). Further, Govindjee has been honoured at his 75th and 80th birthdays.*

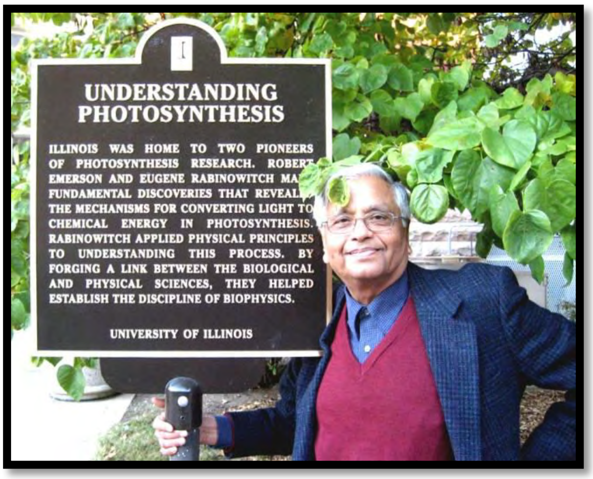
Govindjee's unique teaching of the Z-scheme of photosynthesis, where students act as different intermediates, has been published in Photosynthesis Research by P. K. Mohapatra and N. R. Singh (2015; Volume 123, pp.105–114) and by S. Jaiswal, M. Bansal, S. Roy, A. Bharati and B. Padhi (2017; Volume 131, pp. 351–359). Since 2007, each year, a ***Govindjee and Rajni Govindjee Award*** *is given to graduate students, by the Department of Plant Biology (odd years) and by the Department of Biochemistry (even years), at the UIUC, to recognize excellence in biological sciences.*

Further information on Govindjee is at
at http://www.life.illinois.edu/govindjee is a goldmine of information on him and on photosynthesis.

*Photosynthesis Research: My Personal Story**

Dedicated to Robert Emerson (1903- 1959) and Eugene I. Rabinowitch (1901- 1973)

Govindjee
Department of Biochemistry, Department of Plant Biology and the Center of Biophysics & Quantitative Biology, University of Illinois at Urbana-Champaign, Urbana,IL 61801, USA
(e-mail: gov@illinois.edu; **url:** http://www.life.illinois.edu/gvindjee)



My interest in photosynthesis research has its beginning in MSc (final) at Allahabad University, India, in early 1954 when our Plant Physiology Professor,ShriRanjan, asked us to write *a term paper* and deliver *aseminar* on a topic of interest to us--I chose "*Role of Chlorophyll (Chl) in Photosynthesis"*—where I discussed its chemistry and function, but what intrigued me most, at that time,was: Why was there a huge "drop" in the maximum quantum yield of photosynthesis beyond 680 nm (the "*Red Drop*"), when Chl*a* was still absorbing light! It is this curiosity that led me to enter the field of photosynthesis, and to work with Robert Emerson for my Ph.D. at the University of Illinois at Urbana-Champaign (UIUC), beginning in September 1956. It turned out that Emerson was already solving the mystery of this "Red Drop", when I reached there, and by 1957 he had discovered the "*Emerson Enhancement Effect",*suggesting the existence of two-light reactions and two pigment systems in photosynthesis! Rajnijoined Emerson's lab in September 1957, to be his PhD student. Neither of us could finish our PhD under Emerson since on Feb.4, 1959, he died in a plane crash. Eugene Rabinowitchaccepted both of usas his graduate students. Working under Rabinowitch, I proved, in 1960, that Emerson's short-wave system was run by a short wavelength form of Chla , i.e., Chl a 670 (a short wavelength form of Chl a), published in the journal *Science*. Soon thereafter, Rajniproved that the Emerson Enhancement Effect was indeed in Photosynthesis (Hill reaction), not in Respiration, also published in *Science*.

In my talk, I will summarize selected highlights of my research (& discoveries), with many wonderful students (including 2 outstanding students from India: the late PrasannaMohanty and Rita Khanna) and scientists, whichhaveled to an understanding of the basics of photosynthesis. My work has included: Excitation energy transfer down to 4 K (liquid helium temperature); primary photochemistry, in both Photosystem (PS) I and PS II, within a few picoseconds; the very basis of thermolumiscence(*after glow*) , and the use of Chl a fluorescence in the understanding of both fast (milliseconds to seconds) and slow (minutes)changes including the so-called "state changes"; and, more importantly the unique and exciting role of *bicarbonate*on the electron acceptor side of PSII. Most of our recent publications can be found on my web site at: http://www.life.illinois.edu/govindjee/recent_papers.html;and all chronologically arranged ones are at :http://www.life.illinois.edu/govindjee/pubschron.html. Now, the future is in making photosynthesis better able to deal with the Global Issues facing us all.

Rajni and I thank Vineet Soni for this wonderful invitation to be here at MohanlalSukhadia University, in Udaipur, Rajasthan, India.

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* Based essentially on an abstract (by Govindjee) on page 30 of the Program and the Abstract Book for the 8th International Conference on "Photosynthesis and Hydrogen Energy Research for Sustainability, held in honor of A.S. Raghavendra. W.A. Cramer and Govindjee, October 30-November 4, 2017, Hyderabad, India" Editors: S. Allakhverdiev, R. Subramanyam and I. Naydov.

Schedule

DAY -1 (08th Dec 2017)		
8:00-9:00	Registrations	
9:00-10:30	Inaugural session	
10:30-11:30	Breakfast	
11:30-12:30	**Key Note Lecture** **Prof. Dr. Govindjee** Professor Emeritus of Biophysics, Biochemistry and Physiology, University of Illinios, USA **Title:** *Photosynthesis research: Past-Present-Future*	**Chairperson** Prof. Ashwani Kumar **Co-chairperson** Prof. Arvind Kumar
	Rapporteurs: Ms Deepa Hada, Mr.Deepak Kumar	
Plenary Session 1st- Climate change and Photosynthesis		
12:30-1:30	**Prof. Dr. Ashwani Kumar** *Alexander von Humboldt Fellow (Germany), INSA-DFG Fellow, JSPS Fellow (Japan), British Council Visitor Fellow (UK) FBS, FPSI, FISMPP. V.Puri Medal* Professor Emeritus of Botany University of Rajasthan, Jaipur, India **Topic: Does phosphoenol pyruvate carboxylase plays a central role in stress resistance *in vitro* and *in vivo* ?**	**Chairperson** Prof. Rajni Govindjee **Co-Chairperson** Prof. Kanika Sharma
	Rapporteurs: Ms Manisha Rathore, Ms. Bhanupriya	
Group Photo		
1:30-2:30	Lunch	

Schedule

Plenary Session II[nd] – Photosynthesis Research in India		
2:30-3:30	**Prof. Dr. Arvind Kumar** Professor Emeritus of Plant Physiology and Former Director, Extension Education & Academic Staff College-cum-Distance Education Center, Swami Keshwanand Rajasthan Agricultural University, Bikaner (Rajasthan) **Topic: *सूरज को दीपक?*** ***Wandering in the lanes of reminiscences***	**Chairperson** Prof. R.K. Raghuvanshi **Co-Chairperson** Dr. Vineet Soni
	Rapporteurs: Mr. Sanjay Parihar, Ms Deepali Chittora	
3:30-4:30	Poster session and High Tea	
4:30-6:00	Cultural event	**Coordinator** Dr. Preetpal kaur

Schedule

DAY -2 (09th Dec 2017)		
09:00-10:00	Registration and High Tea	
Plenary Session IIIrd- Salinity, genomics and photosynthesis		
10:00-11:00	**Prof. Dr. Ashwani Pareek** *Ph.D., FNASc., FNAAS* Professor of Plant Molecular Biology & Biotechnology and Adjunct Professor at University of Western Australia Stress Physiology and Molecular Biology Laboratory, School of Life Sciences, Jawaharlal Nehru University, New Delhi 110067 **Topic: Insight into Salt Tolerance: Peeping via OMICS window**	**Chairperson** Prof. S.D. Purohit **Co-Chairperson** Dr. Harshada Joshi
	Rapporteurs: Ms Shivangi, Ms Kavita	
Plenary Session IVth – Food security		
11:00-12:00	**Prof. Dr. *Sneh Lata Singla-Pareek*** *PhD, FNASc* Group Leader, Plant Stress Biology International Centre for Genetic Engineering and Biotechnology, Aruna Asaf Ali Marg New Delhi-110 067, India **Topic: Ensuring the Food Bowl for Masses: Tackling Multiple Abiotic Stresses**	**Chairperson** Prof. K.G. Ramawat **Co-Chairperson** Prof. N.K. Gupta
	Rapporteurs: Ms. Surbhi Mehta, Mr Tansukh Barupal	
12:00-01:00	Lunch + Photosynthetic Artwork	
1.00-2:00	Valedictory session	
2:00-2:30	Certificate distribution	

Messages for Felicitation to Prof. Govindjee

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November 21, 2017

Govindjee
Professor Emeritus of Biophysics, Biochemistry,
and Plant Biology
University of Illinois at Urbana-Champaign
Urbana, IL 61801

Dear Govindjee,

Many congratulations on the occasion of your 85th birthday!

I remember fondly attending your lectures on photosynthesis at the University of Illinois when I was a member of the Chemistry faculty there, including the Kok cycle and the many other aspects of photosynthesis. I benefited much from these lectures when, at the time, I was writing articles on the early electron transfer steps in the bacterial photosynthetic reaction center.

At age 94, your age of 85, perhaps paradoxically, seems a little young. I am sure that in mind and spirit you are indeed as young as you were in the days when we were both at the University of Illinois.

With all good wishes to you, Rajni, and your family,

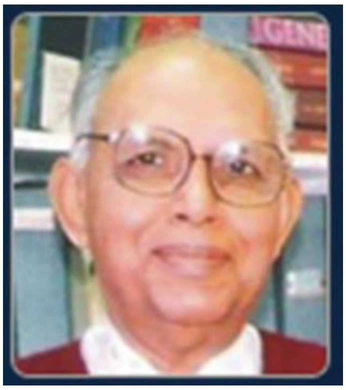
Rudy

Rudolph A. Marcus
Nobel Laureate in Chemistry 1992

Professor S. C. Maheshwari

Fellow, Indian Academy of Sciences,
Fellow, Indian National Science Academy
Fellow, National Academy of Sciences, India
J. C. Bose Gold Medal Awardee, Birbal Sahni Gold Medal
Shanti Swarup Bhatnagar Prize

Former Professor, School of Life Sciences
University of Delhi, New Delhi, India



Message

I regret very much that I am unable to attend the symposium that you are organizing at Udaipur to felicitate Professor Govindjee. But I would like to convey that it has been a great privilege to know Professor Govindjee as well as his wife Rajni who is a scientist herself and has also contributed greatly to research in photosynthesis and photobiology. It may surprise some that my acquaintance with them began through my father (late Professor Panchanan Maheshwari) who examined Govindjee during his final examinations. Already as a student, Govindjee had made an impression -- indeed my father had enquired about Govindjee at a breakfast meeting at our home when Professor Shri Ranjan, his teacher, was visiting Delhi!

Not too long after we proceeded to USA. But before beginning our visits to USA, we had married our class friends. Thus, when Nirmala and I drove from New Haven to Pasadena, and when we passed by Urbana, it was a meeting between four of us. Govindjee and Rajni were still finishing their PhD work (they had begun their research career in Allahabad but opted to finish their doctoral work in US), and I count this meeting as one of the most significant events of our lives since Govindjee in a way became a teacher of photosynthesis for me. We also met Professor Rabinowitch (Govindjee and Rajni had begun their work Robert Emerson, but Emerson had died in a plane crash and now they were Rabinowitch). The Govindjees began their wok during a classic period of photosynthesis research. Their studies importantly contributed to the formulation of the Z scheme which epitomizes the classic period of photosynthesis research'

Since this note has already become a bit too long, let me end by sending my good wishes for the success of your conference. Govindjee is an internationally known authority on photosynthesis. He has also been an excellent teacher and speaker and an author of unmatched productivity. I salute him for his scholarship and hope that young people will profit a great deal by coming in direct contact with this living legend.

Sincerely

(Satish Chandra Maheshwari)

Professor Lars Olof Björn

Professor Emeritus (Molecular Cell Biology)
Department of Biology, Lund University,
Lund, Sweden
Telephone number:+46 46 222 72 53

Message

I have talked to Govindjee face to face only once, and it was long ago and only briefly, perhaps in 1968 at the International Congress of Photosynthesis Research in Freudenstadt, Germany. Then for about 40 years, we had no contact at all, except that in 1999 I wrote a chapter in a book edited by Govindjee. But in the meantime I got acquainted with Govindjee's important scientific work through the literature. After we had both formally retired, we took up contact again. I think that it started when I needed a good coauthor for a chapter on the evolution of photosynthesis in a book published in 2011, because I am not a photosynthesis expert myself. At present we are in almost daily contact via the Internet, and have cooperated on a number of writing projects.

I admire Govindjee not only for his well-known scientific achievements, but also for his interest in education of a younger generation, and his ability to explain different concepts in a way that can be understood also by people who are not already familiar with the topic. He may have struggled hard for being freed from the American norm of having a first name, a middle initial and a family name. He is *Govindjee*. But I have another appropriate name for him: Professor Photosynthesis.

I wish Govindjee many more happy and productive years.

(Lars Olof Björn)

Lund, November 26th, 2017

Professor Arthur M. Nonomura

BA, MA, PhD, (University of California, Berkeley),
PostDoc (University of California, San Francisco)

Carbon Reactions of Photosynthesis
Sector Brandt iHammer
Powell OH 43065 USA

Message

Fiat* Govindjee- *Fiat lux
(Motto of University of California, USA)

As you prepare a seminar on photosynthesis and complete your review of the literature, what do you find? In all likelihood, you will be faced with the most difficult decision of how many publications of the author, Govindjee, to cite. His vast body of scientific investigations speaks with clarity and authority while his breakthroughs come forth, year after year. If you thought that Govindjee was in his prime in 1957, then brace yourself as you read his papers through to 2017, because you will then know that he continues in his prime today, making discoveries with the top scientists in the world. What a marvelous role model we have in Govindjee, who has continuously inspired us for sixty years. On campus, at University of Illinois, generations of students have made Govindjee their favorite. He is greeted by name almost anywhere in town, in part because of his innovative pedagogical approach; and more, because of his engaging personality, humor, and expertise. As anyone who has worked closely with Govindjee knows, besides his lucid scientific life, he stays in tune with contemporary culture by his wife, Rajni, and his children and community. Certainly, as you meet with him during this National Symposium on Photosynthesis, you will agree that Govindjee and Rajni rock!

Evidenced in his many publications, Govindjee is as skilled a wordsmith as he is a scientist. As an editor, not only does Govindjee consider grammar, he also corrects errors in logic and methods; and once that is done, he has a knack for improving the scientific content of the manuscript. As his co-author, I have wrestled with how to express innovations because, by definition, a discovery cannot have been described before; yet, fortunately with Govindjee by my side, we always manage to turn the phrase that clinched the concept. Brilliant! One of his recent projects has been as historian of the journal, Photosynthesis Research, in which Govindjee blended the *art* of writing with the *science* of photosynthesis. That is to say, by celebrating the person within the scientist, Govindjee has established the intangible cultural heritage* of our society of scientists. Effectively, Govindjee has re-created the knowledge and skills, as well as, the path to discovery, that give the members of this National Symposium a sense of continuity and identity. For this reason, may I propose to entitle Govindjee, “Living National Treasure.”

Footnote: *UNESCO recognizes an Intangible Cultural Heritage as “the practices, representations, expressions, knowledge, and skills that communities, groups and, in some cases, individuals recognize as part of their cultural heritage. UNESCO recognizes the titles of, “Living Human Treasure“ and “Living National Treasure.”

(Arthur M. Nonomura)

To Dr. Vineet Soni, *Organizing Secretary,* National Symposium on Photosynthesis

MICHIGAN STATE UNIVERSITY

November 22, 2017

Dr Vineet Soni
Organizing Secretary
National Symposium on Photosynthesis
Plant Bioenergetics and Biotechnology Laboratory

Department of Botany, MLS University

Udaipur, INDIA

Dear Dr. Soni,

I am pleased to provide comments on the importance of Professor Govindjee to the study of photosynthesis. Govindjee's interest in photosynthesis goes back at least to his undergraduate days. Even then, he made photosynthesis come alive by staging a play in which he played the role of Robert Emmerson. Upon coming to the US, Govindjee then studied with Emmerson, where he met Rajini, who would become his wife as well as partner in research.

Govindjee made a number of seminal contributions to our understanding of photosynthesis, especially in the areas of chlorophyll fluorescence and electron transport with a very notable discovery that bicarbonate plays a critical role. However, I leave it to others to describe these contributions more fully.

I want to focus on the role Govindjee has played in publishing material related to photosynthesis. In particular his roles are editor of the history corner in *Photosynthesis Research* and founding series editor for the book series *Advances in Photosynthesis and Respiration Including Bioenergy and Related Processes*.

By these two activities Govindjee has had an immeasurable impact on creating a very diverse community of photosynthesis researchers. In my area of interest, carbon metabolism, the historical remembrances of Andrew Benson, which Govindjee spent some time getting Benson to put onto paper, is and invaluable contribution.

The book series was to be an update of the set of volumes by Rabinowitch. But it was clear that no one person could cover all of photosynthesis. The breadth of interests that Govindjee has brought into the series is remarkable, I am grateful to Govindjee for the opportunity to move the series into ever broader aspects of photosynthesis (a forthcoming volume will be on global photosynthesis). I can also say that Govindjee showed the same keen interest in all of the volumes, regardless of topic.

Govindjee has been interested his whole life in anything related to photosynthesis. The community has benefitted tremendously from his tireless work. On the occasion of Professor Govindjee's 85th birthday and the National Symposium on Photosynthesis, I offer my heartiest congratulations and thanks for his contributions.

Thomas D. Sharkey
Distinguished Professor

MSU-DOE **Plant Research Laboratory**

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Professor C. P. Malik

FNA, FNAAS, FNASc, FISPM

Former Head Botany, Dean College of Basic Science and Humanities, Punjab Agriculture University
Advisor Jaipur National University, Jaipur

Message

PROFESSOR GOVINDJI - *an internationally renowned eminent Biologist (Great Man of Photosynthesis)*

I had heard of Prof. Govindjee for many years from Profs. VS Ramadas and MM Laloraya but had never met him. Both Profs spoke very high of this young man having succinct research contributions in the field of Photosynthesis, having umpteen publications in different aspects of Photosynthesis and photo biology in journals of repute. I vividly recall my visit to University of Illinois, Urbana and several other US universities, in 1980 under National Science Foundation to deliver series of lectures as a visiting professor. I had good fortune to meet him and his gracious wife. He was kind enough to spare some time personally to discuss his work on photosynthesis. I was beholden with his courtesy and ever willing gesture as well as his unassuming nature and deep scholarship.

In 1986 I joined "Advances in Photosynthesis - Project under PL 480 " and was fortunate to come in close contact with him. He was always willing to guide and was full of warmth , respect imbued with human qualities . He goaded young scholars to embrace new challenges and seek vistas in scientific enquiry. I vividly remember not only for his science but for his class leadership qualities. He wanted me to link photosynthetic and non- photosynthetic processes in groundnut as a model system. In 1992 I had the opportunity to attend IndoSoviet Conference on Photosynthesis in USSR. It was another opportunity to watch his brilliance, immense charm and courtesy and open nature, his many admirable qualities, none of them more pronounced than the trust and respect he places in his colleagues. In recognition of his outstanding contributions Dr Govindjee has won several academic distinctions.

He is remarkable in judging people for their organizing skills, human qualities and their scientific acumen. Govindjee is a man driven by loftier goals to do original research in Photosynthesis. He continues to disseminate knowledge to improve the life of students who constitute the future of our society. I hold Prof Govindjee in great awe and wish him many - many years for guiding young scholars and students. For me it is gratifying to pray for his healthy and long life.

(C.P. Malik)

Professor Ashwani Kumar

FABAP, FBS, FPSI, FISMPP, FMA
Alexander von Humoboldt Fellow (Germany)

Professor Emeritus & former Head of the Department of Botany, Director Life sciences, University of Rajasthan, Jaipur 302004 India

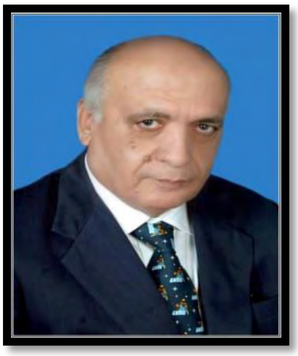
Message

It gives me great pleasure to acknowledge your communication about organization of NATIONAL SYMPOSIUM ON PHOTOSYNTHESIS during 08-09 December 2017 along with felicitation function of Prof. Govindjee and Prof Rajni Govindjee. I have honor to visit lab of Prof Govindjee in UIUC, Illinois and learn from him first hand his views on PSII and role of Carbon di oxide. I have read his book with Prof Rabinowitch way back in 1970 (Eugene Rabinowitch and Govindjee (1969; John Wiley & Sons (available free at:http://www.life.illinois.edu/govindjee/g/Books.html) and his other valuable books during the years. Recently I had an honor to visit 8th International Conference on Photosynthesis and Hydrogen Energy Research for Sustainablity-2017 in honor of Agepati S. Raghvendra, William A. Cramer and Govindjee organized from October 30th to November 4th by Prof Rajagopal at University of Hyderabad, Hyderabad. Hundreds of participants from 25 countries attended the conference which was rated as one of the best organized conference globally. As always his former students had great praise for him and he was star attraction of all the participants. Prof Govindjee motivates young researchers, guides photoysnthesis researchers all over world and advises fellow colleagues and friends with utmost patience and critical observations and comments. He inspires all the persons working in the field of photosynthesis.
He is rightly called Mr Photosynthesis. Govindjee's unique teaching of the Z-scheme of photosynthesis, where students act as different intermediates, has been published in *Photosynthesis Research* by P. K. Mohapatra and N. R. Singh (2015; Volume 123, pp.105–114) and by S. Jaiswal, M. Bansal, S. Roy, A. Bharati and B. Padhi (2017; Volume 131, pp. 351–359). He is extremely good person at heart and mind and his wife Prof Rajni Govindjee is wonderful host also. He has close connections with his former students who themselves have attained great heights. Further information on Govindjee is at https://en.wikipedia.org/wiki/Govindjee; for "Govindjee, the living legend", seehttps://www.linkedin.com/pulse/govindjee-living-legend-imet-dr-ravi-sharma; and for "Govindjee and Rajni Govindjee – Confluence of Photosynthesis and Photobiology", seehttps://www.linkedin.com/pulse/govindjeerajni-confluence-photosynthesis-dr-ravi-sharma.
On a personal note he has been very kind to write foreword for our forthcoming book **Biofuels: Greenhouse Gas Mitigation and Global Warming. Next Generation Biofuels and Role of Biotechnology** jointly edited by me and Prof Shinjiro Ogita from Japan and Professor Yuan-Yeu Yau from USA which is 41 contributions from 9 countries. He has made many valuable suggestions during book writing/editing stage which have significantly enhanced the value of our book. Finally, Govindjee's website at http://www.life.illinois.edu/govindjee is a gold mine of information on him and on photosynthesis.

I congratulate **Dr Vineet Soni,** organizer of the valuable conference on Photosynthesis and wish all success for the conference.

(Ashwani Kumar)

Professor A. K. Purohit



Professor of Plant Physiology and Former Director
Extension Education & Academic Staff College-cum-Distance Education Center, Swami Keshwanand Rajasthan Agricultural University
Bikaner (Rajasthan), Camp: Jodhpur

Message

My Dear Vineet, I am filled with an inexplicable sentiment of happiness to know that Professor Govindjee is coming to Udaipur and you are organizing an National Seminar on Photosynthesis in his honor. The prospect to see, meet and greet Govindjee is like seeing and meeting God of Photosynthesis and looking high to a Sequoia or Banyan of Plant Physiology who has allowed many saplings of scientists to grow and flourish under his gigantic shadow.

The beauty of science, literature and fine arts is that whosoever you are, small or big, if working in the sector, you are contemporary of the giants and trend setters in the field. In that sense, I have derived great delight while working for my Ph.D (1977-82) in the laboratory of Prof. Dr. N. Sankhla, who incidentally was among the trend setters in generating new knowledge about C_4 Photosynthesis that I was able to meet, communicate and correspond with eminent figures of Plant Physiology and Plant Science during my career. Although I worked on "Stomatal Regulation and Water Economy in Desert Plants" for my Doctorate and pursued research on "Drought and Salt Tolerance in Crop Plants' and my area of work (1977-2009) can be identified as "Abiotic Stress Physiology of Plants " yet the time, I reminisce, witnessed the outpouring contributions on Photosynthesis through a series of volumes by Rabinowitch and Govindjee. The Annual Reviews, Encyclopedias, Advanced Treatises, Manual of Methods, Reference and advanced texts, whatsoever, if had article or publication on Photosynthesis, invariably had references of Govindjee in a string. I used to silently wonder in my heart- how a person can do so much quality research and vis a vis can write, edit and publish so much? To me, and I am sure that for persons like me, Govindjee was a superhuman who became synonymous to Photosynthesis and eventually the name equals to that of creator, because of his creations and contributions.

Dear Dr. Vineet, besides everything, you have given me an opportunity to share a fact that it was the book on Photosynthesis, in single authorship of Govindjee, which were made available in Jodhpur in 1972, when I was student of M.Sc. Final (Botany) (at University of Jodhpur, now JN Vyas University of Jodhpur); was instrumental in cuing me toward the pocket of Plant Physiology. The question paper of Plant Physiology, in final theory Examinations that year had the first and compulsory question based on the Preface of the book written by Govindjee. I scored because I had read the book, including the Preface.

Thank you very much Govindjee Sir ! for initiating me and us, I would say, in the wonderful world of Plant Physiology, which is so dynamic, vibrant and jovial. It has given us opportunity of knowing many excellent persons like my teacher **Professor N. Sankhla** and my friend **Professor P.L. Swarnkar**, father of Dr.Vineet Soni. Dear Vineet, you have also identified me as a plenary speaker. Though elated, I am fumbling for appropriate presentation which would match the glory and grace of the persona of Govindjee. Yet, Thank you very much. I will try to do my best. I can see that you have very short time at your disposal for preparations, yet I can foresee a grand success of your contemplation, idea and vision. All the best.

(Arvind Kumar Purohit)

To
Dr. Vineet Soni, *Organizing Secretary,* National Symposium on Photosynthesis

Professor Ashwani Pareek

Ph.D., FNASc., FNAAS

Professor of Plant Mol. Biology & Biotechnology
Adjunct Professor at University of Western Australia
Stress Physiology and Molecular Biology Laboratory, School of Life Sciences, Jawaharlal Nehru University, New Delhi 110067, INDIA

Message

Professor Govindjee, the name that every plant biologist, especially the physiologist working on photosynthesis cannot miss out. Simple and short without any family name or surname his *Name* may be, yet his character and quality cannot be miss-judged with the simplicity of his name.During his visit to JNU, India, as a visiting fellow; he used to correct the undergraduate students not to call him *Sir*(like how teachers are addressed in the country) but to call him Professor Govindjee or just Govindjee, as his name already has the word *-jee* implying respect in the Indian society. Not just the students, but even the guest house worker from JNU liked him for who he is as a person and how he interacts with them. The old saying; age is just a number is meant to be for a person like him. He always talked about his mind not working as it used to be before due to his age but, his memory and activity can be compared with the toddlers who just learnt how to walk. Full of unstoppable energy and momentum he has. He works as if there won't be tomorrow. Like as if, the world is ending tomorrow. Even after travelling for nearly 30 hours by flight from Chicago to New Delhi, he still gets himself ready to discuss science and its application even to the youngest student. One very unique character that I saw in him, which I doubt anyone in this whole wide world will possess, is; he keeps alarm clock not to wake him up from sleep but to remind him it's time for bed. Along with his activeness, his work ethic and commitment to science, especially in the field of photosynthesis is something that the world knows him for. With over 550 publications in peer-reviewed journals (and still counting), members of several international committees, countless honors and academic degree, lead speakers, etc., yet his humbleness remains unaltered. I wish him all the happy, fruitful and cheerful moments all through his life!

Vineet has organized an excellent program for the meeting in honour of his 85th Birthday. I wish all the success to this meeting.

With personal regards

(Ashwani Pareek)

Mr. Subhanu Saxena

Regional Director
The Bill & Melinda Gates Foundation

Former CEO, CIPLA, India

Message

It has been my pleasure and privilege to know Professor Govindjee for over 25 years as my wife's uncle. I have never ceased to be amazed by the youthful dynamism that he brings to everything he does, especially his passion for his chosen field of Photosynthesis. He has enlightened me over the years about the fascinating history of the discovery of photosynthesis and the development of our understanding of this beautiful phenomenon of nature, without which we could not envisage life as we know it. He has not only been a pioneer in the field but also has been a custodian of the body of knowledge that we know have, through his tireless documenting of the history of photosynthesis. Even today he continues to seek out new innovations and looks to support teams that are bringing new insights. I have seen he takes a special interest in sharing his knowledge with Indian scientists, as well as championing them for greater recognition. I am sure many have been inspired by him over the years, and we hope that he will continue to inspire current and future generations for many years to come.

(Subhanu Saxena)

Professor Reto J. Strasser

Professor Emeritus, Laboratory of Plant Bioenergetics, Department of Plant Biology, University of Geneva, Switzerland

At this moment Govindjee is in India. In fact he is a great writer and he always was. A lot would get lost if he would not have written several books about the history of Photosynthesis.
I wish Prof. Govindjee and Prof. Rajni Govindjee long and healthy life. I also congratulate my student Dr. Vineet Soni for organizing National Symposium on Photosynthesis in honor for my friend Govindjee.

With regards
(Reto J. Strasser)

Professor John R Evans

Ph.D., FAA
Division of Plant Sciences, Research School of Biology
The Australian National University
134 Linnaeus Way Acton, ACT, 2601, Australia

Message

I had the good fortune to attend a series of lectures on Photosynthesis that Govindjee delivered here at ANU. He is inspirational. He wove history and mystery together to create excitement about the wonderful reaction that has led to and underpins most of the biology on Earth . His demonstration of celestial blue fluorescence from tonic water in the darkened theatre is a memory that deeply resonated with me. His passion and drive to excite and educate others is a rare thing that should be celebrated.

Sincerely
(John R Evans)

Dr. Rita Khanna

Ph.D., J.D

6533 Kenhill Road, Bethesda, MD 20817
Home Address: 6533 Kenhill Rod. Bethesda
MD 20817, USA

Message

Dear Govindjee, I admire you for your commitment, contribution and distinguished career in the field of photosynthesis. Your reputation is truly legendary and you are regarded as one of the pioneers in the field. In addition to your scientific contributions, you have diligently remembered and highlighted the contributions of others. The field has and will continue to benefit from your deep and encyclopedic knowledge. I feel very fortunate to have had the opportunity to work under your guidance. I am also ever so grateful to you, Rajniand your family for providing me a home away from home when I first came to Urbana in 1974 and I cherish the warmth and friendship that you continue to extend to me and my family. Being part of your research group was not only a great learning experience but I was alsoable to develop bonds with others who were part of the "Photosynthesis Family". Here is wishing you good health and many more years of fun with photosynthesis.

(Rita Khanna)

Prof. Govindjee,
Dr. P. Mohanty and
Dr. Rita Khanna
(Urbana, IL 1976)

Professor Michael Seibert

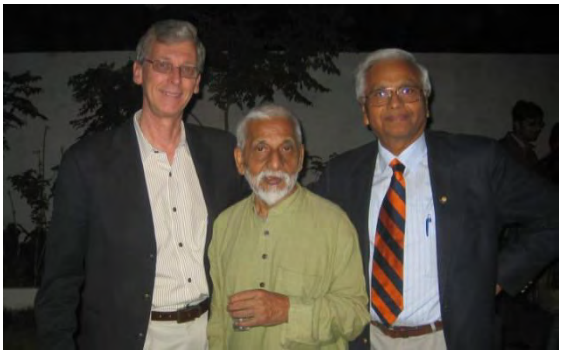
Ph.D., Senior Fellow Emeritus

Past Operating Agent, International Energy Agency HIA Task 21
AAAS Fellow, Scientific Advisory Board, BETCy
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401, USA

Message

Best wishes upon the occasion of your 85th Birthday. You have been an inspiration since I first met you over 40 years ago at a Photosynthesis Gordon Conference. You have always been very generous with your knowledge of and experience with many aspects of photosynthesis research. You have a remarkable memory of past and present literature, which has been very helpful to me and many others. Your many years of contributions and ground-breaking discoveries in photosynthesis research have made me feel very fortunate to have known and worked with you. One of the great pleasures of my career was collaborating with you (and Michael Wasielewski) in making the first direct femtosecond measurements of primary-charge-separation events in isolated photosystem II (PSII) reaction center complexes. You pushed this research, and the results we reported are still relevant and cited to this day (see Seibert and Wasielewski [2003] *Photosynth. Res.* **76**, 263-268, as well as Govindjee and Seibert [2010] *Photosynth. Res.***103**, 1-6, for historical descriptions of this work). Over the years, through the stories you have shared with me, I have also had the pleasure of learning about the lives and contributions of past generations of photosynthesis research giants, including Robert Emerson and Eugene Rabinowitch. However, besides your contributions to fluorescence studies of PSII and ensuring that the history of photosynthesis is well documented, perhaps your most important contribution to the field is your unending support and encouragement of students both in India and the US, especially at the beginning of their careers. Your students will carry on your legacy by making many more important contributions to the understanding of photosynthesis in the future.

(Michael Seibert)



Professor Morten H. Christiansen

Professor, Department of Psychology, Cornell University, Ithaca, NY 14853
Co-Director, Cornell Cognitive Science Program
Professor in Cognitive Science of Language, Aarhus University, Denmark
Senior Scientist, Haskins Laboratories

Message

Not being a biologist, my understanding of the intricacies of photosynthesis and its illustrious history was limited. Fortunately, this educational gap has been rectified over the past couple of decades thanks to Prof. Govindjee. I now know much more about the Z-scheme and other aspects of photosynthesis as well as the many pioneers who have pursued its study over the years. I'm also grateful for his time and generosity in advising and guiding me when I started out on my own academic career. Prof. Govindjee is an exceptional scientist to the world but to me he is also a wonderful mentor and father-in-law.

(Morten Christiansen)

Professor Robert E. Blankenship

Lucille P. Markey Distinguished Professor of Biology and Chemistry,
One Brookings Drive
Campus Box 1137, Washington University in St. Louis, St. Louis, MO 63130

Message

I am pleased to extend my congratulations to my very good friend Govindjee on the occasion of his 85th birthday. He has had such a remarkable career in photosynthesis, lasting over 50 years. During this time he has made many important contributions to the understanding of this essential process. These include, among many others, his research on the role of bicarbonate in Photosystem II and his extensive analysis of chlorophyll fluorescence as a probe of photosynthesis. In addition, he has more than any other person contributed to the dissemination of information about photosynthesis and education of students by virtue of his numerous books and editorial projects, in particular the Advances in Photosynthesis and Respiration series of books, which collectively summarize the field in a definitive way. I am honored to have been selected to replace him as the Historical Editor for Photosynthesis Research, and will do my best to live up to the high standard he has set.

(Robert E. Blankenship)

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INSTITUTE OF BIOSCIENCES AND APPLICATIONS

A salutation for Professor Govindjee on the occasion of the Symposium on Photosynthesis, organized in his honor at Mohantal Sukhadia University, Udaipur, India

By GEORGE C. PAPAGEORGIOU (ΓΕΩΡΓΙΟΣ Χ. ΠΑΠΑΓΕΩΡΓΙΟΥ)

Director of Research (retired) **December 1, 2017**

Dr. Vineet Soni, secretary of the Symposium on Photosynthesis, organized in honor of Professor Govindjee at **Mohanlal Sukhadia University, Udaipur, India**, invited me to write a message for Govindjee (Γκόβιντζη) on this occasion. I do gladly take the opportunity to salute here Govindjee, my distinguished Professor, collaborator and dear friend. I was his first graduate student at the University of Illinois, Urbana-Champaign, IL, USA, to finish PhD in Biophysics, under his supervision. That made me also the first degree biophysicist in Greece.

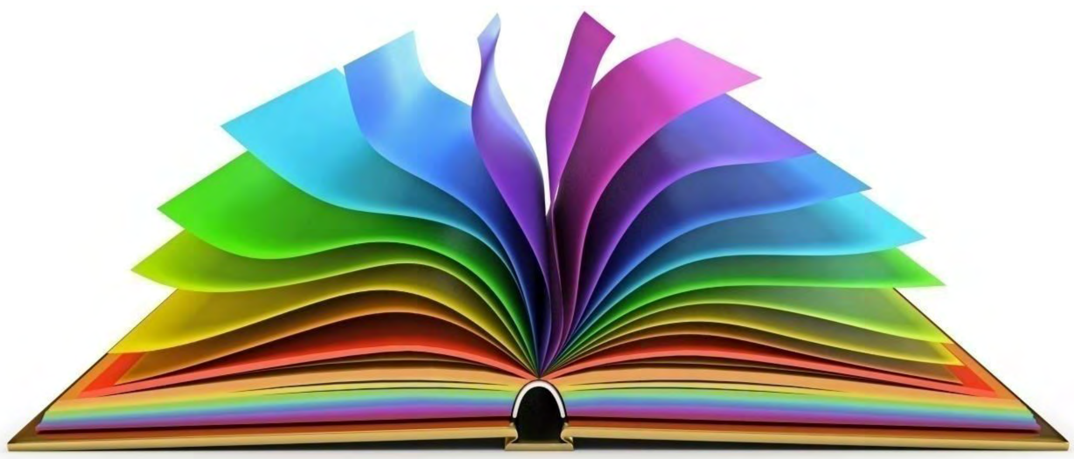
After those magic early times in the famous Photosynthesis Laboratory of Robert Emerson, Eugene Rabinowitch and Govindjee (which ceased to exist after Govindjee's retirement in 1999) I had the good fortune, the pleasure and the honor to continue cooperating with him. We have been in touch for more than fifty years. Today, at our advanced ages, we do still make plans and designs for various collaborative projects.

Detailed information about Govindjee can be found on his excellent web site, http://www.life.illinois.edu/govindjee. Very very briefly, Govindjee made pioneering discoveries in the field of oxygenic photosynthesis, focusing on how Photosystems II and I of plants, algae and cyanobacteria transduce visible light into chemical energy. It was further he, who as an editor upgraded *Photosynthesis Research*, the flag journal of the science of photosynthesis, to its present form and did, further, enrich it with the *Historical Corner*, a unique column for a scientific journal. *Photosynthesis Research* now publishes in its issues Tributes and *Memorials of* distinguished research scientists in the field of Photosynthesis. Govindjee has authored several remarkable *Memorials*.

Ending this salutatory note, I wish the Organizers a most successful scientific meeting and my dear friends Govindjee and Rajni Govindjee a most enjoyable experience in their "Old Land".

Γεώργιος Χ. Παπαγεωργίου
George C. Papageorgiou

Abstracts



DOES PHOSPHOENOL PYRUVATE CARBOXYLASE PLAYS A CENTRAL ROLE IN STRESS RESISTANCE *IN VITRO* AND *IN VIVO*?

Ashwani Kumar

Alexander von Humoboldt Fellow (Germany)
Professor Emeritus and former Head of the Department of Botany,
Director Life sciences, University of Rajasthan, Jaipur 302004 India.

Phosphoenolpyruvate carboxylase (PEPC; EC 4.1.1.31), a cytosolic enzyme, catalyzes irreversible β-carboxylation of phosphoenolpyruvate (PEP) in the presence of HCO3 − and Mg2+ to yield oxaloacetate (OAA) and inorganic phosphate (Pi). PEPC is widely distributed in all photosynthetic organisms including vascular plants, algae, cyanobacteria, and photosynthetic bacteria, and also in nonphotosynthetic bacteria and protozoa. In vascular plants, the reaction catalyzed by PEPC is the primary fixation step of photosynthetic CO2 assimilation in C4 photosynthesis and crassulacean acid metabolism (CAM). In most nonphotosynthetic tissues and in the leaves of C3 plants, the primary function of PEPC is anaplerotic, replenishing the tricarboxylic acid (TCA) cycle with intermediates that are withdrawn for a variety of biosynthetic pathways and nitrogen assimilation. Consistent with this wide range of roles, PEPC is encoded by a small gene family and expressed in various tissues of plants. The activity of vascular plant PEPC is further regulated through reversible phosphorylation of a conserved Ser residue near the N terminus. Upon phosphorylation, PEPC becomes less sensitive to its feedback inhibitor malate and more sensitive to the activator glucose 6-phosphate (Glu6P), thereby attaining higher activity. The plant-type PEPCs studied so far are classified into three groups, the C3, C4, and root types. *In vitro* studies on PEPcase activity in carrot system was studied.

Plant growth is greatly affected by a combination of environmental stresses such as extreme temperatures, drought, or high salinity. From an agricultural point of view, such stresses are among the most significant factors responsible for substantial and unpredictable losses in crop production. The physiological mechanisms governing the plant responses to salinity and drought show high similarity, suggesting that both stresses must be perceived by the plant cell as deprivation of water. NaCl salinity had adverse effects on elongation growth of maize leaves in the first phase of salt stress. It was proposed that reduced H^+ pumping of plasmalemma H^+ ATPase is involved in the reduction of leaf growth of maize during the first phase of salt stress.

Young shoots of resistant maize genotypes showed an increase in PEP-carboxylase activity during the first phase of salt stress. This study investigates the role of PEP-carboxylase activity C3 and C4 plants in stress resistance *in vitro* and *in vivo*. Studies with newly developed resistant maize genotypes. (Schubert and Zörb 2005) documented a better plant growth due to maintenance of cell wall acidification and thus

cell extension growth. PEP-carboxylase is assigned a central role to in the plant pH-stat system. This study investigates the reason for enhanced PEP-carboxylase activity in maize in regard to salt stress during the first phase. Growth reduction can be ascribed to a reduced cell extension growth due to a lower apoplastic acidification caused by osmotic stress.

In most saline environments, NaCl is the predominant salt species which inhibits cell division and expansion, resulting in slower cell growth and smaller plants. Under saline conditions, plants suffer both osmotic stress and stress caused by disorder of ion homeostasis. Therefore, a salt-resistant plant should possess mechanisms to adapt to osmotic and ion stress. During a long-term breeding program for salt-resistant maize genotypes we established an inbred line of maize with an extremely high capability to restrict Na^+ accumulation in maize leaves (1). Previous analyses showed a significant increase in PEP-carboxylase activity in young shoots of resistant maize genotypes. Plants of the resistant maize (*Zea mays* L. hybrid SR 03) and wheat (*Triticum aestivum* L. cv. Thasos) were grown under two different light intensities. Analyses of sucrose concentrations showed an increase in the saline treatment of both genotypes independent of the light intensity. Results of sucrose concentrations led to the deduction that an increase in PEP-carboxylase activity was not required for sugar metabolism. Independent of light intensity, alkalinity and malate concentrations were decreased only in wheat. It was concluded that an enhancement of PEP-carboxylase activity in young shoots of maize supports organic acid metabolism under salt stress. Recent studies suggest that under salt stress PEP carboxylase activity was significantly increased in sink leaves and shoot apex of maize, whereas no significant effect was observed in the root apex. In conclusion, PEP carboxylase may have an anaplerotic function supporting the demand for metabolites in sink shoot tissues of young maize plants under salt stress. A review of our work on these aspects shall be presented.

INSIGHT INTO SALT TOLERANCE: PEEPING VIA OMICS WINDOW

Ashwani Pareek

School of Life Sciences, Jawaharlal Nehru University, New Delhi 110067, INDIA;
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High salinity is one of the major problems for agriculture worldwide asit affects the growth and productivity of crop plants on which countless people rely for survival.In order to enhance salinity tolerance in crop plants, it is essential to understand the underlying physiological and molecular mechanisms. Every plant possess an optimal level of salt tolerance for itself. The tolerance exhibited by the halophytes over glycophytes may simply be a reflection of more efficient performance of a few basic biochemical tolerance mechanisms. To dissect out the basic survival strategies and to know the mechanism behind the contrasting tolerance levels of halophytes and glycophytes, we have initiated a research program in our laboratory. Rice is the principal food crop and also an excellent model system to understand the impact of environmental stress on crop yield. IR64 is widely cultivated, salt-sensitive indica rice, while Pokkali is a well-known, naturally salt-tolerant relative and also considered as a good source for stress-tolerant traits. We found that Pokkali can survive up to 200 mM of salinity, while IR64 isunable to do so. Pokkali showed better growth rate, possesses efficient antioxidant system, as well as better photosynthetic machinery under salinity as compared to IR64.Using the OMICS based tools, we have analyzed the transcriptome, proteome, metabolome and ionome of these contrasting genotypes of rice in response to salinity stress. We have observed a higher and an early abundance of transcripts/proteins and metabolites involved in stress tolerance and photosynthesis in Pokkali in comparison with IR64, which, in contrast, showed greater changes in metabolic machinery even during early duration of stress. Our findings suggest important differences in physicochemical and proteome profiles of the two genotypes, which may be the basis of observed stress tolerance in the salt-tolerant Pokkali.By integrating the information from halophyte and its comparison with glycophyte could give an insight for dissecting out the salt tolerance mechanisms in plants. This may eventually assist in development of salt tolerant crop plants through effective breeding strategies and genetic modification.

सूरज को दीपक ?

Wandering in the lanes of reminiscences

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वक्रतुण्ड महाकाय सूर्य कोटि सम प्रभ: /
निर्विघ्नम कुरु मे देव सर्वकार्येषु सर्वदा //

प्रोफेसर गोविन्दजी के अभिनन्दन हेतु आयोजित इस नेशनल सेमिनार में आये हुए महानुभावों , अतिथियों, संभागियों , विद्यार्थियों , देवियो, सज्जनों एवं मित्रों आप सब का स्वागत, प्रणाम, नमस्कार !

श्री गणेश की इस स्तुति में " सूर्य कोटि सम : प्रभ: " शब्द आये हैं। करोड़ों सूर्य के समान प्रकाशवान। सूर्य जो इस पृथ्वी पर जीवन की समस्त गतिविधियों के संचालन के लिए आवश्यक ऊर्जा का स्रोत है , पृथ्वी की हरीतिमा दुनियां के सबसे महत्वपूर्ण रिएक्शन फोटोसिंथेसिस द्वारा , दुनियां के सबसे महत्वपपूर्ण पदार्थ क्लोरोफिल के माध्यम से एक अद्भुत Z स्कीम द्वारा सूर्य की ऊर्जा का रूपान्तरण करती है जिससे पृथ्वी के सारे जीव पोषित होते हैं ,उस फोटोसिंथेसिस शब्द के पर्याय , वैज्ञानिकों और आचार्यों के मंडल में सूर्य की भांति आभावान प्रोफेसर गोविंदजी का हम भारत, राजस्थान ,उदयपुर और सुखाड़िया विश्व-विद्यालय के प्रांगण में हार्दिक स्वागत करते हैं।

मित्रों, सूर्य की सविता शक्ति के रूप में विराजमान उनकी सहधर्मिणी प्रोफेसर डॉ. रजनी गोविंदजी का भी हार्दिक स्वागत,

ॐ भूर्भुवःस्वः तत्सवितुर्वरेण्यम |
भर्गोदेवस्य धीमहि धीयोयोनः प्रचोदयात ||

जब मुझे डॉ विनीत सोनी का एक प्लेनेरी स्पीकर के रूप में भाग लेने का निमंत्रण मिला , तो जो पहला भाव मेरे हृदय में उत्पन्न हुआ कि सब्जेक्ट पर कुछ भी बोलना मेरे जैसे व्यक्ति के लिए सूरज को दीपक दिखाना होगा तो मैंने तय किया कि मैं अपनी स्मृतियों की वीथियों में चक्कर लगाऊं और जितना हो सके गोविंदजी और आप लोगों का मनोरंजन करूँ।

Let me begin with an army joke:
Once a new recruit collided with a Colonel in an evening party. After salutations the conversation ensued:
Col: Hey, soldier, new here?
-Yes sir, joined only yesterday, and yourself, Sir?
-Me, ? ha ha! you were in liquid form when I was in uniform. Ha ha!

Friends, Govindjee did his Ph.D on Photosynthesis in 1960, me and colleagues of my age were studying in VI standard in school at that time.

Is it not a beauty of science that if once entered in a circuit, it makes one, big or small, contemporary to the giants and trend setters? We all are beneficiary of this beauty.

How these stalwarts, the beacons, influence our lives, near or far? I recall it was Professor HD Kumar, in this very department of Botany of the University of Udaipur whose aura made me to seek admission in M.Sc. (Botany) in 1969, though I completed M.Sc. From University of Jodhpur in 1971, let me share this less known secret that it was Govindjee who cued me to the pocket of Plant Physiology in conjunction with the magnetic charm of my teacher Professor N. Sankhla.

That was the time when the air was laden with names like Rabinowitch and Govindjee, volumes after volumes on Advances on Photosynthesis, that was the period of Devlin, Devlin and Barker as far as general text on Plant Physiology, that a small book appeared on Photosynthesis in a single authorship of Govindjee. Salisbury and Ross came much later.

That book was written for students to understand the complex process of Photosynthesis in a very communicative way. I remember, the terms ***Path of Electron and Path of Carbon*** were first used for Light and Dark reactions of Photosynthesis, respectively. The style was so captivating that I was tempted to read the entire book from Preface to Epilogue in few sittings.

The interesting thing which happened that in the Question paper of Plant Physiology final examinations (1971) the first question, which was compulsory also, ran into two and half pages, as it reproduced the entire Preface of Govindjee's book and then about ten small questions were asked. Never before any student had faced that kind of situation, many had not even seen the book , rest had not read the Preface, so I scored and the success pushed me toward Plant Physiology and Dr. Sankhla.

Govindjee, Sir! Thank you very much for the favour you did to an unknown student studying in Jodhpur so far away from Illinois, USA that he, and many like him were granted an opportunity of wandering like Alice in the wonderful world of dynamic and vibrant discipline of Plant Physiology, learning, earning their livelihood, becoming teachers themselves, doing some research, producing their own students and enjoying life.

Friends, in the land mark movie of Spielberg-Jurassic Park, a professor says " A butterfly flutters her wings in jungles of Congo and an earthquake is caused in Lativia..sort of " meaning there by that it is very difficult to understand the mystic ways our lives are influenced in time and space, yet it is certain that in academics and in pursuits of learning, Banyans like Govindjee nourish several saplings to grow in their gigantic shade. As Sadhguru puts it, the purpose of life is to become a full fledged life, Govindjee is an icon of a full fledged life who has inspired many to follow the suit of their own ways.

I seek to bow out while expressing my thanks to Dear Vinit, for giving me this opportunity to see Govindjee in person, with a couplet of Firaq Gorakhpuri, with a due apology for swapping his name with an equally renowned legend......

आने वाली नस्लें तुम पर फ़ख़्र करेंगी हम-असरो
जब भी उन को ध्यान आएगा तुमने " गोविंदजी ' ' को देखा है

(Dear Contemporaries! The coming generations would hold you in proud esteem/ when they know that you have actually seen Govindjee).

Thank you.

ENSURING THE FOOD BOWL FOR MASSES: TACKLING MULTIPLE ABIOTIC STRESSES

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Abiotic stresses reduce the crop yield significantly and hence, pose a major threat to agriculture. It is thus, much desirable to generate crops which are resilient to stress conditions. In this endeavor, knowledge of processes related directly or indirectly to mechanisms of stress tolerance is vital which can then be altered for raising stress-tolerant plants. Our studies show that plants accumulate methylglyoxal (MG), a cytotoxic metabolite, as a common consequence of various stresses and that its efficient detoxification via glyoxalase pathway overexpression imparts tolerance against abiotic stresses in rice. Further, we have stacked various pathways of stress response for their overexpression in transgenic rice which has resulted in raising the limits of tolerance to multiple abiotic stresses and improved yield. Simultaneously, we demonstrate that a significant enhancement in total yield of rice, under both non-stress and stress conditions, can be realized by RNAi based knockdown of a cytokinin metabolism gene to maintain hormone homeostasis. We are also taking new initiatives to explore the "unknowneome" for functional validation of several "so far uncharacterized" stress-responsive genes/proteins with the aim of identifying novel candidate genes for raising stress-tolerant crops. Considering the complexity of stress response, our results suggest that a combinatorial approach targeting diverse pathways is better than the 'single gene approach' to tame the harmful effects of environmental extremes for genetic improvement of crops for sustainable agriculture.

Photosynthesis and salinity: from halophytes to crop plants

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Salinity stress is perceived as one of the major threats to agriculture as it can cause an irreversible damage to the photosynthetic apparatus at any developmental stage of the plant. However, different halophytes have evolved different structural and physiological modifications enabling them to carry out photosynthesis under hypersaline conditions and thus enabling their survival. Of paramount importance is their capability to reduce water loss by minimizing stomatal conductance, maintaining PSII activity along with the capacity to with stand photooxidative stress is conferred through a regulatory mechanism that accord adaptability to halophytes under saline conditions. Understanding this adaptability mechanism of halophytes can provide a valuable genetic resource for improving salt stress tolerance in glycophytes. In addition, delineating the suite of genes regulating tolerance mechanism of halophytes under saline conditions using various omics approaches can be extremely useful in designing food crops to feed the burgeoning population under extreme climatic conditions.

Functionally Annotating “Unknowneome” of Rice

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Although the field of omics is progressing, much fraction of the sequenced genome still possesses genes that have not been characterized yet and encode conserved hypothetical proteins, i.e., they are conserved in different taxons but their function is still unknown. CBS domain containing proteins (CDCPs), bearing a conserved Cystathionine β-Synthase (CBS) domain, are an example of such conserved hypothetical proteins. We have identified 59 CDCPs (encoded by 37 genes) in rice of which some are found to be responsive to salinity stress. Besides salinity, we have also analyzed the expression profile of CDCPs in response to various abiotic stresses. Importantly, expression of two CDCPs viz. OsCBSX4 (containing only a single CBS domain) and OsCBSCBSPB4 (containing two CBS domains along with one PB1 domain) is found to be highly up-regulated under multiple stress conditions in rice seedlings. In order to functionally validate the CBS domain containing proteins of rice, both OsCBSX4 and OsCBSCBSPB4 have been overexpressed independently using the transgenic tobacco system. Both type of transgenic plants demonstrated improved tolerance when subjected to various abiotic stress treatments in terms of delayed leaf senescence, profuse root growth and increased biomass as compared to the wild type counterparts, thereby establishing a link between CBS domains of unknown function and stress tolerance. Overall, our findings suggest that these genes function in multiple stress response and can act as potential candidates for raising stress tolerant plants.

Enhancing grain yield in rice by silencing cytokinin oxidase

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Cytokinins (CKs) play a significant role in determining plant's grain yield by regulating panicle branching. However, plants contain an enzyme -cytokinin oxidase (CKX) which catalyzes their reversible degradation of cytokinins. To maintain active CK levels, one needs to silence CKX which will result in CK accumulation leading towards more panicle branching and thus more grains per plant. In this study, we found that the expression of OsCKX2 is inflorescence meristem-specific and highest after panicle initiation. To reduce its levels in rice, RNAi-based approach has been used which resulted in a significant increase in CK in the inflorescence meristem of OsCKX2-knockdown rice plants. Enhanced CK levels correlated with enhanced grain yield under non-stress conditions. Further, to check if the OsCKX2 knockdown plants maintain their yield even under salinity stress condition, we assessed their growth, physiology and grain yield under stress. OsCKX2-knockdown plants showed better vegetative growth, higher relative water content and photosynthetic efficiency and reduced electrolyte leakage as compared to the wild type plants under salinity stress. Importantly, a positive correlation between CK levels and plant productivity has been observed as the OsCKX2-knockdown plants show enhanced panicle branching, more grains per plant, and better harvest index both under control and salinity stress conditions. Together, these results suggest that OsCKX2 may be explored as a unique regulator of floral primordial activity for enhancing grain production in rice under normal as well as abiotic stress conditions.

Chloroplast DNA for Biological identifications as DNA barcodes

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DNA bar-coding is the use of a short DNA sequence or sequences from a standardarised locus (or loci) as a species identification tool. DNA bar-coding has the potential to deliver a universal tool kit and web accessible framework for the rapid application of molecular diagnostics to global bio-diversity. DNA bar-coding has already proved useful for identification of animal species, but plants (in a broad sense including land plants, algae and lichens) are only beginning to attract the attention. "CONSORTIUM OF THE BARCODE OF LIFE (CBOL)" has been established to stimulate the creation of a database of documented and vouchered reference sequences to serve as universal library to which comparison of unidentified taxa can be made. Ribulose Biophosphate Caboxylase Sub-unit L (*rbc*L), *psb*A- *trn*H spacer, Maturation Kinase (*mat* k) are the plastid genes currently used in barcoding. *trn*H- *psb*A spacer- is a non-coding intergenic spacer region found in plastid DNA (Kress *et al*., 2005; Shaw *et al*., 2007). This region is one of the most variable non-coding regions of the plastid genome in angiosperms in terms of having the highest percentage of variable site (Shaw *et al.,* 2007). This variation means that this inter-genic spacer can offer high levels of species discrimination (Shaw *et al*., 2007). With the advent of molecular biology and DNA sequencing, it has been suggested that universally amplified, short, and highly variable DNA markers (DNA barcodes) may help identify organisms to species with a high confidence, which would be useful in a wide array of applications, including biodiversity surveys (Moritz and Cicero, 2004)**.** The mitochondrial marker *cytochrome c oxidase I* (CO1) has met with some success for animal groups. In plants, the search for suitable genomic regions has proven more challenging. Several regions in the plastid genome (e.g. *rbcL, rpoC1, rpoB, ycf5, psbA-trnH, trnL, atpF-atpH, psbK-psbI*) as well as the internal transcribed spacer (ITS) of the ribosomal nuclear DNA have emerged as good candidates for plant DNA barcoding.

Latest discoveries in photosynthesis pertinent to crop improvement

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Photosynthesis is one of the most important biological processes in the world. It uses photosynthetic reaction centers (RC) — specialized membrane proteins — which collect the energy from light and use it to pump electrons across a biological membrane from one cellular electron carrier to another, resulting in the conversion of electromagnetic into chemical energy, which can be used by organisms.

Discoveries made during 2017 constitute the theme of this paper.

A team of scientists from Arizona State University (ASU) and Pennsylvania State University has unlocked the secrets of photosynthesis. The team believes that the first reaction center was simpler than the versions available today. In terms of the protein structure, it was a homodimer — that is, two copies of the same polypeptide came together to form a symmetric structure. The reaction centers whose structures we know are all heterodimers in which this inherent symmetry has been broken, although at their heart they still retain the vestiges of the original symmetric architecture.
The overall architecture of the protein is very similar to photosystems of plants and cyanobacteria and the RC of the purple sulfur bacteria.

http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=15749

Research findings published in the journal *Proceedings of the National Academy of Sciences*, provide quantitative evidence that inverted-region electron transfer is responsible for the very high efficiency associated with solar energy conversion in photosynthesis. Dr. Gary Hastings, professor in the Department of Physics and Astronomy at Georgia State point to new ways on how one might think about designing artificial solar cells that can be used, for example, for producing hydrogen gas, which can be used as a clean and renewable fuel. Their work has revealed one design principle that is at play in efficient solar energy conversion in plants, and the hope is that this principle could be utilized in the design of new and better types of artificial solar cells.

Hiroki Makita, Gary Hastings. Inverted-region electron transfer as a mechanism for enhancing photosynthetic solar energy conversion efficiency. *Proceedings of the National Academy of Sciences*, 2017; 201704855DOI:10.1073/pnas.17048551

Scientists at Carl R. Woese Institute for Genomic Biology, University of Illinois at Urbana-Champaign Designed plants with light green leaves with hopes of allowing more light to penetrate the crop canopy and increase overall light use efficiency and yield. This strategy was tested in a recent modelling study that found leaves with reduced chlorophyll content do not actually improve canopy-level photosynthesis, but instead, conserve a significant amount of nitrogen that the plant could reinvest to improve light use efficiency and increase yield.

Berkley J Walker, Darren T Drewry, Rebecca A Slattery, Andy VanLoocke, Young B. Cho, Donald R. Ort. Chlorophyll can be reduced in crop canopies with little penalty to photosynthesis. *Plant Physiology*, 2017; pp.01401.2017 DOI: 10.1104/pp.17.014

Using infrared gas analyzers connected to a miniature controlled environment chamber, botanists at Lancaster University have simulated a sudden increase in sunlight following shade, and measured the time it took for the plant to regain its maximum photosynthesis efficiency and take full advantage of the extra energy from light. They found it took about 15 minutes for photosynthesis to reach maximum efficiency.Crops such as wheat could be up to 21% more efficient at turning the sun's energy into food

Samuel H. Taylor, Stephen P. Long. Slow induction of photosynthesis on shade to sun transitions in wheat may cost at least 21% of productivity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 2017; 372 (1730): 20160543 DOI: 10.1098/rstb.2016.0543

The Isolated from Arabidopsis and peas, the C2S2M2-type supercomplex is the largest stable form of PSII-LHCII supercomplex, and crucial for plants to achieve optimal light-harvesting efficiency when they are under low-light conditions. Structural analysis of the C2S2M2 supercomplex is an important step to understanding the molecular mechanisms that plants use in light harvesting, light energy transfer, and PSII functional regulation.

A team of researchers from the Institute of Biophysics (IBP) at the Chinese Academy of Sciences (CAS) used cryo-electron microscopy (cryo-EM) to resolve structures of C2S2M2-type PSII-LHCII supercomplex from peas at 2.7 and 3.2Å resolution, respectively. The study revealed the overall structural features and the arrangement of each individual subunit, as well as the sophisticated pigment network and the complete energy transfer pathways within the supercomplex. The comparison of two C2S2M2 structures suggests the potential mechanism of functional regulation on the light-harvesting process and the oxygen-evolving activity of plant PSII.

http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=15724

A team of researchers led by chemists from the U.S. Department of Energy's (DOE) Brookhaven National Laboratory and Virginia Tech has designed two photocatalysts that combine individual components for light absorption, charge separation, or catalysis into a single "supramolecule." Each supramolecule is made up of multiple light-harvesting ruthenium (Ru) metal ions connected to a single catalytic center of rhodium (Rh) metal ions. The researchers found that the supramolecule with six Ru centers and one Rh center was seven times more efficient than the other, cycling 300 times to produce hydrogen for 10 hours. The larger of the supramolecules was slightly electron-deficient, making it more receptive to electrons needed for synthetic photosynthesis.

Rice 'supercharged' with maize gene may help boost yields

To improve photosynthesis in rice and increase crop yields, scientists working on the Oxford University-led C4 Rice Project have, by introducing a single maize gene to the plant, moved towards 'supercharging' rice to the level of more efficient crops.

Rice uses the C3 photosynthetic pathway, which in hot, dry environments is much less efficient than the C4 pathway used in other plants such as maize and sorghum. Scientists thought that if rice could be 'switched' to use C4 photosynthesis, its productivity will increase by 50%.

The researchers showed how they took the first step on this journey called the 'proto-Kranz' anatomy by introducing a single maize gene known as *GOLDEN2-LIKE* to the rice plant. This step increased the volume of functional chloroplasts and mitochondria in the sheath cells surrounding leaf veins, mimicking the traits seen in proto-Kanz species.

Professor Jane Langdale, Professor of Plant Development in the Department of Plant Sciences at Oxford University, and Principal Investigator on this phase of the C4 Rice Project, opined that this This research introduces a single gene to the rice plant to recreate the first step along the evolutionary path from C3 to C4. It's a really encouraging development, and the challenge now is to build on that and find the right genes to tweak to complete the remaining steps in the process."

http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=15895

Jason Yeo Boon Siang from the Department of Chemistry at NUS Faculty of Science and the Solar Energy Research Institute of Singapore (SERIS)d has published in the scientific journal *ACS Sustainable Chemistry & Engineering*. He has developed a prototype device that mimics natural photosynthesis to produce ethylene gas using only sunlight, water and carbon dioxide. The novel method, which produces ethylene at room temperature and pressure using benign chemicals, could be scaled up to provide a more eco-friendly and sustainable alternative to the current method of ethylene.

National University of Singapore. "Scientists develop artificial photosynthesis device for greener ethylene production." ScienceDaily. See-www.sciencedaily.com/releases/2017/11/171124084755.html

Photoprotection of reaction centers in lichens

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During desiccation, fluorescence emission and stable light-dependent charge separation in the reaction centers (RCs) of photosystem II (PSII) declined strongly in three different lichens: in Parmelia sulcata with an alga as the photobiont, in Peltigera neckeri with a cyanobacterium and in the tripartite lichen Lobaria pulmonaria. Most of the decline of fluorescence was caused by a decrease in the quantum efficiency of fluorescence emission. It indicated the activation of photoprotective thermal energy dissipation. Photochemical activity of the RCs was retained even after complete desiccation. It led to light-dependent absorption changes and found expression in reversible increases in fluorescence or in fluorescence quenching. Lowering the temperature changed the direction of fluorescence responses in P. sulcata. The observations are interpreted to show that reversible light-induced increases in fluorescence emission in desiccated lichens indicate the functionality of the RCs of PSII. Photoprotection is achieved by the drainage of light energy to dissipating centers outside the RCs before stable charge separation can take place. Reversible quenching of fluorescence by strong illumination is suggested to indicate the conversion of the RCs from energy conserving to energy dissipating units. This permits them to avoid photoinactivation. On hydration, re-conversion occurs to energy-conserving RCs.

Biophysical characterization of drought tolerance in wheat through polyphasic chlorophyll fluorescence OJIP analysis

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Drought tolerance is the essential trait that needs to be incorporated in cereal crops, particularly those grown under the rainfed cultivation. Understanding the biophysical basis of drought tolerance will be helpful in developing selection strategies for improving various crop varieties. Therefore, present investigation was aimed to evaluate the drought-induced changes in photosynthetic machinery of drought-tolerant (Harshita: HI-1531) and drought-susceptible (Raj-4037) varieties of wheat (*T. aestivum* L.). Maximum quantum efficiency of PS II photochemistry (Fv/Fm) parameter was found sensitive to drought stress in Raj-4037 as compare to HI-1531. Study of other parameters *i.e.* specific energy fluxes (per QA-reducing PSII reaction center- RC), phenomenological fluxes (per cross section-CS), quantum efficiencies and density of active reaction centers indicates the higher potential of drought tolerance in HI-1531 variety of *T. aestivum.*

Nanoparticles and Photosynthesis

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Nanoparticles have been used in agriculture in various ways. Preliminary studies show the potential of nanomaterials in improving seed germination, plant growth, plant protection, pathogen detection, pesticide/herbicide residue detection etc. There are a number of reports available on beneficial effects of nanoparticle treatment on crop plants. The interface between plant organelles and non-biological nanostructures has the potential to impart organelles with new and enhanced functions. Single-walled carbon nanotubes (SWNTs) passively transport and irreversibly localize within the lipid envelope of extracted plant chloroplasts, promote over three times higher photosynthetic activity than that of controls, and enhance maximum electron transport rates. Nanoparticles of various metals such as Silver and Copper have been found to increase root length, seed germination and photosynthetic activity. CeO_2 nanoparticles have been shown to increase photosynthesis in soyabean plants. The nano TiO_2 can enhance light absorbance, accelerate transport and transformation of light energy and can prolong the effective photosynthetic tenure of chloroplasts by protecting the chloroplast from aging. Mn nanoparticles were also found to be efficient in enhancing the photosynthetic electron transport rate and O_2 evolution in *in vitro* model system. Photosynthetic rate was found to be increased when iron oxide nanoparticles were sprayed foliarly on Soyabean plants. This increase in photosynthetic rates was attributed to increase in stomatal opening. Carbon nanotubes also can enhance the light reaction rate. The development of nanodevices and nanomaterial can open up novel applications in plant biotechnology and agriculture. Nanoparticles which can improve the photosynthetic properties are of great interest to researchers and are extensively investigated as potential plant growth promoter.

Early detection of leaf spot disease in *Tinospora cordifolia* through chlorophyll fluorescence OJIP analysis

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The aim of the present work was to study the impact of fungal pathogen *Phoma putaminum* on various photosynthetic parameters of tissues adjacent to the infection sites on leaves of *Tinospora cordifolia* which visually appear healthy. Changes in chlorophyll fluorescence data, specific and phenomenological fluxes, density of active reaction centers and maximal photochemical activity of PSII (Fv/Fm) indicate that toxins produced from *P. putaminum* impair photosynthesis before the appearance of visual symptoms of infection. The chlorophyll fluorescence OJIP analysis revealed that changes of the photosynthetic apparatus at an early stage can be used as measurable markers for detection of leaf spot disease in *Tinospora cordifolia*.

Biophysical characterization of drought tolerance in *Sorghum bicolor*

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In the present time, one of the most common and critical abiotic stresses is water deficiency. Drought stress leads to a series of morphological, physiological, biochemical and molecular changes that adversely affect plant growth and productivity.
Sorghum bicolor (L.) Moench is a cereal crop which is grown in arid and semi-arid regions.It is well adapted to areas with low rainfall, where it is difficult to grow other crops.Sorghum is a C_4 grass, it ranks fifth and is an economically important cereal crop worldwide. It is an important source of food and fodder. Plant growth depends on photosynthesis, which is affected by drought and PS II is accepted to be the most vulnerable part of the photosynthetic apparatus to light induced damage. Sorghum, like maize and sugarcane, carries out C_4 photosynthesis, a special character that makes these grasses well adapted to environments subject water limitation.Chlorophyll*a* fluorescence measurement is a useful tool for quantification of the effect of stress on photosynthesis.Hence, this crop isconsidered as one of the most drought tolerant crop species and is an important model system for studying effect on photosynthesis underlying drought.

Drought tolerance: a magnificent characteristic of *Sorghum bicolor*

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Plants are exposed to various abiotic factors throughout the course of their growth and development. The greatest abiotic stress that limits crop growth worldwide is low water availability or drought.It results in dramatic losses of the yield of various crops by adversely affecting their growth and physiology.Sorghum (*Sorghumbicolor* (L.) Moench is a C_4 plant commonly cultivated in the drought-prone areas of the semi-arid tropics.It ranks fifth amongst other cereal crops and is a multipurpose crop which is highly used as food and fodder. This crop exhibits various physiological responses i.e., osmotic adjustment, stay-green, C_4photosynthesis, thick leaf wax and deep root system etc., that allow continued growth under drought.To improve crop productivity, it is necessary to understand the mechanism of plant responses to water limiting conditions. Hence, sorghum is a magnificent drought tolerant model crop for evaluating biochemical and physiological mechanism during drought.

Photosynthesis and indoor plants

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Plants are bestowed with unique process of converting light energy to chemical energy by distinctive procedure called photosynthesis. This process in presence of plant pigments harnesses the light energy and utilizes it for converting CO_2 into usable carbohydrate product. Photosynthesis is largely responsible for producing and maintaining the oxygen content of the Earth's atmosphere. It thus serves as our lifeline. The pollution we face today can largely be controlled by plants alone. Plants inside homes, offices, institutions or commercial buildings are referred to as indoor plants. Most of these plants live well in low light conditions, including both lower wavelengths and light duration. Also these plants face lesser temperature fluctuations. The photosynthesis of these plants keeps the indoor environment clean thereby absorbing CO_2 and other VOCs (Volatile Organic Compounds) and releasing O_2 that is most vital requirement of our life. Various studies have shown that photosynthesis of indoor plants is largely affected by temperature and water availability. Also, succulents have proven better in indoor conditions. Light quality and duration have also been studied and it is found that LED can mimic sunlight. Presence of indoor plants not only reduces indoor pollution but also adapts to indoor environment and provides us their benefits. The photosynthetic adaptability of indoor plants has provided them the ability to grow in light stresses and proving them as low cost cleansers that can be deployed indoors.

Hardening of tissue cultured plants improves photosynthetic activity

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Hardening is a crucial step prior to transplantation of plants to soil/field. The failure in transplantation is mostly because of aberrant characteristic of in vitroraised plants. Poor or no development of cuticular wax or cuticle, impaired stomatal mechanism, poor photosynthetic ability because of availability of sugar in medium, vitrification of shoots and rooting of shoots preceded by intervening callus adversely affect the establishment of plants in soil. In order to solve this problem, the tissue culture plants are subjected to gradual and systematic hardening and acclimatization procedures enabling them to establish in soil successfully. Hardening is a step in which a tissue culture plant is made to harden with respect to physiological disorders which it develops in culture.
In our experiments plantlets of *Achrassapota*could be hardened by improvised methods. Plantlets were removed from culture medium, transferred to culture bottles containing soilrite for 15 days. The caps of bottles were gradually removed and plantlets were transferred to pots containing autoclaved garden soil-vermiculite (1:3) and kept in mist house. The plants were covered by polybags and exposed gradually to external environment. By doing so, the tissue culture plants resume normallywith respect to photosynthesis and became autotrophic. Adopting the above procedures, a large number of tissue culture plants can be established in soil.

Photosynthesis in Bryophytes (the amphibians of plant kingdom)

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Bryophytes, which are important constituents of ecosystems globally and often dominate carbon and water dynamics at high latitudes and elevations, were also among the pioneers of terrestrial photosynthesis. Consequently, in addition to their present day ecological value, modern representatives of these groups contain the legacy of adaptations that led to the greening of Earth. This volume brings together experts on bryophyte photosynthesis whose research spans the genome and cell through whole plant and ecosystem function and combines that with historical perspectives on the role of algal, bryophyte and vascular plant ancestors on terrestrialization of the Earth. The gametophyte is the dominant phase in the life cycle of moss plants. This is the form of the plant most people are familiar with since it is often seen carpeting trees, rocks, and parts of the forest floor. Photosynthesis takes place in the gametophyte phase.Moss reproduces by the creation of spores held within sporophytes. These sporophytes have no photosynthetic capabilities, so they are dependent on the gametophytes for nutrition needs.

Role of photosynthesis in medicinal plant for anthelminthic activity

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The medicinal plants plays important role for anthehelmintic activity against helminth parasites. Many medicinal plantsare used till now are Tulsi, Anar, Kaliziri, Papaya, Neem, Meetha Neem, Guggul, Kali Mirch, Kala Jira, Bhilwa, Ajowan, Tobacco, Hul Hul etc. The screenings of the studies reported are mainly *in vitro*, using some worms like Ascaris, *Ascardia galli*, trematodes and cestodes. These medicinal plants have been used to treat parasitic infections in man and animals and providea rich source of botanical helmintholytic. The ethnobotanical uses of these plants include its use as an abortifacient, cathartic, purgative and vermifuge, and for the treatment of fever, cancer, amenorrhea, jaundice, leukemia, rheumatism and tumour.Medicinal plants are reported with positive results because photosynthesis increase phytochemical and anthelminthic elements.

Photosynthesis enhances anthelminthic effect ofmedicinal plant *Citrullus colocynthis*

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Photosynthesis improved anthelminthic elements, biochemical and physiochemical substances in medicinal plant*Citrulluscolocynthis*.The experimental plant *Citrulluscolocynthis*commonly known as bitter apple, bitter cucumber, Gavakshi or Indravaruni is a viny plant, native to the Mediterranean basin and Asia especially Turkey, Nubia, Desert area of India and Pakistan. In Rajasthan, this plant occurs in Jaisalmer, Barmer and Shriganganagar. Its fruit extracts have shown anthelminthic against helminth parasites, antibacterial and antimicrobial effect against *Pseudomonas*, *Staphylococcus, Candida sps.,*antifungal property against *Aspergillusflavus*and antihyperglycemic effect on type 2 diabetic patients and rats. Photosynthesis is necessary to increase anthelminthic activity in medicinal plant *Citrulluscolocynthis*. Present study revealed that aqueous and alcoholic extracts of *Citrulluscolocynthis*found to be potential sources for novel anthelmintic and justify their ethno-veterinary use.

Aquaponics: a sustainable and water efficient production system

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One of the greatest challenges that we face today is to achieve global food security by producing enough nutritious food for continuously growing world's population and doing so sustainably. It is estimated that by 2050, there will be 9.5 billion people on the planet so there is a growing need for local sustainable food production technologies.
Aquaponics is the combined culture of fish and plants in closed recirculating system of the water from the fish tanks through hydroponic system to produce horticultural plants. Waste materials, which are excreted directly by the fish or generated by the microbial breakdown of organic wastes, are absorbed by plants cultured hydroponically (without soil). This technique is based on the natural process called nitrogen cycle where the ammonia excreted by fish is broke down into useful nutrients and cleaned water is reused back into the system. This system can be scaled from household backyards / balcony or up to commercial enterprises.
The aquaponics system represents an appropriate sustainable agriculture technique due to its unlimited advantages over conventional agriculture. Some of them are -

- Protects lakes and rivers- no use of chemical fertilizers,
- Land conservation-no requirement of farmland with fertile soil, can be grown on sand, gravel or rocky surface,
- Water conservation- uses 90% less water than traditional farming.

Effect of boron on the chlorophyll contents of mung bean and wheat

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The chlorophyll is the photosynthetic pigment found in green plants, some protists and cyanobacteria. The chlorophyll content depends on environmental changes and abiotic factors and therefore provides valuable information about physiological status of plants, photosynthetic potential and primary production. Greenhouse experiments were conducted to study the effect of different concentrations of boron on the chlorophyll contents in mung bean [*Vigna radiata* (L.) Wilczek] and wheat [*Triticum aestivum* L.]. Boron was applied as boric acid (H_3BO_3) at the concentrations of 1, 2, 4, 8, 16 and 32 $\mu g\ B\ g^{-1}$ soil. Pots without added boron constituted the control. Results indicated that lower applied doses of boron were found to increase the chlorophyll contents in both mung bean and wheat. In mung bean, maximum chlorophyll a, b and total chlorophyll contents were observed at boron levels of 4 μg g^{-1}, which was respectively 31.91%, 28.02% and 29.84% higher, over the control. In case of wheat, an increment in chlorophyll contents was seen up to boron concentrations of 8 μg g^{-1}. However, the maximum increment in chlorophyll a, b and total chlorophyll contents were observed at boron levels of 4 μg g^{-1}, which were found to be respectively 10.51%, 17.60% and 12.92% higher, over the control. Higher applied doses (16 and 32 μg g^{-1}) were found to adversely affect the contents of chlorophyll pigment in both experimental crops.

Effect of LEDs (light-emitting diode) irradiation on photosynthesis and phytochemical compositions in micro-propagated plants: A Review

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Light-emitting diodes (LEDs) are a promising technology with a potential to improve the irradiance efficiency, light quality as well as light spectrum for increasing plant yield and quality. LEDs light sources have the capability of controlling true spectral composition, permitting wavelengths to match plant photoreceptors to deliver more optimal production to regulate plant morphology and nutritional quality. LEDs can impressionist natural light to ensure the growth and development of photosynthetic organisms,changes in intensity and wavelength can operate the plant metabolism with the desire to produce functionalized foods.The available literature has also been surveyed sternly in order to extract-out the information oninfluential aspects of LEDs

light irradiation on photosynthetic characters and phytochemical composition within micro-propagated plants. Conclusively, proposed investigations are an attempt to provide a comprehensive understanding on how LEDs light effects on plant photosynthetic characters as well as phytochemical composition in micro-propagated plants.

A new chemical compound isolated from green leaves of *Litsea glutinosa*

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Litsea glutinosa (Lauraceae) is a medium sized tree distributed throughout India. The bark and leaves of this plant used as demulcent and mild astringent for diarrhea and dysentery due to balsamic and mucilaginous nature. The methanol extract of bark showed antibacterial activity against sixteen tested microorganisms, both gram-negative and gram-positive bacteria. A water soluble new arabinoxylan was isolated from aqueous extract of the green leaves of *L. glutinosa* (Lauraceae) and purified by gel-filtration chromatography. This arabinoxylan was new because the xylose residues of the backbone were α-anomers and the arabinose residues, responsible for branching at backbone were mixture of α and β anomers, whereas in case of all other arabinoxylans reported earlier, the xylose and arabinose residues were α and β-anomer respectively with different types of branching. In future efforts should be made in increase secondary plant metabolites through enhancement of photosynthesis in plant.

Influence of Salinity on Photosynthetic Machineryin Halophytes: A Review

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Halophytes could easily withstand the hyper-saline soil and thus, they can survive in the areas with intense salt content. The tolerance of halophytic photosynthetic apparatus in contradiction to saline stipulations is brought about by a series of adaptions, straight away from biochemical adaptions to specialized morphologies. The impact of salt stress on the photosynthetic activity is either direct (as the diffusion limitations through the stomata and mesophyll as well as the alterations in photosynthetic metabolism) or secondary (as the oxidative stress arising from superimposition of various stresses). The available literature has also been surveyed sternly so as to pull the information out in regard of influential aspects of salinity on photosynthesis within the halophytic species. Henceforth, the proposed investigation is an attempt to provide a well- proportioned apprehension on "how halophytic plants protect and modify their photosynthetic machinery under various altered saline circumstance''.

Chemical constituents from the heartwood of *Tecomella undulata*

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Tecomella undulata is a medium sized tree, which is commonly known as Rohida. It is widely used for treatment of several diseases like liver, spleen, blood purifier, syphilis, internal tumours, wound healing, conjunctivitis, hepatosplenomegaly, gonorrhea and rewarding in hepatitis. A reinvestigation of chloroform extract of its heartwood led to the isolation of lapachol, radermachol, 2-isopropenylnaptho[2,3-b]furan-4,9-quinone, tecomaquinone-I, α-lapachone, β-lapachone, β-sitosterol and stigmasterol. Compounds were characterized on the basis of UV, IR, ^{1}H and ^{13}C NMR and mass spectral studies. In future efforts should be made to increase quinone biosynthesis through enhancement of photosynthesis in the plant.

Phytotoxicity of fluoride

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Fluoride is an important phytotoxic pollutant that can enter plants through the roots as well as stomata and be translocated to transpiratory system of the plants. Among all halides, F causes adverse effects on plants by interfering with various physiological and biochemical processes associated mainly with photosynthesis and respiration. Both these processes are critical for plants to acquire energy and its utilization. Vegetation grown in the vicinity of phosphate fertilizer factories, brick kilns and other fluoride fumes emitting industries were examined for visible symptoms of fluoride toxicity. The morphological alterations observed in the plants included chlorosis, necrosis, tip burning, stunted growth, loss of foliage etc. Due to its high phytotoxicity and electro negativity fluoride accumulation through soil or air causes damage to the photosynthetic machinery of plants. Chlorosis or yellowing of leaves and loss of foliage can be probably due to the disruption of thylakoid system, inhibition of chlorophyll biosynthesis or increased chlorophyll degradation. It was observed that the damage to plants in the vicinity of industries depended on an array of factors such as plant species, plant age, amount of fluoride uptake, and duration of fluoride exposure.

Termite mound soil: Plant growth enhancer

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Termites are the most dominant macroinvertebrates in soil ecosystems. They considerablymodify the soil within the soil nest. They promote soil alterations by disruption processes so they are also known as “ecosystem engineers”. Chemicalcharacteristicsof epegial mound soil differ from the surrounding surface soil in physical as well as chemical aspects. Termites are common biological agents that produce chemical alterations to mound soils. The activity of termites induced significant chemical changes in the materials that they use to build their mounds, increasing major and minor elements, i .e. organic carbon,nitrogen, phosphorus, potash, zinc, copper etc.Zinc is necessary for the formation of chlorophyll. The copper is essential for plant such as a catalyst in photosynthesis, respiration, severalenzyme systems for carbohydrate and protein metabolism. Thus termites play a major beneficial role through promotion of essential ecological processes like photosynthesis in agro ecosystems in argument with their deep-rooted role as pests.

Effect of manufactured metal oxides nanoparticles on algal physiology

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Utilization of nanotechnology based items is developing everywhere scale internationally; thus releasing nanoparticles are entering into oceanic biological systems. The higher surface area versus volume proportion in comparison with mass materials makes nanoparticles naturally more reactive. Therefore, exploring the potential aquatic toxicity of nanoparticles has turned into a vital issue. Green growth are a perfect gathering to examine reactions of various built nanoparticles. Show audit expect to break down the nanoecotoxicological affect of engineered metal oxide nanoparticles on algal physiology. Diverse elements like size, shape, pH, measurements, presentation time, photograph reactant action and so forth influences poisonous quality of nanoparticles. Further, a large group of reactions appeared by green growth like increment in responsive oxygen species, lipid peroxidation, diminish in chlorophyll content and photosynthetic effectiveness are featured after the nanoparticle exposure.

Algal Biofuel: As a practical wellspring of vitality and its potential

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Weight on our planet has expanded because of wellspring of vitality on the grounds that ordinary fuel are exhausting at fast speed and they are additionally connected with many issues like emanation of carbon dioxide, unsafe green house gasses and corrosive rain and so forth. As of late, much accentuation have been given on non-ordinary wellspring of vitality and biofuel have demonstrated some potential for this. Biofuel by microalgae are dependable source on the grounds that microalgae have high sum and reasonable nature of lipid for biofuel generation which can be extricated by doable physical and compound techniques. They have alluring unsaturated fat which are similarly steady at wide scope of temperature. Not every single algal specie have these qualities for biofuel creation. Green growth can settle 70-75% of carbon radiated by the vehicles and businesses, so we can state that it is carbon unbiased wellspring of vitality and by implication it keep up the green house gasses underneath their upper esteems. Dissimilar to current oil creating crops it doesn't require so much gainful land, labor and vitality contribution for biofuel generation. There is no race for sustenance and grain with green growth. Gathering should be possible day by day since rate of biomass creation is high. Ethanol, stream fuel, creature encourage, bio composts are acquired as results. These qualities make it more financially savvy, more maintainable and more eco-accommodating. Current examination is subjected to how to overcome from display vitality catastrophes of the world with the generation of algal biofuel and its application with present day innovations which are financially savvy and reasonable.

Nanobionics

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Photosynthesis is the process by which plant can convert solar energy into chemical energy in food supplies and carbon-based fuel. Approximately, 100 terawatts energy is captured by photosynthesis from sunlight that is six times higher than the power consumption need of human civilization (Whitmarsh and Govindjee, 1999). Nanotechnology has emerged as a frontier field in science.Nanoparticles due to their size havenovel properties which have found application in every field. nanobionics or the application of nanoparticles for enhancement of functions of pant cell organs by studying the electronic interactions in biological systems infast gaining momentum. The interaction of plant cell organelles and nanoparticles is endowing enhanced native

functions to cell leading to a new field of nano-bioengineering.There have been a number of studies that have shown **enhanced photosynthesis** by use of nanomaterial like SWNTs (single-walled carbon nanotubes). SWNT-chloroplast assemblies have shown ahigher rate of leaf electron transport *in vivo* through a mechanism consistent with augmented photo-absorption. Plasmon resonance of metal nanoparticles can increase the absorption of solar energy and lead to enhance carbon fixation (Giraldo*et al*., 2014). Nanoparticles such as SiO_2 change the activity of carbonic anhydrase and synthesis of photosynthetic pigments, TiO_2 increase the photosynthetic carbon assimilation by activating Rubisco.AuNPs and AgNPs can induce the efficiency of energy production in photosynthetic machinery. Cerium oxide nanoparticles scavenge ROS that might damage the proteins involved in photosynthesis is a promising nanoprotective mechanism by which increase photosynthesis can be approached. It is further open for research to find out if nanoparticles are safe for use to increased photosynthesis.

Assessment of Biochemical Studies in Azadirachta indica as affected by Madri Industrial Area, Udaipur, (Raj.) India

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Clean air requires a periodical assessment of existing and new scientific methods that underlie the regulation of major ambient pollutants– particulate matter and tropospheric ozone. There is a need for inter-disciplinary research and analysis strategies to provide more comprehensive assessment of associated health complications and biological risks. A biomonitoring study was conducted to investigate the responses of plants exposed Industrial area emission in a dry tropical environment. Exposure to Industrial pollution can cause damage to plants by imposing conditions of oxidative stress. Plants combat oxidative stress by inducing antioxidant metabolites, enzymatic scavengers of activated oxygen and heat shock proteins.

Pea aphid *Acyrthosiphon pisum*, a photosynthetic hemipteran insect

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Insects of the order hemiptera and family aphididae, are commonly called aphids. These insects have sucking type of mouth parts,long antennae and are of different colours like brown, black, white, green and red. They are pests on the cultivated plants and are carried long distances by wind owing to their light body weight and small size.

Amongst different species of aphids, the pea aphid, *Acyrthosiphonpisum*, possesses carotenoids, the pigments present in chloroplasts and chromoplasts. The carotene pigments are

placed just underneath the cuticle from where they can appropriately absorb sunlight. These carotenoids harness solar energy and convert it to ATP and utilize this energy for metabolic processes. All other animals obtain carotenoids by consuming plants, algae and fungi naturally synthesizing this orange-red compound. Thus pea aphids are known to be the only species of animals having photosynthesis ability, like plants.

Role of nanoparticles as a catalyst in organic synthesis

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Heterocyclic compounds are important scaffolds in synthetic organic chemistry having both industrial and pharmaceutical applications. These motifs can be prepared using wide variety of reaction conditions such as the use of expensive catalysts, toxic solvent, harsh reaction condition like the use of base, high temperature, and multistep reaction. In the current scenario, the chemistry arena is shifted towards the greener way of synthesis. Nanocatalyst constitutes an important role in the green synthesis since the activity of the catalyst resides in the exposed portion of the particles. By decreasing the size of the catalyst, more surface area would be exposed to the reactant and only negligible amount would be required to give the significant result and selectivity could be achieved, thereby, eliminating the undesired products. Our current approach is formulated towards the use of TiO_2 nanoparticles as catalyst in the synthesis of heterocyclic compounds.

Conversion of C_3 plants into C_4 plants

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Mostly conventional crops assimilate atmospheric CO_2 by the C_3 pathway of photosynthesis. C_3plants have a single chloroplast type (in mesophyll cells of leaves) that performs all of the reactions that convert light energy into the chemical energy that is used to fix CO_2 and to synthesize the reduced carbon compounds. These plants are underachievers due to the dual function of the key photosynthetic enzyme, ribulose 1,5-bisphosphat carboxylase/oxygenase (Rubisco). High CO_2 favors the carboxylase reaction and thus net photosynthesis; whereas high O_2 promotes the oxygenase reaction leading to photorespiration. Photorespiration reduces net carbon gain and productivity of C_3 plants by as much as 40%. This renders C_3 plants less competitive in certain environments. In contrast, with some modifications in leaf anatomy, some tropical species (e.g., maize and sugarcane) have evolved a biochemical CO_2 pump, the C_4 pathway of photosynthesis, to concentrate atmospheric CO_2 in the leaf and thus overcome photorespiration. Therefore, C_4 plants exhibit many desirable agronomic traits: high rate of photosynthesis, fast growth, and high efficiency in water and mineral use. Unfortunately, there are no closely related C_3 and C_4 crops that we can use to transfer the C_4 traits to C_3 crops by a traditional breeding approach. In engineering C_4 photosynthesis, there are two important components to be considered: the biochemical pathway (enzymes) and the specialized leaf structure. The coordination of two specialized leaf cells in C_4 leaves, namely mesophyll and bundle sheath cells (together termed Kranz leaf anatomy), is important for pathway function. The enzymes and their corresponding genes involved in the C_4 pathway of photosynthesis have been characterized. Using an Agrobacterium-mediated transformation system, three maize genes encoding the C_4 photosynthetic pathway enzymes: phosphoenolpyruvate carboxylase (PEPC); pyruvate, orthophosphate dikinase (PPDK); and NADP-malic enzyme (ME) independently introduced into rice. The transgenic rice plants express high levels of these genes and the maize enzymes remain active. Most importantly, PEPC and PPDK transgenic rice plants exhibit higher photosynthetic capacity than untransformed plants, mainly due to an increased stomatal conductance (i.e., more atmospheric CO_2 becomes available for fixation). However, increased synthesis of organic solutes (e.g., malate) by the enzymes in the guard cells may be responsible for the enhanced conductance of CO_2 by the stomates since stomates open by pumping up their levels of solutes. Ultimately, for most efficient operation of the pathway to concentrate CO_2 around Rubisco in the leaf, the concomitant installation of Kranz leaf anatomy will be essential. More work is needed in order to convert the less efficient C_3 plant to a more efficient C_4 plant.

Effects of Fluoride Toxicity on Plants

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In the environment fluoride occurs naturally and from anthropogenic source like superphosphate fertilizer factories, aluminium smelter, brick works etc. Fluoride accumulates in plants through leaves and roots. A wide variety of plants are sensitive to high fluoride levels. Generally roots take up small amount of fluoride from soil but gaseous intake of fluoride by leaves are higher due to its solubility. Fluoride is an accumulative poison in plant foliage. Fluoride impedes the photosynthesis and other vital processes of plants. Typical and visible symptoms of fluoride toxicity in plants are chlorosis, tip burning, tip necrosis and marginal necrosis. Yellowing of the leaves and slow growth of the leaf area are also side effects of excessive fluoride uptake. Although fluoride is not lethal to plant but damage done by fluoride in leaves is not reversible. In order to avoid fluoride toxicity in plants excessive use of fertilizers and fluoridated water should be avoided.

Photoprotection and Antioxidant Activity under Drought Stress in *Aloe barbadensis* Miller

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Aloe barbadensis Miller is adapted to tolerate severe drought and high irradiance levels. Photoprotective, photosynthetic and antioxidative potentials were investigated in plants grown under drought stress. Prolonged periods of drought caused high level accumulation of carotenoids which suggest their role in photoprotection. Due to the presence of strong photoprotective response, plants were found capable to maintain their photosynthetic performance even in severe drought conditions. The high activity of reaction centers, despite their low density in drought stressed plants, indicate strong phytosynthetic plasticity in *A. barbadensis*. Water deprivation triggered activities of superoxide dismutase (SOD) and catalase (CAT) to minimize the effects of drought-induced photodamage. The present findings indicate that *A. barbadensis* plants are physiologically quite resistant to extreme water deficit conditions. This study will therefore be useful in transgenics for the development of drought tolerant plants.

Photosynthesis researches in India

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Photosynthesis researches in India done by several Indian scientists and Indian origin scientists can be traced from several thousand years. Sun light used by plants which form food for living beings. Some researches is done like ability of plants to make own food, due to their pigments. Research work of several scientists in field of photosynthesis like Sir J.C. Bose - Pioneering work of photosynthesis during mid of 20th century, Sir J.C. Bose, Rao, Bhagwat and R. Singh, researches like malate metabolism in *Hydrilla*, spectrophotometric estimation of chlorophylls importance of special quality for photosynthesis an indication of two photosystem, photoinactivation of photosynthesis and importance of flag leaf photosynthesis. In late 20's researches into the area of molecular biology of chloroplasts, regulation of photosynthesis and stress tolerance done by several scientists like P. Mohanty, A.S. Raghavendra, S.K. Sinha, P. Vishnu Sane, Narendra Sankhla, C.P. Malik, Ashwini Pareek and by Vineet Soni. India is an agriculturally important country and photosynthesis research in India has always found report from the people and the government. In future research work in India is focused on some aspects like elucidation of genes, evolution of enzymes, development of transgenics and modeling

Photoprotection: a safe guard mechanism of photosynthesis

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Photosynthesis is a process used by plants and other organisms to convert light energy into chemical energy that can later be released to fuel the organisms' activities. Photoinhibition is light-induced reduction in the photosynthetic capacity of a plant, alga, or cyanobacterium. Photosystem II (PSII) is more sensitive to light than the rest of the photosynthetic machinery, and most researchers define the term as light-induced damage to PSII. In living organisms, photoinhibited PSII centers are continuously repaired via degradation and synthesis of the D1 protein of the photosynthetic reaction center of PSII. The mechanism of photoinhibition are under debate, several mechanisms have been suggested. Reactive oxygen species, especially singlet oxygen, have a role in the acceptor-side, singlet oxygen and low-light mechanisms. In the manganese mechanism and the donor side mechanism, reactive oxygen species do not play a direct role. Photoinhibited PSII produces singlet oxygen, and reactive oxygen species inhibit the repair cycle of PSII by inhibiting protein synthesis in the chloroplast. Photo protection is a biochemical process in which organisms subsist with the molecular damage caused by Ultra Voilet Radiation (Sun light). Photosynthetic pigments like Carrotenoids prevents the chlorophyll from photooxidation by absorbing excess blue light . Carrotenes appears to prevents from oxygen free radical. Non Photochemical Quenching is the quenching of Chlorophyll fluorescence. Three carotenoids ,called xanthophylls are involved in Non- Photochemical Quenching , Viloxanthin , Anthraxanthin and Zeaxanthin.

Q - Cycle at a glance

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The cytochrome b_6f complex and related complex are central component of photosynthetic electron transport chain. Peter Mitchell proposed a general mechanism for these complexes, which he called a Q–cycle. Cytochrome bc_1 complex provides a niche in which the lipophilic quinol can be exchanged in membrane bilayer. The cytochrome b_6f complex mediates the electron transfer reaction between PS-II and PS-I. It catalyzed the oxidation of plastoquinol and the reduction of plastocyanin which operate different redox potential and semiquinone as an intermediate. Semquinone cycle has been proposed by Wikstrom and Krab. In this mechanism plastohydroquinone (QH_2) is oxidized and one of the two electron is passed along linear electron transport chain towards PS-I while other electron goes through a cyclic process that increase the number of proton pump across the membrane.In the linear electron transport chain, the oxidized Reiske iron-sulfur protein (2Fe-2S) accepts an electron from plastohydroquinone (QH_2) and transfers it to cytochrome and then transfer an electron to plastocyanin. In the cyclic part of the electron transport chain plstosemiquinone transfer its other electron to one of b-type hemes, releasing both of its protons to the luminal side of the membrane. Overall four protons are transport across the membrane for every two electron delivery to P_{700}.

Photophosphorylation in plants

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There are three energy transducing membrane system were able to link electron transport with ATP synthesis. One of them is thylacoid membrane where photophosphorylation takes place. In the presence of photosynthesis the phosphorylation of ADP to form ATP using the energy of sunlight is called photophosphorylation. The photophosphorylation of ADP by the ATP synthase is driven by chemiosmotic mechanism (Mitchell 1961;Nicholls1982). Mitchell's hypothesis is based upon two fundamental requirement 1) energy transducing membrane are impermeable to proton 2)electron Carrier. There are two type of photo phosphorylation occurs cyclic photo phosphorylation and noncyclic photo phosphorylation both processes are at the end produces ATP and ATP,NAPDH2 respectively. Photophosphorylation is very important because in addition to using ATP for the reduction of CO2 a continual supply of ATP is required to support a variety of metabolic activity in the chloroplast also.

Photorespiration: Evolutionary Boon or Bane?

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Photorespiration takes place in the presence of light under high temperature and oxygen concentration. As a result of photorespiration excess amount of Co_2 is evolved. It is the alternative pathway used by the enzyme RuBisCo. This enzyme being both a carboxylase and a oxygenase, does not have the capability to differentiate between Co_2 molecule and O_2 as a result of which it can assist in both the reaction of photorespiration and photosynthesis, even though they are the opposite pathway.

It is interesting to note that photorespiration only occurs in C3 plants where the oxygenase play its role. It is important because it is a major source of H_2O_2 in photorespiration cell. Through H_2o_2 production and pyrimidine nucleotide interaction, photorespiration makes a key contribution to cellular redox homeostasis while photorespiration also work as a wasteful pathway, because it prevent from using the ATP & NADPH to synthesize carbohydrate.

Evolution of photosynthesis

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Photosynthesis was well-established on the earth at least 3.5 thousand million years ago, and it is widely believed that these ancient organisms had similar metabolic capabilities to modern cyanobacteria. This requires that development of two photosystems and the oxygen evolution capability occurred very early in the earth's history, and that a presumed phase of evolution involving non-oxygen evolving photosynthetic organisms took place even earlier. The evolutionary relationships of the reaction center complexes found in all the classes of currently existing organisms have been analyzed using sequence analysis and biophysical measurements. The results indicate that all reaction centers fall into two basic groups, those with pheophytin and a pair of quinones as early acceptors, and those with iron sulfur clusters as early acceptors. No simple linear branching evolutionary scheme can account for the distribution patterns of reaction centers in existing photosynthetic organisms, and lateral transfer of genetic information is considered as a likely possibility. Possible scenarios for the development of primitive reaction centers into the heterodimeric protein structures found in existing reaction centers and for the development of organisms with two linked photosystems are presented.

Effect of Herbal Formulation on Growth of Potato Crop

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In the present study investigates the *in vivo* management of early blight disease of potato by herbal formulation from *Cassia fistula* L. fruit pulp extract in combination with neem oil cake and cow dung. The preventive action was studied as a function of decrease in disease severity, change in growth characteristics of host plant due to changes in photosynthetic activity such as number of leaves/plant, plant height, number of tubers, tuber weight, and tuber size of healthy, infected and treated plants. Six treatments i.e. T1, T2, T3, T4, T5 and T6 were applied in different combinations. Four different controls i.e. C1, C2, C3 and C4 were also maintained. Results suggested that T4 treatment not only reduces the infection but also leads to increased growth, health and vigour of the host plant as compare to other treatments. This combination observed to show significant activity against *Alternaria solani* and also increase the rate of photosynthesis of crop plant which improves all the growth parameters. This can also help to minimize the economical loss of potato crop.

Lactic acid bacteria provides protection of photosystem from fungal infection

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Lactic acid bacteria (LAB) are known to hinder the growth of fungi and other pathogenic bacteria and it can be used as biocontrol agent. Literature revealed that the fungi *Fusarium oxysporum* suppress the photosynthetic activity in plants. The aim of this study was to estimate the efficiency of selected lactic acid bacteria isolated from rhizospheric soil was effective against *Fusarium oxysporum*. The isolated lactic acid bacteria were having property to inhibit the fungal biomass in the de Man, Rogosa and Sharpe Broth (MRSB). So that the isolated lactic acid bacterial isolates was have ability to improve the efficiency of photosystem by providing protection from fungal infection.

Improvement of photosynthesis using antibacterial activity of Cyanobacterial exopolysaccahride

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The pathogen cause a progressive decrease in the rate of photosynthesis that is followed by destruction of chloroplast membrane, the saprophyte cause a sharp transitory reduction in the rate of photosynthesis that is not associated with structural change in chloroplast, neither the pathogen nor the saprophyte alter photosynthesis products in leaves. These plant pathogenic bacterias growth controlled by using cyanobacterial (*Anabaena anamola*) exopolysaccahride was tested *invitro* for their antibacterial activities against *Pseudomonas sp*., *Bacillus sp*., *Staphylococcus sp.*, with Disc diffusion method. The maximum antibacterial activity shows against *Pseudomonas sp.* These results confirm that presence of promising antibacterial compounds in the cyanobacterial exopolysaccharides under study.

Chlorophyll fluorescence as a tool for evaluating status of *Triticum aestivum* l under drought stress

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Drought stress is one of the most important environmental factors inhibiting plant productivity by inhibiting growth and photosynthesis.Many studies have shown that the decreased photosynthesis under water stress can be associated with the perturbations of the biophysical processes resulted in damage to thephotosystem II(PSII). Chlorophyll fluorescence analysis is widely used to estimate PSIIactivity, which is an important target of drought stress. The aim of this study was to determine the effects of drought stress on chlorophyll fluorescence parameters in leaves of two wheat (*Triticumaestivum* L.) varietiesHD-2932and HI-1500. PS II photochemistry (Fv/Fm) parameter was found more sensitive to drought stress in HD-2932 when compare to HI-1500. Study of other parameters i.e. specific energy fluxes (per Q_A-reducing PSII reaction center- RC), phenomenological fluxes (per cross section-CS), quantum efficiencies,chlorophyll content, Fm,Fv/Fm and density of active reaction centers indicates the higher potential of drought tolerance in HI- 1500 variety of wheat.

CAM Pathway in succulent plants

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Crassulacean acid metabolism (CAM) is a photosynthetic adaptation in succulent plants. Succulent plant, also known as fat plants, are xerophytic plants adapted to arid climate or soil condition. Succulent plant store water in their leaves and stems. The storage of water often gives succulent plants a swollen or fleshy appearance than other plants. The best known succulents are cacti. These plants open their stomata during the night and close then during the day. Closing stomata during the day helps succulent plants conserve water, but it also prevents CO_2 from entering the leaves. During the night, when their stomata are open, these plants take up CO_2. Assimilation of CO_2 occurs into malic acid at night which is stored in the vacuole. This mode of carbon fixation is called Crassulacean acid metabolism, after the plant family Crassulaceae, the succulents in which the process was first discovered. During the day time, when the light reaction can supply ATP and NADPH for the Calvin cycle, CO_2 is released from the malate for fixation through Calvin cycle. This cycle differs from the C_4 cycle. In C_4 plants, formation of the malic acid in the mesophyll is separated from the Calvin cycle in the bundle sheath. In CAM plants, the two steps occur at separate time but within same cell.

Ecological potential of a drought enduring tropical tree *Bombax ceiba* L. in forests of Rajasthan, India

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Bombax ceiba L. locally known as *Semal*; is a deciduous tropical tree species growing widely in Southeast Asia, Africa and Australia. It is also cultivated for its commercial and ornamental values in many parts of the world. During its leaf fall period from November to March, its stem bark tissues assist in photosynthesis and contribute to the annual carbon balance even also during drought periods. Due to its high drought endurance capacity, medium shade density and medium growth, this tree has been recommended for Enviroscaping that is growing of trees around houses and buildings to reduce the temperature and thereby saving the electricity. It acts as an umbrella tree by providing food and shelter to many bird and animal species and also possesses soil binding capacity and SO_2 absorption efficacy. In addition to this, timber and silk-cotton of tree are commercially valuable while all other plant parts are medicinally very important. Looking to its ability to tolerate drought stress, capacity to grow in dry areas and other associated ecological benefits; it can be a potential bio-resource in forests of Rajasthan. The present paper will mainly discuss ecological benefits of this tree in view of present researches and its potential significance in western India particularly Rajasthan.

National Symposium on Photosynthesis

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