Sammy Boussiba

December 2013

CURRICULUM VITAE AND LIST OF PUBLICATIONS

Personal Details

Name:	**Sammy Boussiba**
Date and Place of Birth:	August 30, 1947, Fes, Morocco
Date of Immigration:	1956
Regular Military Service:	8/1966-9/69
Address at Work:	Microalgal Biotechnology Laboratory Jacob Blaustein Desert Research Institute Ben-Gurion University of the Negev Sede-Boker Campus 84990, Israel Tel: 972-8- 6596795, 6596796
Address at Home:	Ya'ara 16, Omer , 84965 Israel

Education

B.Sc. - 1969-72 - Hebrew University of Jerusalem and Ben-Gurion University of the Negev.

M.Sc. - 1973-75 - Hebrew University of Jerusalem and Ben-Gurion University of the Negev.
Advisor - Prof. A. Richmond.
Title of thesis: The Involvement of Abscisic Acid in the Interrelationships between Various Stresses and Recovery.

Ph.D. - 1976-81 - Ben-Gurion University of the Negev.
Advisor - Prof. A. Richmond.
Title of thesis: The Biliprotein C-Phycocyanin: Its Possible Role and Influence of Environment Factors on Its Metabolism.

Employment History

A. Employment

2001	Professor, The Jacob Blaustein Institute for Desert Research, BGU.
1995	Associate Professor, The Jacob Blaustein Institute for Desert Research, BGU.
1989	Researcher Grade A, The Jacob Blaustein Institute for Desert Research, BGU.
1985-88	Senior Researcher, The Jacob Blaustein Institute for Desert Research, BGU.
1978-84	Research Fellow - The Jacob Blaustein Institute for Desert Research, BGU.
1973-77	Research Assistant. Biology Department - Ben-Gurion University of the Negev.

B. Employment abroad

2005	Visiting Professor (sabbatical), Instituto Bioquimica Vegetal y Fotosintesis, Sevilla, Spain (with Prof. Miguel Guerrero)
1991-92	Visiting Res. Prof. (sabbatical), Arizona State University, Department of Botany (with Prof. Wim Vermaas)
1982-84	Postdoctoral Fellow, Biochemistry Department, Cornell University, Ithaca, N.Y.

Professional Activities

(a) Positions in academic administration

2009-	Member, Governing Council of the Inter-University Institute for Marine Sciences, Eilat
2008-	Director, French Associates Institute for Agriculture and Biotechnology of Drylands
2004-10	Member, Promotions and Nominations Supreme Committee, BGU
2003-	Member in the Research Committee of the Ben-Gurion University
2001-05	Deputy Director, The Jacob Blaustein Institute for Desert Research, BGU

1998-01 Head, The Department of Dryland Biotechnologies, The Jacob Blaustein Institute for Desert Research, BGU.
1995- Head, Microalgal Biotechnology Laboratory, The Jacob Blaustein Institute for Desert Research, BGU.
1980-82 Acting Head of the Laboratory of Applied Hydrobiology, BGU.

(b) Professional functions outside universities/institutes

2012 A member in the Editorial Board of the journal "Industrial Biotechnology".
2011 A member of a Committee appointed by the American National Academy of Sciences, to examine "Sustainable Development of Algal Biofuels".
2011 Vice-President of the International Society of Applied Algology.
2009 Scientific Director, Scientific Committee of the European Algae Biomass Association - Conference and general Assembly Meeting, Italy.
2008-10 President of the International Society of Applied Algology.
2008 Chairperson of the Session "Microalgae and seaweed in encountering environmental problems and in animal feeding", 4th Symposium of European Society of Microalgal Biotechnology: Microalgae and Seaweed Products in Agriculture, Mosonmagyarovar, Hungary.
2008 Convener, Mini-Symposium on "Microalgae as natural source for carotenoids and PUFAs, 11th International Conference on Applied Phycology, Galway, Ireland.
2007 Member in the International Organizing Committee of the 7th European Workshop on Biotechnology of Microalgae, The European Society of Microalgal Biotechnology, Nuthetal, Germany.
2007 Chairman of the Session Environmental affairs with microalgae, at the 7th European Workshop on Biotechnology of Microalgae, The European Society of Microalgal Biotechnology, Nuthetal, Germany
2006 Member in the International Organizing Committee of the 6th Asia-Pacific Conference on Algal Biotechnology, Makati City, Philippines.
2006 Chairperson of the session "Presence and function of microalgae and cyanobacteria in soil" at the 3rd Symposium on Microalgae and Seaweed Products in Agriculture. Mosonmagyrovar, Hungary
2006 Member in the International Advisory Board of the European Society of Microalgal Biotechnology. 3rd Symposium on Microalgae and Seaweed Products in Agriculture. Mosonmagyrovar, Hungary.
2005 President-Elect of the International Society of Applied Algology.
2005 Member of the Editorial Board of Archiv fur Hydrobiologie, supplement Algological Studies.
2004 Member of the Advisory Board of the International Society of Applied Phycology.
2004 Member in the International Advisory Board of the European Society of Microalgal Biotechnology. 2nd Symposium on Microalgae and Seaweed Products in Plant/Soil-Systems. Mosonmagyrovar, Hungary.
2003 Co-Convenor of the Symposium “A future for microalgal biotechnology?”, at the Third European Phycological Congress, Queen’s University of Belfast, Ireland.
2002 Chairperson of the session “Carotenoids from Microalgae” at the 13th International Carotenoid Symposium, Univ. of Hawaii, Honolulu, Hawaii USA.
2000 Roundtable Moderator of the session Photoautotrophic cell cultures” in the 4th European Workshop on Biotechnology of Microalgae, Germany.
2000 Chairperson of the session “Algae as potential sources of pharmaceuticals and functional foods” at the 4th Asia-Pacific Conference on Algal Biotechnology”, Hong-Kong.
1999-2002 Member in the International Advisory Board of the newly established Society of Applied Algology.

1999-2001 Member in the Professional Committee for reviewing the work-plan of the Israel Oceanographic & Limnological Research Ltd., in the fields of biology and marine biotechnology.
1999 Member in the International Advisory Board of the International Workshop and Training Course on Microalgal Biology and Biotechnology, Pannon University of Agriculture, Mosonmagyaróvár, Hungary.
1999 Invited Professor in a Ph.D.-accreditation Program of Pannon University of Agriculture, Mosonmagyaróvár, Hungary.
1999 Chairperson of the session "Pigments and antioxidants from microalgae" at the 8th International Conference on Applied Algology, to be held in Montecatini Terme, Italy.
1998 Member in the International Advisory Board of the 8th International Conference on Applied Algology, to be held in Montecatini Terme, Italy, 1999.
1997 Member in the Scientific Committee of the 'First Regional Conference on Interdisciplinary Strategies for Development of Desert Agriculture', held in the Jacob Blaustein Institute for Desert Research, Ben-Gurion University at Sede-Boker.
1997 Member in the International Advisory Board of the 'Conference on Progress in Plant Sciences from Plant Breeding to Growth Regulation', held in Hungary.
1995 Member in the International Advisory Board of the 'Conference on Progress in Plant Sciences from Plant Breeding to Growth Regulation', held in Hungary.
1990 Member in the Organizing Committee of the Advanced Course on Inorganic Nitrogen Metabolism, held in 1992 in Israel.
1988 Evaluation of UNDP project CHI/87/031 (Obtaining Products of Nutritional and Biological Interest from Microalgae) in Chile.

(c) Significant professional consulting
1980-82 Consultant to Koor LTD - Commercial *Spirulina* Production, Eilat, Israel.
1984-86 Consultant to Ein-Yahav Algae, Commercial *Spirulina* Production, Israel.
1999- Consultant to Algatechnologies, Israel, Production of astaxanthin from *Haematococcus*.
2004- Consultant to Colors, Israel, Tropical Fish Production Farm

(d) Membership in professional/scientific societies
American Society of Microbiology
American Society of Plant Physiology
Japanese Society of Plant Physiology
International Phycology Society
Israel Society of Botany
Israel Society of Microbiology
Society of Plant Molecular Biology
International Society of Applied Phycology

Educational Activities

(a) Courses taught (Dept. of Life-Sciences, BGU)
2001 Microalgal Biotechnology
2000 Microalgal Biotechnology
1999-2000 Biological Control (with Prof. A. Zaritsky and colleagues)
1999 Microalgal Biotechnology
1998-99 Biological Control (with Prof. A. Zaritsky and colleagues)
1995-98 Microalgal Biotechnology
1993 Algal Biotechnology
1988 Algal Biotechnology (with Prof. A. Richmond, Dr. A. Vonshak and Dr. Z. Cohen)
1987 Nitrogen Assimilation (with Prof. H. Lips)

1973-77 Plant Physiology, Cell Biology, Algal Development (Teaching Assistance)

(b) Courses taught (Albert Katz International School for Desert Studies)

2001- Microalgal Biotechnology

Others

2009 Advanced Training Course in Algal Biotechnology. King Mongkut's University of Technology Thonburi, Thailand

2004 Training Course on Microalgal Biotechnology. Ege University, Turkey

2004 Training Course on Microalgal Biotechnology. Univ. of Costa Rica.

2002 International Workshop and Training Course on Microalgal Biotechnology. Gangzhou, China.

1999 Cyanobacteria for agricultural Applications. ICRO-UNESCO International Workshop and Training Course on Microalgal Biology and Biotechnology, Mosonmagyaróvár, Hungary.

1998 Regional Short Course on Microalgal Cultivation Technology, Organized by Asia-Pacific Society for Applied Phycology, The University of the Hong-Kong.

1997-99 Algal Biology, Hebrew University, Jerusalem (course leader - Prof. Aharon Kaplan)

1998 Plants as a mean for production of natural products and description of the environment. The Faculty of Agriculture, Rehovot, Israel (course leader - Prof. Elisha Tel-Or)

1996 International Course on Biotechnology in Agriculture, The Faculty of Agriculture, Rehovot, Israel.

1993 International Advanced Training Course on Photosynthesis and Algal Biotechnology for graduate students, 6 weeks, Sede-Boker, Israel.

1991 International Advanced Training Course on Photosynthesis and Algal Biotechnology for graduate students, 6 weeks, Sede-Boker, Israel.

1988 International Advanced Training Course on Algal Biotechnology for graduate students, 2 weeks, Sede-Boker, Israel.

(c) Research students

Post-doc

1985-86 Zimmerman, W. - Ammonium translocation in *Anabaena azollae.*

1989-90 Selwin, T.P. - Isolation and characterization of mutant strains excreting ammonia from *Anabaena siamensis*

1993-94 Krishna, K.B. - *Haematococcus* biochemistry and physiology

1993-94 Govidanchary S. - Isolation of herbicide-resistant strains from N_2-fixing cyanobacteria isolated from rice fields

1994 Xu, X. - Transformation of N_2-fixing cyanobacteria

1995 Singh, A.K. - N_2-fixing cyanobacteria as biofertilizers

1996 Vennison, J. - Cloning BTI toxin genes into free-living nitrogen-fixing cyanobacteria.

1998-00 Ben-Dov, E. (Eshkol Fellowship) - Transgenic cyanobacteria carrying Bti toxins as vectors controlling tropical diseases

1999 Kildibekov, N.A. – Isolation and characterization of lipid globules from *Haematococcus*

1999-01 Luisma, A. – Cloning of Bti toxins in cyanobacteria

2009- Guihéneuf, F. – Production of secondary metabolities by microalgae regulation and cellular aspects

2010- Kaye Y. - AlgaL biotechnology for biodiesel and EPA production.

2013- Zorin, B. – *Parietochloris* incisa transformation.

Ph.D.

1991-95 Fan, L. - The physiological role of astaxanthin accumulation in a green alga *Haematococcus pluvialis*.

1991-95 Ben-Dov, E. - Combinations of [Delta]-Endotoxin genes from Bacillus thuringiensis subsp .israelensis in Escherichia coli

1994- Wu, X. - Expression of *cry* genes from *Bacillus thuringiensis* subsp. *israelensis* in filamentous nitrogen-fixing cyanobacteria

1996- Wang B. - Photoprotective mechanisms in *Haematococcus pluvialis*: astaxanthin accumulation and oxidative enzymes

1999- Hasdan V. – Cloning combinations of CryIVAa, CryIIAa, and TMOF for expression in various bacteria

2000- Hoffman, Y. – Isolation and characterization of two novel chytrid (Chytridimycota) species

2001-05 Ngalo, Z. - Use of transgenic *Anabaena* for mosquito control

2005- Melnikov, O. - Exploiting site-specific recombination in the nitrogen-fixing cyanobacterium *Anabaena* PCC 7120 catalyzed by the integrase of coliphage HK022

2006- Peled, U. – Isolation and characterization of astaxanthin rich oil globules from *Haematococcus pluvialis*

2009 Recht, L. – Regulation of secondary metabolites production in a fresh and a marine microalga, *Haematococcus* and *Nannochloropsis salina*, respectively

2009 Reinecke, D. – Nitrogen assimilation in *Haematococcus* and the role of glutamine synthetase in stress response

2009- Sharon-Gojman, R – Modulation of carbon allocation in *Haematococcus pluvialis* by genetic engineering

2009- Shtaida, N. - Molecular cloning and characterization of enzymes involved in the induction of fatty acid biosynthesis in the oleaginous microalga *Parietochloris incise*

2011 Shemesh, Z. - Genetic engineering of secretion system in microalgae for high value metabolite products

2011 Pal, D. - Elucidation of key regulatory factors in production of LC-PUFA by the green microalga *Parietochloris incisa*

2012- Asatryan, A. – Characterization of the infection between the alga Haematococcus pluvilais and its blasto-clade *Paraphysoderma sedebokerense*

2012- Portugal, I. – Δ-5 desaturase mutant of *Parietochloris incise* – Optimizing DGLA production on a large-scale and testing its applications as a dietary supplements in fish.

2013- Maimon, E. – Development of strains improvement of the alga *Haematococcus pluvialis* by metabolic engineering and random mutagenesis.

M.Sc.

1988-89 Palacpac, N. - Biomass production of the nitrogen fixing cyanobacterium *Gleotrichia natans*, possible application.

1991-93 Schlesinger (Fleischberg), P. – The role of sodium in the survival of the cyanobacterium *Spirulina platensis* in extreme alkaline environments.

1991-94 Dahan, E. - Refined restriction map of the *Bacillus thuringiensis* subsp. *israelensis* plasmid carrying the mosquito Larvicidal genes

1992-96 Peleg, N. - Problems and partial solutions in constructing a transformation system for *Anabaena Siamensis*

1993-94 Guevarra, H. - Calcium induced colony formation in the N_2-fixing rice field isolate *Nostoc commune*.

1996-98 Nissan, G. - Mapping of the large plasmid of *Bacillus thuringiensis var. israelensis.*

1999-01 Montsant, A. – Cell wall modifications during the process of encystment in the green alga *Haematococcus pluvialis*
1999-02 Zhekisheva M. – Correlation between astaxanthin accumulation and fatty acid content in the green alga *Haematococcus pluvialis*
1999-01 Karmacharya, N. – Characterization of transgenic Anabaena sp. PCC7120 clones expressing] delta]-endotoxin genes from *Bacillus thuringiensis* subsp. *Israelensis*
2000-02 Castillo A. – Synchronized culture of *Haematococcus pluvialis* (Chlorophycea:Volvocales)
2000-02 Gao, Q. – Response of environmental stresses and accumulation of arachidonic acid in two green algae *Parietochloris incisa* and *Neochloris cohaerens*
2001-04 Ben-Abou, Y. - The relationship between nitrogen availability and astaxanthin accumulation in the green alga *Haematococcus pluvialis*
1999- Ferber, A. – Identifying the genes encoding for the protein acetyl CoA carboxylase in the green alga *Haematococcus pluvialis*
2001-03 Maimon, S. - Expanding the application potential of an environmental-friendly, biological mosquito larvicide
2002-04 Meshulam Yuval – Environmental factors effecting cell division cycle in *Haematococcus pluvialis*
2004-06 Hubashi, R. – Molecular aspects related to *Haematococcus* transformation.
2004-06 Peled, E. – Isolation and characterization of astaxanthin-rich oil globules from *Haematococcus pluvialis*
2005-08 Gutman, G. – Investigating the recognition process between chytrid parasite and its host *Haematococcus pluvialis*.
2005-07 Agranat, O. - Optimization of inorganic carbon sources in open pond cultures of *Haematococcus pluvialis*
2007-09 Recht, L – Elucidation of the metabolic and regulatory components involved in microalgae response to environmental stress
2007-09 Reinecke, D. – Conditions controlling contamination of *Scenedesmus* sp. in cultures of the green alga *Haematococcus pluvialis*.
2009-11 Tabah, B. – Lipid production in *Nanochloropsis salina*
2009-11 Richter, K. – Studying the mechanisms of chytrid and *Haematococcus* infections
2012- Maimon, E. – Development of strains improvement of the alga *Haematococcus pluvialis* by metabolic engineering and random mutagenesis.
2013- Blaschkauer M. – Characterization of bacteria infecting the green alga *Haematocooccus pluvialis*.
2013- Martinsen, N. – Physiology of cultivation of *Nannochloropsis* DCMU resistant-mutant outdoors.
2013- Yang, R. – Isolation of heat-resistant mutants from the green alga *Haematococcus pluvialis*.
2013- Bar, N. – The importance of Pleckstrin Homology (PH) domain in acyl-CoA:diacylglycerol acyltransferase 1-like gene (PtDGAT1) for TAG accumulation in *Phaeodactylum tricornutum*.
2013- Riklin, R. - development of novel integrative waste management practice for production of bioenergy and GHG sequestration
2013- Sibiriak, M. – Development of molecular tools for down regulation of gene expression in the microalga *Parietochloric incisa*.

Awards, Citations, Honors, Fellowships

(a) Awards
1987 Chaim Sheaba Award for Achievements in Desert Development.
1988 Exchange Program Award for Senior Scientist between Italy and Israel.

2000 Genius Biotech Award - International Business Plan Competition of Start-up Companies, Baden-Wuerttemberg, Germany. Transgenic cyanobacteria expressing combinations of genes for □-endotoxin as pesticide-free alternatives for biological control of mosquitoes (with Ben-Dov, E. and Zaritsky A.).
2002- The Miles and Lillian Cahn Chair of Economic Botany in Arid Zones.
2003 Doctor Honoris Causa by the University of West Hungary.

(b) Fellowships
1982-83 Rothschild Fellowship (for post-doctoral studies at Cornell University, Ithaca, USA)
1982-83 Fullbright Scholarship, United States-Israel Educational Foundation.
1993 Member of the UNESCO-MCBN (Molecular and Cell Biology Network)

Scientific Publications

A. Chapters in Books:

1986 Boussiba, S. and Blum, S. Ammonium uptake and assimilation in the alkalophilic Nitrogen Metabolism, held in Jarandilla de la Vera, Spain. Ullrich, W.R., P.J. Aparicio, P.J. Syrett and F. Castillo (Eds.). Springer-Verlag, Berlin. pp. 217-219.
1990 Boussiba ,S. Nitrogen fixing cyanobacteria. Proceedings of the Fifth international Symposium on Nitrogen Fixation with Non Legumes. Florence Italy. Polsinelli, M. Materassi, R. and Vincenzini, M. (Eds.) Kluwer Academic Publishers. pp. 487-491.
1990 Boussiba, S. Ammonium transport systems in cyanobacteria. In: Inorganic Nitrogen Metabolism. Ullrich, W.R., Rigano, C., Fuggi, A. and Aparicio, P.J. (Eds.). Springer Verlag, Berlin. pp. 99-105.
1992 Boussiba, S. and Zaritsky, A. Mosquito biocontrol by the□-endotoxin genes of *Bacillus thuringensis var.* cloned in an ammonium excreting mutant of rice field isolate of the nitrogen- fixing cyanobacterium *Anabaena siamensis*. In: Advances in Gene Technology: Feeding the World in the 21st Century. Proceedings of the 1992 Miami Biotechnology winter symposium. Whelan, W.J., Ahmad, F., Bialy, H., Black, S., King, M.L., Rabin, M.B., Solomonson, L.P. and Vasil, I.K. (Eds.). IRL Press/Oxford Univ. Press. pp. 89.
1992 Boussiba, S. and Vermaas W. Creation of a mutant with an enriched photosystem II/pigment ratio in the cyanobacterium *Synechosystis* sp. PCC 6803. Research in Photosynthesis, Vol. III. Murata, N. (Ed.). Kluwer Academic Publishers, pp. 429-432.
1995 Boussiba, S. and Wu X. Genetically engineered cyanobacteria as BTI toxin genes delivery system - A biotechnological approach to control Malaria mosquitoes. In: Combating Malaria. UNESCO Conference, Jan. 1994, Paris.
1995 Boussiba, S., Wu, X., Peleg, N., and Zaritsky, A. N_2-fixing cyanobacteria as BTI toxin genes delivery system - a biotechnological approach to control malaria mosquitoes. In: Nitrogen Fixation - Fundamentals and Applications. Proceedings of the 10th International Congress on Nitrogen Fixation, St. Petersburg, Russia. Tikhonovich, I.A. et al. (Eds.). Kluwer Academic Publishers, Dordrecht, pp. 665-670.
1997 Boussiba, S., Wu, X. and Zaritsky, A. Nitrogen fixing cyanobacteria as BTi toxin genes delivery system - a Biotechnological approach to control malaria mosquitoes. In: Modern Agriculture and the Environment. Rosen et al. (eds.). Kluwer Academic Publishers. pp. 97-108.
1997 Boussiba, S. Ammonia assimilation and its biotechnological aspects in cyanobacteria. In: Cyanobacterial Nitrogen Metabolism and Environmental Biotechnology. Rai, A.K. (Ed.). Narosa Publishing House, pp. 36-72.
1997 Boussiba, S. N_2-fixing cyanobacteria: potential application. In: Biofertilizer Technology. Kannaiyan, S. (ed.). Wiley & Sons.

1998 Wu, X., Vennison, J., Ben-Dov, E., Zaritsky, A. and Boussiba, S. Expression of mosquitocidal *Bacillus thuringiensis* subsp. *israelensis*. □-endotoxin genes in filamentous cyanobacterium *Anabaena* PCC 7120. In: Biological Nitrogen Fixation for the 21st Centruy. Elmerich, C., Kondorosi, A. and Newton, W.E. (Eds.). Kluwer Academ. Pub. London.

2000 Boussiba, S. and Wu, X.Q. N_2-fixing Cyanobacteria. In: Recent Research Developments in Microbiology. Pandalai, S.G. (ed.). Research Singpost, India.

2000 Boussiba, S., Wu, X.Q. and Zarka, A. Alkaliphilic Cyanobacteria. In: Microbial Diversity. Seckbach, J. (ed.). Kluwer Academic Publishers, Dordrecht, The Netherlands.

2004 Boussiba, S.and Zaritsky, A. N_2-fixing cyanobacteria as a gene delivery system for expressing mosquitocidal toxins of *Bacillus thuringiensis* subsp. *israelensis*. In: Handbook of Microalgal Culture: Biotechnology and Applied Phycology. Richmond, A. (ed.). Blackwell Science, pp. 525-533.

2013 Khozin-Goldberg, I., Solovchenko,, A., Pal, D., Cohen, Z. and Boussiba, S. Omega-3 and omega-6 LC-PUFA from photosynthetic microalgae: Studies on *Parietochloris incisa* and *Nannochloropsis sp*. In: Polyunsaturated Fatty Acids – Sources, Antioxidant Properties and Health Benefits. Catalá, A. (Ed.), Nova Biomedical, NY., pp. 1-22.

B. Refereed Articles in Scientific Journals:

1. 1973 Rikin, A., Boussiba, S. Mizrahi, Y. and A.E. Richmond. The role of abscisic acid in the interrelationship between plant response to environmental stress. Isr. J. of Bot.: 265-266.

2. 1975 Boussiba, S., Rikin, A., and A.E. Richmond. The role of ABA in cross adaptation in Tobacco plants. Plant. Physiol. 56: 337-339.

3. 1976 Boussiba, S. and A.E. Richmond. Abscisic acid and the after effect of Tobacco plants. Planta , 217-219.

4. 1979 Boussiba, S. and A.E. Richmond. Isolation and characterization of Phycocyanins from the blue-green alga *Spirulina platensis*. Arch. Microbiol. 120: 155-159.

5. 1980 Boussiba, S. and A.E. Richmond. C-phycocyanin as a storage protein in the blue-green alga *Spirulina platensis*. Arch. Microbiol. 125: 143-147.

6. 1982 Richmond, A.E., S. Karg and S. Boussiba. Effect of bicarbonate and carbon dioxide on the competition between *Chlorella vulgaris* and *Spirulina platensis*. Plant and Cell Physiol. l23: 1411-1417.

7. 1982 Vonshak, A., Abeliovich, A., Boussiba, S., Arad, S. and A.E. Richmond. Production of *Spirulina* biomass: Effects of environmental factors and population density. Biomass 2: 175-185.

8. 1983 Vonshak, A., Boussiba, S., Abeliovich, A. and A.E. Richmond. Production of *Spirulina* biomass: Maintenance of monoalgal culture outdoors. Biotechnol. and Bioeng. 25: 341-349.

9. 1984 Boussiba, S., Resh, C.M. and J. Gibson. Ammonia uptake and retention in some cyanobacteria. Arch. Microbiol. 138: 287-292.

10. 1984 Boussiba, S., X.G. Liu and J. Gibson. Endogenous ammonium production by *A. nidulans* R-2 induced by methionine sulfoximine. Arch. Microbiol. 138: 217-219.

11. 1984 Boussiba, S., Dilling, W. and J. Gibson. Methylammonium transport in *Anacystis nidulans* R-2. J. of Bacteriol. 160: 204-210.

12. 1985 Boussiba, S. and Gibson, J. The role of glutamine synthetase activity in ammonium and methylammonium transport in *Anacystis nidulans*. Febs Letter, 180: 13-16.

13. 1987 Boussiba, S. and Gibson, J. Regulation of methylammonium/ ammonium transport in the unicellular cyanobacterium *Synechococcus* R-2 (PCC 7542). FEMS Microbiol. Lett., 43: 289-293.

14. 1987 Zimmerman, W.J. and Boussiba, S. Ammonia assimilation and excretion in an asymbiotic strain of *Anabaena azollae* from *Azolla filiculoides lam*. J. of Plant Physiology, 127: 443-450.

15. 1987 Boussiba, S., Vonshak, A., Cohen, Z., Avissar, Y. and Richmond, A. Lipid and biomass production by the halotolerant microalga *Nannochloropsis salina*. Biomass, 12: 37-47.

16. 1988 Boussiba, S., Sandbac, E. Cohen, Z., Vonshak, A., Ben-Amotz, A., Shelef, G., Arad, S. and Richmond, A. Outdoor cultivation of the marine microalga *Isochrysis galbana* in open raceways. Aquaculture . 72: 247-253.

17. 1988 Stone, B., Boussiba, S. and Gibson, J. Penicillin-binding proteins in the unicellular cyanobacterium *Synechococcus* sp. strain R-2 (PCC-7942): Implications for membrane identification. J. of General Microbiology. 134: 2951-2958.

18. 1988 Boussiba, S. Cyanobacteria as nitrogen biofertilizers: A study with the isolate *Anabaena azollae*. Symbiosis . 6: 129-138.

19. 1989 Boussiba, S. Ammonium uptake in the alkalophylic cyanobacterium *Spirulina platensis.* Plant and cell Physiology 32: 303-314.

20. 1989 Herrera, A., Boussiba, S., Napoleone. V. and Holhberg, A. Recovery of C-phycocyanin and □-linoleic acid rich lipids from the cyanobacterium *Spirulina platensis* . J. Appl. Phycol. 4: 325-331.

21. 1990 Querijero-Palacpac, N. M., Martinez, M. R. and Boussiba, S. Mass cultivation of the nitrogen-fixing cyanobacterium *Gleotrichia natans*, indiginous to rice fields. J. Appl. Phycol. 2: 319-325.

22. 1990 Thomas, S.P., Zaritsky, A. and Boussiba, S. Ammonium excretion by a methionine sulfoximine resistant mutant of the rice field cyanobacterium *Anabaena siamensis*. Appl. Environm. Microbiol. 56: 3499-3504.

23. 1991 Boussiba, S. and Gibson, J. Ammonia translocation in cyanobacteria. FEMS Microbiol. Rev. 88: 1-14

24. 1991 Belkin, S. and Boussiba, S. High internal pH conveys ammonia resistance in *Spirulina platensis*. Bior. Technol. 38: 167-169

25. 1991 Belkin, S. and Boussiba, S. Resistance of *Spirulina platensis* to ammonia at high pH values. Plant Cell Physiol. 32 : 952-958

26. 1991 Thomas, S.P., Zaritsky, A. and Boussiba, S. Genetic improvement of *Anabaena siamensis* for ammonium hyperproduction and excretion. Bior. Technol. 38: 161-166.

27. 1991 Boussiba, S. Nitrogen-fixing cyanobacteria potential uses. Plant and Soil. 137: 177-180.

28. 1991 Boussiba, S. and Vonshak, A. Environmental conditions affecting astaxanthin accumulation in the green alga *Haematococcus pluvialis.* Plant Cell Physiol. 32: 1077-1082.

29. 1992 Boussiba, S., Lu, F. and Vonshak, A. Methods for enhancement and determination of astaxanthin accumulation in the green alga *Haematococcus pluvialis.* Methods in Enzymol. 213: 387-391.

30. 1993 Boussiba , S. Production in tubular reactor of the nitrogen-fixing rice field isolate cyanobacterium *Anabaena siamensis* for rice farming. Microbial Releases 2: 35-39.

31. 1993 Richmond, A., Boussiba, S., Vonshak, A. and Kopel, R. A new tubular reactor for mass production of microalgae outdoors. J. Appl. Phycol. 5: 327-332.

32. 1993 Shen, G., Boussiba, S. and Vermass, F.G. *Synechocystis sp* PCC 6803 strains lacking photosystem I and phycobilisome function. The Plant Cell, 5: 1853-1863.

33. 1993 Martinez-Goss, M.R., Palacpac, N.Q., Guevarra, H.T. and Boussiba, S. An assessment of the production of indigenous and inoculated nitrogen-fixing blue-green algae in rice paddies of the Philippines. The Philippine Journal of Biotechnology, 4: 155-175.

34. 1994 Lu, F., Vonshak, A. and Boussiba, S. Effect of environmental factors on growth of *Haematococcus pluvialis*. J. Phycol. 30: 829-833

35. 1994 Xu, C., Nagidat, A., Belkin, S. and Boussiba, S. Isolation and characterization of plasma membrane by two-phase partitioning from the alkalophilic cyanobacterium *Spirulina platensis*. Plant Cell Physiol. 35: 737-741.

36. 1995 Ben-Dov, E., Boussiba, S. and Zaritzky, A. Mosquito larvicidal activity with combinations of genes from *Bacillus thuringiensis* subsp. israelensis. J. Bacteriol. 177: 2851-2857.

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C. Refereed articles (others):

1988 Boussiba, S. *Anabaena azollae* as a nitrogen biofertilizer. In Algal Biotechnology. Proc. 4th Internat. Meet. SAA (France), pp. 169-178.

1988 Cohen, Z., Vonshak. A., Boussiba, S. and Richmond, A. The effect of temperature and cell concentrations on the fatty acid composition of outdoor cultures of *Porphyridium cruentum.* In Algal Biotechnology. Proc. 4th Internat. Meet. SAA (France), pp. 421-429.

2008 Boussiba, S. From Firenze to Sede-Boker and back… Giornata di studio su: La coltura delle microalghe: il contributo della Scuola fiorentina. Academia dei Georgofili, Firenze

Lectures and Presentations at Meeting and Invited Seminars

A. Invited Lectures:

1985 Boussiba, S. Development of outdoor system for production of lipid rich halotolerant microalgae. Solar Energy Research Institute (SERI). Proceedings of the Principal Investigator Meeting, March 1985.

1985 Boussiba, S. and Gibson, J. Regulation of ammonium and methylammonium transport in cyanobacteria. The 5th International Symposium on Photosynthetic Prokaryotes. Grindelwald Swizerland, September 1985.

1986 Boussiba, S. and Blum, S. Ammonium uptake and assimilation in the alkalophytic cyanobacterium *Spirulina platensis*. Advanced Course of Inorganic Nitrogen Metabolism, held in Jarandilla de la Vera, Spain, June 1986.

1987 Boussiba, S. Ammonium transport in cyanobacteria. EMBO Workshop on Oxygenic and anoxygenic electron transport systems in cyanobacteria (Blue-Green Algae), Cape Sounion, Greece.

1988 Boussiba, S. Ammonium translocation in *Anabaena azollae* and its possible use as a nitrogen biofertilizer. National Council for Research and Development. Nitrogen fixation in symbiotic systems, Finland- Israel (Shoresh).

1989 Boussiba, S. Ammonia uptake and assimilation in cyanobacteria. Adv. Course on Inorganic Nitrogen Metabolism. Napoli, Italy.

1989 Boussiba, S. Ammonium transport systems in cyanobacteria. EMBO Workshop on Comparative structure and function of membranes in chloroplasts and cyanobacteria. Corfu, Greece.

1990 a) Boussiba, S. and Vonshak, A. Growth conditions affecting astaxanthin accumulation in the green alga *Haematococcus pulavialis*.

b) Belkin, S. and Boussiba, S. Resistance of *Spirulina platensis* to ammonia at high pH values.

In: The 5th Int. Conf. Soc. Appl. Algol. on Recent Advances in Algal Biotechnology, Tiberias, Israel.

1990 Boussiba, S. Nitrogen fixation in blue-green algae: potential uses. In: Biological Nitrogen Fixation Meeting. Israel Society for Microbiology, Jerusalem, Israel.

1990 Boussiba, S. Ammonium excretion by an MSX-resistant mutant of the rice-field cyanobacterium *Anabaena siamensis*. First European Workshop on the Molecular Biology of the Cyanobacteria, Durdan, France.

1990 Boussiba, S. Nitrogen fixing cyanobacteria - potential uses. Fifth Internat. Symp. Nitrogen Fixation with non-legumes. Florence, Italy.

1991 Boussiba, S. and Vonshak, A. *Haematococcus* - Recent Advances. In Fourth Internat. Phycol. Cong. Duke University, Durham, North-Carolina, USA.

1991 Boussiba, S. and Martinez, M.R. Ammonium translocation in cyanobacteria and their possible use as nitrogen biofertilizer. Biological Nitrogen Fixation. Networking workshop USAID meeting of principal investigators. Banff. Canada.

1991 Martinez, M.R., Querijero-Palacpac, N.M., Guevarra, H.T. and Boussiba, S. Production of indigenous nitrogen-fixing blue-green algae in paddy field in the Philippines. UNESCO Workshop on Mass Culture of Microalgae, Silpakorn University, Thailand.

1992 Boussiba, S. and Zaritsky, A. Mosquito biocontrol by the □-endotoxin genes of *Bacillus thuringensis var.* cloned in an ammonium excreting mutant of rice field isolate of the nitrogen-fixing cyanobacterium *Anabaena siamensis*. Advances in gene technology: Feeding the World in the 21st Century. The 1992 Miami Biotechnology Winter Symposium. pp. 89.

1992 Boussiba, S., Thomas, S.P., Douek, j., Einav, M., Ben-Dov, E. and Zaritsky, A. Mosquito biocontrol by the □-endotoxin genes of *Bacillus thuringensis var.* cloned in

an ammonium excreting mutant of rice field isolate of the nitrogen-fixing cyanobacterium *Anabaena siamensis*. 25th Annu. Meeting of the Society for Invertebrate Pathology. Heidelberg, Germany.

1994 Boussiba, S. Genetically engineered nitrogen-fixing cyanobacteria as BTI toxin genes delivery system - A biological approach to control Malaria mosquitoes. 2nd Asia-Pacific Conference on Algal Biotechnology. Trends and Opportunities. Shangri-La's Rasa Sentosa Resort, Singapore.

1994 Boussiba, S. Alkalophilic properties of *Spirulina platensis*. VIII International Symposium on Phototrophic Prokaryotes, Urbino, Italy.

1995 Boussiba, S. N_2-fixing cyanobacteria as BTI toxin genes delivery system - a biotechnological approach to control malaria mosquitoes. 10th International Congress of Nitrogen Fixation, May 1995, San-Petersburg, Russia.

1995 Boussiba, S., *Spiruina* life in extreme alkaline environments, Faculty of Life Sciences, Hebrew University, Jerusalem, Israel.

1995 Boussiba, S., Sodium sustains the growth of *Spirulina* in extreme alkaline environments. Fourth International Symposium on Inorganic Nitrogen Assimilation and First Fohs Biostress Symposium, July 1995, Secheim, Germany.

1996 Boussiba, S. Sodium sustains the growth of *Spirulina platensis* in extreme alkaline environments. Conference of Plant Sciences, February 1996, Ben-Gurion University, Beer-Sheva, Israel.

1996 Boussiba, S. *Haematococcus*: from agar slant to salmon flesh... 7th Int. Conf. on Applied Algology, April, 1996, South-Africa.

1996 Boussiba, S., Nitrogen fixing cyanobacteria - potential uses. Conference on Progress in Plant Sciences from Plant Breeding to Growth Regulation. June 996, Mosonmagyaróvár, Hungary.

1996 Boussiba, S., *Haematococcus*: from agar slant to salmon flesh... 11th International Symposium on Carotenoids, August 1996, Leiden, The Netherlands.

1998 Boussiba, S. Production of astaxanthin from the alga *Haematococcus*. 52nd Annual Meeting of the Phycological Society of America, Flagstaff, Arizona, August 1998.

1998 Boussiba, S. Carotenogenesis of the green alga *Haematococcus*. XIth International Congress on Photosynthesis, Budapest, Hungary.

1999 Boussiba, S. Pigments and antioxidants from microalgae. 8th International Conference on Applied Algology, Montecatini Terme, Italy.

2000 Biological approaches in utilizing nitrogen-fixing cyanobacteria to encounter environmental problems. Botany Dept., The Hebrew University, Jerusalem.

2000 Boussiba, S. Production of valuable products by microalgae. 4th European Workshop on Biotechnology of Microalgae, Germany.

2000 Boussiba, S. Production of carotenoids from microalgae with special emphasis on astaxanthin from the green alga *Haematococcus*. 4th Asia-Pacific Conference on Algal Biotechnology, Hong-Kong.

2001 Boussiba, S. Biotechnology for large scale production of astaxanthin-rich Haematococcus biomass. Special Workshop on Natural Products – Recent Development. The Otto Warburg Center for Agricultural Biotechnology, Faculty of Agriculture, Hebrew Univ.

2001 Boussiba, S., Wu, X.-Q., Ben-Dov, E., Zarka, A. and Zaritsky, A. Nitrogen-fixing cyanobacteria as gene delivery system for expressing mosquitocidal toxins of *Bacillus thuringiensis* ssp. *israelensis*. Ann. Meet. of the Israeli Society for Microbiology, BGU, Beer-Sheva.

2001 Boussiba, S. and Lluisma, A. Use of genetically modified cyanobacteria for environmental protection and improvement. Symposium of the European Society of Microalgal Biotechnology on "Microalgae and seaweed products in plant/soil-systems", Mosonmagyaróvár, Hungary.

2002 Boussiba, S. Production of carotenoids by microalgae with special emphasis on astaxanthin from the green alga *Haematococcus pluvialis*. 13th International Carotenoid Symposium, Univ. of Hawaii, Honolulu, Hawaii, USA.

2002 Boussiba, S. Use of genetically modified cyanobacteria for environmental protection and improvement. The 1stCongress of the International Society for Applied Phycology. 9th International Conference on Applied Algology. Almeria, Spain.

2003 Boussiba, S. Astaxanthin from *Haematococcus* – commercial production. 5th European Workshop of the European Society of Microalgal Biotechnology, Germany.

2003 Boussiba, S. The physiological approach for induction of high value products in microalgae. Workshop on "Physiological, Genetical and Technical Manipulation in Algal Biotechnology. Academic and University Center Nova Hrady, Czechoslovakia.

2003 Boussiba, S. Genetically modified microalgae for better environment and new products development. The Third European Physiological Congress, Queen's University, Belfast.

2003 Production of astaxanthin-rich *Haematococcus* biomass – The Biotechnology. Biotech Israel.

2004 Boussiba, S. Bioremediation of polluted surface water by nitrogen-fixing cyanobacteria. 2nd Symposium on Microalgae and Seaweed Products in Plant/Soil-Systems, Mosonmagyrovar, Hungary.

2005 Boussiba, S. Astaxanthin production in the green alga *Haematococcus pluvialis*: Cellular and biotechnological aspects. Plant Science Dept., Weizmann Inst., Rehovot.

2005 Boussiba, S. Microalgae to encounter environmental problems – an outline. 6th Workshop of the European Society of Microalgal Biotechnology, Nuthetal, Germany.

2005 Boussiba, S. Plenary lecture: An insight into the future of microalgal biotechnology: the *Haematococcus* case study. 3rd International Congress of the International Society of Applied Phycology, Kunming, China

2005 Boussiba, S. An insight into the future of microalgal biotechnology – the Haematococcus case study. Key note lecture at the 5th Phycological Congress, Phycological Society of Chinese, Taipei, Taiwan

2006 Boussiba, S. Astaxanthin production by Haematococcus. Aqua 2006, Firenze.

2006 Boussiba, S. and Cardachi, M. Isolating cyanobacteria from polluted habitats for use in bioremediation. 3rd Symposium on Microalgae and Seaweed Products in Agriculture. Mosonmagyrovar, Hungary

2006 Boussiba, S. Plenary lecture: Large-scale production of astaxanthin from the green alga *Haematococcus pluvialis*. Asia-Pacific Conference on Algal Biotechnology, The Philippines, 2006.

2007 Boussiba, S. and Leu, S. Microalgal biotechnology for environmental remediation. The 7th European Workshop on Biotechnology of Microalgae, The European Society of Microalgal Biotechnology, Nuthetal, Germany

2007 Boussiba, S. Keynote lecture: Commercial production of the pigment astaxanthin from the alga *Haematococcus pluvialis*. First International Conference "From Invention and Development to Product. From Research Institutes to the Water Industry". BIDR, BGU, Sede-Boker, Israel.

2008 Boussiba, S. Application of microalgae in fish production, The 3rd Conference of the Negev for Agricultural Research and Development, Yotveta, Israel.

2008 Boussiba, S., Commercial production of carotenoids by microalgae. 11th International Conference on Applied Phycology, Galway, Ireland.

2008 Boussiba, S. Green solution to global problems. 4th Symposium of European Society of Microalgal Biotechnology: Microalgae and Seaweed Products in Agriculture, Mosonmagyarovar, Hungary.

2008 Boussiba, S., Up-scaling and yield extrapolation of industrial microalgae production. Algae Biomass Summit, Seattle, USA.

2009 Boussiba, S., Green solution to global problems. Workshop on "Bioenergy: Harnessing Plant Metabolism", at the Otto Warburg Minerva Center for Agricultural Biotechnology, The Hebrew University of Jerusalem.

2009 Boussiba, S., Renewable Biofuels. Symposium: Renewable Energy. 39th Meeting of BGU Board of Governors.

2009 Boussiba, S., Astaxanthin from *Haematococcus* – the Ketura pilot plant. The 1st European Algae Biomass Association Conference and general Assembly Meeting, Italy

2009 Boussiba, S., Up-scaling and yield extrapolation of industrial microalgae production. International Seminar of Biofuel of Algae, Antofagasta, Chile

2009 Boussiba, S. Microalgae to encounter environmental problems. ABIC – Agricultural Biotechnology for Better Living and a Clean Environment, Bangkok, Thailand.

2009 Boussiba, S. Challenges in up-scaling industrial microalgae production. 2nd World Asia: Expanding Algae Markets with Technology Advances.

2009 Boussiba, S. Up-scaling and yield extrapolation of industrial microalgae production. 2nd International Workshop – Carbon Capture and storage Technologies. Fortaleza, Brazil.

2010 Boussiba, S. Microalgae to encounter environmental problems. Sociedad Latinoamericana de Biotecnologia Ambioental y Algal, Segundo Congreso, Cancun, Mexico.

2010 Boussiba, S. Commercial production of carotenoids by microalgae.
Elucidation of the metabolic and regulatory components involved in microalgae response to environmental stress.
8th European Workshop - Biotechnology of Microalgae.

2010 Boussiba, S. Green solutions to global problems – The use of microalgae to encounter environmental constrains. Thai-Israeli Science and Technology Cooperation Project 2010.

2010 Boussiba, S. Biofuel from microalgae. Colloque Franco-Israelien "La voie des energies renouvelables", Musée des arts et métiers de Paris.

2011 Boussiba, S. Production of high value products by microalgae. European Workshop, CO_2: From Waste to Value. Brussels, Belgium

2011 Boussiba, S. How can algae biology and biotechnology help to improve the efficiency of algae-to-biofuels production strains. European Biodiesel Board. Brussels, Belgium.

2011 Peled, E., Leu, S., Zarka, A., Pick, U., Weiss, M. and Bousisba, S. Isolation of a novel oil globule protein from the green alga *Haematococcus pluvialis* (Chlorophyceae).4th Congress of the International Society for Applied Phycology: Scaling-up for new opportunities in applied phycology. Halifax, Canada

2012 Boussiba, S. Microalgae as a source of ingredients. Coca-Cola, Internal, 1-Day Workshop on Algae Technology. Atlanta, Georgia.

2012 Boussiba, S. Microalgal biotechnology and the sustainable development of biofuels. ESF/LESC (European Science Foundation) Strategic Workshop. Biological Containment of Synthetic Microorganisms: Science and Policy. Heidelberg, Germany.

2012 Boussiba, S. Microalgal biotechnology – Green solution to global problems. Algae Technology Platform Europe – Inventors meet Developers. Ghent, Belgium.

2012 Boussiba, S. Genetic improvement of algae for value added products -The GIAVAP concept. 6th International Algae Congress. Rotterdam, Holland.

2013 Boussiba, S. High-value products from microalgae. 6th Symposium on Microalgae and seaweed products in plant/soil-systems. "Contribution to sustainable agriculture". Mosonmagyarovar, Hungary.

2013 Boussiba, S. Advances in biofuel and PUFAs production by microalgae. Keynote lecture. 11th Euro Fed Lipid Congress and 30th ISF lecture series. Antalya, Turkey.

B. Presentation of papers at conferences:

1975 Boussiba, S. and Richmond, A. Abscisic acid and the interrelationship between various stresses. Israel J. Bot. 24: 54.

1975 Boussiba, S., Rikin, A and Richmond, A. Cross adaptation in plants. Plant Physiol. Supplement, 56: 12.

1976 Boussiba, S. and Richmond, A. Abscisic acid and the after effect of Tobacco plants. Isr. J. of Bot. 25: 97.

1977 Boussiba, S. and Richmond, A. C-phycocyanin from the blue-green alga *Spirulina platensis*. FEBS.

1979 Boussiba, S. and Richmond, A. Phycocyanin as a storage protein in the blue-green alga *Spirulina platensis*. In the 3rd International Symposium on Photosynthetic Prokaryotes. Oxford.

1982 Boussiba, S. and Richmond, A. A non-specific protease degrading C-phycocyanin during nitrogen starvation in the blue-green alga *Spirulina platensis*. In the 3th Symposium on Photosynthetic Prokaryotes. Bombane, France.

1982 Richmond, A., Karg, S and Boussiba, S. Effects of bicarbonate and carbon dioxide on the competition between *Chlorella vulgaris* and *Spirulina platensis*. In the 4th Symposium on Photosynthetic Prokaryotes. Bombane, France.

1983 Boussiba, S. and Gibson, J. Characterization of ammonium transport in a unicellular cyanobacterium. In ASM Conference on Bacterial Periplasmic Transport Systems. Berkeley.

1984 Boussiba, S. and Gibson, J. Methylammonium and ammonium translocation by *Anacystis nidulans*. In the Mampet Meetings; Northeast Microbiologists: Physiology, Ecology, Taxonomy. Ithaca, N.Y.

1985 Boussiba, S. and Gibson, J. Regulation of ammonium and methylammonium transport in cyanobacteria. In the 5th Symposium on Photosynthetic Prokaryotes. (Grindelwald, Switzerland)

1987 Boussiba, S. *Anabaena azollae* as a nitrogen biofertilizer. In the 4th International Meeting of the French Society of Applied Algology. Villeneuve D'ascq , France.

1987 Cohen, Z., Vonshak, A., Boussiba, S. and Richmond, A. The effect of temperature and cell concentrations on the fatty acid composition of outdoor cultures of *Porphyridium cruentum* . In the 4th International Meeting of the French Society of Applied Algology. Villeneuve D'ascq , France.

1988 Boussiba, S. and Gibson, J. Ammonium translocation in cyanobacteria. 6th Symp. on Photosynthetic Prokaryotes. (Oordwijkerhout, Netherlands)

1988 Belkin, S., Boussiba, S., Mehlhorn, R.J. and Packer, L. ESR determination of internal pH in intact cyanobacteria. 6th Symp. on Photosynthetic Prokaryotes. Noordwijkerhout, The Netherlands.

1988 Boussiba, S. Ammonium uptake in the alkalophilic cyanobacterium *Spirulina platensis*. 6th Symp. on Photosynthetic Prokaryotes. Noordwijkerhout, The Netherlands.

1989 Boussiba, S. Biomass production of nitrogen fixing cyanobacteria. Adv. Course on Inorganic Nitrogen Metabolism. Napoli, Italy.

1989 Boussiba, S. and Belkin, S. Cyanobacterial resistance to ammonia at high pH values. Adv. Course on Inorganic Nitrogen Metabolism. Napoli, Italy.

1990 a) Herrera, A., Boussiba, S., Napoleone, V. and Hohlberg, A. Recovery of C-phycocyanin and □-linolenic acid rich lipids from the cyanobacterium *Spirulina maxima*.

b) Palacpac, N., Martinez, M. and Boussiba, S. Mass cultivation of an indigenous nitrogen-fixing blue-green alga *Gleotrichia natans*.

c) Thomas, S., Zaritsky, A. and Boussiba, S. Genetic improvement of *Anabaena siamensis* for ammonium hyperproduction and excretion.
The 5th Internat. Conf. Soc. Appl. Algol. on: Recent Advances in Algal Biotechnology, Tiberias, Israel.

1991 Zaritsky, A., Einav, M., Ben-Dov, E., Khawaled, K., Zalkinder, V., Douek, J., Boussiba, S. and Barak, Z. Mosquito biocontrol by means of microbial delivery systems for the □-endotoxin of *Bacillus thuringiensis* var. *israelensis*. Ann. Meet. Isr. Soc. Microbiol., Bar-Ilan Univ. Israel.

1992 Boussiba, S. Production in tubular reactor of the nitrogen fixing rice field isolate cyanobacterium *Anabaena siamensis* for rice farming. 9th International Congress on Nitrogen Fixation. Cancun, Mexico.

1992 Shen, G., Boussiba, S. and Vermaas, S. *Synechosistis* sp. PCC 6803 mutants lacking photosystem I and phycobilisome function: Towards "in vivo photosystem II particles". IX International Congress on Photosynthesis. Nagoya, Japan.

1994 a) Ben-Dov, E., Boussiba, S. and Zaritsky, A. Combinations of genes from *Bacillus thuringienesis var. israelensis* cloned for expression in *Escherichia coli*. Ann. Meet. Isr. Soc. Microbiol., Weizmann Inst. of Science, Israel.

b) Peleg, N., Wu, X., Zaritsky, A. and Boussiba, S. Screening for type II restriction endonucleases in *Anabaena siamensis*. Ann. Meet. of the Israel Society for Microbiology. Weizmann Inst. of Science, Israel.

1994 a) Ben-Dov, E., Boussiba, S. and Zaritsky, A. Mosquito larvicidal activity of *Escherichia coli* with combinations of genes from *Bacillus thuringiensis* var. *israelensis*. 7th Congress of Bacteriology and Applied Microbiology. July 1994, Prague, Czechoslovakia.

b) Peleg, N., Wu, X., Zaritsky, A. and Boussiba, S. Screening for type II restriction endonucleases in *Anabaena siamensis*. 7th Congress of Bacteriology and Applied Microbiology. July 1994, Prague, Czechoslovakia.

1994 Ben-Dov, E., Boussiba, S. and Zaritsky, A. Mosquito larvicidal activity of *Escherichia coli* with combinations of genes from *Bacillus thuringiensis* var. *israelensis*. 6th International Colloquium on Invertebr. Pathol. and Microbial Control, 2nd International Conference on *Bacillus Thuringiensis*. Montpellier, France.

1994 Ben-Dov, E., Boussiba, S. and Zaritsky, A. Mosquito larvicidal activity of *Escherichia coli* with combinations of genes from *Bacillus thuringiensis var. israelensis*. 8th European Meet. Soc. for Vector Ecology. Barcelona, Spain.

1994 Ben-Dov, E., Boussiba, S. and Zaritsky, A. Mosquito larvicidal activity of *Escherichia coli* with combinations of genes from *Bacillus thuringiensis* var. *israelensis*. 7th Conference Isr. Soc. Entomol., p. 25-26.

1994 Peleg, N., Nissan, G., Ben-Dov, E., Boussiba, S., and Zaritsky, A. Partial restriction mapping of the 72 MDa plasmid of *Bacillus thuringiensis* var. *israelensis*. 7th Conference Isr. Soc. Entomol., p. 24.

1994 Barak, Z., Zaritsky, A., Markus, A., Boussiba, S., Cohen, S., Grinberg, M., Manasherob, R., and Ben-Dov, E. Improving efficacy of the bacterium *Bacillus thuringiensis* var. *israelensis* as a mosquito control agent. 7th Conference Isr. Soc. Entomol., p. 9-10.

1994 Boussiba, S., Ben-Dov, E., and Zaritsky, A. N_2-fixing cyanobacteria as *Bacillus thuringiensis* var. *israelensis* toxin gene delivery system: Biotechnological approach to control malaria mosquitoes. International Conference on Modern Agriculture and the Environment. Rehovot, Israel.

1995 a) Wu, X., Zaritsky, A. and Boussiba, S. Transformation of the ricefield isolate of filamentous cyanobacterium *Anabaena siamensis*. Third European Workshop on the Molecular Biology of Cyanobacteria, May 1995, Univ. of Sevilla, Spain.

b) Wu, X., Xu, X., Ben-Dov, E., Dahan, E., Zaritsky, A. and Boussiba, S. Expression of mosquitocidal Bacillus thuringiensis SUBSP. israelensis □-endotoxin genes in the filamentous cyanobacterium *Anabaena* 7120. Third European Workshop on the Molecular Biology of Cyanobacteria, May 1995, Univ. of Sevilla, Spain.

1995 Lu, F. and Boussiba, S. A novel photoprotective role of astaxanthin in a green alga *Haematococcus pluvialis*. 10th International Photosynthesis Congress, August 1995, Montpellier, France.

1995 Peleg, N., Nissan, G., Ben-Dov, E., Boussiba, A., and Zaritsky, A. Current restriction mapping of the 75 MDa plasmid of *Bacillus thuringiensis* subsp. *israelensis*. Annu. Meet. Isr. Soc. Microbiol., p. 160.

1995 Zaritsky, A., Boussiba, S., Ben-Dov, E., and Manasherob, R. Transgenic organisms for control of mosquito-borne diseases. Euroasian Symposium on Current Trends in Biotechnology: Gene Diagnostics, Gene Therapy and Informational Immunity. Ankara, Turkey.

1996 7th Int. Conf. on Applied Algology, South-Africa:

a) Lu, F., Vonshak, A. and S. Boussiba. Does astaxanthin play a photoprotective role in *Haematococcus pluvialis* (chlorophyceae).

b) Liu, H., Vonshak, A. and S. Boussiba. Morphological and structural changes during the growth cycle of *Haematococus pluvialis*.

c) Singh, A.K., Zarka, A. and Sammy Boussiba. The existence of a Na^+/H^+ antiporter in the alkaliphilic cyanobacterium *Spirulina platensis*

d) Wu, X., Zaritsky, A. and Boussiba, S. Transformation of a ricefield isolate *Anabaena siamensis*

e) Wu. X., Ben-Dov, E., Dahan, E., Vennison, J., Zaritsky, A. and Boussiba, S. Expression of mosquitocidal *Bacillus thuringiensis Var. Israelensis* □-endotoxin genes in filamentous cyanobacterium *Anabaena siamensis* 7120.

1997 Boussiba, S. Mosquito larvicidal activity of *Anabaena* PCC 7120 expressing *Cry*IVA, *Cry*IVD and *p20* from *Bacillus thuringiensis* sp. *israelensis*. IXth ISPP, Vienna, Austria.

1997 Wu, X., Vennison, J., Ben-Dov, E., Zaritsky, A. and Boussiba, S. Expression of mosquitocidal *Bacillus thuringiensis Var. Israelensis* □-endotoxin genes in filamentous cyanobacterium *Anabaena siamensis* 7120. 11th International Congress on Nitrogen Fixation, Institut Pasteur, Paris, France.

1997 Wu, X., Zaritsky, A. and Boussiba, S. Transformation of a ricefield isolate *Anabaena siamensis*. Sixth International Phycological Congress. Leiden, The Netherlands.

1998 Ben-Dov, E., Wang, Q.-F, Saxena, D., Manasherob, R., Boussiba, S. and Zaritsky, A. Protection by ingested particles of insect larvae from *Bacillus thuringiensis* toxicity. 11th European SOVE (Society for Vector Ecology) Meeting, Lisbon, Portugal. Book of Abstracts (Acta Parasitólogia Portuguesa, Vol. 5, p. 34.

1998 Manasherob, R., Boussiba, S., Ben-Dov, E., Wu, X.-Q. and Zaritsky, A. Protection of heterologous *Bacillus thuringiensis* subsp. israelensis toxin from UV-B in *Anabaena* PCC 7120. 11th European SOVE (Society for Vector Ecology) Meeting, Lisbon, Portugal, Book of Abstracts, p. 31.

1998 Wu, X.Q., Zaritsky, A. and Boussiba, S. Expression of mosquitocidal *Bacillus thuringiensis* subsp. *israelensis* □-endotoxin genes in filamentous cyanobacterium *Anabaena*. International Symposium on Progress and Prospect of Marine Biotechnology (ISPPMB). Qingdao, China.

1999 Boussiba, S. Oxidative stress regulates astaxanthin accumulation in the green alga *Haematococcus pluvialis*. 8th Western Photosynthesis Conference. Asilomar, USA.

1999 Boussiba, S., Zaritsky, A., Wu, X.Q., Ben-Dov, E. and Zarka, A. Transgenic *Anabaena* PCC 7120 and *Escherichia coli* expressing mosquito larvicidal □-endotoxins from *Bacillus thuringiensis* subsp. *Israelensis*. European Commission Sectorial Meeting Controlling the Proliferation of the Microbial Cell Factory, Verona, Italy. Book of Abstracts, p. 31.

1999 Boussiba, S. Carotenogenesis in the green alga *Haematococcus pluvialis*. 12th International Carotenoid Symposium, Cairns, Australia.

1999 8th International Conference on Applied Algology. Montecatini Terme, Italy.

a) Boussiba, S., Aflalo, C., Bing, W. and Zarka, A. The effect of the herbicide glufosinate (BASTA) on astaxanthin accumulation in the green alga *Haematococcus pluvialis*.
b) Boussiba, S., Zarfati, U. Zarka, A. The relationships between cell wall and astaxanthin accumulation process in the green alga *Haematococcus pluvialis*.
c) Boussiba, S., Zarka, A., Aflalo, C. and Singh A.K. Effect of amiloride on pH regulation in the alkaliphilic filamentous cyanobacterium *Spirulina platensis*.
d) Boussiba, S., Zarka, A., Lu, F., Lu, C.M. and Vonshak, A. Characterization of physiological changes during encystment in a green alga *Haematococcus pluvialis*.
e) Boussiba S., Wu, X., Zarka A ., Ben-Dov, E . and Zaritsky, A. Recombinant mosquito larvicidal *Anabaena* PCC 7120.
f) Clarkson, N., Zarka, A., Pick, U., Young, A.J. and Boussiba, S. Initial studies concerning the isolation and protein characterisation of astaxanthin rich globules in *Haematococcus pluvialis*.
g) Yan, J., Boussiba, S., Cohen, Z. and Vonshak, A. Quantitative studies on the growth and EPA productivity of *Monodus subterraneus*.
h) Manasherob, R, Boussiba, S., Ben-Dov, E., Wu, X.-Q. and Zaritsky, A. Protection of heterologous *B. thuringiensis* subsp. *israelensis* toxin from UV-B in *Anabaena* PCC 7120.
i) Vonshak, A., Torzillo, G., Yan, J. and Boussiba, S. On-line and off-ine fluorescence measurements as a tool to estimate photosynthesis and productivity of *Monodus subterraneus*.
j) Zarka, A., Wang, B., Trebst, A. and Boussiba, S. The role of D1 protein subunit of Photosystem II in the accumulation of astaxanthin in *Haematococcus*.

1999 Manasherob, R., Boussiba, S., Ben-Dov, E., Wu, X.-Q. and Zaritsky, A. Protection of heterologous *Bacillus thuringiensis* subsp. *israelensis* toxin from UV-B in *Anabaena* PCC 7120. 32nd Annu. Meet. Soc. Invertebr. Pathol., Irvine, USA.

1999 Ben-Dov, E., Wang, Q., Saxena, D., Manasherob, R., Boussiba, S. and Zaritsky, A. Ingested particles protect *Aedes aegypti* larvae from *Bacillus*

thuringiensis subsps. *israelensis* toxicity. 32nd Annu. Meet. Soc. Invertebr. Pathol., Irvine, USA.

2000 Ben-Dov, E., Zarka, A., Zaritsky, A., Mansherov, R. and Boussiba, S. Biological control of mosquitoes using transgenic cyanobacterium expressing genes for specific toxins from *Bacillus thuringiensis* subsp. *israelensis*. Entomology Conference, Beit-Dagan.

2001 7th International Phycological Congress, Thessaloniki, Greece:

i) Zhekisheva, M., Boussiba, S., Khozin-Goldberg, I., Zarka, A. and Cohen, Z. Accumulation of triacylglycerols in *Haematococcus pluvialis* is correlated with that of astaxanthin esters.

ii) de Padua Castillo Flores, A., Zarka, A. and Boussiba, S. Synchronous culture of *Haematococcus pluvialis* Flotow.

iii) Karmacharya, N., Lluisma, A.O., Zarka, A., Ben-Dov, E., Zaritsky, A. and Boussiba, S. Suitability for biotechnological application of recombinant *Anabaena* PCC7120 expressing mosquitocidal toxin genes.

2001 Bagherpour, S., Gellenbeck, K., Mody, D., Coin, M., Vonshak, A. and Boussiba, S. The design of a large scale photobioreactor for production of *Spirulina platensis*. Teknolojisi Sempozyumu, Ege Univ., Turkey.

2002 The 1st Congress of the International Society for Applied Phycology. 9th International Conference on Applied Algology. Almeria, Spain:

- Castillo, F., Zarka, A. and Boussiba, S. Synchronized culture of *Haematococcus pluvialis*.
- Ben-Abou, Y. Zarka, A., Tel-Or, E. and Boussiba, S. Effects of the herbicides glufosinate (BASTA) and methionine-s-sulfoximine on glutamine synthase in the green alga *Haematococcus pluvialis*.
- Gao, Q.T., Boussiba, S. and Vonshak, A. Accumulation of arachidonic acid and response to environmental stresses in two green algae *Parietochloris incisa* and *Neochloris cohaerens*.
- Hoffman, Y., Zarka, A. and Boussiba, S. Isolation and characterization of a parasitic chytrid from a culture of the chlorophyte *Haematococcus pluvialis*.
- Wang, B., Zarka, A., Trebst, A. and Boussiba, S. Accumulation of astaxanthin in *Haematococcus pluvialis*: An active photo-protective process under high light conditions.
- Zhekisheva, M., Boussiba, S., Khozin-Goldberg, I., Zarka, A. and Cohen, Z. Accumulation of triacylglycerols in *Haematococcus pluvialis* is correlated with that of astaxanthin esters.
- Cohen, Z., Bigogno, C., Boussiba, S., Khozin-Goldberg, I., Shrestha, P. and Vonshak, A. *Parietochloris incisa*, the richest plant source of the polyunsaturated fatty acid (PUFA), arachidonic acid.
- Karmacharya, N., Lluisma, A.O., Zarka, A., Ben-Dov, E., Zaritsky, A. and Boussiba, S. Suitability for biotechnological application of recombinant *Anabaena* PCC7120 expressing mosquitocidal toxin genes.
- Ferber, A., Rouwendel, G., Kok, G.R., Zarka, A. and Boussiba, S. Up-regulation of genes transcription of acetyl-CoA carboxylase during astaxanthin accumulation in *Haematococcus pluvialis*.

2006 Boussiba, S. Phycobillin and astaxanthin concentrations in microalgae. Pre-Conference Workshop on Measurements of Algal Growth and Photosynthesis, Asia-Pacific Conference on Algal Biotechnology, Univ. of Santo Tomas, Philippines.

2011 4th Congress of the International Society for Applied Phycology: Scaling-up for new opportunities in applied phycology. Halifax, Canada:

- Guiheneuf, F., Leu, S., Zarka, A., Khozin-Goldberg, I., Khalilov, I. and Boussiba, S. Characterization of a key enzyme in triaglycerol biosynthesis: a novel acyl-

CoA:diacylglycerol acyltransferase 1-like gene from the diatom *Phaeodactylum tricornutum*.

- Recht, L., Fait, A., Zarka, A. and Boussiba, S. Elucidation of the metabolic and regulatory components involved in microalgae response to environmental stress.
- Shtaida, N., Khozin-Goldberg, I., Cohen, Z., and Boussiba, S. Elucidating the role of the enzymes of central carbon metabolism in induction of neutral lipid accumulation in the microalga *Parietochloris incisa*.
- Grundman, O., Hacohen, Z., Khozin-Goldberg, I., Shapira, M. and Boussiba, S. Cloning and characterization of the green microalga *Parietochloris incisa* AHAS gene, to be used as a selection marker for genetic transformation.
- Reinecke, D., Zarka, A. and Boussiba, S. Autolysin extraction for improved protoplast preparation in the green alga *Haematococcus pluvialis* (Chlorophyceae, Volvocales).
- Richter, K., Zarka, A. and Boussiba, S. Characterizing the biochemical basis for the specific interaction between the chytrid parasite *Sdebokerensis* and its algal host *H. pluvialis*.

2013 3rd International Conference on Algal Biomass, Biofuels and Bioproducts. Toronto, Canada.

- Reinecke, D.L., Leu, S., Zarka, A. and Boussiba, S. Molecular characterisation of two newly identified glutamine synthetase isoforms in the green microalga *Haematococcus pluvialis* (Chlorophyceae, Volvocales).
- Zorin, B., Grundman, O., Khozin-Goldberg, I., Leu, S., Shapira, M. and Boussiba, S. Development of nuclear transformation system for the oleaginous green microalga *Parietochloris incisa*
- Sharon-Gojman, R., Maimon, E. , Leu, S. , Zarka, A. and Boussiba, S. Genetic Engineering of *H. pluvialis* by nuclear and chloroplast genome transformation.
- Kaye, Y., Diaz-Reck, D., Guheneuf, F., Tabah, B., Leu, S., Zarka, A. and Boussiba, S. An integrated approach for increasing feasibility of microalgal biofuels and value-added bioactive compounds production.

2013 European symposium on Plant Lipids. Bordeaux, France.

- Pal., D., Khozin-Goldberg, I., Batushansky, A., Fait, A. and Boussiba, S. Growth, lipid production and metabolic adjustments in the microalga *Nannochloropsis oceanica* CCALA 804 in response to osmotic downshift.
- Khozin-Goldberg, I., Pal, D., Sitnik, S., Shtaida, S., Iskandarov, U., Leu, S. and Boussiba, S. Manipulation of lipid productivity in microalgae cultures by alterations in environmental conditions and molecular engineering.

Patents

1997 Boussiba, S., Vonshak, A., Cohen, Z. and Richmond, A. A procedure for large-scale production of astaxanthin from *Haematococcus*. World Patent appl. No. PCT/IL97/00042.

1997 Boussiba, S., Zaritsky, A., Ben-Dov, E. and Wu, X. A biocontrol agent containing an endotoxin gene. Israel Patent appl. No. 120441.

2003 Boussiba, S. and Zarka, A. A disposable flat panel photobioreactor. Patent No. 60/488,876.

2007 Cohen Z., Khozin-Goldberg I., Boussiba S. and Vonshak A. Production of dihomo-γ-linolenic acid (DGLA) by the mutant microalga. PCT application no. IL07/001012 filed on 13/8/07; US appl. no 11/919,006 filed on 21/10/07.

2010 Khozin-Goldberg, I., Iskandarov, U., Cohen, Z., Boussiba, S. and Vonshak, A. Δ5 desaturase-defective mutant gene and use thereof.. US Filing Date: 10-JUN-2010.

2010 Guihéneuf, F., Leu, S., Zarka, A., Khozin-Goldberg, I. and Boussiba, S. A novel acyl-CoA: diacylglycerol acyltransferase 1-like gene from the diatom and uses thereof. P-74542-USP. Publication No. WO/2012/059925. Internation Application No. PCT/IL2011/000863. Publication date: 10.05.2012. Internation Filing Date: 03.11.2011.

2011 Grundman, O., Khozin-Goldberg, I., Raveh, D., Cohen, Z., Boussiba, S., Shapira, M. The use of the endogenous AHAS gene as a selection marker for the genetic transformation of P. incisa. (provisional patent is pending).

Research Grants

A. Completed and on-going

1983-86 Solar Energy Research Institute (SERI). A. Richmond, S. Boussiba, A. Vonshak and Z. Cohen. Development of outdoor raceway capable of yielding oil rich halotolerant microalgae, $180,000.

1985-88 National Council for Research and Development. Z. Cohen, S. Boussiba. and A. Richmond. Production of chemicals from the alga *Porphyridium*. $63,000.

1986-89 US-Agency for International Development. A. Vonshak, S. Boussiba and A. Richmond. Study of a non-conventional system of industrial wastewater treatment: high rate anaerobic digestion and high rate oxidation ponds, a cooperative project with the Central American Research Institute for Industry in Guatemala. $28,000.

1986-90 US-Agency for International Development . S. Boussiba. The use of cyanobacteria as biofertilizers, a cooperative project with the Philippines. $150,000.

1988-92 US-Agency for International Development. Z. Cohen., A. Richmond and S. Boussiba. Production of Eicosapentaenoic Acid (EPA) by microalgae, a cooperative project with Thailand. $ 200,000.

1989-92 US-Israel Binational Science Foundation (BSF). Boussiba, S. Regulation of the internal pH in the alkalophilic cyanobacteruim *Spirulina platensis*. (with L. Packer, Univ. of Berkeley, CA), 3 years. $129,150.

1992-95 German -Israel Agricultural Research Agreement (GIARA). Boussiba, S., Tel Or, E., Boger, P. and Bogarin, C.L. (Costa Rica). Use of nitrogen-fixing cyanobacteria and the aquatic fern *Azolla sp*. as biofertilizer in flooded rice farming (Proposal code number, F-10). DM 560000.

1992-95 Binational Agricultural Research and Development Fund (BARD). E. Gantt, A. Vonshak, S. Boussiba, Z. Cohen and A. Richmond. Carotenoid-rich algal biomass for aquaculture: astaxanthin production by *Haematococcus pluvialis*. (US-1863-90)

1992-95 System Research Institute, Japan. Research on the utilization of snow algae. Vonshak, A. Vonshak, Boussiba, S., Cohen, Z. and Richmond, A. $300,000.

1994-96 RASHI Fund, Astaxanthin production by *Haematococcus pluvialis*. Boussiba, S., Vonshak, A., Cohen, Z. and Richmond, A. $340,000.

1995 UNESCO-MCBN (Global Network for Molecular and Cell Biology). Boussiba, S. Cloning the BTI □-endotoxin gene into a nitrogen-fixing rice-field cyanobacterium isolate *Anabaena siamensis*. $5,500.

1995 Moriah Fund. Boussiba, S. and Zaritsky, A. Biological control of mosquitoes born diseases. $15,000.

1996-97 Harry Stern and Helen Tzoref Applied Research Program. Boussiba, S. and Zaritsky, A. Biological control of mosquito-borne diseases: The use of N_2-fixing cyanobacteria to deliver Bti toxins against mosquito larvae. $16,000.

1996-98 German-Israel Fund for Research and International Development (GIFRID). Tel-Or, E., Boussiba, S. and Bogarin, C.L. (Costa Rica). Biofertilized rice production, combined with efficient weed control, for flooded rice in Costa-Rica. DM 20,000.

1997 BASF. S. Boussiba. Production of astaxanthin from *Haematococcus*. $30,000.

1997-01 BRITE-EuRAM. Cohen, Z., Vonshak, A., Boussiba, S. and Richmond, A. An integrated production of highly purified EPA from algae. ECU 228,000.

1997-98 Harry Stern Applied Research Program. Boussiba, S., Sharoni, Y., Levy, J., Wisniak, J. and Korin, E. Astaxanthin as a potent antioxidant agent. $16,000.

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Synopsis of research

1. Identifying the mechanisms sustaining the growth of the filamentous cyanobacterium *Spirulina platensis* under alkaline conditions

Cyanobacteria can be found in diverse environmental conditions; the filamentous *Spirulina platensis* which thrives at extreme alkaline habitats, is a good example. We have studied this exceptional behavior of *Spirulina* and looked for possible mechanism(s) involved in this adaptation.

Similar to other alkaliphiles, we have found that the cyanobacterium *Spirulina platensis* maintains a pH gradient across the plasma membrane (at external pH of 10.0 with an internal pH of 8.5 has been measured). We have found that as in the case of heterotrophic alkaliphiles, this ability of *Spirulina* is sodium dependent. The research thus aims at present to investigate the mechanisms which allow growth of this cyanobacterium at high pH values, with special emphasis on the cellular sodium cycle. Using amiloride and its analogs which are known to interact specifically with Na^+ binding sites, we have indicated the existence of an Na^+/H^+ antiporter in *Spirulina* with the aid of the fluorescent dye atebrin. The results obtained so far support the involvement of an Na^+/H^+ antiporter in pH regulation; its nature is currently under investigation in isolated plasma membrane vesicles (Xu et al. 1994).

2. *Haematococcus* - a model organism to study biotechnological approaches for the utilization of microalgae for products of high value

Recently considerable interest has been focused on the unicellular green alga *Haematococcus pluvialis* Flotow because of its capacity to amass large amounts of the ketocarotenoid astaxanthin (3,3'-diketo-4'dihydroxy □-carotene), widely used commercially to color salmonids' flesh. Astaxanthin accumulation in *Haematococcus* is induced by a variety of environmental stresses which limit cell growth in the presence of light. It is accompanied by a remarkable morphological and biochemical "transformation" from green motile cells into inert red cysts. During recent years we have studied this transformation process from several aspects: defining conditions governing pigment accumulation, working out the biosynthetic pathway of astaxanthin accumulation (Lu et al. 1995), and questioning the possible function of this secondary ketocarotenoid in protecting *Haematococcus* cells against oxidative damage. We have found that this exceptional stress response is mediated by reactive oxygen species (ROS) through a mechanism which is now under investigation. The results are not supporting in-vivo chemical quenching of ROS by the pigment, although in vitro it was shown to quench radicals very efficiently. The finding that most of the pigment produced is esterified and deposited in lipid globules outside the chloroplast further supports this assumption. We have suggested that astaxanthin is a by-product of a defense mechanism rather than the defending substance itself. Further research is required to pursue other possible alternative functions of this pigment. Other defense systems known to operate under oxidative stress conditions such as antioxidative enzymes (SOD, catalase etc.) and the xantophyll cycle, are under current investigation. The above findings (Boussiba 1999) have provided a rational approach for the development of a unique process for the production of astaxanthin rich *Haematococcus* mass. The core of this biotechnology is a two-step process, a green and a red one, yielding a product with one of the highest pigment contents so far produced (4 to 6% of cellular dry weight) (US Patent No. PCT/IL97/00042).

3. N_2-fixing cyanobacteria – Biotechnological and ecological potential

Nitrogen fixing cyanobacteria occur worldwide in a wide range of terrestrial, freshwater, and marine environments. This large and diverse group of Gram-negative prokaryotes, long employed for research in photosynthesis and nitrogen fixation, is now widely used in agriculture, and is being utilized and further explored for biotechnological development.

During recent years several aspects of these algae have been studied for different agricultural and environmental uses:

a) Application as nitrogen biofertilizers in rice fields. Two major problems limiting this biotechnology have been addressed – the release of ammonia for the benefit of rice plants and production of good quality innocula.
b) The possible use of valuable compounds. The utilization of a nitrogen-fixing strain isolated from rice paddy fields was studied as a source of valuable compounds such as phycobiliproteins.
c) As potential candidates for expressing desirable genes to combat environmental hazards. We have focused mainly on developing the biotechnology of cloning *Bacillus thuringiensis* subsp. *Israelensis* (Bti) toxin genes into N_2-fixing cyanobacteria. The use of the current preparation of Bti (a natural biocontrol agent for combating tropical diseases such as malaria) is limited by its short half-life under field conditions. One way to overcome this limitation is by cloning the genes coding for the toxins into organisms inhabiting the breeding zones of mosquitoes such as rice paddies. Introducing Bti toxin genes into cyanobacteria would provide a form of pest control with higher persistence in nature and replace multiple applications of Bti formulations. As such, cyanobacteria are promising candidates for toxin delivery systems. Mosquitocidal genes *cry4A*, *cry11A*, and regulatory gene *p20* of *Bacillus thuringiensis* subsp. *israelensis* (Bti.) were cloned as artificial operons (Bti-toxon) in various combinations (Ben-Dov et al. 1995). These operons were subcloned into *E.coli-Anabaena* shuttle vector pRL488p, then introduced into nitrogen fixing filamentous cyanobacterium *Anabaena* strain PCC 7120 via conjugation under control of tandem strong promoters (P_{psbA}- P_{T7}) (Wu et al. 1997). Transgenic lines of *Anabaena* strain PCC 7120 carrying various Bti-toxons were isolated and showed different levels of toxicity against mosquito larvae of *Aedes aegypti;* they also exhibited various degrees of stability. The highest bioactivity was found in lines carrying *cry4A* and *cry11A*, with or without *p20* (Bti-*cryADR* or Bti-*cryAD*) at LC_{50} of about 0.3 g of total soluble protein ml^{-1}; that is the highest bioactivity ever achieved in any other engineered cyanobacteria expressing Bti toxin genes. To date, 3 years after the isolation of our clones, their stability is maintained. We are currently investigating the possibility that the Bti toxin genes introduced to *Anabaena* PCC 7120 via a shuttle vector PRL488 were integrated into the host genome. To the best of our knowledge, this is one of the first examples ever reported for long lasting engineered cyanobacteria expressing few proteins.

4) Green Solutions to Global Problems

Microalgae are photoautotrophic microorganisms that inhabit the photic zone of almost all water bodies, including highly polluted environments. In the face of rising awareness to environmental problems and the need to developing alternative, green solutions, microalage are often considered as green vector to encounter some of those environmental challenges. As such renewable fuels, microalgae have gained interest as a means of biofuel production under utilization of exhaust CO_2. In contrast to currently explored biofuel options microalgae have higher productivity and can be cultivated on marginal land using poor quality water or sea water. Commercialization of microalgal biomass production in the large scale however is still limited and significant investments into research and development will be required for improving the biological material and the biomass production and processing technologies. Algal biomass production under purification of waste water has also been successfully demonstrated. We are studying the option of waste water treatment under production of algal biomass for fodder or energy, and recovery of waste nutrients and carbon in integrated waste management systems. This approach will be of high relevance in context of the looming food and resource scarcity, whereby integrated utilization of waste resources and water can guarantee further sustainable development of agriculture and aquaculture also in drylands. The algal biomass produced can be widely applied, e. g. as protein rich fodder, energy or for the substitution of high value petrochemicals.

In addition to those popular and intensively investigated applications microalgae also can play a central role in management of acute pollution problems, whereby the possibilities of genetic engineering allow for creation of highly efficient algal strains for addressing specific tasks. In

contrast microalgae can pose a significant environmental threat by causing sometimes toxic algal blooms in polluted water bodies, requiring close monitoring.