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Table:1, Figs :1

Pioneers of Allelopathy: XVI. Shaolin Peng

Shaolin Peng

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ABSTRACT

Shaolin Peng contributed immensely to restoration ecology research in last 40- years and has published > 700 papers. He has made innovative and theoretical breakthroughs in vegetation restoration, ecological restoration of invaded ecosystems, interaction between ecological restoration and global change, etc. One of his key achievements is vegetation restoration in subtropical South China. He has developed new models of vegetation in natural succession, replacement and fluctuation, advanced theory and proved that extremely degraded tropical forests can be restored. He established that allelopathy is one of the driving forces of forest succession and did related studies on systematic sampling and analysis of several forest communities from south to north in China. He has done outstanding research on invasive plants and examined the Novel Weapon Hypothesis (allelopathic inhibition) of invasive alien plants in South China and determined the various aspects of invasive mechanism of alien plants (molecular mechanism of elevated temperature and CO_2 effects in allelopathy of invasive plants). He put forward the 'Allelopathic resistance hypothesis (native plants resistance to invasive plants)' and 'ecological control theory'. In recognition of his contributions to *Allelopathy* field, he was awarded the *Outstanding Achievement Award* by the International Allelopathy Foundation. He also did in-depth studies on ecological impacts of invasive plants, specifically focusing on plant-soil feedback and plant-AMF symbiosis. Besides, Peng has mentored 68 Ph.D. and 38 M.Sc graduates, and was recognized as "Prominent Teacher" by Sun Yat-sen University. He has been the Vice President, Ecological Society of China, Vice Chairman, Nature Conservation and Eco-Environment Teaching Steering Committee, Ministry of Education, Member, Academic Degree Commission of State Council, Awarded 'Top Ten Outstanding Youth in China', Young Scientist Award, Chinese Academy of Sciences and National Outstanding Scientific and Technical Worker of China.

Keywords: Allelochemicals, allelopathy, chemical ecology, ecological restoration, forest succession, invasive plants

1. PERSONAL LIFE

I was born to Shaoheng Peng and Ruiqin Ma in Chaoyang county, Shantou City, Guangdong (China) on October 16, 1956. My father was the Director of Agricultural Bureau of Chaoyang county, while my mother was a manager of the Chaoyang Coal Company. I have three sisters. My eldest sister Shaoyin Peng was born in 1954, She worked in the Tax Bureau of Longhu District in Shantou City. My second-elder sister Shaoying Peng was born in 1955, retired from the Hospital of Traditional Chinese

Medicine of Chaoyang District in Shantou city. My younger sister Shaofang Peng was born in 1963. She is a Chief Physician in Shantou Central Hospital. I married Zhelin Li in 1982 when I worked in South China Institute of Botany of Chinese Academy of Sciences. Zhelin worked for Guangdong government as a Logistics officer from 1980s till her retirement in 2018.

Prof. Shaolin Peng

In year 1984 my daughter Lijing Peng was born in Guangzhou. She studied at Peking University (B.Sc.) and National University of Ireland (Ph.D. Anthropology), now teaching at Trinity Centre for Literary and Cultural Translation, Trinity College Dublin, Ireland. Her research and publications are mainly on linguistic anthropology.

2. EDUCATION

I studied in the Chaoyang No. 1 Public School (1969- 1973). In 1982, I completed my Bachelor's degree (Botany) in the Department of Biology at Sun Yat-sen University, China, where I obtained a Ph.D. (Ecology) in 1989. During my Ph.D. study, I was recommended to be a visiting scholar basing at the Department of Ecosystem Management in the University of New England，Australia for one year. Then I completed my postdoctoral work in the System Analysis Institute at University of Kassel, Germany in 1990. Soon afterwards, I visited Europe again as a senior visiting scholar basing at the Systematics Geobotany Institute in Goettingen University, Germany for six months in 1992. In 1996, I visited America as senior visiting scholar basing at the Department of Ecology and Evolution in the State University of New York, US for three months.

3. PROFESSIONAL CAREER

Table 1 lists a chronology of my employment, volunteer and elected professional positions, and major honours and awards. In 1982, after receiving a BSc degree from the Department of Biology, Sun Yat-sen University, I started my early research career in South China Institute of Botany, Chinese Academic of Science (SCIB, CAS; renamed as South China Botanical Garden in 2003). The first research project that I participated in was the set-up of permanent forest plots in Dinghushan Biosphere Reserve. Dinghushan is China's first national nature reserve, established to protect the lower subtropical evergreen broadleaved forest. It is reputed as "an oasis in deserts" because of the wide prevalence of deserts in subtropical regions across the world. For years, my colleagues and I conducted vast vegetation investigations in the whole nature reserve and hundreds of other tropical/subtropical forest communities in South China. In the daytime, I participated in field investigation and identification of plant species, while, at night, I helped with specimen preservation. These years of hard training in field had built a solid foundation for my later career as a botanist and plant ecologist. Having tremendous amounts of field data at hand, I started to think of quantitatively analyzing and modelling forest dynamics. In 1983, I received my first scientific funding from Chinese Academic of Science, entitled "Analyses of Forest Dynamics of Dinghushan". In 1986, I became one of the first young scholars to lead a project funded by National Natural Science Foundation of China (NSFC), entitled "Study of the Ecology of Forest Communities". In 1992, I was again funded by NSFC to lead the project of "Simulation and Management of Forest Ecosystem Dynamics". The quantification and modelling methods used in my work had greatly changed how vegetation dynamics were documented and studied in China, enabling me and my colleagues to make exciting theoretic breakthroughs in a solid number of high-profile papers and thus to receive many scientific awards.

Table 1. Chronology of Selected Major Events

Period	Academic activities
1982- 1985	Intern Researcher, South China Institute of Botany, Chinese Academy of Sciences
1985 - 1989	Assistant Research Professor, South China Institute of Botany, Chinese Academy of Sciences
1989 - 1993	Associate Research Professor, deputy director of the ecology, South China Institute of Botany, Chinese Academy of Sciences
1993 - 1997	Research Professor, Director of Ecology Office, Master of Heshan Station, Assistant Director, South China Institute of Botany, Chinese Academy of Sciences
1997- 2001	Executive Vice President, Chinese Academy of Sciences Guangzhou Branch, and Guangdong Academy of Sciences; Research Professor
1999	Distinguished Professor, Chang Jiang Scholars Program, Ministry of Education, China
2001- 2003	Director, Research Professor, South China Institute of Botany, Chinese Academy of Sciences
2003- Present	Professor, Principal of Ecology, Sun Yat-sen University

Selected Volunteer and elected Positions

1994-2003	Deputy Director, the Professional Committee on Plant Ecology, Botanical Society of China
1996-2000	Member, the 6th and 7th discipline Evaluation Group of National Natural Science Foundation of China
1998-2003	Vice Chairman, Chinese Ecosystem Research Network, Chinese Academy of Sciences
1998-2013	Chairman, Ecological Society of Guangdong Province
1999-Present	Associate Editor, *Acta Ecologica Sinica* (in Chinese)
2004-2009	Member of the Academic Committee of State Key Laboratory of Biocontrol (Sun Yat-sen University)
2004-2020	Associate Director, Evaluation Committee of Guangdong Nature Reserve, Guangdong Gov.
2004-Present	Member, Chinese National Committee for DIVERSITAS
2006-2010	Member, the third and fourth Expert Advisory Committee of the Earth Science, Department of the National Natural Science Foundation of China
2008-Present	Associate Editor, *Acta Ecologica Sinica* Editorial Board
2009-2018	Vice President, the 8th and 9th Council of Ecological Society of China
2010-Present	Vice President, Guangdong Society of Environmental Sciences
2010-Present	Director, Key laboratory of vegetation restoration and management of degraded ecosystems, Chinese Academy of Sciences
2011-Present	Member, the Academic Committee of the State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, Chinese Academy of Sciences
2013-2017	Vice Chairman, Nature Conservation and Eco-Environment Teaching Steering Committee under the Ministry of Education
2014-Present	Member, The 7th Academic Degree Commission of the State Council
2015-Present	Associate Editor, *Allelopathy Journal*
2016-Present	Associate Editor, *Chinese Journal of Applied Ecology*
2019-Present	Vice Director, Fujian Provincial Key Laboratory of Marine Ecological Conservation and Restoration, Third Ministry of Oceanography, Ministry of Natural Resources
2019-Present	Member, Academic Committee of Key Laboratory of Tropical Island Ecology, Ministry of Education, Hainan Normal University

Selected Honours and Awards

1991	Young Scientist Award, Chinese Academy of Sciences
1992	Nomination Awards, the 3rd Top Ten Outstanding Youth of China
1994	Natural Science Award of Guangdong Province, 2nd prize, "Recent Progress in Plant Community Ecology"
1998	Natural Science Award of Guangdong Province, 2nd prize, "Study on biomass, productivity and energy use efficiency of southern subtropical forest vegetation"
1999	Natural Science Award of Guangdong Province, 1st prize, "Theory and application for forest dynamics in south Tropical Asia"
1999	Science and Technology Progress Award of the Chinese Academy of Sciences, 1st prize, "Restoration and reconstruction of vegetation in tropical and subtropical degraded ecosystems"
1999	Top Ten Young Scientist Award of Guangdong Province
2000	Top Ten News of Basic Scientific Research of China, "Interaction between the terrestrial ecosystem in eastern China and global change"
2000	Advanced Individuals -for Poverty Alleviation through Technology, China
2000	Zhu Kezhen Field Work Award, Chinese Academy of Sciences
2002	Science and Technology Awards of Guangdong Province, 1st prize, "Meizhou Golden Pomelo's high-quality and high-yield"
2003	Science and Technology Awards of Guangdong Province, 1st prize, "Main agricultural situation dynamics and rapid forecast in Guangdong Province"
2005	Science and Technology Awards of Guangdong Province, 1st prize, "Interaction between Global Change and Chinese main agricultural ecosystem"
2009	Outstanding Achievements Awards, International Allelopathy Foundation
2010	Environmental Science Award of Guangdong Province, 1st prize, "Biodiversity survey of Guangdong Province"
2010	National Outstanding Scientific and Technical Workers of China
2014	Teaching Achievement Award of Guangdong Province, 2nd prize, "Innovation and Development of Ecology Textbooks"
2018	National Teaching Achievement Award of China, 2nd prize, "An Innovative Biology Field Practice Teaching Model Based on "One Body, Two Wings""
2019	"The 30th Anniversary Commemorative Medal of Ecological Network" awarded by the Chinese Academy of Sciences

In 1987, I started to work on the processes and patterns in vegetation succession, species regeneration and community dynamics. I went back to Sun Yat-sen University to further my study as a PhD candidate under the supervision of Professor Hong-da Zhang, while at the same time, I continued working in SCIB. In 1989, I finished my PhD dissertation of "Study on the Forest Dynamics of Lower Subtropical China". Soon afterwards, I was promoted as an associate research fellow in SCIB. Four years later, at the age of 37, I was promoted again and became a full research fellow, even though there is usually a minimal of 5-year interval between two promotions. I was elected as the director of the Ecology Department of SCIB and Heshan Research Station to lead the research on ecological restoration of degraded tropical and subtropical forests. In 1994, I led several large projects funded by Chinese Academic of Science and the NSFC project to restore degraded subtropical ecosystems, in collaboration with Jing-wei Zhang, another research fellow in SCIB. Through in-depth studies, we provided strong evidence against the then globally acknowledged notion which claims that severely degraded tropical forests are

unrestorable. We further proposed reference conditions for the ecological restoration of such ecosystems, as well as an array of species/technologies for efficient restoration. It is important to note that, for most of these early works, allelopathy was an indispensable component, which will be introduced in detail in the following sections. The theories and technologies developed from our studies are well received and broadly used in the restoration practice in degraded ecosystems in China, which produces significant ecological and socioeconomical benefits. As a result, my works have become well-known and well-recognized. Some important personal awards of mine were received during this period [e.g., "Dingying Technology Award of Guangdong Province", "Young Scientist Award" from CAS, "Subsidy for National Outstanding Science and Technology Personnels", and "Top Ten Young Scientist Award of Guangzhou City"]. In addition, I also got nominated as "Top Ten Young Scientist Award" at the provincial and national levels. My research team was also rewarded for all these hard work by one first prize of "Science and Technology Progress Award" from CAS, four first prizes for "Exceptional Science and Technology Progress Awards of Guangdong Province", "Advanced Research Group for Important Scientific Missions of the 7th National Five-Year Plan of CAS", "Excellent Young Research Group of Guangdong Province" and "Advanced Field Workers of CAS".

In 1989, I finished my Ph.D. dissertation of "Study on the Forest Dynamics of Lower Subtropical China" under the supervision of Professor Hong-da Zhang, Sun Yat-sen University and continued working in SCIB. Thereafter, I was promoted as Associate Research Fellow in SCIB and due to my good research 4-years later, I became Full Research Fellow. I was elected Director, Ecology Department of SCIB and Heshan Research Station to lead the research on ecological restoration of degraded tropical and subtropical forests. In 1994, I led several large projects funded by Chinese Academic of Science and the NSFC project to restore degraded subtropical ecosystems, in collaboration with Jing-wei Zhang, another research fellow in SCIB. Through in-depth studies, we disproved the globally acknowledged notion that severely degraded tropical forests cannot be restored. We developed efficient technologies to restore degraded forest lands. Our developed technologies are now broadly used to restore the degraded ecosystems in China.

In 1997, I was elected as the executive Vice President of the Chinese Academic of Science, Guangzhou. In 1999, as the youngest scientist who ever led a NSFC major research project, I collaborated with Bo Li (academician of the Chinese Academy of Science) and Xiao-dong Zhou to work on a joint project funded by NSFC and Global Change and Terrestrial Ecosystem (GCTE) objective to study "Vegetation Transects under Global Changes" and established the North-South Transect of Eastern China, which became one of the 15- standard terrestrial transects of the International Geosphere-Biosphere Programme (IGBP). Using this transect as a study system, my research team conducted some in-depth studies to explore the interaction between global change and China's agroforestry ecosystems and the importance of vegetation restoration in counteracting global warming through enhanced carbon fixation. The series of innovative discoveries basing on this project were emphasized in "Top Ten News of Basic Scientific Research of China" in 2000. I was also awarded "National Model Worker", "Ke-zhen Zhu Field Work Award of CAS" and "National Advanced Individual for Poverty Alleviation through Technology" for the excellent work on this project.

In 2003, Principle Da-ren Huang of my old school invited me to work as a full-time professor there, so I went back to Sun Yat-sen University to continue my research on ecological restoration. Since then, I have paid more attention to the control of exotic plant invasion and the ecological restoration of invaded ecosystems. Based on our findings of different allelopathic effects of dominant tree species at different successional stages, me and my research team published a paper in *Allelopathy Journal* to propose a new hypothesis about the role of allelopathy as a potential driving force of forest succession. From 2007 to 2009, my team sampled a substantial number of forest communities from southern to northern China and conducted systematic analyses to testify our hypothesis. This period's works were well approved by Prof. Shamsher Narwal, the Editor-in-Chief of *Allelopathy Journal*, who has reckoned them pioneering works in the field of allelopathy. From then on Narwal and I have started many productive collaborations.

In 2010, I began a research project on the mechanisms of resistance to invasion by different native functional groups (a NSFC key project). My team further improved our allelopathic-driving-force theory and discovered that late-successional species and the high concentration of allelochemicals in late-successional forest can exert strong inhibitory effect on invasive species. This finding inspired us to propose a new hypothesis: some specific native plant species might form an allelopathic functional group, which is able to resist exotic plant invasion through allelopathic interaction. Based on this hypothesis, we conducted experiments on the ecological control of invasive species in multiple places throughout southern China and constructed several pilot sites to demonstrate the effective modes of the ecological control of invasive plants. So far, we have successfully prevented the re-occurring outbreak of *Mikania micrantha* H.B.K. and *Ipomoea cairica* (L.) Sweet in Baiyunshan, Guangzhou and Neilingding Island, Shenzhen. In addition, we had proposed an ecological replacement model to effectively control the invasion of *Spartina alterniflora* on Qi-ao Island, Zhuhai, based on light and allelopathic competitions between invasive and native species. These practices have been contributing greatly to the control of invasive plants in South China.

In recent years, my research team has also started to work on the molecular aspect of plant allelopathic effects under global changes. So far, we have discovered that elevated ambient CO_2 concentration can have profound effect on invasive plants' production of allelochemicals, which in turn affects the allelopathic interaction between invasive and native species. This climatic effect on allelopathy does not only affect plant-plant interaction, but also has profound effects on many other aspects of native communities, such as soil nutrient cycling, soil microbes and insect herbivores etc. Therefore, since 2006, we started some projects on the allelopathic effects of invasive species on soil microbial community structure and functions (especially those relating to nutrient cycling), aiming to have a more comprehensive understanding of the mechanisms driving the influence of invasive plants on native ecosystems. In 2017, putting together recent advances of allelopathy researches achieved by my team and other researchers, we reviewed the role of allelopathy in exotic plant invasion and ecological controls of invasive plants from three different aspects viz., (i) Invasiveness, (ii) Invasibility and (iii) Practice of ecological control. We highlighted the importance of using allelopathy in restoration of invaded ecosystems.

During my study and my research career, I have the pleasure to work with many excellent respected scientists that are both mentors and friends to me. They have kindly given me important guidance for my research and helped me develop my own thoughts. I am forever indebted to Zuo-yue Yu (SCIB), Dao-quan He (SCIB), Hong-da Zhang (Sun Yat-sen University) and Bo-sun Wang (Sun Yat-sen University), Roger Kiching (the University of New England, Australia), Leonard Webb (Griffith University), Hartmut Bossel (the University of Kassel), Michael Runge (the University of Göttingen), Jessica Gurevitch (the State University of New York) and many other researchers and friends. Upon returning to Sun Yat-sen University, my alma mater, I paid greater attention to teaching and to sharing knowledge. I have taken on the job of Vice Chairman of Nature Conservation and Eco-Environment Teaching Steering Committee (National Ministry of Education, 2013-2017) and the member of Academic Degree Commission (State Council, 2014 till now). I also wrote and compiled several textbooks, including "Ecological Restoration", which received the "Three One-Hundred Original Books Publishing Project Award" from National Press and Publication Administration in 2008. I was nominated as "Prestigious Teachers of Sun Yat-sen University" in 2009 and won the 2nd prize of "National Teaching Achievement Award" with my colleagues in 2018. So far, I have mentored a total of 106 graduate students (68 PhD and 38 master graduates).

4. ALLELOPATHY AND RELATED RESEARCH

My greatest research interest is in ecological restoration. I studied the applied aspects of allelopathy in ecological restoration, hence, allelopathy is an indispensable component in my most studies. I took interests mainly in (i) Restoration of degraded/damaged vegetation, (ii) Restoration of invaded areas and (iii) Interplay between ecological restoration and global changes. Till now, I have completed > 50 Research Projects on Ecological Restoration and Allelopathy and published > 200 papers on these topics in both English and Chinese and received numerous National Awards for these contributions."

In 2009, my contribution to allelopathy research was recognized by the International Allelopathy Foundation, which granted me the "Outstanding Achievements Award".

I. General

In my early studies on vegetation restoration, my key research topic was "community dynamics and the ecological restoration of degraded vegetation in tropical and subtropical forests". At that stage my major research questions were "How do the common species in forest interact with each other through allelopathy?" and "Can these interspecific allelopathic interactions drive species replacements and community dynamics?" Afterwards in late 1990s, my research topics were related to global changes as the leader of IGBP "Chinese Vegetation Transect" project. My research team studied the (i) Interplay between the global change and ecological restoration, (ii) Conservation and restoration of biodiversity, (iii) Plants invasion and (iv) Restoration of invaded areas. These studies answered the following scientific questions viz., (i) How climate change

affects the allelopathy of native and invasive plants, as well as their allelopathic interaction with each other? (ii) How climate change indirectly affects the ecosystem functions by changing the allelopathic processes? (iii) What are the mechanisms behind the strong allelopathic effects of invasive species on native species?

II. Allelopathy in Restoration of Degraded Forests

The first and foremost problem during the vegetation restoration was, the selection and combination of plants species for community restoration and their allelopathic interactions. In our 3- Research Stations at Zhaoqing, Heshan and Xiaoliang, in Guangdong Province, China for the restoration studies, we found many bare lands and degraded forests due to severe soil erosion and overlogging. In the early stage we faced severe ecological and socioeconomical consequences of large areas of degraded lands, which prompted us to work to effectively restore the local vegetation. During extensive field investigation, we found an interesting pattern, there were no *Castanopsis tibetana* plants in the communities dominated by *Calamus simplicifolius* and vice versa. This observation indicated the importance of studying the interspecific allelopathic interaction to restore the degraded communities, to avoid wrong plants species combination. Improper plants species combination may cause strong interspecific allelopathic inhibitions. After comprehensive pair-wise study of common plant species in Xiaoliang, we identified compatible species that were nor allelopathically inhibitory to each other (11,15) and proposed several potential plant species combinations to quickly restore the degraded lands (18). Our continuing efforts have successfully restored the degraded forests in Xiaoliang, which became a Model for the restoration of degraded tropical forest. The badly eroded hills in Heshan had been successfully transformed from bare lands to typical subtropical monsoon forests, which provided guidance to many other regions in China under the concept of "ecosystem management". These progresses in research and restoration practice lead to the Awarded "Science and Technology Progress Awards of the Chinese Academy of Science" in 1999.

III. Chemistry-Driving Hypothesis on Forest Succession

The physical and biological driving force hypotheses are two classical theories on the forest succession, highlighting the intra-/interspecific competitions and the environmental adaptation respectively. I discovered that allelopathic effects among dominant species are highly related to the driving force of forest succession. Therefore, I coined the hypothesis "*Chemistry Driving"* and tested it in experiments in different climatic zones, to prove that this theory is universal (27,60).

Chemistry driving hypothesis was a novel hypothesis after the physical and biological driving forces hypothesis. This pioneering work was awarded "Outstanding Achievements Awards" by the International Allelopathy Foundation. Most of my ecological studies focus on the structure, function and productivity in different stages of forest succession (1-4,10,13,14,17,52). I have discovered that there is an acceleration period of biodiversity in the early and middle stages of forest succession, and that the highest biodiversity was at the beginning of late stage of succession rather than at the end of succession. I had suggested the fluctuations in climax communities, measurement of

fluctuation and edge effects (4-9). Based on the general rule of forest succession, I have established the reference framework and suggested technical methods for vegetation restoration in South China (12,16), for that, I was awarded the first prize of Science and Technology Awards of Guangdong Province.

IV. Allelopathy of Exotic Invasive Plants

For the ecological restoration of invaded areas, control of invasive species is necessary, which depends on understanding the form of invasiveness. Allelopathy is one of the major factors, to ensure successful plant invasions. We have systematically studied the allelopathy of invasive plants (29,37,75,79). We also determined the mechanisms of invasion of exotic invasive plants related to the nutrients absorption, resources use, competition, adaptability and evolution (38,53,59,65,69,72,73,76,77,85,86,88,90,91) and found a novel mechanism of successful invasion: Higher Energy Utilization Efficiency and Lower Construction Cost (38). We studied the allelopathy of main invasive plants in South China from various aspects, which testifies the Novel Weapon Hypothesis (23-25,32,35,36,40,41,45,46,62,87). Molecular biotechnology was applied to effectively understand the allelopathic metabolic mechanism of *M. micrantha* (45,47,63). In 2017, I was invited to organize a Special Issue, "Allelopathy of Invasive Plants" (80) and gathered 10 papers in this special issue of *Allelopathy Journal*. Recently, the coexistence mechanism and co-evolution of plant species have been studied from the perspective of allelopathy of invasive plants, and a breakthrough had been made. We discovered the variability in secretion of allelochemicals have genetic differentiation, and that the evolution of related characteristics of allelopathy of invasive plant species has potential to influence the coexistence of species (87).

V. Allelopathy and Control of Invasive Plants

How to control repeated outbreaks of invasive plants in invaded areas is very difficult in Invasive Ecology and Restoration Ecology. Physical, chemical and biological methods control the invasive plants at the beginning of invasion, but they could not prevent the recurrence of invasive plants, which is a great problem worldwide. Our earlier studies found that allelopathy of invasive plants such as *M. micrantha* contribute to their successful invasion (37,39,84). Meanwhile, we also found that some allelopathic substances of native plants or foreign non-invasive plants have strong inhibitory effects on the growth of invasive plants e.g. *M. micrantha* and *Spartina alterniflora* (43,57,64). Therefore, we proposed that native plants can be divided into different functional groups in the invaded communities based on plant allelopathy, thus we can use the native plants having specific functions to inhibit the invasion of alien plants (66,70). Our further studies revealed that the allelochemicals of native plants inhibited the growth of invasive plants (71,81). Based on these studies, we can select native plants capable of inhibiting the growth of invasive plants to construct plant community, to prevent the invasion of specific alien plants. We call them new ecological control methods (68,70,74,87). The application of these ecological control methods in south China have greatly prevented the invasion of invasive alien plants.

In our studies to control the invasive alien plants, we found that degraded

mangrove wetlands invaded by *Spartina alterniflora* can be restored, by replacement approach to control the *S. alterniflora*, and it was a big success. To be specific, exotic *Sonneratia apetala* and *Sonneratia caseolaris* were planted as pioneer species, due to their fast-growth and allelopathic effects. These plants eradicated the *S. alterniflora* through shading and allelopathy and native mangroves were planted to replace the exotic *Sonneratia* species and restore the communities because the exotic plant seedlings cannot regenerate in understory shade, whereas, native mesophytic mangrove plants seedlings can grow (70). In addition, we tested the possibility of using *M. micrantha* wilt virus and parasites to inhibit the growth of *M. micrantha* (44,49,54).

VI. Global Change and Plant Allelopathy

Using the international standard transect of IGBP "North-South Transect of Eastern China", my research team has done much work to find the interactive mechanisms between global change and terrestrial ecosystems. We studied the impacts of global environmental changes on plant physiology and ecology. Here is another finding: plants at various stages of succession have different responses to temperature, rainfall, CO_2 and UV-B radiation, accordingly they influence the succession (26,42,61). In addition, we also studied the effects of global environmental changes (extreme temperature, rising CO_2 concentration, etc.) on invasiveness of exotic plants and underlying mechanisms of resource utilization (48,55,61,67,82).

The effects of global changes on allelopathy of exotic invasive plants had been less investigated before. We have discovered that the gene expression of β-caryophyllene synthase in *M. micrantha* leaves was strongly induced by elevated CO_2, which increased production of many allelochemicals including β-caryophyllene, thereby strengthens and may help in its allelopathic potential and helps in its further invasion (45,56). These studies revealed that plant secondary metabolites have high adaptability to environment.

In addition, we have studied the allelopathic effects on soil nutrients cycling, soil microbial structure and function, and underlying mechanisms. We found that *M. micrantha* allelopathy accelerated the soil nutrients cycling, their availability and changed the soil microbial community structure (34,39,50,51,92). On the one hand, environment affects the plant allelopathy; while on the other hand, it affects the soil environment and affects the plant growth. This change helps in growth and further invasion of *M. micrantha*. The plant-soil feedback caused by allelopathy may be one of the reasons for successful invasion of *M. micrantha*.

VII. Exploitation and Utilization of Allelochemicals

With my long-term research, I have learnt that invasive plants are rich in allelochemicals and these chemicals may be extracted and used for different purposes. Hence, I advised my students to design a collection device and they found that allelochemicals of plants are safe under natural conditions (28). Besides, 2,3-epoxy-1-hydroxy-4,9-germacradiene-12,8:14,6-diolide extracted from the invasive plant *M. micrantha* is pollution-free pesticide (30-33), achieving the resource utilization of invasive plants.

VIII. Other Research

I introduced the importance of meta-analysis to my colleagues and had been promoting the development of meta-analysis in ecology in China (19-22). Now, meta-analysis is major aspect of ecological research. Our many large-scale ecological studies have achieved good results by meta-analysis (58,76,78,83,89).

My 2-most influential works were (i) Dynamics of South Subtropical Forest Community and Restoration Ecology. and (ii) Dynamics of South Subtropical Forest Community introduced the theoretical and methodological guidance to study the forest community and it was recognized as classic vegetation dynamics (Book 3). I gave new definition and complete disciplinary framework on Restoration Ecology (Book 11), hence, now the Restoration Ecology, is an important teaching topic for undergraduate and graduate students.

My other studies are (i) Biodiversity conservation, (ii) Vegetation science, (iii) Vegetation Ecology, (iv) Endangered Plants in Guangdong, (v) Catalogue of Ecological Diversity of Guangdong and (vi) Vegetation of Macau.

IX. Future Study of Allelopathy

(i) Molecular Biology: Use of Molecular biology methods in allelopathy research. Allelopathy studies should not limit to identifying and isolating the allelochemicals. We must use molecular biology techniques to reveal the mechanism of synthesis and metabolism of allelochemicals. We need to strengthen the applied aspects of molecular biology and proteomics in revealing the mechanisms of allelopathy in future.

(ii) Invasive plants: Study the allelopathic interactions between the invasive plants and native community. The interactive network between species is complex. Plants tend to co-evolve with local herbivores and symbiont. Future research should strengthen the role of allelopathy of invasive plants in influencing the co-evolution with native communities from the point view of multi-trophic levels.

PUBLICATIONS

I have authored > 700 peer-reviewed publications, edited over 20 books. The following is list of my main publications related to Allelopathy, Chemical Ecology and Restoration Ecology.

A. Edited Books

1. Krieger, H., H. Schaefer and S.L., Peng (Eds.) (1990). *Adaptation of a Generic Simulation Model of System Analysis for Forest Ecosystem*. Kassel University, Germany.
2. Wang, B.S., M.G. Li and S.L. Peng (Eds.) (1995). *Phyto Populology*. Guangdong Higher Education Press, Guangzhou, 358pp.
3. Peng, S.L. (Ed.) (1996). *Dynamics of South Subtropical Forest Community*. Science Press, Beijing, 444pp.
4. Yu, Z.Y. and S.L. Peng (Eds.) (1996). *Ecological Studies on Vegetation Rehabilitation of Tropical and Subtropical Degraded Ecosystems*. Guangdong Science & Technology Press, Guangzhou, 266pp.
5. Wang, B.S. and S.L. Peng (Eds.) (1997). *Vegetation Ecology*, China Environmental Science Press, Beijing, 384pp.
6. Peng, S.L. and H. Ren (Eds.) (1998). *Research on Energy Ecology of Subtropical Forest, South China*. Meteorological Press, Beijing, 127pp.

7. Peng S.L. (Ed.) (2001). *Comprehensive Utilization of Degraded Slope Land and Green Food Production in Guangdong Province*. Guangdong Science & Technology Press, Guangzhou, 192pp.
8. Ren, H. and S.L. Peng (Eds.) (2001). *Introduction of Restoration Ecology*. Science Press. Beijing China, 144pp.
9. Peng, S.L. (Ed.) (2003). *Research and Practice of Restoration Ecology in Tropics and Subtropics.* Science Press, Beijing China, 506pp.
10. Zhou, T., H.X. Liao and S.L. Peng (Eds.) (2017). *Construction and Application of A Quantitative Assessment Framework for Natural Resources and Environmental Quality*. Science Press, Beijing China, 140pp.
11. Peng, S.L., T. Zhou, H.X. Liao, H.J. Zhang and B.M. Chen (Eds.) (2020). *Restoration Ecology*. Higher Education Press, Beijing China, 360pp.

B. Book Chapters:

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