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Pioneers of Allelopathy: XV. Stephen O. Duke

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ABSTRACT

Stephen O. Duke has a research career of almost 50 years in plant science and chemical ecology, with much of it in allelopathy. Virtually all of his almost 500 publications have dealt with pest management, especially weed management. He has been inolved in discovery of natural phytotoxins (including allelochemicals) with new molecular targets that might be used to develop new herbicides, elucidation and manipulation of allelochemical biosynthetic pathways, and determinaiton of mechanisms of avoiding allelochemical-caused autoxicity. He has been President or Chair of numerous scientific societies, including the International Allelopathy Society (IAS), the International Weed Science Society, and the Agrochemical Division, American Chemical Society. His awards include the Molisch Award (IAS) and Fellow of the American Chemical Society and the American Association for the Advancement of Science.

Key words: Allelochemicals, allelopathy, chemical ecology, mode of action, natural products, secondary products

1. PERSONAL LIFE

My identical twin brother (Prof. Stanley H. Duke, University of Wisconsin) and I were born to Azalee R. and Oscar Duke in Battle Creek, Michigan (USA) on October 9, 1944. My father was a career soldier, so the family moved around the United States during my youngest years. In 1953, my father retired from the US Army, and our family settled in Arkadelphia, Arkansas (USA), near to the native place of my parents. My mother taught in elementary school there, while, my father worked in U.S. Postal Service. I married my first wife in 1967, while in graduate school at the University of Arkansas (Fayetteville, Arkansas). A year later, I entered the U.S. Army as a Medical Service Corps 2nd Lieutenant. A year (July, 1969 - July, 1970) of my military time was spent in Viet Nam with the 25th Infantry Division. Two children were born from the first marriage. I now have five grandchildren and two great grandchildren. I divorced in 1993. In 2009, I married my second wife Mary V. Duke, a Molecular Biologist. From the mid-1970s until the mid-1990s, I was heavily involved in Football (Soccer) as a player, coach, referee, referee instructor and referee assessor.

2. EDUCATION

My twin brother and I were educated in the Arkadelphia Public Schools and attended Henderson State University in the same town, where we both received a B.S. degree (Biology) in 1966. After this Degree, we both attended the University of Arkansas, where we received M.S. degrees (Botany) in 1968. There, I was first introduced to the concept of allelopathy in a plant ecology course. My M.S. thesis research was on "*Photobiology of the Maize Coleoptile*" under the supervision of Prof. James L. Wickliff. My education was then interrupted by US Army Service in the Viet Nam war.

Prof. Stephen O. Duke

Immediately upon returning from Viet Nam (Fall, 1970), I began a Ph.D. degree (botany) with biochemistry as minor at Duke University, finishing the degree in the Spring of 1975. My Dissertation advisor was Prof. Aubrey W. Naylor, and Prof. Irwin Fridovich (Discoverer of superoxide dismutase), was member of my Dissertation committee. Both men had profound positive influences on my development as a scientist. My Ph.D. research was on the 'Photobiology of anthocyanin synthesis in maize, including light regulation of extractable phenylalanine ammonia-lyase activity', a required enzyme for the production of phenylpropanoid compounds.

3. PROFESSIONAL CAREER

Table 1 provides a chronology of my employment, volunteer and elected professional positions, and significant honours and awards.

I. USDA, ARS, Southern Weed Science Laboratory, Stoneville, Mississippi, USA (1975-1996)

I arrived at USDA's Southern Weed Science Laboratory (SWSL) in 1975 in Stoneville, Mississippi as a National Research Council postdoctoral scientist to do research on the photobiology of weeds. After a year, I became a permanent scientist with more latitude in choosing research topics. While there, I studied the mode of action of both synthetic and natural phytotoxins. I also developed an interest in all aspects of secondary products of both plants and microbes, but was limited by lack of collaborations with good natural product chemists. However, I had the good fortune to have many productive interactions with USDA Scientists (permanent and postdoctoral) and a steady stream of excellent Visiting Scientists. Relatively little of my research during this time dealt directly with plant-plant allelochemical interactions. My early work was greatly enhanced by collaborations with post-doctoral scientists (including Kevin Vaughn, Bill Kenyon, John Lydon, Tim, Sherman, and Hee Jae Lee), Visiting Scientists (including Masatoshi Gohbara, Hiroshi Matsumoto, Tadashi Amagasa, Tatsumi Tanaka, and Jose Becerril) and collaborators too numerous to list. In addition to these excellent scientists I had the good fortune to have excellent technician support at Stoneville. I rose to the level of Laboratory Director, SWSL in 1987, but excellent administrative staff allowed me to focus on research. I moved to higher in administrative ranks. In 1996, I had the opportunity to develop research group in Oxford, MS that had strong impact on allelopathy research

II. USDA, ARS, Natural Products Utilization Research Unit, Oxford, Mississippi, USA (1996-2021)

I began assembling a new research group (Natural Products Utilization Research Unit) for USDA in 1996 at the National Center for Natural Products Research (NCNPR) in Oxford, Mississippi. The NCNPR is a research institute in the School of Pharmacy, University of Mississippi. The intent for our USDA group was to work primarily on natural products for pest management, in a facility in which university scientists did research on natural product-based pharmaceuticals and dietary supplements. Synergism between the two groups was sought and found. This opportunity allowed me to hire excellent natural product chemists, who worked well with biologists, as well as plant molecular biologists who would work on allelopathy.

A major project was on genetic manipulation of crops to make them more allelopathic. The greatly expanded chemical and molecular biology capabilities over that in Stoneville, allowed us to make significant progress in several areas of allelopathy. My work in Oxford was greatly enhanced by collaborations with excellent post-doctoral scientists (including Franck Dayan, Kevin Schrader, Daniel Cook, and Joanna Bajsa), Visiting Scientists (including Jens Streibig, Anna Oliva, Luiz Cerdeira, Juan Carlos Galindo, Edivaldo Velini, Caio Carbonari, Antonio Hernández, Adela Sánchez-Moreiras, and Nikolas Fokialakis), and many visiting students and collaborators too numerous to list. My work would have gone nowhere, without the natural product chemists [(Mario Tellez (deceased), Agnes Rimando (deceased), Charles Cantrell, and Kumudini Meepagala)] and plant scientists [Scott Baerson, Camilo Canel, Brian Scheffler, Franck Dayan, and Zhiqiang Pan, Joanna Bajsa- Hirschel] of our USDA group. The technician (mostly Robert Johnson) support during my tenure in this position was excellent. Superb administrative support (particularly Cathy Sabbatini and Peggy Tubertini) for our group and at the next level (particularly Thomas Army, Edward King, and Archie Tucker) allowed me, to have time to focus on research in Oxford for over 20 years. I have been very thankful to the many scientists, administrators and support personnel for their essential contributions to the research that I have had the privilege to conduct.

III. National Centre for Natural Product Research (NCNPR), School of Pharmacy, University of Mississippi

Since the beginning of 2020, I have continued work on natural products as an Adjunct Research Professor at NCNPR. In this capacity, I work with university scientists on natural product-related research.

Table 1. Chronology of Professional Life Events and Awards.

Employment	
1975-1976	ARS-NRC Associateship, USDA, ARS, Stoneville, Mississippi, USA
1976-1985	Plant Physiologist, USDA, ARS, Stoneville, Mississippi, USA
1985-1987	Research Leader, USDA, ARS, Stoneville, Mississippi, USA
1987-1996	Laboratory Director, Southern Weed Science Laboratory, USDA, ARS, Stoneville, Mississippi, USA
1996-2019	Research Leader, Natural Products Utilization Research Unit, Oxford, Mississippi, USA
2020-Present	Adjunct Research Professor, National Center for Natural Products Research, School of Pharmacy, Oxford, Mississippi, USA

Selected Volunteer and Elected Positions

1980-1985	Elected to Editorial Board of *Plant Physiology*
1993-1995	Appointed to Council on Agricultural Science and Technology (CAST) Board of Directors
1993-1995	Chair of CAST Editorial Review Committee
1993-1996	Secretary, Vice Chair, and Chair-Elect of the Natural Products Subdivision, Agricultural and Food Chemistry Section, American Chemical Society
1994-98	Elected Vice President, President-Elect, President and Past President of the Weed Science Society of America (WSSA)
1996-98 and	Elected Member, Executive Committee, Division of Agrochemicals, American

2008-2011	Chemical Society
1997-1999	Member, International Weed Science Society Board of Directors
1998-Present	Appointed to Editorial Board of *Allelopathy Journal*
1999-2008	Elected Vice President, President and Past President of International Weed Science Society (IWSS)
2005-2012	Elected President-Elect, President, and Past President of the International Allelopathy Society
2006-2012	Appointed member, *Journal of Agriculture and Food Chemistry* Advisory Board
2006-Present	Appointed to Editorial Board of *Journal of Chemical Ecology*
2008-Present	Appointed to Editorial Board of *Pesticide Biochemistry and Physiology*
2011-2014	Elected Vice Chair and then became Chair Elect and Chair, Agrochemical Division, American Chemical Society
2012-Present	Appointed Editor-in-Chief of the journal *Pest Management Science*

Selected Honours and Awards

1975	National Research Council Associateship
1984	Weed Science Society of America's Outstanding Young Weed Scientist Award
1987	Outstanding article in *Weed Science* Award presented by WSSA for the best paper of previous year
1988	Outstanding article in *Weed Technology* Award presented by WSSA for best paper of previous year
1988	Distinguished Alumnus Award presented by Henderson State University.
1990	Outstanding Research Award from WSSA
1990	Ciba-Geigy Outstanding Contribution to Agriculture Award
1990	USDA, ARS, Mid-South Area Scientist of the Year
1992	Elected Fellow, Weed Science Society of America
1994	Elected Fellow, American Association for the Advancement of Science (AAAS)
1996	Australian Weed Science Society's Oration Award
2000	Outstanding Senior Scientist Award, USDA, ARS
2001	Awarded the Researcher/Scholar of the Year Award by the University of Mississippi
2001-2007	Elected Extraordinary Professor, Faculty of Natural and Agricultural Sciences, University of Pretoria, South Africa.
2002	Awarded Molisch Award by the International Allelopathy Society.
2004-2020	Listed as Highly Cited Researcher by *Web of Science.* H-Index is now 66 with the Web of Science and 94 with Google Scholar.
2004	Awarded the American Chemical Society International Award for Research in Agrochemicals
2008	Co-author of paper that won the International Allelopathy Society's Grodzinski Award for the best publication on allelopathy of the previous three years (ref. 102).
2008	Honorary Doctorate (Doctor *Honoris Causa*), University of the Basque Country, Bilbao, Spain.
2009	Lifetime Achievements Award, International Allelopathy Foundation.
2012	Outstanding International Achievement Award, International Weed Science Society
2012	Award from the Brazilian Weed Science Society for "Outstanding Contributions to Brazilian Weed Science"
2013	Elected Fellow, Agrochemical Division, American Chemical Society
2017	Elected Fellow, American Chemical Society
2017	Elected to the USDA, Agricultural Research Service, Hall of Fame

4. ALLELOPATHY AND RELATED RESEARCH

I had the great fortune to follow my research interests to a large extent over my career. Although allelopathy and chemical ecology have been my greatest interests, I have published in many other areas. These include antimalarial pharmaceuticals, mosquito repellents, synthetic herbicide mechanisms of action, herbicide resistance, weed biology, risks and benefits of transgenic crops, and basic plant physiology and biochemistry. The 273 publications on these topics are not included in the reference section below.

I. General

My earliest purely allelopathy paper was whether or not there was synergism in the phytotoxic effects of simple phenolic acids (8). Probit analysis of carefully conducted experiments found none. There were other papers on phytotoxicity of simple phenolic acids against blue-green algae (61,70), which found ferulic acid to be an effective blue-green algicide in the laboratory, but ineffective in ponds because of its very short half-life in natural environment, an issue with many putative allelochemicals. I have published several methods papers on allelopathy-related topics (14,64,65,84,138,161,171,184). These include papers on, how to conduct mode of action studies on allelochemicals (e.g. 64) and how to prove that a phytotoxin from a plant actually acts as an allelochemical (e.g., 171). I have also written reviews on use of allelopathy for weed management (73,74,76,108,109,114, 120,127), on allelochemical discovery (77,123,155,166), and the multi-functionality of an allelochemical, the sesquiterpene artemisinin (167). I have co-authored reviews on broader aspects of allelopathy (92,93,142). Two papers disprove claims that (-)-catechin is an allelochemical (137,139). We found that this compound was virtually inactive in soil and that it has a very short half-life. Several papers have dealt with exudation of allelochemicals from the roots (e.g., 95, 164 and see papers on sorgoleone in section of Genetics and Chemical Manipulation below).

II. Mode of Action of Allelochemicals and Other Natural Phytotoxins

My earliest work on the mode of action of natural phytotoxins was with tentoxin, a cyclic tetrapeptide produced by the plant pathogen *Alternaria alternata* (1,5-7,9,33). We found this potent cyclic tetrapeptide stopped the chloroplast development. An interesting effect of tentoxin is the inhibition of movement of the nuclear-coded plastid protein polyphenol oxidase into the plastid. This led to other studies on polyphenol oxidase and its functions. The tentoxin work was followed by mode of action discovery work on a large number of natural compound pesticides from plants, microbes, and even insects [26-29,31,35,37-39,42,44,46,47,52-54,57,59,60,78-80, 88,101,102 (Winner of Grodzinski Award in 2008), 110,116,125,131,134,135,151,152,162,172,191,197,200,202]. We found naturally occurring compounds have wide array of molecular targets, with some of them having more than one target (e.g., sorgoleone, see ref. 143). Evolution of resistance of pests to synthetic pesticides has led to a strong need for new pesticides with new molecular target sites. Much of the research of our group has shown that natural pesticides are excellent sources of pesticides, and good sources of compounds with new and/or multiple molecular targets.

III. Avoidance of Autotoxicity

Several papers and reviews were on plant's mechanisms to avoid autotoxicity (34,36,55,56,58,66,83,94,101). These mechanisms include exudation from root hairs and sequestration into trichomes and vacuoles. Some of these papers discuss how this is related to biosynthesis of the phytotoxic compounds that are sequestered. For example, the last step in the biosynthetic pathway of sorgoleone appears to take place after the precursor is exuded from root hairs.

IV. Natural Pesticides, Including Herbicides

My numerous publications are on natural products as pesticides, especially herbicides (11,12,13,15,16,19,21,22,25,32,40,41,43,45,48,49,51,62,63,67,68,71,75,81,82,85,86,87,90,91,96,98,99,104,107,112,113,115,121,133,141,144,145,147,148,153,159,160,163,165,168-170,173,177,178,181-183,185,186,192,193,196). Many of these papers are the First to describe phytotoxicity of natural compounds and/or their derivatives (e.g.,13). I have particularly enjoyed work on insect repellents from plants, such as callicarpenal from *Callicarpa* spp. Much of this work was funded by the U.S. Armed Forces Pest Management Board.

V. Genetic and Chemical Manipulation of Allelochemical Production

Before I came to Oxford, I did a significant amount of work on the manipulation of production of phenolic compounds (some reported as allelochemicals) by chemical means (2,10,17,18,20,24,30,50). Part of this work involved investigation of enzymes involved in synthesis of these compounds (3,4,23). A major project of our group has been on the allelochemical sorgoleone and its manipulation by modern genetic technology. Three papers were on transgenically improving crop allelopathy (69,72,89). There were several papers on the basic biology of sorgoleone (96,142) and many papers on the molecular genetics of the sorgoleone synthesis pathway (110,116,121,123,128,145, 189). The objective of this massive effort was to increase the production of Sorgoleone in sorghum crops and to impart Sorgoleone production in crops that do not produce it, such as rice and maize. My biggest regret is that this project has not come to fruition yet, but it is still ongoing, and there has been great progress supported by numerous patents. I hope that those who continue to work on this project, will soon get the results needed to create very allelopathic crops that could never have been generated by conventional breeding. There has been unexpected spin-off from this work, such as the finding that a gene for an O-methyltransferase from the sorgoleone biosynthetic pathway can be used to transgenically produce plants that produce pterostilbene, a potent nutraceutical that is also a natural fungicide. I had been interested on the role of competing plants in inducing the production of allelochemicals. We have a recent paper on the transcriptional effects of the presence of a weed on the genetics of the production of the allelochemical momilactone B by rice (201).

VI. Other Research

Several papers are on the isolation, structural characterization, and biological activity of secondary compounds from Sponges (100), plants (103,105,106,118,128, 130, 136,149,150,157,158,180,187,194,204), fungi (132,140,156,175,176,179,188,189,195, 198,199,203, 205) and insects (154,174). Other papers have dealt with the interactions of synthetic pesticides with bio-pesticides (119) and secondary compounds as pharmaceuticals (126).

VII. My Views of Future Needs for Allelopathy Research

There are many areas of allelopathy in which I would like to see progress in the near future.

(i). Allelopathy has yet to have a major impact in agriculture. A better understanding of the biochemical pathways of allelochemical biosynthesis and how they are regulated, both in crops and weeds, should allow future scientists to develop technologies to better utilize allelopathy for weed management by genetic, cultural and chemical means. In view of the rapidly evolving resistance to synthetic herbicides, there is a great and growing need for such technologies.

(ii). From a purely academic standpoint, I would love to see clearer substantiation of the "novel weapon" hypothesis for the success of invasive weed species. Rigorous proof of this attractive hypothesis would be a milestone in chemical ecology.

(iii). These "wish list" future discoveries will require multidisciplinary research involving chemists, geneticists, molecular biologists, agronomists and ecologists.

I do hope that some of my Research has laid the groundwork for such future discoveries.

5. PUBLICATIONS

I have authored 478 peer-reviewed publications, edited 11 books, and co-wrote one Text book. The following list of publications relates only to allelopathy and chemical ecology.

A. Edited Books (Partly related to allelopathy)

1. Duke, S.O. (Ed.) (1985). *Weed Physiology, Vol. I. Reproduction and Ecophysiology*, CRC Press, Boca Raton, FL, 165 pp.
2. Duke, S.O., J.J. Menn, and J.R. Plimmer (Eds.) (1993). *Pest Control with Enhanced Environmental Safety. American Chemical Society Symposium Series* No. **524**. American Chemical Society, Washington, D.C., 357 pp.
3. Rimando, A.M. and S.O. Duke (Eds.) (2006). *Natural Products for Pest Management. American Chemical Society Symposium Series* No. **927.** American Chemical Society, Washington, D.C., 319 pp.
4. Beck, J.J., J.R. Coats, S.O. Duke and M. Koivunen (Eds.) (2013). *Pest Management with Natural Products. American Chemical Society Symposium Series* No. **1141.** American Chemical Society, Washington, D.C., 247 pp.
5. Gross, A.D., J.R. Coats, S.O. Duke, and J.N Seiber (Eds.) (2014). *Biopesticides: State of the Art and Future Opportunities. American Chemical Society Symposium Series* No. **1172**. American Chemical Society, Washington, D.C., 291 pp.
6. Beck, J.J., C.C. Rering, and S.O. Duke (Eds.) (2018). *Roles of Natural Products for Biorational Pesticides in Agriculture. American Chemical Society Symposium Series* No. **1294**. American Chemical Society, Washington, D.C., 175 pp.
7. Korres, N.E., N.R. Burgos, and S.O. Duke (Eds.) (2019). *Weed Control: Sustainability, Hazards and Risks in Cropping Systems Worldwide*. CRC Press, Boca Raton, FL, 664 pp.

B. Patents Pending

1. Sosa, G., Travaini, L.M., Walter, H., Cantrell, C.L., Duke, S.O., Carrillo, N. and Ceccarelli, E. (2019). Herbicidal composition comprising chromene derivatives and method for weed control. Patent pending: US20190021328 A1.

2. Schrader, K.K., Duke, S.O. and Guiliana, R. (2018) Methods of making pyranopyrans and pyranopyran nitrile and methods of using pyranopyran such as pyranopyran nitrile. US20200093132A1 US PROV. Patent.

C. Peer-Reviewed Publications (Allelopathy and Chemical Ecology)

1. Duke, S.O., Paul, R.N. and Wickliff, J.L. (1980). Tentoxin effects on ultrastructure and greening of ivyleaf morningglory [*Ipomoea hederacea* (L.) var *Hederacea*] cotyledons. *Physiologia Plantarum* **49**: 27-36.
2. Duke, S.O. and Hoagland, R.E. (1981). Effects of glyphosate on metabolism of phenolic compounds.VII. Root-fed amino acids and glyphosate toxicity in soybean (*Glycine max*) seedlings. *Weed Science* **29**: 297-302.
3. Vaughn, K.C. and Duke, S.O. (1981). Tissue localization of polyphenol oxidase in *Sorghum. Protoplasma* **108**: 319-327.
4. Duke, S.O. and Vaughn, K.C. (1982). Lack of involvement of polyphenol oxidase in ortho-hydroxylation of phenolic compounds in mung bean seedlings. *Physiologia Plantarum* **54**: 381-385.
5. Vaughn, K.C. and Duke, S.O. (1982). Tentoxin effects on *Sorghum:* the role of polyphenol oxidase. *Protoplasma* **110**: 48-53.
6. Wickliff, J.L., Duke, S.O. and Vaughn, K.C. (1982) Involvement of photobleaching and inhibition of protochlorophyll(ide) accumulation in tentoxin effects on greening mung bean seedlings. *Physiologia Plantarum* **56**: 399-406.
7. Duke, S.O., Wickliff, J.L, Vaughn, K.C. and Paul, R.N. (1982). Tentoxin does not cause chlorosis in greening mung bean leaves by inhibiting photophosphorylation. *Physiologia Plantarum* **56**: 387-398.
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9. Vaughn, K.C. and Duke, S.O. (1984) Tentoxin stops the processing of polyphenol oxidase into an active enzyme. *Physiologia Plantarum* **60**: 257-261.
10. Duke, S.O. (1985). Biosynthesis of phenolic compounds: Chemical manipulation in higher plants. *American Chemical Society Symposium Series* **268**: 113-131.
11. Duke, S.O. (1986). Naturally-occurring chemical compounds as herbicides. *Reviews of Weed Science* **2**: 15-44.
12. Duke, S.O. (1986). Microbial phytotoxins as herbicides - a perspective. In: *The Science of Allelopathy*, (Eds., A.R. Putnam and C.S. Tang). John Wiley. pp. 287-304.
13. Duke, S.O., Vaughn, K.C., Croom, E.M., Jr., and Elsohly, H.N. (1987). Artemisinin, a constituent of annual wormwood (*Artemisia annua*), is a selective phytotoxin. *Weed Science* **35**: 499-505.
14. Lydon, J., Duke, S.O., and Hedin, P.A. (1987). Coextraction of 5-(hydroxy methyl)-2-furaldehyde with phenolic acids in acid-hydrolyzed plant extracts. *Journal of. Chromatography* **410**: 474-479.
15. Duke, S.O. and Lydon, J. (1987). Herbicides from natural compounds. *Weed Technology* **1**: 122-128.
16. Duke, S.O., Paul, R.N., and Lee. S.M. (1988). Terpenoids from the genus *Artemisia* as potential pesticides. *American Chemical Society Symposium Series* **380**: 318-334.
17. Lydon, J. and Duke, S.O. (1988). Glyphosate induction of elevated levels of hydroxybenzoic acids in higher plants. *Journal of Agricultural and Food Chemistry* **36**: 813-818.
18. Lydon, J. and Duke, S.O. (1989). Pesticide effects on secondary metabolism of higher plants. *Pesticide Science* **25**: 361-373.
19. Lydon, J. and Duke, S.O. (1989). The potential of pesticides from plants. In *Herbs, Spices, and Medicinal Plants - Recent Advances in Botany, Horticulture and Pharmacology*, Vol. **4**: 1-41. (Eds., L.E. Craker and J.E. Simon). Oryx Press, Phoenix, USA.
20. Becerril, J.M., Duke, S.O. and Lydon, J. (1989). Glyphosate effects on shikimate pathway products in leaves and flowers of velvetleaf (*Abutilon theophrasti* Medic.). *Phytochemistry* **28**: 695-699.
21. Duke, S.O. (1990). Natural pesticides from plants. In *Advances in New Crops*, (Eds., J. Janick and J.E. Simon). Timber Press, Portland, OR, USA. pp. 511-517.
22. Duke, S.O. (1991). Plant terpenoids as pesticides. In *Handbook of Natural Toxins. Vol.* **6.** *Toxicology of Plant and Fungal Compounds*, (Eds., R.F. Keeler and A.T. Tu.) Marcel Dekker, NY, pp. 269-296.
23. Sherman, T.D., Vaughn, K.C., and Duke, S.O. (1991). A limited survey of the phylogenetic distribution of polyphenoloxidase. *Phytochemistry* **30**: 2499-2506.
24. Duke, S.O., Paul, R.N., Becerril, J.M. and Schmidt, J.H. (1991). Clomazone causes accumulation of sesquiterpenoids in cotton (*Gossypium hirsutum* L.). *Weed Science* **39**: 339-346.

25. Duke, S.O., Abbas, H.K., Boyette ,C.D. and Gohbara. M. (1991). Microbial compounds with the potential of herbicidal use. *Brighton Crop Protection Conference, Weeds -1991*. 155-164.
26. Duke, S.O., Gohbara, M., Paul, R.N., and Duke, M.V. (1992). Colletotrichin causes rapid membrane damage to plant cells. *Journal of Phytopathology* **134**: 289-305.
27. Abbas, H.K., Paul, R.N., Boyette, C.D., Duke, S.O., and Vesonder, R.F. (1992). Physiological and ultrastructural effects of fumonisin on jimsonweed leaves. *Canadian Journal of Botany* **70**: 1824-1833.
28. Duke, S.O. and Paul, R.N. (1993). Development and fine structure of the glandular trichomes of *Artemisia annua* L. *International Journal of Plant Science* **154**: 107-118.
29. Tanaka, T., Abbas, H.K., and Duke. S.O. (1993). Structure-dependent phytotoxicity of fumonisins and related compounds in a duckweed bioassay. *Phytochemistry* **33**: 779-785.
30. Lydon, J. and Duke, S.O. (1993). The role of pesticides on host allelopathy and their effects on allelopathic compounds. In *Pesticide Interactions in Crop Production, Beneficial and Deleterious Effects* (Ed., J. Altman) CRC Press, Boca Raton, FL, pp. 37-56.
31. Abbas, H.K., Duke, S.O. and Tanaka, T. (1993). Phytotoxicity of fumonisins and related compounds. *Journal of Toxicology. - Toxin Reviews* **12**: 225-251.
32. Duke, S.O. and Lydon, J. (1993). Natural phytotoxins as herbicides. *American Chemical Society Symposium Series* **524**: 110-124.
33. Duke, S.O. (1993). Tentoxin effects on variable fluorescence and P515 electrochromic absorbance changes in tentoxin-sensitive and -resistant plant species. *Plant Science* **90**: 119-126.
34. Duke, M.V., Paul, R.N., Elsohly, H.N., Sturtz, G., and Duke, S.O. (1994). Localization of artemisinin and artemisitene in foliar tissues of glanded and glandless biotypes of *Artemisia annua. International Journal of Plant Science* **155**: 365-373.
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39. Abbas, H.K., Tanaka, T., and Duke, S.O. (1995). Pathogenicity of *Alternaria alternata* and *Fusarium moniliforme* and phytotoxicity of AAL-toxin and fumonisin B_1 on tomato cultivars. *Journal of Phytopathololology* **143**: 329-334.
40. Abbas, H.K. and Duke. S.O. (1995). Phytotoxins from plant pathogens as potential herbicides. *Journal of Toxicology - Toxin Reviews* **14**: 523-543.
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