MINI REVIEW

Exploitation of Fungal Phytotoxin as Natural Herbicide for Ecofriendly Weed Management: Problems and Prospects

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DOI: 10.18811/ijpen.v6i03.9

Abstract

Weeds are major problems in crop production, associated with reduction of crop plant growth, reduce the quality by competing for nutrients and water provided to crops and releasing chemicals that suppress crop growth. Current weed control largely relies on chemical herbicide. The increasing prevalence of both herbicide resistant weeds and bans on chemical herbicide use has created a strong option for development of novel method for weed control. Mycoherbicides include phytopathogenic fungi or fungal compounds or fungal cell free broths or fungal crude broth useful for weed control. The major barriers in the application of fungal spores are returns in investment, which may prohibit the development of highly expensive mycoherbicide, and registration may be impeded if safety and efficacy tests required by the environment protection agencies are too critical, dependency on environment conditions for infection and subsequent development are the major barriers for the application of fungal spores as herbicide. The phytotoxin that inhibit the germination and growth of weed species which are produced and released by fungi or other microbes are receiving increased attention for use as weed controls and as herbicides. Fungal phytotoxins often act as the initiator factor for successful pathogenesis. Several phytotoxins are known to be the determinant factor in pathogenesis. Various phytotoxins *viz*., tentoxin, AAL-toxin, auscaulitoxin aglycone, hydantocidin, thaxtomin and tabtoxin have the potential for use as herbicides. Fungal phytotoxins are great source for the development of new herbicides and offer ecofriendly alternative approach to weed control. The use of fungal phytotoxins has stimulated the search for alternative to chemical weed control. This review is to highlight the potential of fungal phytotoxin in the weed control, their current progress, problems and potential in their exploitation as Mycoherbicides.

Keywords: Agriculture, Fungal phytotoxin, Mycoherbicide, Weed control, Weeds.

International Journal of Plant and Environment (2020); **ISSN:** 2454-1117 (Print), 2455-202X (Online)

Introduction

The definition of the term "Weed" is very subjective. They are an integral part of all cropping ecosystems and serve as a major biological constraint preventing crops from achieving their yield potentials. In addition, there are several plants viz., *Parthenium hysterophorus, Rhus radicans Ambrosia* spp., *Amaranthus spinosus, Argemone mexicana, Lantana camara, Xanthium strumarium* etc. which are responsible for major health problems to humans and animals. Problems of weeds in agriculture, forestry, environment and health have extensively been discussed in many publications (Pandey *et al*., 1995, 1996a,b, 2004a,b; Gupta, 1998; Pandey, 1999, 2000). Manual methods of weed control have earlier been considered as one of the most effective way to eradicate weeds. However, Industrialization has resulted in severe labour shortage and drastic increase in labour cost has significantly hampered this method. Synthetic chemical herbicides has played very crucial role in weed management since 1960s, however, due to indiscriminate and excessive use of these chemicals, several problems have arisen. Contamination of ground water, accumulation of residues, development of resistance, narrow spectrum of activity and injury to non-target organismsetc, are the major public concern nowadays. There is urgent need to discover and develop new, economically and environmentally sustainable weed control product. Therefore, the objectives of this article are to highlight the potential of fungi and their secondary metabolites and discuss current progress, problems and potential in their exploitation as mycoherbicides

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How to cite this article: Singh, A.K., & Pandey, A.K. (2020). Exploitation of Fungal Phytotoxin as Natural Herbicide for Ecofriendly Weed Management: Problems and Prospects. International Journal of Plant and Environment 6(3): 211-214.

Source of support: Nil

Conflict of interest: None

Submitted: 17/06/2020 **Accepted:** 10/07/2020 **Published:** 31/07/2020

Possibilities for Fungal Phytotoxins as Mycoherbicides

Phytopathogenic fungi or fungal spores or fungal compounds or fungal cell free broths or fungal crude broth are useful for weed control. All these are collectively are known as Mycoherbicides. The potential of fungal pathogens in the management of weeds is now well established and exploitation of fungi and their byproducts as ecofriendly herbicide has generated significant interest worldwide (Pandey *et al*., 1997, 2001). Phytopathogenic fungi produce toxins which may play a role in the development of plant disease and affect their hosts. These phytotoxins are low molecular weight secondary metabolites producing symptoms in host such as wilting, suppression of growth, chlorosis, necrosis and leaf spots (Abbas and Duke, 1997). The rationale behind this approach is the use of toxic secondary metabolites of fungi, which are considered to be the safest pesticides for the environment and people. Possibilities of exploitation of microbial toxins as herbicides have been reviewed in many publications (Duke, 1986a,b; Hoagland, 1990; Abbas and Duke, 1997). To overcome the problem of environmental dependency of mycoherbicides this approach has been developed. Fungal allelochemicals are secondary metabolites playing an important role in the induction of disease in weeds. They represent an ecofriendly, alternative to manage weeds. Fungal allelochemical compounds can have high target selectivity with potentially reduced risks for humans and non-target organisms. Furthermore, they have a shorter environmental halflife than synthetic compounds thus reducing potential environmental impact.

Since then numerous fungi have been screened for herbicidal potential and several of them were evaluated as mycoherbicides (Auld, 1990; Boyette and Abbas, 1995; Aneja, 1998; Bhan *et al*., 1998; Pandey, 1999, 2000; Kovics *et al*., 2005). Fungal toxins unlike conventional synthetic pesticides, which are classified on the basis of their chemistry, biorational pesticides are grouped on the basis of some shared characteristics. For example, they pose minimal to no risk to the environment due to their chemical make-up, rapid degradation or the small amounts required for effective control. Significant herbicidal activity of partially purified filtrate (CFCF) of *C. gloeosporioides* f. sp. *parthenii* FGCC #18, *C. dematium*, FGCC#20, *F. oxysporum* FGCC#39, *F. solani* FGCC#86, *S. rolfsii* FGCC#19, *Aspergillus flavus* FGCC#14 and *Curvularia lunata* FGCC#41 have been observed against *P. hysterophorus* (Pandey *et al*., 2003, 2004b) and *Lantana camara* (Pandey *et al*., 2002). Saxena and Pandey (2001) reported extremely high biological activity in CFCF of *Alternaria alternata* FGCC#25 against *L. camara*.

Problems in Development

Several fungal strains of phytotoxin although have shown excellent mycoherbicidal potential but failed to develop at commercial scale due to insufficient market potential in terms of registration, formulation, production, and marketing cost (Hoagland, 2001). Several levels of constraints or limitations govern the development and use of mycoherbicides. Some of the major problems and supporting suggestions are listed below:

- The severe constraints in mass production and maximization of phytotoxin production, which hampered mycoherbicide development.
- Non availability of common and ever accepting formulation and application technology. This can be solved with standard formulations and better application.
- Regulation norms for the use of mycoherbicides across the Globe are non-existent and probably never before have been considered. So, it is unclear whether bioherbicides developed in one country could be used in another country without political hurdles. However, scientifically there is strong justification to use bioherbicides within climatically similar zones and intercontinental regions.
- Discovery of host specific herbicidal metabolites of microbial origin that could be used as virulence and host specificity factors for genetic engineering.
- Increased public and private funding as well as administrative support for research and development of mycoherbicides.
- Education of scientists and the user public, who are unfamiliar with mycoherbicides is required for technology transfer. Mycoherbicides, like many other biocontrol agents are sensitive to environmental conditions and need to be handled in strict accordance to the prescribed methods.

Future Prospects in Mycoherbicide

An extraordinary fungal diversity exists in ecosystem and thus, each pathogen should be considered as unique and thoroughly studied to understand its disease cycle and potential as Mycoherbicide. Proper understanding of the disease cycle of a pathogen to be developed as a mycoherbicides is an important step in the success of a programme.

A wealth of knowledge about disease cycles can be obtained with pathogens of economically important crops. However, this knowledge cannot be extrapolated too for because the crop pathogen relationship of disease is usually different than the weed pathogen relationship. Fungi are known to produce variety of phytotoxic metabolites with herbicidal properties (Duke, 1986a,b; Hoagland, 1990, 1999, 2000, 2001; Abbas and Duke, 1997; Joseph *et al*., 2002; Singh and Pandey, 2019a-g, 2020). Still only few have been screened.

They may also offer opportunities for biologically active metabolites with weed control potential. Mycoherbicides present suitable opportunities for return on investment from small market because the cost of developing them may be less than that for a chemical herbicide. Production technology is already available in fermentation industries, thus capital investment for production is low. Registration costs could be significantly less than for synthetic herbicides. Time required for research and development of a potential Biocontrol agent through registration and commercial use may be substantially less than for herbicides, and this would represent a significant saving of developmental costs (Templeton *et al*., 1986). Inadequacies discussed earlier may be amenable to correction either by advances in formulation technology or by advanced molecular techniques (Yoder, 1983; Yoder and Turgeon, 1985).

The use of fungal phytotoxin in lieu of traditional chemical inputs has the potential to offer a number of benefits to managers of ecological systems, pesticide producers and the farmers. Most proponents of application of this approach cite reduced environmental impact. The success of this method depends on a number of factors. Selection of various culture media and fungal growth on the phytotoxicity of culture filtrates allows for selecting the condition which results in highest phytotoxin productions. The selective bioassay to test material in minimal quantity and best process for extraction of product. Finally, selection of better formulation will give a novel product for control of weeds. Therefore, lot of opportunities exists in their integration with mycoherbicidal agents. Although, mycoherbicides have proved to be effective, but there is a need for technological improvement with chemical enhancer, by strain improvement or by combining fungi to increase the spectrum of weed control.

Conclusion

The byproducts of natural sources of fungi development as potential mycoherbicide to control weeds has significant interest in weed control for use in crops, gardens, rights of way parks and the like. Mycoherbicide from natural sources have shown great potential in weed control. The reason for such interest is the importance of the discovery of new molecules with herbicidal activities. Due to increase demand for herbicide for agricultural production due to growing number of biotypes of herbicide resistant weeds, it is great option to discover new compounds with new mechanism of actions. However, they may not present biological or physio-chemical properties suitable for direct use as herbicides these compounds can provide new knowledge about new mechanism of action for study and may severe as models for the development of new herbicide. A more thorough approach is needed to tackle this problem. Some existing fungal weed control or mycoherbicides do not pose risks to health or the environment because they possess host specificity and do not secrete harmful amounts of toxic or recalcitrant metabolites. Development of suitable formulations to improve viability, efficacy and ease of application of mycoherbicides is the need of the hour. Current industrial preference favours submerged liquid fermentation to produce mycoherbicide products (Churchill, 1982; Templeton *et al.*, 1980). Although successful, cost effective and readily available, this technique is not suitable for fungi that do not sporulate in submerged culture. Solid substrate culturing and airlift fermentation can offer solutions. There is a great demand for compounds with selective toxicity that can be readily degraded by either the plant or by the soil microorganisms. In addition, plant, microorganisms, other soil organisms and insects can produce allelochemicals which provide new strategies for maintaining and increasing agricultural production in the future.

Acknowledgements

We are grateful to Head, Department of Biological Science, R.D. University, Jabalpur for library and laboratory facilities. Financial assistance received from Council of Scientific and Industrial Research is also thankfully acknowledged.

References

Abbas, H.K. and Duke, S.O. 1997. Plant pathogens and their phytotoxins as herbicides. In: Upadhyay, R.K. and Mukherji, K.G. (Eds.), *Toxins in Plant Disease Development and Evolving Biotechnology*, Oxford and IBH Publishing Co. Pvt. Ltd., pp. 1-20.

Aneja, K.R. 1998. Biological suppression of aquatic weeds with fungal pathogens. In: Singh, V.P. and Hussaini, S.S. (Eds.), *Biological Suppression of Plant Diseases, Phytoparasitic Nematodes and Weeds*, Project Directorate of Biological Control, Bangalore, pp. 174-191.

Auld, B.A. 1990. Mycoherbicides: One alternative to chemical control of weeds. In: Besset, C., Whitehouse, L.J. and Jakiewcz (Eds.), *Alternatives to the chemical control of weeds*. Proceeding of International Conference Roturcia, New Zealand, July 1989. Ministry of Forestry, FRI Bulletin 155, pp. 71-73.

Bhan, V.M., Kauraw, L.P. and Chile, A. 1998. Biological suppression of weeds with pathogens; Present Scenario. In: Singh, S.P. and Hussain, S.S. (Eds.), *Biological Suppression of Plant Disease, Phytoparasitic Nematodes and Weeds*, Project directorate of biological Control, Bangalore, pp. 164-173.

Boyette, C.D. and Abbas, H.K. 1995. Weed control with mycoherbicides and phytotoxins: A non traditional application of allelopathy. In: Indrajit, Dakshini, K.M.M. and Einhelling (Eds.), *Allelopathy organisms, process and application*, ACS Symposium Series, pp. 281-299.

Churchill, B.W. 1982. Mass production of microorganisms for biological control. In: Charudattan, R. and Walker, H.L. (Eds.), *Biological Control of Weeds with Plant Pathogens*, New York, John Wiley, pp. 139-156.

Duke, S.O. 1986a. Microbial phytotoxins as herbicides: A perspective. In: Putam, A.R. and Tang, C.S. (Eds.), *The Science of Allelopathy*, New York, John Wiley, pp. 287-304.

Duke, S.O. 1986b. Naturally occurring chemical compounds as herbicides. *Reviews of Weed Science* **2**:15-44.

Gupta, O.P. 1998. Modern weed management with special reference to agriculture in the tropics and subtropics. Agro Botanica, Bikaner, Rajasthan, India.

Hoagland, R.E. 1990. Microbes and Microbial products as herbicides. ACS Symposium Series, 439, ACS Washington D.C., USA, pp. 391.

Hoagland, R.E. 1999. Plant pathogens and microbial product as agents for biological weed control. In: Tiwari, J.P., Lakhanpal, T.N., Singh, J., Gupta, R. and Chamola, B.P. (Eds.), *Advances in Microbial Biotechnology*, APH Publishing Corporation, New Delhi-110002, India, pp. 213-255.

Hoagland, R.E. 2000. Plant and Microbial compounds as herbicides. In: Narwal, S.S. *et al*. (Eds.), *Allelopathy in Ecological Agriculture and Forestry*, Kluwer Academic Publishers, Netherlands, pp. 73-99.

Hoagland, R.E. 2001. Microbial allelochemicals and pathogens as bioherbicidal agents. *Weed Technology* **15**:835-857.

Joseph, S., Lal, S. and Pandey, A.K. 2002. Preliminary evaluation of herbicidal potential of *Streptomyces* WC#150 against *Lantana camara*. *Annals of Plant Protection Sciences* **10**:134-136.

Kovics, G.J., Pandey, A.K and Rai, M.K. 2005. *Phoma* Saccordo and related genera: Some new perspectives in taxonomy and biotechnology. In: Deshmukh, S.K. and Rai, M.K. (Eds.), *Biodiversity of Fungi: Their Role in Human Life,* Science Publishers, Enfield (NH), USA, Polymouth, U.K., pp. 29-154.

Pandey, A.K. 1999. Herbicidal potential of microorganisms: Present status and future prospects. In: Rajak, R.C. (Ed.), *Biotechnology for Sustainable Development and Productivity*, Scientific Publishers, Jodhpur, pp. 94-113.

Pandey, A.K. 2000. Microorganisms associated with weeds: Opportunities and challenges for their exploitation as herbicides. *International Journal Mendel* **17**(1-2):59-62.

Pandey, A.K., Chandla, P. and Rajak, R.C. 2002. Herbicidal potential of secondary metabolites of some fungi against *Lantana camara* L. *Journal of Mycology and Plant Pathology* **32**:100-102.

Pandey, A.K., Gayathri, S., Rajak, R.C. and Hasija, S.K. 1996a. Possibilities, problems and prospects of microbial management of *Parthenium hysterophorus* in India. In: Rai, V., Naik, M.L. and Manoharachary (Eds.), *Perspectives in Biological Science*, School of Life Sciences, Pt. R.S. Shukla University, Raipur, pp. 253-267.

Pandey, A.K., Gayathri, S., Rajak, R.C. and Hasija, S.K. 1997. Potential of indigenous *Colletotrichum* species for the management of weeds in India. In: Chahal, S.S., Parashar, L.B., Randha, H.S. and Arya, S. (Eds.), *Achievements and Prospects in Mycology and Plant Pathology*, International Book Distributors, Dehra Dun, pp. 59-85.

Pandey, A.K., Mishra, J., Rajak, R.C. and Hasija, S.K. 1996b. Potential of indigenous strains of *Sclerotium rolfsii* Sacc. for the management of *Parthenium hysterophorus* L.: A serious threat to biodiversity in India. In: Rajak, R.C. and Rai, M.K. (Eds.), *Herbal Medicines, Biodiversity and Conservation Strategies*, International Book Distributors, DehraDun, pp. 104-138.

Pandey, A.K., Pandey, A., Shrivastava, G.M. and Rajak, R.C. 2004b. Potential of microorganisms for the management of *Lantana camara* in India: Possibilities and prospects. In: Jain, P.C. (Ed.), *Microbiology and Biotechnology for Sustainable Development*, CBS Publishers and Distributors, New Delhi, pp. 42-58.

Pandey, A.K., Rajak, R.C. and Hasija, S.K. 1995. Management of water hyacinth (*Eichhornia crassipes* Mart.) Solms through fungal pathogens in India: Present Status and future prospects. *Journal of the Indian Botanical Society* **74**(A):135-144.

Pandey, A.K., Rajak, R.C. and Hasija, S.K. 2001. Biotechnological development of ecofriendly mycoherbicides. In: Maheshwari, D.K. and Dubey, R.C. (Eds.), *Innovative Approaches in Microbiology*, Bishen Singh Mahendrapal Singh, Dehra Dun, India, pp. 1-21.

Pandey, A.K., Shrivastava, G.M., Singh, A.K. and Verma, S.K. 2003. Herbicidal potential of secondary metabolites of *Sclerotium rolfsii* against Parthenium: A preliminary observation. *Journal of Basic and Applied Mycology* **2**(1):27-30.

Pandey, A.K., Singh, A.K., Quereshi, S. and Agrawal, D. 2004a. Herbicidal activities of secondary metabolites of *Streptomyces* sp. against *Hyptis suaveolens*. *Journal of Basic and Applied Mycology* **3**:95-97.

Saxena, S. and Pandey, A.K. 2001. Preliminary Evaluation of fungal metabolites as natural herbicides for the management of *Lantana camara*. *Indian Phytopathology* **53**:490-493.

Singh, A.K. and Pandey, A.K. 2019a. Selection of mycoherbicidal potential of *Fusarium* spp. against a noxious weed *Parthenium hysterophorus*. *Journal of Research in Weed Science* **2**(1):33-42.

Singh, A.K. and Pandey, A.K. 2019b. Standardization of various parameters for Mycoherbicidal metabolites production from *Fusarium* sp. FGCCW#16 for Weed *Parthenium hysterophorus* management. *Journal of Research in Weed Science* **2**(3):203-215.

Singh, A.K. and Pandey, A.K. 2019c. Preliminary screening of isolated mycoherbicidal fungi for the management of noxious weed *Xanthium strumarium*. *Journal of Agri-Search* **6**(2):92-95.

Singh, A.K. and Pandey, A.K. 2019d. Mycoherbicide research for controlling weeds: Status, opportunities and future needs. *International Journal of Science and Research* **8**(2):1645-1660.

Singh, A.K. and Pandey, A.K. 2019e. Fungal metabolites as a natural source of herbicide: a novel approach of weed management. *Journal of Applied and Natural Science* **11**(1):158-163

Singh, A.K. and Pandey, A.K. 2019f. Discovery and development of mycoherbicide for biological control of *Parthenium hysterophorus*: Opportunities and future needs. *International Journal of Recent Scientific Research* **10**(05):32198-32205.

Singh, A.K. and Pandey, A.K. 2019g. The potential for the use of fungal pathogen as mycoherbicide to manage some noxious weeds in India. *International Journal of Current Advanced Research* **08**(06): 19189-19196.

Singh, A.K. and Pandey, A.K. 2020. Microbial phytotoxins as sources of herbicides: Current development and future scope. *Acta Scientific Biotechnology* **1**(3):06-11.

Templeton, G.E., Smith, R.J. and Klomparens, W. 1980. Commercialization of fungi and bacteria for biological control. *Biocontrol News and Information* **1**:291-294.

Templeton, G.E., Smith, R.J. Jr. and TeBeest, D.O. 1986. Progress and potential of weed control with mycoherbicides. *Reviews of Weed Science* **2**: 1-14.

Yoder, O.C. 1983. Use of pathogen- produced toxins in genetic engineering of plants and pathogens. In: Kosgue, C.P., Meredith and Hollaender, A. (Eds.), *Genetic Engineering of Plants*, Plenum Press, New York, pp. 335-353.

Yoder, O.C. and Turgeon, B.G. 1985. Molecular analysis of the plant-fungus interaction. In: Timberlake, W.E. (Ed.), *Molecular Genetics of Filamentous Fungi*, Alan R. Liss, New York, pp. 383.