

Review Article

Volume 3 Issue 3 – May 2017
DOI: 10.19080/AIBM.2017.03.555615

Adv Biotech & Micro

Copyright © All rights are reserved by Ajit Varma

Biotechnological Applications of *Piriformosporaindica* (*Serendipitaindica*) DSM 11827



Uma¹, RuchikaBajaj², Diksha Bhola¹, Sangeeta Singh³ and AjitVarma^{1*}

¹Amity Institute of Microbial Technology, Amity University, India

²University of Minnesota Twin Cities, Minneapolis, United States

³ICFRE, Arid Forest Research Institute, India

Submission: March 14, 2017; Published: May 30, 2017

*Corresponding author: Ajit Varma, Amity Institute of Microbial Technology, Amity University, NOIDA, Uttar Pradesh 201303, India, Email: ajitvarma@amity.edu

Abstract

Piriformospora indica (Hymenomycetes, Basidiomycota) is a cultivable endophyte that colonizes roots and has been extensively studied. *P. indica* has multifunctional activities like plant growth promoter, biofertilizer, immune-modulator, bioherbicide, phyto remediator, etc. Growth promotional characteristics of *P. indica* have been studied in enormous number of plants and majority of them have shown highly significant outcomes. Certain secondary metabolites produced by the intense interaction between the mycobiont and photobiont may be responsible for such promising outputs. *P. indica* has proved to be highly beneficial endophyte with high efficacy in field. This article is a review where this mycobiont has added value to these medicinal plant with special emphasis on *Curcuma longa* L. (Turmeric) and *Plantago ovata* (Isabgol) in the agricultural field.

Keywords: *Piriformospora indica*; Medicinal plants; Growth promoter

Introduction

Piriformospora indica, a model organism of the order Sebaciales, promotes growth as well as important active ingredients of several medicinal as well as economically important plants by forming root endophytic associations [1-7]. *P. indica* can be easily maintained and axenically cultured, it positions as an ideal models for beneficial fungus-plant interactions studies and has a promising perspective for application in sustainable horticulture and agriculture [8-12]. Exploiting these plant benefitting properties, a formulation of *P. indica* with magnesium sulphite was prepared where magnesium sulphite acts as a carrier. For this, 2% (w/w) of fungal biomass served as effective and stable formulation. On an average the colony forming unit (CFU) count was maintained as 10⁹ and moisture content was 20%. Application of this formulation on plants presented enhanced overall growth and resistance to biotic and abiotic stress.

The fungus has been established as bio protector [13], immuno regulator and agent for biological hardening of tissue culture raised plants [14]. Recently, *P. indica* was named as *Serendipita indica* [15] functions, in nutrient deficient soils, as a bio protector against biotic and abiotic stresses [16]

including root and leaf pathogens and insect invaders, induces early flowering [17-19] and promotes growth [20] as shown in Figure 1. Entire genomic sequence of the fungus is available [21,22]. Decoding of *P. indica* genome has revealed its potential for application as bio agent and for targeted improvement of crop plants in biotechnological approaches [23]. In this communication, we report the applications of *P. indica* on medicinal plants with special emphasis on *Curcuma longa* L. (Turmeric) and *Plantago ovata* (Isabgol).

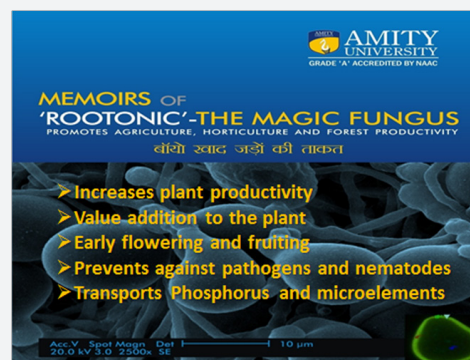


Figure 1: Functional Characteristics of *Piriformospora indica*.

Cultivation and morphological characteristics

Simple morphological features of *P. indica* contain hyphae and pear shaped large spores. Expensive Hill and Kaefer medium is routinely used for the cultivation of fungus. The nutrient has been suitably modified and now we are growing on Jaggery as a sole nutrient energy source, a natural product from sugarcane (*Saccharum officinarum*). Mass cultivation of *P. indica* was done on Gur (Jaggery), the procedure used for extraction is highly simplified as shown in Figure 2. It is grown both in batch culture and fermenter using (4% w/v) Jaggery as shown in Figure 3. The optimum temperature and pH are 25°C±2, 6.8 respectively. Maximum biomass production was obtained after 7days incubation at 120rpm [24]. This innovation is patented [25] (Patent number: 944/DEL/2012 dt: 27.03.12)



Figure 2: Innovation : Jaggery (Gur)

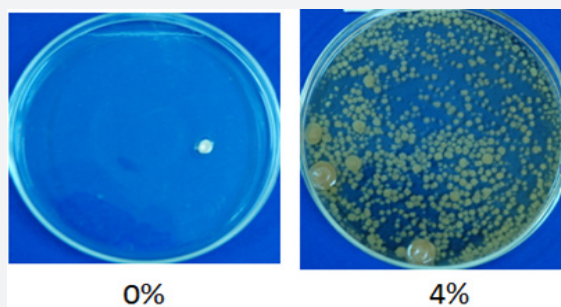


Figure 3: Cultivation of *P. indica* on Jaggery. Optimum concentration was 4% (w/v).

Jaggery composition

- A. The Jaggery contains approximately:
 - a. 60-85% Sucrose
 - b. 5-15% Glucose
 - c. Variable-Fructose
 - d. 0.4% of protein
 - e. 0.1g of fat
 - f. 0.6 to 1.0g of minerals (8mg -calcium, 4mg - phosphorus and 11.4mg - iron)
 - g. Traces of vitamins
 - h. Amino acids
- B. 100g of Jaggery gives 382 Kcal of energy

Functional characteristics of *P. indica*

Plant growth promotion: *P. indica* promotes growth of plants of forestry, horticulture and agriculture importance. Numerous plants have been tested for the effect of *P. indica* on their growth and interestingly majority of them have shown beneficial effect. Few results of its effect on sugarcane, Pinus and potato are also reported. It is important to note that in addition to enhancement of plant growth, the fungus also helps in enhancement of active ingredients in plants. In the case of Ratoon crop of sugarcane it was seen that plants not associated with *P. indica* turned yellow due to iron deficiency, whereas plants subjected to *P. indica* treatment remained green, indicating that the fungus also helps in iron transport. Almost 39% enhancement in iron content and 16% increase in sugar content were recorded in *P. indica* treated plants. Noticeable increase in plant size and tuber size was observed in the case of Pinus and potato, respectively.

Value addition in plants of medicinal importance

Effect of *P. indica* has been studied on large number of spices and plants of medicinal importance. To name few are *Curcuma longa*, *Spilanthescalva*, *Artemisiaannua*, *Anacyclus pyrethrum*, *Cyamopsistetragonoloba*, *Tridaxprocumbens*, *Aloe vera*, *Abrusprecatoriu*, *Bacopamonneri*, *Coleusforskohlii*, *Ocimumtenuiflorum*, *Brassica rapa*, *Adhatodavasica*, *Helianthus annuus*, *Abrusprecatorius*, *Withaniasomnifera*, *Chenopodium album*, *Chlorophytumtuberosum*, *Foeniculumvulgare*, *Linum album*, *Stevia rebaudiana*, *Podophyllumsp*, etc [26]. The organism has shown significant increase in concentration of active ingredients like curcumin, artemisinin, podophyllo-toxin and bacoside leading to value addition to the plant. In this communication, out of 24 plants tested we are giving elaborated on the following:

Turmeric (*Curcuma longa* L.)

Turmeric (*Curcuma longa* L.) is a medicinal plant belonging to the family of Zingiberaceae and is a medicinal plant. Its modified underground stem (rhizome) is extensively used as alternative medicines (Ayurveda, Unani and Siddha) and has a long history and is known to exhibit a variety of pharmacological effects including anti-inflammatory, anti-tumor, anti-HIV and anti-infectious activities. It is taken as the blood purifier and is very useful in the common cold, leprosy, intermittent, affections of the liver, dropsy, inflammation and wound healing. The rhizome of the turmeric plant is highly aromatic and antiseptic. It is even used for contraception, swelling, insect stings, wounds, whooping cough, inflammation, internal injuries, pimples, injuries, as a skin tonic. Sweetened milk boiled with the turmeric is the popular remedy for cold and cough. It is given in liver ailments and jaundice [27-31].

The secondary metabolite curcumin scavenges active oxygen species including superoxide, hydroxyl radical and nitric

oxide [32]. Furthermore, the yellow powder and raw rhizome is widely used as flavoring and coloring agent in the Asian diet. Curcumin (diferuloylmethane) comprises of Curcumin I (curcumin), Curcumin II (demethoxycurcumin) and Curcumin III (bisdemethoxycurcumin), which are found to be natural antioxidants [33]. Its yellow color is imparted by curcumin (diferuloylmethane), a polyphenolic pigment [34]. The powdered rhizome of this plant is used as an condiment and as a yellow dye. It is used to colour and flavour the foodstuff. It is used in the preparation of medicinal oils, ointments and poultice. It is even used in the cosmetics.

Table 1: Results showing effect of *P. indica* on *Curcuma longa* (Turmeric) by studying various parameters.

Parameters	Percent Increase Over Control
Volatile Oil	21.09
Curcumin	19.00
Yield in quintal/Kanal	12.69

Interaction of *P. indica* with *C. longa* resulted in approximately 21, 19 and 13% increase in essential oil, Curcumin and rhizome yield as shown in Table 1. Field trials showed that increase in rhizome yield after treatment with *P. indica* would benefit a farmer with Rs.16,000/(US\$280.00) per hectare of land as shown in Figure 4. It is also probable that healthy and shiny rhizomes would fetch better price. *P. indica* promotes growth and development of turmeric, similar to reports for other plant species. This has agricultural implications, because the increase growth rate and better performance of the plant is associated with higher levels of curcumin, an important spice in Asia, structure is described in Figure 5.

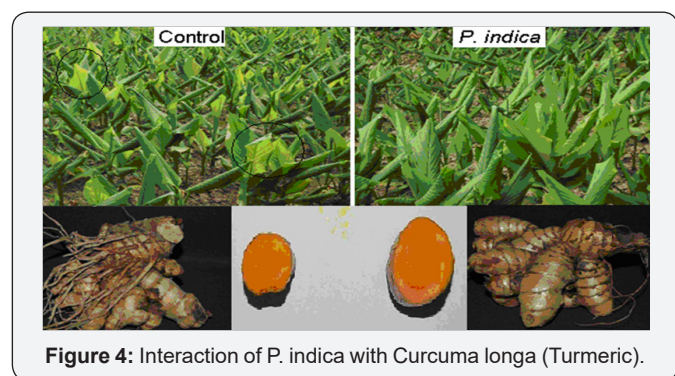


Figure 4: Interaction of *P. indica* with *Curcuma longa* (Turmeric).

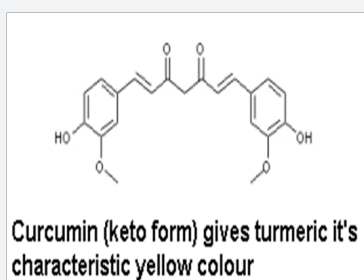


Figure 5: Chemical structure of an active ingredient Curcumin in *Curcuma longa* (Turmeric).

Application of *Piriformosporaindica* on *Plantagoovata* (Isabgol)

Isabgol (*Plantagoovata*) are annual plant species that majorly grow in the arid and semi-arid regions and are extensively used in conventional and modern pharmacology. The seeds of blond psyllium are mainly valued for mucilaginous rosy white husk. The mucilage comprises of reserve carbohydrates mainly pentosans [35]. The husk is commonly used for getting relief from constipation as per being a dietary fiber supplement acting as a bulk-forming laxative. It releases constipation through mechanically stimulating the intestinal peristalsis.

Table 2: Effect on Isabgol crop yield on interaction with *P. indica*.

Treatment	Average Yield	% increase
Control	283.3	
<i>P. indica</i>	375.0	32.3

The seeds of Isabgol (*Plantagoovata*) were treated with formulation of the AM fungi *Piriformosporaindica* to study the effect on the growth and development of plant species. Nursery trails were conducted based on the season in the month of November. On application of *Piriformosporaindica*, it was observed that the overall growth of the plant was promoted. Table 2 shows the mean yield in Isabgol husk, increased to 33% in *P. indica* treated seeds. There also was observed an early flowering in case of *P. indica* treated seeds as shown in Figure 6. Psyllium or ispaghula is the common name used for several members of the plant genus *Plantago* whose seeds are used commercially for the production of mucilage. Psyllium is mainly used as a dietary fiber to relieve symptoms of both constipation and mild diarrhea and occasionally as a food thickener. Research has also shown benefits in reducing cholesterol levels.

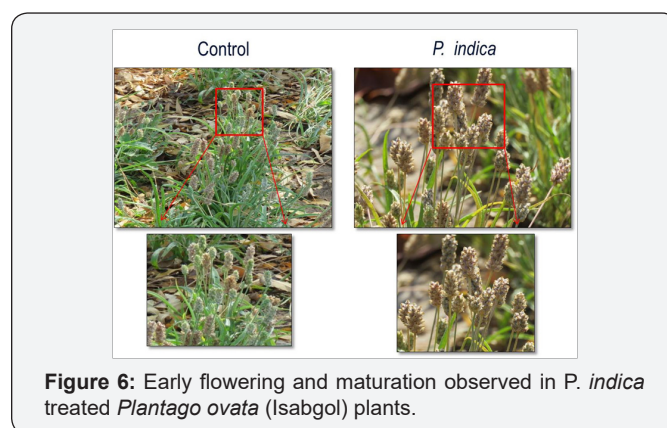


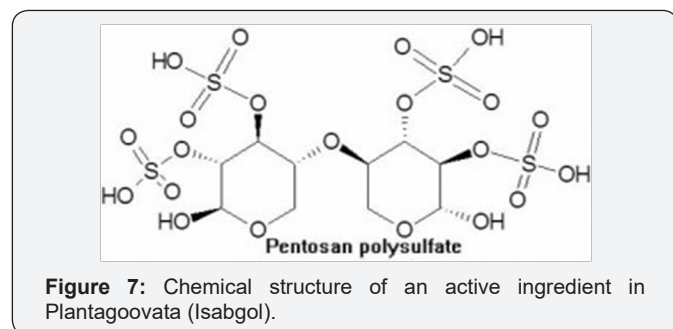
Figure 6: Early flowering and maturation observed in *P. indica* treated *Plantago ovata* (Isabgol) plants.

The soluble fiber in psyllium is arabino xylan, a hemicellulose. Psyllium is produced mainly for its mucilage content. The term mucilage describes a group of clear, colorless, gelling agents derived from plants. The *mucilage* obtained from psyllium comes from the seed coat. Mucilage is obtained by mechanical milling (i.e. grinding) of the outer layer of the seed. Mucilage

yield amounts to about 25% (by weight) of the total seed yield. Plant ago-seed mucilage is often referred to as husk, or psyllium husk. The milled seed mucilage is a white fibrous material that is hydrophilic, meaning that its molecular structure causes it to attract and bind to water. Upon absorbing water, the clear, colorless, mucilaginous gel that forms increases in volume by tenfold or more.

Mechanisms behind the unique action of *P. indica*

The fungal interactions are characterized by increase in efficiency of nutrient uptake from soil due to better hyphal penetration as compared to thicker root hairs. Plants deliver phosphorus assimilates to fungus and during mycorrhizal associations; plants acquire phosphates from extensive network of extra radical hyphae. Interaction of *P. indica* with plant alters pathway for nitrogen metabolism, thereby helping plants to absorb more nitrogen. This phenol-menon gives higher resistance to water deficiency and makes plants drought tolerant. Enhanced growth of plants under mycorrhizal condition amplifies its starch requirement. This starch is obtained from deposition in root amyloplasts. Thus, it is interpreted that one of the major starch degrading enzymes, the glucan-water dikinase is activated by *P. indica* [36]. Uptake and transportation of important macronutrients like iron, zinc, manganese, copper, etc. are also regulated by the fungus. Along with this, beneficial phyto hormones are synthesized by plants associated with *P. indica*. The cumulative effect of macro-micro-nutrients and phyto-hormones regulates plant metabolism leading to value addition, early flowering, plant growth promotion, etc. Massive proliferation of useful rhizospheric micro-organisms sustains soil fertility (Figure 7).



Conclusion

P. indica is a rewarding organism with its huge and distinguished properties. Colonization by *P. indica* increases nutrient uptake, allows plants to survive in drought, salt-stress and temperature stress. Excellent plant growth promotion, growth at extremes of climate and bio-protecting capability of the organisms has paved way for its varied field applications. Large field trials at various locations in India showed beneficial effects of *P. indica* on plant growth and development. Promising outputs of field trials showed that it should be used at large scale so that common farmers are benefited and finally countries economy is at profit. Increase in productivity of certain crop

upon interaction with *P. indica* will increase total land usage. Enhanced field usage of the microorganisms requires its mass production. Field trials of the same are done by formulating biomass with powder and inoculating the mixture into root of plants. The formulation is termed "Rootonic". The journey from *P. indica* to Rootonic is exciting and very fulfilling. Large scale production and application of the product is still under process and we are looking forward to its commercialization soon.

Acknowledgement

The authors are thankful to DSF-ICAR, India for partial financial funding. The authors are also thankful to DST-FIST programme for providing confocal microscopy facility.

References

- Monreal M, Dalpe Y (2013) Arbuscularmycorrhizal fungi strain potential on flax, In: 7th International Conference on Mycorrhiza "Mycorrhiza for All: An Under- Earth Revolution, New Delhi, India.
- Prasad R, Kamal S, Sharma PK, Oelmüller R, Varma A (2013) Root endophyte *Piriformosporaindica* DSM 11827 alters plants morphology, enhances biomass and antioxidant activity of medicinal plant *Bacopamonniera*. *Journal of Basic Microbiology* 53(12): 1016-1024.
- Qiang X, Weiss M, Kogel KH, Schafer P (2012) *Piriformosporaindica* a mutualistic basidiomycete with an exceptionally large plant host range. *Mol Plant Pathol* 13(5): 508-518.
- Rai M, Gade A, Rathod D, Dar M, Varma A (2012) Review: Mycoendophytes in medicinal plants: diversity and bioactivities. *Nusantara Bioscience* 4(2): 86-96.
- Varma A, Bakshi M, Lou B, Hartmann A, Oelmüller R (2012) *Piriformosporaindica*: A novel plant growth-promoting mycorrhizal fungus. *Agric Res* 1(2): 117-131.
- Varma A, Kharkwal AC, Bains KS, Agarwal A, Bajaj R, et al. (2012) *Piriformosporaindica*: The model microbes for organic green revolution. *Organic Farming Newsletter* 20: 3-8.
- Weiss M, Sykorova Z, Garnica S, Riess K, Martos F, et al. (2011) Sebacinale everywhere: previously over looked ubiquitous fungal endophytes. *PLOS ONE* 6(2): e16793.
- Waller F, Achatz B, Baltruschat H, Fodor J, Becker K, et al. (2005) The endophytic fungus *Piriformospora indica* reprograms barley to salt-stress tolerance, disease resistance and higher yield. *Proc Natl Acad Sci* 102(38): 13386-13391.
- Godoy AV, Lazzaro AS, Casalongue CA, Segundo BS (2000) Expression of a *Solanum tuberosum* cyclophilin gene is regulated by fungal infection and abiotic stress conditions. *Plant Sci* 152(2): 123-134.
- Kong HY, Lee SC, Hwang BK (2001) Expression of pepper cyclophilin gene is differentially regulated during the pathogen infection and abiotic stress conditions. *Physiol Mol Plant Pathol* 59(4): 189-199.
- Ruan SL, Ma HS, Wang SH, Fu YP, Xin Y, et al. (2011) Proteomic identification of OsCYP2, a rice cyclophilin that confers salt tolerance in rice (*Oryza sativa* L.) seedlings when over expressed. *BMC Plant Biol* 11: 34.
- Trivedi DK, Bhatt H, Johri AK, Tuteja N, Bhavesh NS (2012) Sequence-specific H, C and N NMR assignments of Cyclophilin A like protein from *Piriformosporaindica* involved in salt stress tolerance. *Biomol* 7(2): 175-178.
- Varma A, Tripathi S, Prasad R, Das A, Sharma M, et al. (2013) The symbiotic fungus *Piriformosporaindica*: update. In: Hock B (ed) *The Mycota IX*, Springer Verlag, Berlin, pp: 231-254.

14. Deshmukh S, Hückelhoven R, Schäfer P, Imani J, Sharma M, et al. (2006) The root endophytic fungus *Piriformosporaindica* requires host cell death for proliferation during mutualistic symbiosis with barley. *Proc Natl Acad Sci* 103(49): 18450-18457.
15. Weiß M, Waller F, Zuccaro A, Selosse MA (2016) Sebaciales-one thousand and one interactions with land plants. *New Phytol* 211(1): 20-40.
16. Kumar M, Sharma R, Jogawat A, Singh P, Dua M, et al. (2012) *Piriformosporaindica*, a root endophytic fungus, enhances abiotic stress tolerance of the host plant. In: Tuteja N, et al. (Eds) *Improving crop resistance to abiotic stress*. Wiley-Blackwell, Weinheim 1&2: 543-548.
17. Sherameti I, Shahollari B, Venus Y, Altschmied L, Varma A, et al. (2005) The endophytic fungus *Piriformosporaindica* stimulates the expression of nitrate reductase and the starch degrading enzyme glucan-water dikinase in tobacco and *Arabidopsis* roots through a homeodomaintranscription factor that binds to a conserved motif in their promoters. *J Biol Chem* 280(28): 26241-26247.
18. Vadassery J, Ritter C, Venus Y, CamehII, Varma A, et al. (2008) *Piriformosporaindica* mediated growth promotion in *Arabidopsis* is sensitive to high auxin levels, requires trans-cytokinin biosynthesis and the cytokinin receptor combination CRE1/AHK2. *Mol Plant Microbe Interact* 21: 1271-1282.
19. Das A, Kamal S, Shakil NA, Sherameti I, Oelmüller R, et al. (2012) The root endophyte fungus *Piriformosporaindica* leads to early flowering, higher biomass and altered secondary metabolites of the medicinal plant, *Coleus forskohlii*. *Plant Signaling & Behavior*. 2012, 7(1): 103-112.
20. Pedersen BP, Kumar H, Waight AB, Risenmay AJ, Roe-Zurz Z, et al. (2013) Crystal structure of a eukaryotic phosphate transporter. *Nature* 496(7446): 533-536.
21. Zuccaro A, Basiewicz M, Zurawska M, Biedenkopf D, Kogel KH (2009) Karyotype analysis, genome organization, and stable genetic transformation of the root colonizing fungus *Piriformosporaindica*. *Fungal Genet Biol* 46(8): 542-550.
22. Zuccaro A, Lahrman U, LdenerUG, Langen G, Pfiffi S, et al. (2011) Endophytic life strategies decoded by genome and transcriptome analyses of the mutualistic root symbiont *Piriformosporaindica*. *PLoS Pathog* 7(10): e1002290.
23. Qiang XY, Zechmann B, Reitz MU, Kogel KH, Schafer P (2012) The mutualistic fungus *Piriformosporaindica* colonizes *Arabidopsis* roots by inducing an endoplasmic reticulum stress-triggered caspase-dependent cell death. *Plant Cell* 24(2): 794-809.
24. Varma A, Bajaj R, Agarwal A, Asthana A, Rajpal K (2013). *Memoirs of 'Rootonic'- The Magic Fungus*. Promotes agriculture, horticulture and forest productivity. Amity Institute of Microbial Technology, Amity University Uttar Pradesh, Noida.
25. Monika arora, Amit Chandra Kharkwal, Bains KS, Ajit Varma (2012) Novel and new nutrient for cultivation of *Piriformosporaindica*; Application-944/DEL/2012.
26. Mazumder A, Wang S, Neamati N, Nicklaus M, Sunder S, et al. (1996) Antiretroviral agents as inhibitors of both human immunodeficiency virus type 1 integrase and protease. *J Med Chem* 39(13): 2472-2481.
27. Allen PC, Dan forth HD, Augustine PC (1998) Dietary modulation of avian coccidiosis. *Int J Parasitol* 28(7): 1131-1140.
28. Chan MMY, Huang HI, Fenton MR, Fong D (1998) In vivo inhibition of nitric oxide synthase gene expression by curcumin, a cancer preventive natural product with anti-inflammatory properties. *Biochem Pharmacol* 55(12): 1955-1962.
29. Vlietinck AJ, Debruyne T, Apers S, Pieters LA (1998) Plant-derived leading compounds for chemotherapy of human immunodeficiency virus (HIV) infection. *Planta Med* 64(2): 97-109.
30. Ammon HPT, Wahl MA (1991) Pharmacology of *Curcuma longa*. *Planta Med* 57: 1-7.
31. Sreejayan A, Rao MNA (1997) Nitric oxide scavenging by curcuminoids. *J Pharm Pharmacol* 49: 105-107.
32. Ruby AJ, Kuttan G, Dinesh Babu K, Rajasekharan KN, Kuttan R (1995) Antitumor and antioxidant activity of natural curcuminoids. *Cancer Letters* 94(1): 79-83.
33. Cooper TH, Clark G, Guzinski J (1994) Teas, spices and herbs. In: *Food Phytochemicals, C.T Volume I*, American Chemical Society, Washington DC, pp. 231-236.
34. Patel BS, Patel JC, Sadaria SG (1996) Response of blond psyllium (*Plantagoovata*) to irrigation and phosphorus. *Indian J Agron* 41: 311-314.
35. Karawya MS, Balba SI, Afifi MSA (1971). Investigation on carbohydrate contents of certain mucilaginous plants. *PlantaMedica*, 20(1): 14-23.
36. Iris C, Sherameti I, Venus Y, Bethke G, Varma A, et al. (2010) Ethylene signalling and ethylene targeted transcription factors are required for balancing beneficial and non-beneficial traits in the symbiosis between the endophytic fungus *Piriformosporaindica* and *Arabidopsis thaliana*. *New Phytologists* 185(4): 1062-1073.



This work is licensed under Creative Commons Attribution 4.0 License
DOI: [10.19080/AIBM.2017.03.555615](https://doi.org/10.19080/AIBM.2017.03.555615)

Your next submission with Juniper Publishers

will reach you the below assets

- Quality Editorial service
- Swift Peer Review
- Reprints availability
- E-prints Service
- Manuscript Podcast for convenient understanding
- Global attainment for your research
- Manuscript accessibility in different formats
(Pdf, E-pub, Full Text, Audio)
- Unceasing customer service

Track the below URL for one-step submission

<https://juniperpublishers.com/online-submission.php>