NUSANTARA BIOSCIENCE
Vol. 6, No. 2, pp. 132-139
November 2014

ISSN: 2087-3948
E-ISSN: 2087-3956
DOI: 10.13057/nusbiosci/n060205

Endophytic *Phoma* sp. isolated from medicinal plants promote the growth of *Zea mays*

ASHWINI KEDAR, DNYANESHWAR RATHOD, ALKA YADAV, GAURAVI AGARKAR, MAHENDRA RAI♥
Department of Biotechnology, Sant Gadge Baba Amravati University, Amravati- 444602, Maharashtra, India. Tel.: +91-721-2662206 to 8, Fax.: +91-721-2662135, 2660949, ♥email: mkrai123@rediffmail.com

Manuscript received: 20 May 2014. Revision accepted: 7 June 2014.

Abstract. *Kedar A, Rathod D, Yadav A, Agarkar G, Rai M. 2014. Endophytic* Phoma *sp. isolated from medicinal plants promote the growth of* Zea mays*. Nusantara Bioscience 6: 132-139.* Fungal endophytes are reported as rich sources of valuable secondary metabolites and could be used as bio-fertilizers. In the present study, we report growth promotion potential of two *Phoma* species isolated from *Tinospora cordifolia* and *Calotropis procera* on maize. The fungal endophytes enhanced growth in inoculated maize plants compared to non-inoculated plants. The main aim of this work was to assess the growth promotion activity of endophytic *Phoma* species on maize isolated from *T. cordifolia* and *C. procera*.

Key words: *Calotropis procera,* endophytes, growth promotion, *Phoma*, *Tinospora cordifolia.*

INTRODUCTION

Endophytes comprise a major part of fungal symbionts related with plants and reside entirely within plant tissues associated with roots, stems and/or leaves (El-Tarabily et al. 2009; Jalgaonwala et al. 2010; Khan et al. 2012). Almost all the plant species possess either one or more endophytes but to date only a few plant species have been explored for their endophyte diversity (Bandara et al. 2006; Verma et al. 2011; Silva et al. 2012). These fungi do not depict any symptom but protect the plants against predators like insects, pests, herbivores and environmental stress conditions (Khan 2008; Khan and Lee 2013; Thakur et al. 2013; Rai et al. 2014b). The endophytic fungi also promote the growth of plants in various ways by secretion of plant growth regulators, by enhancing hyphal growth and mycorrhizal colonization, production of siderophores and by supplying biologically fixed nitrogen (Bandara et al. 2006; Herre et al. 2007; Hamayun et al. 2010; Verma et al. 2011; Rai et al. 2014b). However, in recent studies it was revealed that plant growth promotion may be attributed to the secretion of plant growth promoting secondary metabolites (gibberellins, auxin, cytokinin) by the endophytic fungi in the rhizosphere (Khan et al. 2008; Waller et al. 2005; Hamayun et al. 2010; Waqas et al. 2014). This growth enhancement effect is at least in part due to the endophytes producing phytohormones, such as indole-3-acetic acid (IAA), cytokines and other plant growth-promoting substances (Zou and Tan 1999) and partly owing to the fact that endophytes could have enhanced the hosts uptake of nutritional elements such as nitrogen and phosphorus (Ryan et al. 2008; Kumar et al. 2011).

Recently, Prasad et al. (2013) reported enhancement of biomass and antioxidant activity in *Bacopa monnieri* when co-cultivated with *P. indica.* Similar activity of *P. indica* was demonstrated for *Barley* in cool climate showing early flowering and significantly higher grain yield (Murphy et al. 2014). Different *Colletotrichum* species isolated as endophyte from medicinal plants have been inhibitory to plant pathogens (Rai et al. 2014a). Endophytic *Colletotrichum* sp. isolated from a Chinese medicinal plant exhibited antifungal activity against phytopathogenic fungi such as *C. gloeosporioides*, *Scopulariopsis* sp., *Trichoderma viride, Fusarium* sp., *Phytophthora nicotianae*, *Scopulariopsis* sp. and *Verticillium* species (Li et al. 2005). The root endophyte *Heteroconium chaetospira*, significantly increased the biomass of Chinese cabbage due to nitrogen transfer (Usuki and Narisawa 2007). Rai et al. (2001) suggested that the significant increase in growth and yield of *Spilanthes calva* and *Withania somnifera* plants inoculated with an endophyte *P. indica* caused by greater absorption of water and mineral nutrients due to extensive colonization of roots by *P. indica*. Endophytic fungi thus facilitate their host plants to survive under stress condition by secreting favorable secondary metabolites (Khan et al. 2012).

Some endophytes synthesize plant growth hormones such as indole-3-acetic acid, cytokinines and gibberellins that promote plant growth (Contreras-Cornejo et al. 2009; You et al. 2012; Khan and Lee 2013) and can also increase aboveground photosynthesis through the modulation of endogenous sugar and abscisic acid (ABA) signaling (Zhang et al. 2008). Hill et al. (1990) found that infection with endophytes resulted in augmented leaf area of *Festuca arundinacea* and that increase was correlated with higher concentrations of secondary compounds such as alkaloids. The endophytic fungi may have the metabolic machinery to produce plant growth regulators and thereby promote seed germination in crop plants (Bhagobaty and Joshi 2009). In the present study, we report endophytic *Phoma* species isolated from *Tinospora cordifolia* and *Calotropis procera* and their positive effect on growth enhancement of *Zea mays*.

MATERIALS AND METHODS

Isolation of endophytic fungi

Asymptomatic healthy leaves and stem samples of *T. cordifolia* and *C. procera* were washed thoroughly in running tap water to remove dust particles on leaf surfaces, then rinsed thrice in sterile distilled water. Thereafter, the samples were immersed in sodium hypochlorite for 2-3 min, followed by 70% ethanol for 1 min. Finally, the explants were rinsed three times in sterile distilled water and dried on sterile filter paper to remove excess moisture. After surface sterilization, the leaf and stem segments were cut into approximately 0.5 cm pieces using a flame-sterilized scalpel. About 5-6 segments were placed on each Petri dish containing potato dextrose agar (PDA) medium supplemented with streptomycin (250 µg/L) to suppress bacterial growth. Petri dishes were sealed with parafilm and incubated at 25°C for up to one week. After growth of endophytes from explants the pure cultures were stored and maintained on PDA slants at 4°C for further study.

Identification of fungal isolates

The fungal isolates were mounted on the sterile slides, stained with lactophenol cotton blue and examined under 40X light microscopy. The fungal cultures were identified on the basis of microscopic characters, such as spore size, shape and phenotypic characteristics, e.g. colony morphology, surface texture, colony color, etc at genus level using standard key to the identification.

Pot experiment

The isolated endophytic fungi were screened for their plant growth promotion activity on maize (*Zea mays*) plants. Pot soil (mixture of soil: sand-3:1) was autoclaved and sterilized three times for 3-consecutive days at the interval of 24 hrs. Maize seeds were surface sterilized with 5% sodium hypochlorite solution for 10 min and 70% ethanol for 1 min. Finally, the seeds were washed 3-4 times with sterilized distilled water and sown in pots.

Fungal inoculum

The fungal culture was inoculated in Potato Dextrose Broth (PDB) and incubated at 25±2ºC for 21 days. Fungal mycelium was harvested and homogenized to break and loosen the fungal mat. Then it was inoculated (10 mg/mL) in soil near the roots of seedlings. The control was untreated. The pots were kept under normal growth conditions at 25±2ºC and 12 hrs daylight and were monitored regularly. All the experiments were performed in triplicate. The experiment was set up as below: (i) Endophytic *Phoma* species (*T. cordifolia* isolate) inoculated to maize seedlings; (ii) Endophytic *Phoma* species (*C. procera* isolate) inoculated to maize seedlings; (iii) Non-inoculated maize seedlings (control).

Measurements of growth promotion characteristics

Plant height was measured at the intervals of three days. The plantlets were harvested 45 days after sowing. Growth parameters such as shoot height, root length, fresh and dry weight of shoots and roots were measured.

Chlorophyll a fluorescence measurements

Fluorescence measurements were recorded from detached 1 hr dark-adapted leaves by Handy PEA (Plant Efficiency Analyzer, Hansatech Instruments Ltd, King's Lynn, Norfolk, UK) fluorimeter. All the measurements were noted at room temperature. The dark-adapted samples were illuminated homogenously over an area of 4 mm diameter with three light-emitting diodes (LEDs). The induced fluorescence was quickly measured. Digitalization starts with 10 mm resolution and increases with time. A time of 1 sec was used for measurement throughout the experiment.

Effect of fungal extract on seed germination

Maize seeds were surface sterilized as described in pot experiment and inoculated on MS media (Himedia) in petri plates. The fungal broth was filtered to separate mycelium and the filtrate was treated as fungal extract. 1 mL of fungal extract of both *Phoma* sp. was loaded over the seeds in each petri plate. 1 mL of sterile distilled water loaded on seeds in control plate. All plates were wrapped in aluminium foil and kept at 25ºC to check the effect of fungal extracts. All these experiments were carried out in triplicates.

RESULTS AND DISCUSSION

Isolation and identification of *Phoma* species

Phoma can be characterized by the formation of single celled, hyaline pycnidiospores born inside a fruiting body referred to as pycnidium, which varies from globose, sub-globose to coalesce forms. The conidial fructification is a pycnidium which is dark, flask-shaped structure opening usually by a single circular ostiole and lined inside by hymenium of conidiogenous cells which are enteroblastic, philiadic, integrated or discrete, ampuliform to doliform and opening by minute aperture. In the present study, the cultural studies were done on PDA. Colonies were dark grey with compact aerial mycelium, attaining a diameter of 4.5-5.5 cm in 7 days. Pycnidia black, sub-globose to globose, 80-153 µm; conidia hyaline, 1-celled, mostly ovoid and size 3.6-10.2 x 2.4-3.9 µm.

Assessment of growth promotion of *Zea mays* by endophytic *Phoma* species

In the present study, two endophytic *Phoma* species were isolated from *T. cordifolia* and *C. procera*. These *Phoma* species were evaluated for their plant growth promotion activity on *Zea mays* seedlings in pot experiments. We found that the endophytic *Phoma* species significantly influenced the growth of inoculated *Zea mays* plants as compared to non-inoculated (control) plants. After inoculation of endophytic *Phoma* species with maize seeds, a profound effect on shoot height, root length, fresh and dry weight of shoot and root of experimental plants was observed as compared to non-inoculated (control) plants (Table 1). Similar results have been recorded by many researchers, that the endophytic fungi ameliorate the growth of plants. Ting et al. (2007), where increase in height, diameter of pseudo-stem and number of leaves of

Table 1. Interaction of endophytic *Phoma* species isolated from *T. cordifolia* and *C. procera* with maize

Parameters	Height (shoot length) of plant (cm)	Length of roots (cm)	Fresh shoot weight (g)	Fresh Root weight (g)	Dry shoot weight (g)	Dry Root weight (g)
Control	27.7±3.12	11.9 ±2.30	3.4826±0.0102	0.1044±0.0079	0.4763±0.0025	0.069 ±0.0007
Phoma sp. (*T. cordifolia*)	29.83±3.51	16.7±4.14	5.04±0.09	0.9421±0.0019	1.0192±0.003	0.3912±0.0018
Phoma sp. (*C. procera*)	30.1±3.09	18 ±2.23	5.2034±0.032	1.839±0.013	1.2987±0.0059	0.7743 ±0.021

Note: All values are means ± S.D. Mean value are significantly differently at P 0.05.

banana plants inoculated with endophytic *Fusarium oxysporum*. Rai and Varma (2005) observed the fast growth and profuse proliferation of roots of *A. vasica* when inoculated with endophytic *P. indica.* Humayun et al. (2010) observed an increase in plant length, shoot length, fresh weight and dry weight of plants which was in accordance with the above study.

Among the two *Phoma* sp., *C. procera* isolate was showing highest increase in all the growth parameters measured. This indicates that the endophytic species of same genus isolated from different plant host can have varied effect on the growth of plants. Moreover, the plants inoculated with endophytic *Phoma* species were maximum green as compared to non-inoculated plants. The inoculated plants were healthy as compared to non-inoculated plants, which provide evidence that endophytic *Phoma* species helped disease management apart from boosting the growth of the plants.

Effect of fungal extract on seed germination

The growth performance of endophytic *Phoma* species was also assessed by studying the effect of endophytic *Phoma* extract on the germination of maize seeds on MS medium. In the study, it was observed that the inoculated plates with *Phoma* extract depicted maximum seed germination rate as compared to control. The germinated seeds in experimental plates showed greater shoot and root length than the control seeds (Figure 3 A, B, C). Moreover, it was also found that the roots of germinated seeds treated with endophytic *Phoma* extract evidenced profused root hairs. These root hairs help to absorb more nutrients and subsequently the growth and increase in biomass of plants. These results support that the endophytic fungi show their effect on plants, right from the germination of seeds (Rai et al. 2014b). Endophytic fungi help to degrade cuticle cellulose during seed germination and thereby available carbon for growing seedling, which improves seed germination, vigor and establishment (Jerry 1994). Furthermore, the endophytic fungi may have the metabolic machinery to secrete plant growth hormones such as cytokinins, auxins and gibberellins which promote seed germination and growth in crop plants (Bhagobaty and Joshi 2009). There are various reports of endophytic fungi producing growth hormones (Bhagobaty and Joshi 2009; Hamayun et al. 2010; Khan et al. 2013)

Chlorophyll a fluorescence analysis by Handy Plant Efficiency Analyzer (PEA)

The growth performance of the maize plants was also detected by measuring Chlorophyll a (Chl a) fluorescence to calculate the specific energy fluxes (ABS/RC, ETo/RC, TRo/RC and DIo/RC), RC/CSo and PIabs. When the maize seedlings were exposed to the endophytic Phoma species for assessment of growth promotion, little changes were

Figure 1. Height difference of *Zea mays* plants A. Control, B. Inoculated with extracts of *Phoma* species isolated from *T. cordifolia* and C. Inoculated with extracts of *Phoma* sp. isolated from *C. procera.*

Figure 2. Root difference between A. Control, B. *Phoma* sp. isolated from *C. procera* and C. *Phoma* sp. isolated from *T. cordifolia*

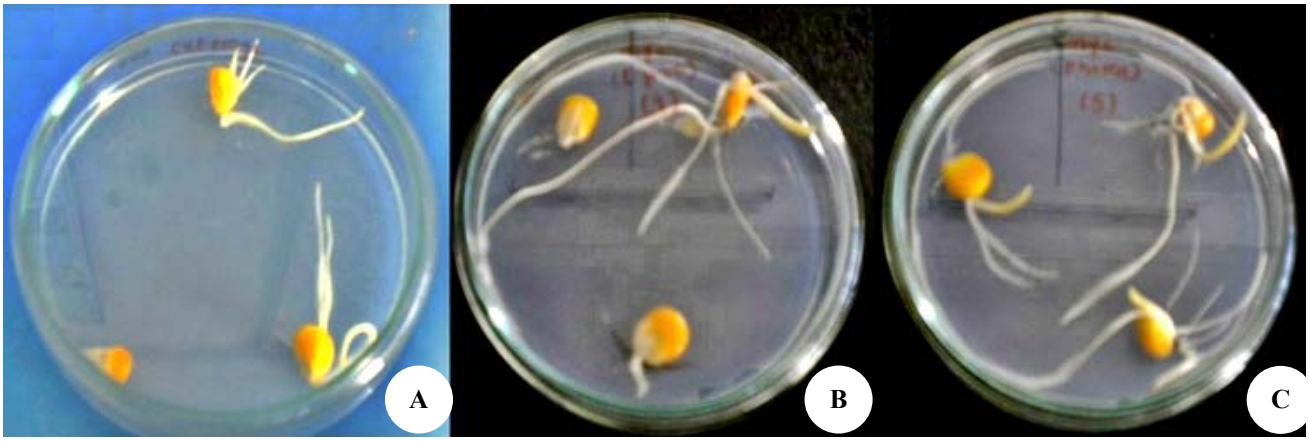

Figure 3. Germination of maize seeds on MS medium after treatment with endophytic *Phoma* extract; A. Control, B. *Phoma* species (*C. procera* isolate), C. *Phoma* species (*T. cordifolia* isolate).

observed into the fluorescence transients after a week. But, after 8 days the effects on the Performance index per absorption (PIabs) and absorption per reaction center (ABS/RC) demonstrated considerable deviation as compared to non-inoculated plants. The changes in quantum efficiencies and absorption per reaction center (ABS/RC) also showed significant effect on the performance index (PIabs) of inoculated maize plants. PI_{ABS} describes the plant vitality and provides quantitative information on current state of plant performance (Strasser et al. 2004). The plants inoculated with extract of both *Phoma* species isolated from *T. cordifolia* and *C. procera* demonstrated maximum performance per absorbance (PI/abs), Absorbance per reaction center (ABS/RC), Electron transport per reaction center (ETo/RC), Trapping per reaction center (TRo/RC) and minimum dissipation per reaction center (DIo/RC) as compared to non-inoculated plants (Figures 2, 6). The effect of endophytic *Phoma* species depicted increase in the performance per absorption (PIabs) and decreases dissipation per reaction center (DIo/RC) values for inoculated plants, whereas non-inoculated (control) plants depicted decrease in performance per absorption (PIabs), Absorbance per reaction center (ABS/RC), Electron transport per reaction center (ETo/RC), Trapping per reaction center (TRo/RC) and increased dissipation per reaction center (DIo/RC) (Figures 3, 4, 5).

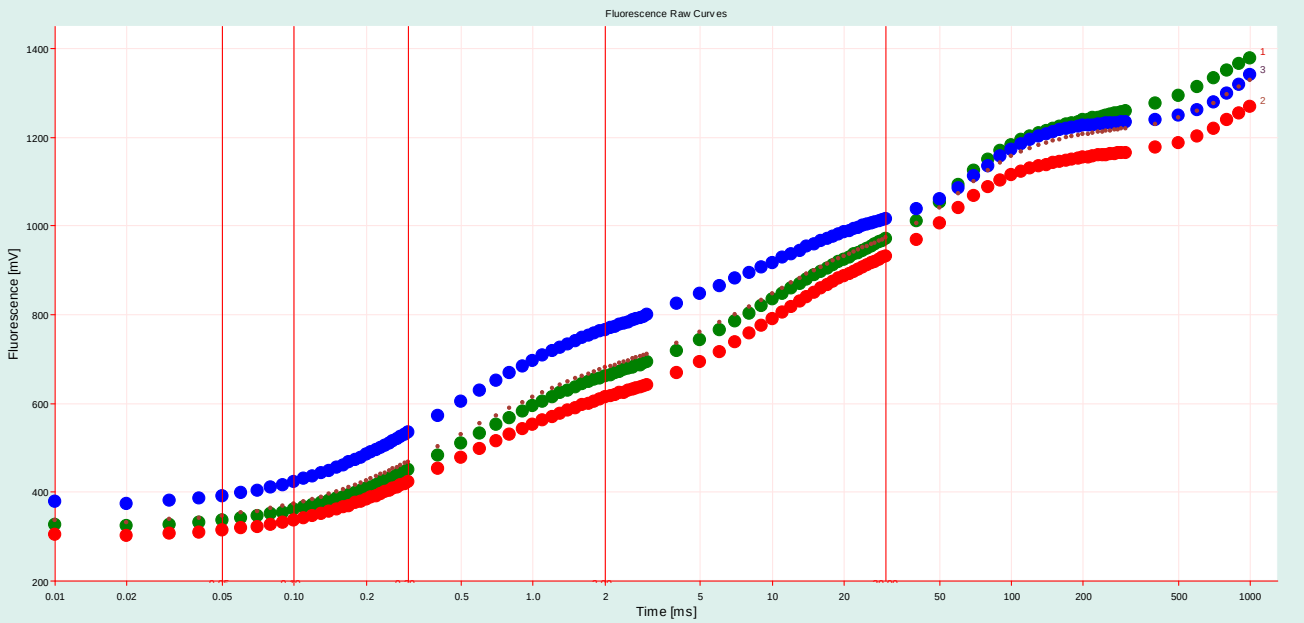

Figure 4. Fluorescence plot of *Zea mays* showed the fluorescence difference between experimental and control plants**;** where, Green - Control, Red - *Phoma* sp. (*T. cordifolia* isolate), Blue - *Phoma* sp. (*C. procera* isolate).

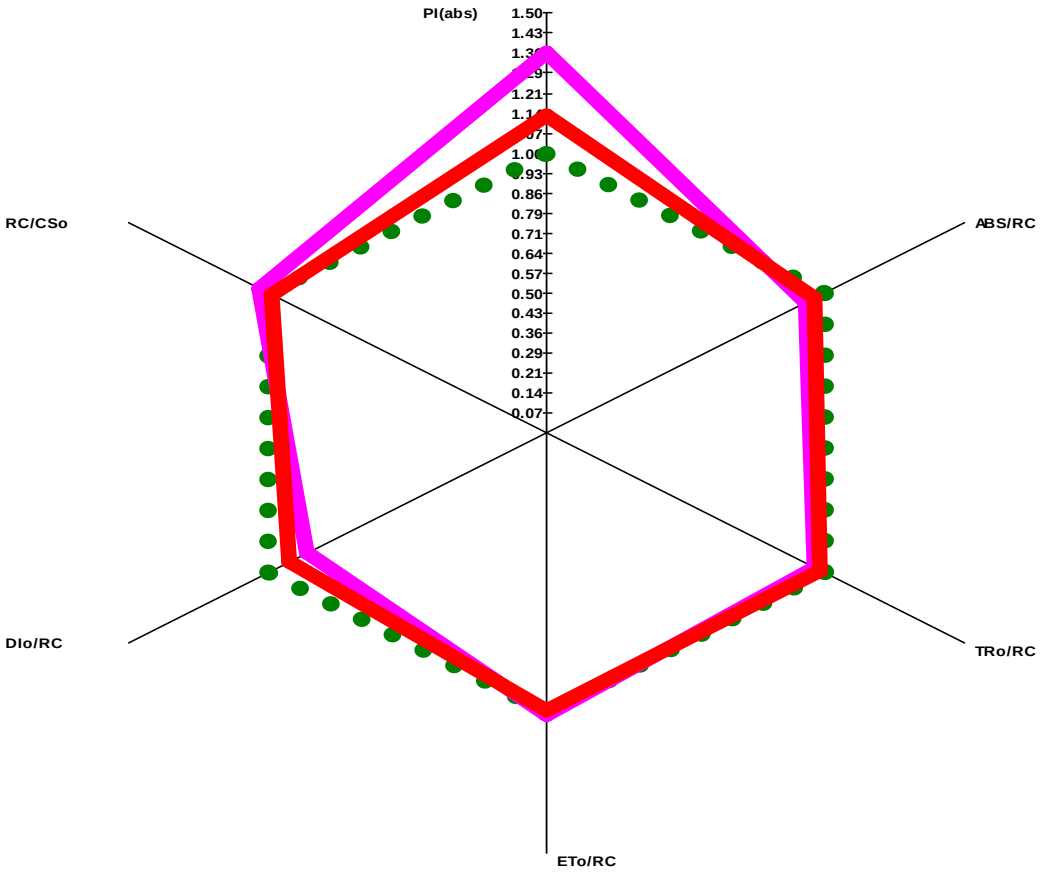

Figure 5. Radar plot of endophytic *Phoma* species isolated from *C. procera*, and *T. cordifolia* shows difference between performance and dissipation of inoculated and non-inoculated (Control) plants; where, Green - Control, Red - *Phoma* sp. (*C. procera* isolate), Pink - *Phoma* sp. (*T. cordifolia* isolate).

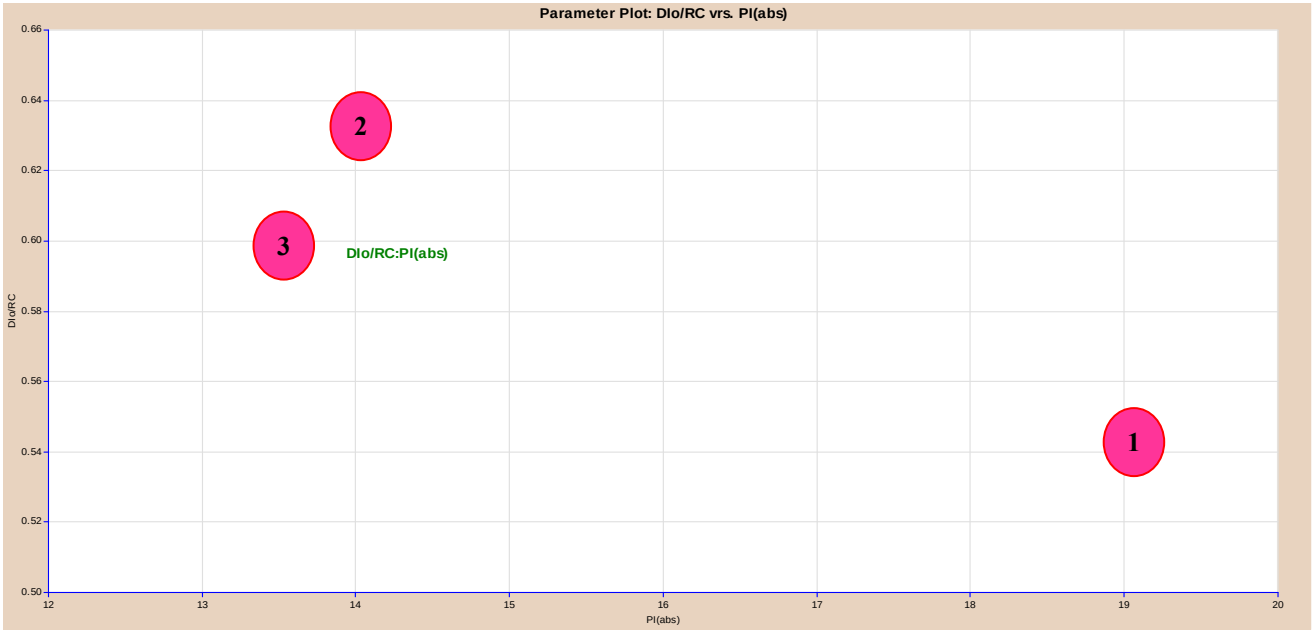

Figure 6. Parameter plot of endophytic *Phoma* species isolated from *C. procera* and *T. cordifolia* shows difference between performance and dissipation of inoculated and non-inoculated (control) plants; where, 1. *Phoma* sp. (*C. procera* isolate), 2. *Phoma* sp. (*T. cordifolia* isolate) and 3. Control.

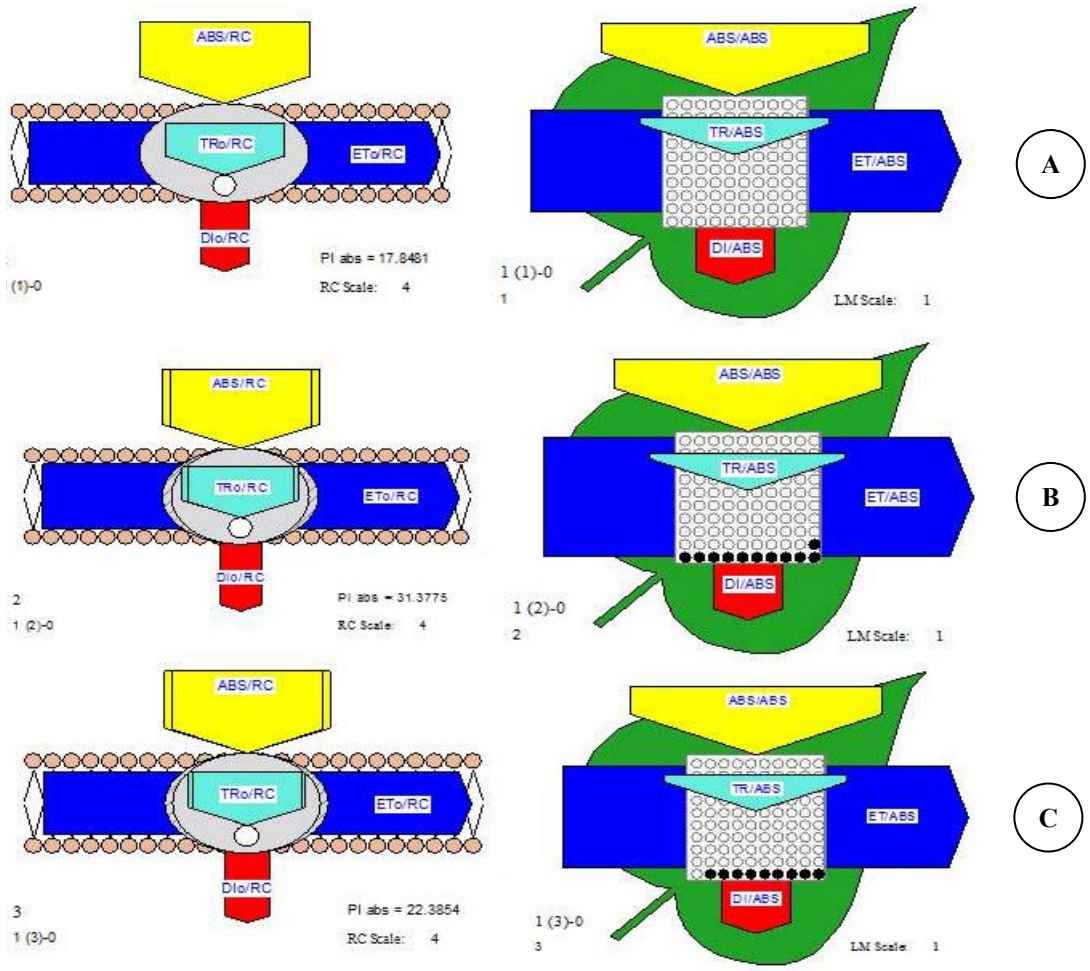

Figure 7. Pipeline model shows membrane and leaf model of experimental and control plants difference between Performance per index (PIabs) and dissipation per reaction center (DIo/RC). A . Membrane and leaf model of Control, B . Membrane and leaf model of *Phoma* sp. isolated from *T. cordifolia*, C . Membrane and leaf model of *Phoma* sp. isolated from *C. procera*.

The pipeline model shows two another models, membrane and leaf model. In this model, the active reaction centers are indicated by open circles while inactivated reaction centers by closed circles (Strasser et al. 2004). The membrane and leaf model of control showed the minimum Performance per index (PIabs) (17.84) and maximum dissipation per reaction center (DIo/RC) (0.65) (Figure 7.A). The membrane and leaf model of *Phoma* species isolated from *T. cordifolia* showed the maximum Performance per index (PIabs) (31.37) and minimum dissipation per reaction center (DIo/RC) (0.51) with high photosynthetic rate in absorbance area as compared to control (Figure 7.B). The membrane and leaf model of *Phoma* species isolated from *C. procera* showed the maximum Performance per index (PIabs) (22.38) and minimum dissipation per reaction center (DIo/RC) (0.54) with maximum photosynthetic rate in absorbance area as compared to control (Figure 7.C). The *Phoma* species isolated from *T. cordifolia* showed the best performance as growth promoter followed by *Phoma* species isolated from *C. procera* and control.

CONCLUSION

In the current study, it was found that the endophytic *Phoma* species isolated from *T. cordifolia* and *C. procera* significantly influenced the growth promotion activity in maize. The endophytic fungi also demonstrated positive effect on seed germination of maize seeds on Murashige-Skoog media as compared to non-inoculated plants. Hence, from the above discussion it can be concluded that the endophytic *Phoma* species can be used as an efficient biofertilizer after extensive field trials.

REFERENCES

Bandara WMMS, Senevirante G, Kulasooriya SA. 2006. Interactions among endophytic bacteria and fungi: effects and potential. J Biosci 31 (5): 645-650.

Bhagobaty RK, Joshi SR. 2009. Promotion of seed germination of Green gram and Chick pea by *Penicillium verruculosum* RS7PF, a root endophytic fungus of *Potentilla fulgens* L. Adv Biotech 16-18.

Contreras-Cornejo HA. 2009. *Trichoderma virens*, a plant beneficial fungus, enhances biomass production and promotes lateral root growth through an auxin-dependent mechanism in *Arabidopsis*. Plant Physiol 149:1579-1592.

El-Tarabily KA, Nassar AH, Hardy GE, Sivasithamparam K. 2009. Plant growth promotion and biological control of *Pythium aphanidermatum*, a pathogen of cucumber, by endophytic actinomycetes. J Appl Microbiol 106 (1): 13-26.

Herre EA, Mejia LC, Kyllo DA, Rojas E, Maynard Z, Butler L, Van bael SA. 2007. Ecological implications of anti-pathogen effects of tropical fungal endophytes and mycorrhizae. Ecology 88 (3):550-558.

Hill NS, Belesky DP, Stringer WC. 1990. Competitiveness of tall fescue as influenced by *Acremonium coenophialum*. Crop Sci 31: 185-190.

Humayun M, Khan SA, Khan AL, Rehman G, Kim YH, Iqbal I, Hussain J, Sohn EY, Lee IJ. 2010. Gibberellin production and plant growth promotion from pure cultures of *Cladosporium* sp. MH-6 isolated from cucumber (*Cucumis sativus* L.). Mycologia 102 (5): 989-995.

Jalgaonwala RE, Mohite BV, Mahajan RT. 2010. Evaluation of Endophytes for their Antimicrobial activity from Indigenous Medicinal Plants belonging to North Maharashtra region India. Int J Pharm Biomed Res 1 (5): 136-141.

Jerry B. 1994. A role of endophytic fungi in regulating nutrients and energy in plants within a desert ecosystem. International symposium and workshop on desertification in developed countries.

Khan AL, Lee IJ. 2013. Endophytic *Penicillium funiculosum* LHL06 secretes gibberellin that reprograms *Glycine max* L. growth during copper stress. BMC Plant Biol 13 (1):86.

Khan R. 2008. Isolation, identification and cultivation of endophytic fungi from medicinal plants for the production and characterization of bioactive fungal metabolites. [Ph.D. Dissertation], University of Karachi, Karachi, Pakistan.

Khan S, Muhammad H, Yoon H, Kim H, Suh S, Hwang S, Kim J, Lee I, Choo Y, Yoon U, Kong W, Lee B, Kim J. 2008. Plant growth promotion and *Penicillium citrinum*. BMC Microbiol. 8: 231 doi:10.1186/1471-2180-8-231.

Khan SA, Hamayun M, Khan AL, Lee IJ, Shinwari ZK, Kim JG. 2012. Isolation of plant growth promoting endophytic fungi from dicots inhabiting coastal sand dunes of Korea. Pak J Bot 44 (4): 1453-1460.

Kumar M, Yadav V, Kumar H, Sharma R, Singh A, Tuteja N, Johri AK. 2011. *Piriformospora indica* enhances plant growth by transferring phosphate. Plant Signal Behav 6 (5):723-725

Li H, Qing C, Zhang Y, Zhao Z. 2005. Screening for endophytic fungi with antitumour and antifungal activities from Chinese medicinal plants. World J Microbiol Biotechnol 21: 1515-1519.

Murphy BR, Doohan FM, Hodkinson TR. 2014. Yield increase induced by the fungal root endophyte *Piriformospora indica* in barley grown at low temperature is nutrient limited Symbiosis 62:29-39

Prasad R, Kamal S, Sharma PK, Oelmüller R, Varma A. 2013. Root endophyte *Piriformospora indica* DSM 11827 alters plant morphology, enhances biomass and antioxidant activity of medicinal plant *Bacopa monnieri.* J Basic Microbiol. doi: 10.1002/jobm.201200367.

Rai M, Acharya D, Singh A, Varma A. 2001. Positive growth responses of the medicinal plants *Spilanthes calva* and *Withania somnifera* to inoculation by *Piriformospora indica* in a field trial. Mycorrhiza 11: 123-128.

Rai M, Agarkar G, Rathod D. 2014a. Multiple Applications of Endophytic *Colletotrichum* Species Occurring in Medicinal Plants. In: Gurib-Fakim A. (ed). Novel Plant Bioresources: Applications in Food, Medicine and Cosmetics, John Wiley & Sons, Ltd, Chichester, UK.

Rai M, Rathod D, Agarkar G, Dar M, Brestic M, Marostica Junior M R. 2014b. Fungal growth promotor endophytes: A pragmatic approach towards sustainable food and agriculture. Symbiosis 62: 63-79.

Rai M, Varma A. 2005. Arbuscular mycorrhiza-like biotechnological potential of *Piriformospora indica*, which promotes the growth of Adhatoda vasica Nees. Electron J Biotechnol 8 (1): 107-112

Ryan RP, Germaine K, Franks A, Ryan DJ, DowlingDN. 2008. Bacterial endophytes: recent developments and applications. FEMS Microbiol Lett 278 (1): 1-9

Silva HSA, Tozzi JPL, Terrasan CRF, Bettiol W. 2012. Endophytic micro-organisms from coffee tissues as plant growth promoters and biocontrol agents of coffee leaf rust. Biol Control 63 (1): 62-67.

Strasser RJ, Tsimilli-Michael M, Srivastava A. 2004. Analysis of the fluorescence transient. In: George C, Papageorgiou C, Govindjee (eds.): Chlorophyll Fluorescence: A Signature of Photosynthesis. Advances in Photosynthesis and Respiration Series. Springer, Dordrecht.

Thakur A, Kaur S, Kaur A, Singh V. 2013. Enhanced resistance to *Spodoptera litura* in endophyte infected cauliflower plants. Environ Entomol 42 (2): 240-246

Ting ASY, Meon S, Kadir J, Radu S, Singh G. 2007. Endophytic microorganisms as potential growth promoters of banana. J Biocontrol 53:541-553

Usuki F, Narisawa K. 2007. A mutualistic symbiosis between a dark, septate endophytic fungus, *Heteroconium chaetospira* and a non-mycorrhizal plant, Chinese cabbage. Mycologia 99:175-184.

Verma VC, Singh SK, Prakash S. 2011. Bio-control and plant growth potential of siderophore producing endophytic streptomyces from *Azadirachta indica* A. Juss. J Basic Microbiol 51 (5): 550-556.

Waller F, Achatz B, Baltruschat H, Fodder J, Becker K, Fischer M, Heler T, Hockelhoven R, Neumann C, Wettstein D, Franken P, Kogel KH. 2005. The endophytic fungus *Priformospora indica* reprograms barley to salt-stress tolerance, disease resistance and higher yield. P Natl Acad Sci 102:13386-13391.

Waqas M, Khan AL, Lee IJ. 2014. Bioactive chemical constituents produced by endophytes and effects on rice plant growth. J Plant Interact 9:1, 478-487.

You YH, Yoon H, Kang SM, Shin JH, Choo YS, Lee IJ, Lee JM, Kim JG. 2012. Fungal diversity and plant growth promotion of endophytic fungi from six halophytes in Suncheon Bay. J Microbiol Biotechnol 22 (11):1549-1556.

Zhang HM. 2008. Soil bacteria augment *Arabidopsis* photosynthesis by decreasing glucose sensing and abscisic acid levels in planta. Plant J 56: 264-273.

Zou WX, Tan RX. 1999. Advances in Plant Science. Vol. 2. China Higher Education Press, Beijing.