The Pharma Innovation Journal 2023; 12(3): 5591-5597

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(3): 5591-5597
© 2023 TPI
www.thepharmajournal.com
Received: 10-01-2023
Accepted: 11-02-2023

Sunita J Magar
Department of Plant Pathology, College of Agriculture, Latur, Maharashtra, India

HB Nagargoje
Department of Plant Pathology, College of Agriculture, Latur, Maharashtra, India

VG Mulekar
Department of Plant Pathology, College of Agriculture, Latur, Maharashtra, India

SD Somwanshi
Krishi Vigyan Kendra, Badnapur, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Corresponding Author:
Sunita J Magar
Department of Plant Pathology, College of Agriculture, Latur, Maharashtra, India

Exploration of endophytic microbes tomanage *Fusarium* wilt of tomato (*Lycopersicon esculentum* L.)

Sunita J Magar, HB Nagargoje, VG Mulekar and SD Somwanshi

Abstract
Tomato (*Lycopersicon esculentum* L.) is affected by accountable quantitative and qualitative losses due to, *Fusarium* wilt caused by *Fusarium oxysporum* f. sp. *Lycopersici.* It is a common vascular disease, resulting in extensive yield losses inmany tomato producing countries. In this, use of various chemicals for growth enhancement and disease control in plants has resulted in hazardous influence to the plant and human health. Thus, endophytic microbes assemblage have been known to decrease disease incidence in some crops and promote plant growth including tomato. Therefore, less harmful methods should be implemented and the possibility of using endophytic microbes for this purpose has been investigated.
The test pathogen, *Fusarium oxysporum* f. sp. *lycopersici* was isolated on PDA medium and proved its pathogenicity by sick soil method. A total of 12 endophytic fungi were isolated from tomato plant samples. Four isolates from stems such as; *A. Alternata*, *Phomopsis* sp., *A. Solani* and *Pseudomonas sp.*; three isolates from leaves such as; *Paecilomyces sp.*, *Cladosporium sp.* and *Chaetomium sp.*; four isolates from roots such as; *A. Niger*, *Aspergillus flavus*, *F. solani*, *Rhizopus sp.* and *Bacillus sp.* were tested by sick soil method in polybags. The results revealed that, *A. flavus* was found most effective in controlling disease and recorded wilt incidence (29.37%) with 62.50% disease inhibition followed by *A. Niger*, *Rhizopus sp.*, *Chaetomium sp.* and *Pseudomonas sp.*, which recorded wilt incidence (30.09, 31.05, 34.94 and 36.28%, respectively) and which inhibited disease incidence (61.59, 60.36, 55.39 and 53.68 %, respectively) and were found effective in growth promotion.

Keywords: *Lycopersicon esculentum* L., *Fusarium oxysporum f. sp. lycopersici*, Efficacy, Endophytic microbes, Pot culture

Introduction
Tomato (*Lycopersicon esculentum* L.) a most important solanaceous crop belongs to the family solanaceae and it is native of South America. This is most popular vegetable crop next to potato. It is very popular vegetable grown in home gardens and which is cholesterol free highly nutritious, rich sources of vitamins (A and C) and minerals. Tomato is one of the most important "Protective foods" because of its special nutritive value. It is used for soup, salad, pickles, ketchup, puree, sauces and in many other ways.
India is leading producer of tomato and ranks second in production. In India, the area under tomato cultivation was 781 thousand ha. Average production 19007 MT and average productivity of 24.33 MT/ha. The major tomato producing states are Uttar Pradesh, Madhya Pradesh, Orissa, Karnataka, Bihar, Punjab, West Bengal and Andhra Pradesh. In Maharashtra, the area under tomato cultivation was 40 thousand ha, average production, 805.90 MT and average productivity 20.01 MT/ha, respectively (Anonymous, 2019) [2].
Tomato is affected by many fungal, bacterial and viral diseases Wilt, Crown and Root rot diseasesin tomato caused by *Fusarium* species have been most intensively studied (Laurence, *et al*., 2014) [7]. *Fusarium* wilt is a common vascular disease caused by *Fusarium oxysporum*, resulting in extensive (10–80%) yield losses in many tomato producing countries.
Endophytic microbes are microorganisms that live within plant tissues without causing diseases during part of their life cycle. The term "endophyte" is springs from the Greek word "Endon" means within and "Phyte" means plant. The term "endophyte" originally introduced by Anton de Bary (1866) [3]. "Endophytes" are commonly defined as those organisms whose infections are inconspicuous, the infected host tissues are at least transiently symptomless, and the microbial colonization can be demonstrated to be internal (Stone *et al*., 2000) [13]. Endophyte-plant, associations have been found to improve plant health and may help host plant to rescue from various biotic and abiotic stresses.

Several endophytes have been shown to support plant growth and increase nutrient uptake by providing phytohormones, low molecular weight compounds, enzymes, antimicrobial substances like antibiotics. Numerous plant growth promoting endophytic strains have been isolated from the internal tissues of various crops and reported effective against diseases.

Use of chemicals for growth enhancement and disease control in plants has resulted in hazardous influences to the environment and human health. Therefore, less harmful methods should be implemented and the possibility of using microbes for this purpose has been investigated. Therefore, this study will be aimed to examine the possibility of using them for management of wilt disease incidence in tomato. Hence, the present study on endophytic microbes of tomato against wilt of tomato was planned.

Materials and Methods

To study the efficacy of endophytic microbes fungi/bacteria against *F. oxysporum* f. sp. *Lycopersici*, pot culture experiment was conducted *in vitro* at Department of Plant Pathology, College of Agriculture, Latur during *Rabi*, 2020-2021.

The fungal and bacterial endophytes were tested against *Fusarium* wilt disease in polybags. Sand: maize medium was used for mass multiplication of *F. Oxysporum* f. sp. *lycopersici.* Sand: maize medium (3 part partially broken grain + one part sand + distilled water to moisten the medium) was prepared, filled into polythene bags (9×12 cm) and autoclaved at 15 LBS pressure for 30 min., for two consecutive days. After cooling at room temperature, autoclaved sand: maize medium in the bags were inoculated with 8-10 mycelial discs (5 mm dia.) obtained from a week old pure culture of *F. oxysporum* f. sp. *lycopersici* and inoculated at room temperature, for two weeks. Black colored nursery polybags (size 20×30 cm) filled with the autoclaved potting mixture of soil : sand (3:1) were inoculated (each @ 50g / kg mixture) with the test pathogen mass multiplied (sand : maize medium) culture, watered lightly and incubated in screen house for two weeks, so as to proliferate the pathogen and make the potting mixture sick. After two weeks of incubation, these polybags was sown with tomato seeds of Cv. Alankar, which was sterilized using (2-3 % sodium hypochlorite solution for 5 min.). Before sowing, seeds were soaked in the potato dextrose broth / nutrient broth of mass multiplied with each effective endophytic fungi / bacteria for ±12 hrs. Then, such seeds was sown (10 seeds / bag), watered regularly and maintained in the screen house. At the control treatment, a seed submersion was performed using sterile distilled water was maintained as untreated control (Plate I and II).

The experiment was carried out in polybags by applying CRD (Completely Randomized Design) design with three replications and thirteen treatments as follows.

Tr. No.	Treatments	Tr. No.	Treatments
T_1	*Aspergillus niger*	T_8	*Phomopsis* sp.
T_2	*A. flavus*	T_9	*Alternaria alternata*
T_3	*Chaetomium* sp.	T_{10}	*A. solani*
T_4	*Rhizopus* sp.	T_{11}	*Fusarium solani*
T_5	*Cladosporium* sp	T_{12}	*Paecilomyces* sp.
T_6	*Bacillus* sp.	T_{13}	Control (untreated)
T_7	*Pseudomonas* sp.		

Observations

Observations on per cent wilting were recorded after 30, 45, 60, 75 and 90 days after sowing. Per cent wilting was calculated wilt incidence by following formula (Trapero-casas, 1983) [15].

$$\text{Wilt incidence (\%)} = \frac{\text{No. of plants wilted}}{\text{Total No. of plants}} \times 100$$

Observations on per cent seed germination, shoot length, root length and seedling vigour index were recorded at 14 days after sowing. Per cent seed germination was calculated by following formula (Elwakil and Ghoneem, 1991).

$$\text{\% seed germination} = \frac{\text{Total number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

Seedling vigour index was calculated by the following formula, given by Abdul-Baki and Anderson (1973) [1].

SVI = % seed germination x (Root length in cm + shoot length in cm)

The data obtained in all the experiments were statistically analyzed as per the procedure given by Panse and Sukhatme (1978).

Results and Discussion

Efficacy of 12 endophytic microbes evaluated *in vitro* against *Fusarium oxysporum f. sp. lycopersici* by sick soil method in polybags and results obtained on per cent wilting and reductions over untreated control are presented in Table 1, Plate III and IV and fig. 1.

Results indicated that, at 30 days after sowing (DAS), the lowest per cent wilting recorded in *Aspergillus flavus* (2.99 %) followed by *A. Niger* (3.21%), *Rhizopus* sp. (3.77 %), *Pseudomonas* sp. (3.89 %) and *Phomopsis* sp. (4.14 %). Rest of the endophytic microbes showed per cent wilting in the range of 4.72 to 5.67 %, respectively.

At 45 DAS, the lowest per cent wilting w a s recorded in *A. flavus*, *A. Niger* and *Chaetomium* sp. (6.38 %), followed by *Rhizopus* sp. (6.40 %), *Bacillus* sp. And *Pseudomonas* sp. (6.52 %), *A. alternata* and *A. solani* (6.54 %) and *F. Solani* and *Phomopsis* sp. (6.68 %), respectively. Rest of the endophytic microbes were also found effective.

Table 1: *In vitro* efficacy of endophytic microbes against *Fusarium oxysporum f. sp. lycopersici*,causing *Fusarium* wilt

Tr. No.	Endophytic microbes	Germin ation %*	30 DAS	Wilt incidence (%)* 45 DAS	60 DAS	75 DAS	90 DAS	Total wilt inciden	Disease inhibition per cent
								Ce (%)*	Over control
T_1	*Aspergillus*	76.66	3.21	6.38	6.52	6.98	6.98	30.09	61.59
	Niger	(61.12)	(10.32)	(14.63)	(14.79)	(15.31)	(15.31)	(33.26)	
T_2	*A. flavus*	78.33	2.99	6.38	6.66	6.52	6.82	29.37	62.50
		(62.26)	(9.95)	(14.63)	(14.95)	(14.79)	(15.13)	(32.81)	
T_3	*Chaetomium*	73.33	5.41	6.38	6.38	8.47	8.30	34.94	55.39
	sp.	(58.90)	(13.44)	(14.63)	(14.63)	(16.91)	(16.74)	(36.23)	
T_4	*Rhizopus* sp.	71.66	3.77	6.40	6.40	6.26	8.22	31.05	60.36
		(57.83)	(11.19)	(14.65)	(14.65)	(14.48)	(16.66)	(33.86)	
T_5	*Cladosporium*	71.66	5.48	8.94	9.03	11.73	8.86	44.04	43.78
	sp.	(57.83)	(13.53)	(17.39)	(17.48)	(20.02)	(17.31)	(41.57)	
T_6	*Bacillus* sp.	73.33	5.67	6.52	8.14	6.52	9.55	36.40	53.53
		(58.90)	(13.77)	(14.79)	(16.57)	(14.79)	(18.00)	(37.11)	
T_7	*Pseudomonas*	75.00	3.89	6.52	8.74	8.40	8.73	36.28	53.68
	sp.	(59.97)	(11.37)	(14.79)	(17.19)	(16.84)	(17.18)	(37.03)	
T_8	*Phomopsis* sp.	73.33	4.14	6.68	10.04	8.90	9.10	38.09	51.37
		(58.90)	(11.73)	(14.97)	(18.47)	(17.35)	(17.55)	(38.10)	
T_9	*Alternaria*	71.66	4.72	6.54	8.98	10.92	11.06	42.22	46.10
	alternata	(57.83)	(12.54)	(14.81)	(17.43)	(19.29)	(19.42)	(40.52)	
T_{10}	*A. solani*	73.33 (58.90)	5.30 (13.30)	6.54 (14.81)	7.72 (16.13)	11.70 (20.00)	11.41 (19.74)	42.67 (40.78)	45.53
T_{11}	*Fusarium*	71.66	5.61	6.68	11.19	9.82	11.29	44.59	43.08
	solani	(57.83)	(13.70)	(14.97)	(19.54)	(18.26)	(19.63)	(41.89)	
T_{12}	*Paecilomyces*	75.00	4.74	7.69	9.64	9.75	13.64	45.46	41.97
	sp.	(59.97)	(12.57)	(14.97)	(18.90)	(18.19)	(21.67)	(42.39)	
T_{13}	Control	66.66	10.21	12.8	17.02	17.84	20.47	78.34	00
	(untreated)	(54.72)	(18.63)	(20.96)	(24.36)	(24.98)	(26.90)	(62.26)	
	SE(m)	1.53	2.42	0.90	0.99	1.00	0.81	1.22	
	C.D. @ 1%	4.48	0.82	2.64	2.90	2.94	2.39	2.33	

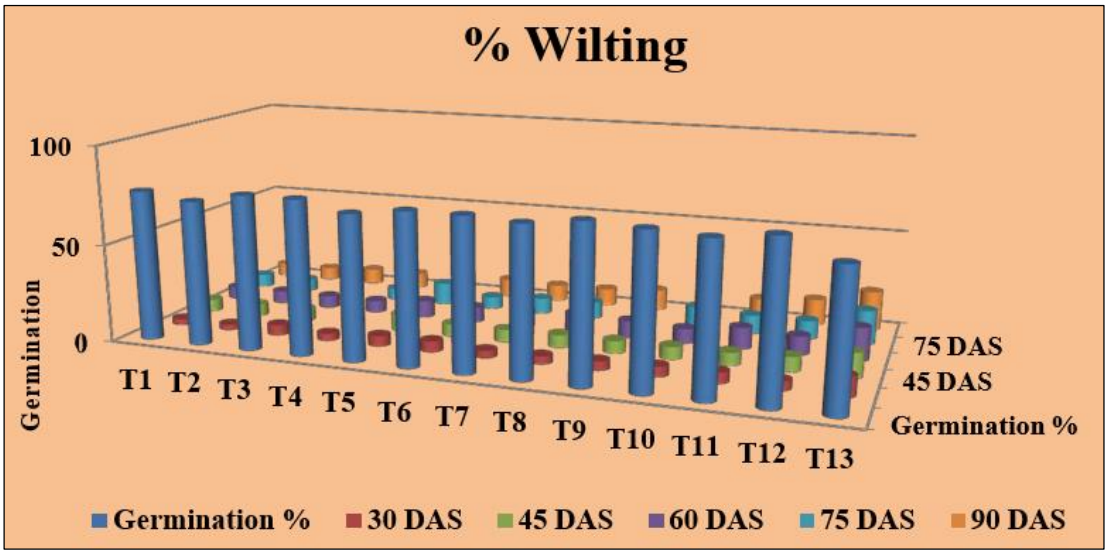
*Mean of three replications, figures in parentheses are Arc sine transformed values,

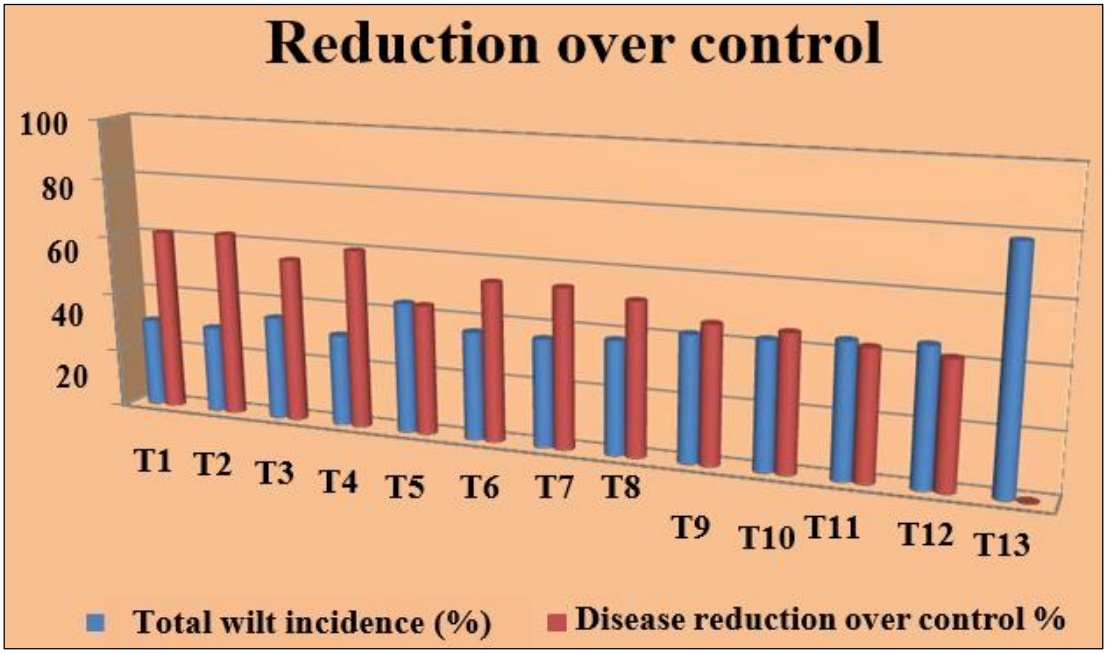
Plate 1: Multiplication of effective fungal endophytic cultures in Potato dextrose broth

Plate 2: Soaking of seed of tomato (Cv. Alankar) in fungal endophytic culture

Plate 3: Efficacy of endophytic microbes against *F. oxysporum* f. sp. *lycopersici*, causing *Fusarium* wilt of tomato in Cv. Alankar at 30 days after swing

Plate 4: Efficacy of endophytic microbes against *F. oxysporum* f. sp. *lycopersici*, causing *Fusarium* wilt of tomato in Cv. Alankar at 60 days after sowing





Tr. No.	Treatments	Tr. No.	Treatments
T_1	*A. Niger*	T_8	*Phomopsis* sp.
T_2	*A. Flavus*	T_9	*A alternata*
T_3	*Chaetomium* sp.	T_{10}	*A. solani*
T4	*Rhizopus* sp.	T_{11}	*F. solani*
T_5	*Cladosporiums* sp	T_{12}	*Paecilomyces* sp.
T_6	*Bacillus* sp.	T_{13}	Control (untreated)
T_7	*Pseudomonas sp.*	-	-

Fig 1: Efficacy of endophytic microbes against *F. Oxysporum* f. sp. *Lycopersici*, causing *Fusarium* wilt of tomato Cv. Alankar

At 60 DAS, the lowest per cent wilting was recorded in *Chaetomium* sp. (6.38 %), followed by *Rhizopus* sp. (6.40 %), *A. Niger* (6.52 %) and *A. Solani* (7.72 %), respectively. Rest of the endophytic microbes showed per cent wilting in the range of 8.14 to 11.19 %, respectively.

At 75 DAS, the lowest per cent wilting was recorded in *Rhizopus* sp. (6.26 %), followed by *A. Flavus* and *Bacillus* sp. (6.52 %), *A. Niger* (6.98 %), *Pseudomonas* sp. (8.40 %) and *Chaetomium* sp. (8.47 %), respectively. Rest of the endophytic microbes showed per cent wilting in the range of 8.90 to 11.70 %, respectively.

At 90 DAS, the lowest per cent wilting was recorded in *A. Flavus* (6.82 %) followed by *A. Niger* (6.98 %), *Rhizopus* sp. (8.22 %), *Chaetomium sp*. (8.30 %) and *Pseudomonas* sp. (8.73 %), respectively. Rest of the endophytic microbes showed per cent wilting in the range of 8.86 to 13.64 %, respectively.

Results revealed that, all treatments significantly improved the wilt disease control per centage as compared with untreated control. The disease control per centage recorded was ranged from 41.97 to 62.50 per cent over untreated control. The highest disease control per centage recorded in seed treatments with *A. flavus* (62.50 %) followed by *A. Niger* (61.59 %), *Rhizopus* sp. (60.36 %), *Chaetomium* sp. (55.39 %), *Pseudomonas* sp. (53.68 %), *Bacillus* sp. (53.53 %), *Phomopsis* sp.(51.37 %), *A. Alternata*, (46.10 %), *A. Solani*

*(*45.53 %*)*, *Cladosporium* sp. (43.78%) and *F. Solani* (43.08 %), respectively. *Paecilomyces* sp. recorded lowest disease control per centage (38.67 %). Similar results regarding effect of endophytic microbes on disease control in many crops were reported earlier by several workers. Ramesh *et al.* (2009) [11] tested the efficacy of 28 bacterial endophytes of eggplant against bacterial wilt pathogen caused by *R. solanacearum* under greenhouse conditions. Muthukumar *et al*. (2010) [8] studied*in vitro* efficacy of bacterial endophytes against the chilli damping-off pathogen *Pythium Aphanidermatum* obtained from the chilli plants. Talapatra *et al*. (2017) [14] studied *in vitro* antagonistic potential of endophytic *T. viride* isolated from roots of *Cynedrilla nodulofora* against nine endophytic pathogenic fungi isolated from roots of various hosts. Priyadarshini *et al*. (2018) evaluated the efficacy of six endophytic fungi of rice variety Ld 368 against brown spot of rice caused by *Bipolaris oryzae* under greenhouse condition by two inoculation methods (i.e. seedling and soil inoculation). Reported that biocontrol efficacy of endophytic fungi of cotton against *Verticillium* wilt by seed soaking and matrix inoculation method in greenhouse under pots.

Efficacy of plant growth potential of endophytes in tomato by pot culture method

The results on effect of endophytic microbes on plant growth promotion were depicted in Table 2 and Fig. 2.

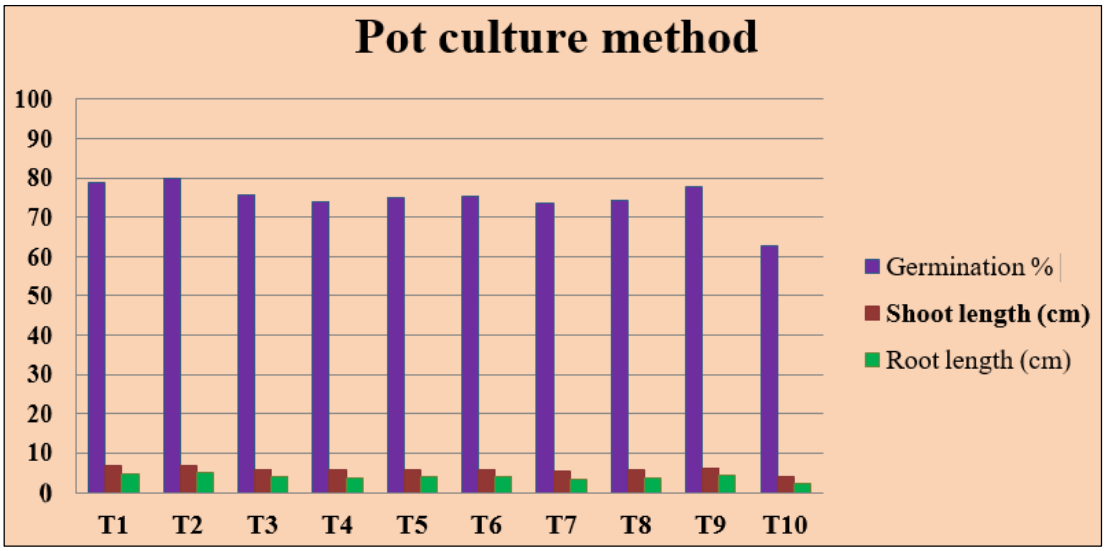
Results from, the *Aspergillus Niger* resulted with highest seed germination (80 %), shoot length (5.95 cm), root length (4.21 cm) and SVI (954.40), followed by *Aspergillus flavus* (78.67 %, 6.65 cm, 4.70 cm and 892.90, respectively), *Rhizopus* sp.(77.67 %, 6.26 cm, 4.34 cm and 823.30 respectively), *Chaetomium* sp. (75.67 %, 5.95 cm, 4.21 cm and 768.81, respectively), *Pseudomonas* sp. (75.33 %, 5.89 cm, 4.17 cm and 757.82, respectively), *Bacillus* sp. (75.00 %, 5.84 cm, 3.97 cm and 735.75, respectively), *Paeciliomyces* sp. (74.33 %, 5.80cm, 3.58cm and 697.21, respectively), *Phomopsis* sp. (74.00 %, 5.72 cm, 3.57 cm and 667.46, respectively) and *F. solani* (73.66 %, 5.63 cm, 3.21 cm and 651.15, respectively). Whereas, untreated control showed significantly lowest seed germination (62.67 %), 4.04 cm, 2.21 cm and 391.69, respectively).

Similar results regarding effect of endophytic microbes on growth parameters inmany crops were reported earlier by several workers (Priyadarshani *et al*., 2018 and Urooj *et al*., 2018) [10, 16]. Harish *et al.* (2008) [5] studied 40 endophytic bacteria isolated from the corm and roots of banana plants and assessed for their efficacy on plant growth promotion. Endophytic bacterial isolates EPB5, EPB22 and EPB31 were found to increase the vigour index of rice seedlings significantly in both roll towel and pot culture methods.

Table 2: Effect of endophytic microbes on growth parameters in tomato cropby pot culture method

Tr. No.	Endophytic microbes	Germination (%)	Shoot length (cm)	Root length (cm)	SVI
T_1	*Aspergillus flavus*	78.67(62.48)	6.65	4.70	892.90
T_2	*Aspergillus niger*	80.00(63.41)	6.83	5.10	954.40
T_3	*Chaetomium* sp.	75.67(60.42)	5.95	4.21	768.81
T_4	*Phomopsis* sp.	74.00(59.32)	5.72	3.57	667.46
T_5	*Bacillus* sp.	75.00(59.97)	5.84	3.97	735.75
T_6	*Pseudomonas* sp.	75.33(60.20)	5.89	4.17	757.82
T_7	*F. solani*	73.66(59.10)	5.63	3.21	651.15
T_8	*Paeciliomyces* sp.	74.33(59.54)	5.80	3.58	697.21
T_9	*Rhizopus* sp.	77.67(61.78)	6.26	4.34	823.302
T_{10}	control	62.67(52.32)	4.04	2.21	391.69
	SE(m)±	0.86	0.14	0.11	
	C.D. @ 1%	2.56	0.42	0.34	

*Mean of three replications, Figures in parentheses are arc sine transformed values, SVI: Seedling vigour index



Tr. No. Treatments Tr. No. Treatments

T_1	*Aspergillus flavus*	T_6	*Pseudomonas* sp.
T_2	*Aspergillus niger*	T_7	*F. solani*
T_3	*Chaetomium* sp.	T_8	*Paeciliomyces* sp.
T_4	*Phomopsis* sp.	T_9	*Rhizopus* sp.
T_5	*Bacillus* sp.	T_{10}	Control (untreated)

Fig 2: Evaluation of endophytic microbes on growth parameters in tomato by pot culture method

Conclusions

From the results obtained on varying aspects during present study on endophytic microbes of tomato against (*Fusarium oxysporum* f. sp. *lycopersici*), following conclusions are being drawn. All 12 endophytic microbes evaluated *in vitro* were proved potential antagonists against *Fusarium oxysporum* f. sp. *lycopersici.* However, *A. flavus*, *A. Niger*, *Rhizopus* sp., *Pseudomonas* sp., *Chaetomium* sp. and *Bacillus* sp. were found most potential fungal endophyte as antagonists against *F. Oxysporum* f. sp. *lycopersici*. Among all fungal endophytes *Aspergillus Niger*, *Aspergillus flavus* and bacterial both *Pseudomonas sp.* and *Bacillus sp.* were found effective in plant growth promotion.

References

1. Abdul-Baki AA, Anderson JD. Vigor Determination in Soybean Seed by Multiple Criteria. Crop Science. 1973;13(6), 630-633.
2. Anonymous. Area production statistics; c2019. http://www.nhb.gov.in.
3. De Bary A. Morphology and physiology of fungi, lichens and myxomycetes Hofmeister's Handbook of physiological Botany: Leipzig; c1866.
4. Elwakil MA, Ghoneem KM. Detection and location of seed borne fungi of blonde psyllim and their transmission in seedlings. Pakistan Journal of Biological Sciences. 1991;2(1):38-44.
5. Harish S Kavino M, Kumar N, Saravanakumar D, Soorianathasundaram K, Samiyappan R. Biohardening with plant growth promoting rhizosphere and endophytic bacteria induces systemic resistance against banana bunchy top virus. Applied Soil Ecology. 2008;39(2):187–200.
6. Kesavan V, Choudhary B. Breeding for multiple disease resistance in vegetables: A Review. SABRAO, Journal. 1977;9:57-65.
7. Laurence MH, Summerell BA, Burgess LW, Liew ECY. Genealogical concordance phylogenetic species recognition in the Fusarium oxysporum species complex. Fungal Biology. 2014;118, 374-384.
8. Muthukumar A, Nakkeeran S, Eswaran E, Sangeetha G. In vitro efficacyof bacterial endophytes against the chilli damping-off pathogen Pythium aphanidermatum. Mediterranean Psychopathological Union. 2010;49:179–186
9. Panse VG, Sukhamte PV. Statistical methods for agricultural workers. IARI, New Delhi. Third Publications; c1978. p. 157-165.
10. Priyadarshani CDN, Deshappriya N, Sandamal TGI. Effect of fungal endophytes of rice variety Ld 368 on growth and brown spot disease incidence of rice. Journal by the Society for Tropical Plant Research. 2018;5(3):292–302.
11. Ramesh R, Joshi AA, Ghaneka MP. Pseudomonas: Major antagonistic endophytic bacteria to suppress bacterial wilt pathogen, Ralstonia solanacearum in the eggplant (Solanum melongena L.).World Journal of Microbiology and Biotechnology. 2009;25:47–55.
12. Shenthilkumar A, Kannathasan K, Venkatesalu V. Antibacterial activityof the leaf essential oil of Blumea mollis (D. Don) Merr. World Journal of Microbiology & Biotechnology. 2009;25(7):1297-1300.
13. Stone JK, Bacon CW, White JF. An overview of endophytic microbes: endophytism defined. In: Bacon CW, White JF, (edit.): Microbial endophytes. New York: Marcel Dekker Inc; c2000.
14. Talapatra K, Das AR, Saha AK, Das P. In vitro antagonistic activity ofa root endophytic fungus towards plant pathogenic fungi. Journal Applied Biology Biotechnology. 2017;5(2):068-071.
15. Trapero-Casas A. Wilt and root rot of chickpea in the Guadelquivir valley: Importance distribution, ecology, epidemiology and control (Original in spinach), (Doctoral Thesis).University of Cordoba; c1983.
16. Urooj F, Farhat H, Ali SA, Ahmed M, Sultana V, Shams ZI, Ara J, Ehteshamul-Haque R. Role of endophytic Penicillium species in suppressing the root rotting fungi of sunflower. Pakisthan Journal of Botany. 2018;50(4):1621-1628.
17. Yuan Y, Feng H, Wang L, Li Z, Shi Y, Zhao L, Feng Z, Zhu H. Potential of endophytic fungi isolated from cotton roots for biological control against Verticillium wilt diseases. Public Library of Science. 2017;12(1):1-12.