Int.J.Curr.Microbiol.App.Sci (2016) *5*(12): 919-929

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 5 Number 12 (2016) pp. 919-929**
Journal homepage: http://www.ijcmas.com

Original Research Article http://dx.doi.org/10.20546/ijcmas.2016.512.100

Study on Fungi Associated with Tuber Vegetables during Storage in Markets of Telangana State, India

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Keywords

Mycoflora, tuber vegetables, carrot, beet root, sweet potato and corm.

Article Info

Accepted:
25 November 2016
Available Online:
10 December 2016

A B S T R A C T

Fungi deteriorate the quality and quantity of the vegetables during transit and storage. An attempt was made to isolate and identify storage rot fungi associated with tuber vegetables collected from local markets of five districts in Telangana State, India. This study also reported the occurrence and distribution of fungi associated with four tuber vegetables viz., carrot, beetroot, sweet potato and corm during storage in all the five districts. Standard methods were followed to isolate and identify the fungi. A total of 41 fungal species belonging to 22 genera were observed. Among the four root vegetables, fungi were found predominantly on carrots while sweet potato had lesser dominance of fungi. Most predominant fungal species isolated from four tuber vegetables were recorded in Mahabubnagar followed by Rangareddy, Karimnagar,, Nizamabad and Nalgonda. *Fusarium* species was found to be the most dominant fungi. Among the *Fusarium* sp., *F. solani* was the common fungus isolated from all four root vegetablesin all the five districts. Eight plant fungal species viz., *Byssochlamys nivea, Conifera* sp., *Cunnighamella echinulata, Chaetomium mollicellum, Monilina fructicola, Monodictys fluctuate, Trichoderma hargianum*and *Trichothecium roseum* were found for the first time to be associated with the tuber vegetables during the storage in Telangana state.This study underscores the implementation of post-harvest technology to prevent the economic loss due to fungal infestation of tuber vegetables during transit and storage at market level in Telangana state.

Introduction

Fruits and vegetables are important food commodities throughout the world. Fruits and vegetable are rich sources of vitamins, such as vitamin C, folic acid (useful in synthesis of DNA), vitamin A, including minerals such as calcium and iron (Obetta *et al.*, 2011). These also contain dietary fibres which add bulk to intestinal content and are useful in preventing constipation.

Fruits and vegetables have similar nutritive properties; 70% of their weight is water, 3.5% protein and about 1% fat (Obetta *et al.*, 2011). Consumption of fruits and vegetables can help achieve or maintain a healthy body weight (National Institute of Research on Food and Nutrition Rome, Italy, 1998). Today, one of the main global challenges is how to ensure food security for a world

growing population whilst ensuring long-term sustainable development. According to the FAO, food production will need to grow by 70% to feed world population which will reach 9 billion by 2050 (FAO/OECD, 2011). The pressure on demand for food is mainly due to the rapid growth of human population stressed the importance of fruits and vegetables in the human diet, especially in developing countries. India is the second and fourth largest producer of vegetables and fruits in the world, respectively.

Although adequate quantities of fruits and vegetables are produced, they become inadequate to feed huge population due to losses in the field as well as during storage. Generally, about 30 % fruits and vegetables are rendered unfit for consumption owing to spoilage after harvesting. Microbes responsible for fruit and vegetable spoilage include bacteria and fungi. Spoilage microbes make fresh fruits and vegetables unfit for human consumption; by deteriorating their nutritional quality, normal texture and flavour.

In India, post-harvest loss of perishables is estimated to vary from 25 to 50% for fruits (Coursey and Booth, 1972) and 30-32 % for vegetables (Robinson, 1983), 12-32 % for root and stem tubers. In India, 20-30 % of the produce is spoiled in the markets (FAO, 1977; FAO, 2002; Deka *et al*., 2006). India annually produces fruits and vegetables of the value of about Rs. 7000 crores and wastage may be of the order of Rs. 2100 crores. This is a huge loss of valuable food even when the minimum food requirement of the population is not met. Therefore, it is important not only to produce more, but also save what is grown at high cost. In order to find ways to reduce post-harvest loss, we need to conduct survey on factors such as mechanical, physiological, pathological and environmental that contributes to spoilage.

There is no published data on fungi which cause the post- harvest diseases connected with tuber vegetables from local markets of Telangana state, India. This study was aimed at isolation and identification of fungi, responsible for storage -rot associated with four root vegetables viz., carrot, beet root, sweet potato and corm, were collected at regular interval from local markets in five districts of Telangana during storage period. This study can also alert vegetables venders and public about the incidence of storage rot fungi in the markets of Telangana state, India.

Materials and Methods

Sample collection and Isolation of fungi

Sample collection and isolation of fungi was done by following the method reported by Odebode and Unachulwu (1997). Samples of rotted root vegetables namely carrot, beet root, sweet potato and corm were collected at regular interval into fresh polythene bags from five districts' local markets belonging to Telangana state, India. Samples were brought to the labs within 24 hours. Care was taken to avoid secondary infection by parasites.

Samples of rotted vegetables were surface sterilised with 70% alcohol for 1 minutes or 1% sodium hypochlorite solution for 2 minutes and washed twice with sterile distilled water and blotted dry with sterile filter paper. The infected parts were sliced aseptically into small cubes and placed onto potato dextrose agar (PDA). The plates were incubated at 28± 2ºC for 3 days. Petridishes were observed daily and colonies of fungi were chosen. The fungi were further purified using single spore technique, and then kept in a refrigerator on PDA slants in Mc cartney bottles (Gams *et al*., 1998 and Nagamani *et al*., 2006).

Identification of fungi

The pure isolated fungi were identified using cultural and morphological features such as spore size, length, conidia formation, colony colour and diameter of colonies (Barnett and Hunter, 1972 (used for genus identification); Ellis, 1971 and 1976; Domsch *et al*., 1993; Moubasher 1993; Pitt and Hocking, 1997; Klich, 2002; Nagamani *et al*., 2006; Samson and Varga, 2007).

Results and Discussion

Fungi were isolated and identified from rotten tuber vegetables namely carrot, beet root, sweet potato and corm collected from local markets of Mahabubnagar, Nalgonda, Nizamabad, Karimnagar and Ranga Reddy districts during storage in Telangana state, India. Occurrence and distribution of fungi is presented in Table 1-5 and Fig. 1. Among the four tuber vegetables, carrot had the highest number of fungi (24), while Sweet potato had the lowest number of fungi (14) (Fig.1).

Out of 24 fungal species found to be associated with post-harvest samples of carrot, 23 fungal species were recorded from MBNR district followed by 20 from RR, 15 from NZB, 12 from NLD and 11 from KNR district (Table -1). *Aspergillus niger*, *F. oxysporum, F. solani, R. arrhizus, R. solani*, *Rhizoctonia* sp., *S. sclerotiorum, S. rolfsii* and *Mycelia sterilia* (black) were predominant in all the five districts compared to other fungi (Table-1). Less predominance was observedfor*A. radiciana* and *T. hargianum*. It is interestingly to note that the fungi viz., *A. radicina, F. culmorum, F. oxysporum, M. phaseolina, M. fructicola, M. varians, R. arrhizus, R. stolonifer, R. carotae, R. solani S. minor, S. sclerotiorum, S. racemosum, T. harzianum and T. roseum* are being reported as new host records to carrot.

A total of 18 fungal species were isolated from the beet root samples (Table -2). Out of which, 16, 8, 12, 11 and 16 fungal species were isolated from MBNR, NLG, NZB, KNR and RR districts, respectively. Among the 18 fungal spp. isolated, *A. fumigatus, F. moniliforme, F. oxysporum, F. solani, P. funiculosum, R. arrhizus, R. stolonifer* and *S. rolfsii* were predominantly occurring in the samples of all the five districts. *Aspergillus flavus* and *M. varians*were restricted to NZB and MBNR, respectively. This is the first report on the isolation and identification of *A. fumigatus, F. solani, M. varians, R. stolonifer, S. racemosum, T. harzianum* and *T. roseum*as being associated with beet root from Telangana.

A total of 15 fungal species were isolated from rotten sweet potato samples(Table -3). Out of which 13 fungi were recorded in MBNR as well as in RR districts, 9 from NLG, 8 from NZB as well as KNR.Within the 14 fungal species isolated, *A. terreus, F. oxysporum .f. batatus, F. solani, P. decumbens* and *R. oryzae* were observed to be predominant occurring in the samples of the all five districts while least predominance was found by *B. nivea*. *Thielaviopsis paradoxa, M. fluctuata* and *M. phaseolina* were recorded to be the new host records of sweet potato from Telangana.

A total of 21 fungal species were isolated from the corn samples (Table -4). Out of 21 fungi, 14, 12, 15 and 18 species were isolated from MBNR, NLGD, NZB, KNR and RR districts respectively Among the 21 fungal species isolated from corm samples *A. niger, F. moniliforme, F. oxysporum, F. solani, G. candidum, M. phaseolina, R. arrhizus, S. sclerotiorum, S. rolfsii* and *S. racemosum* were most frequently recorded from the samples of all the five districts. *A. radicina* was restricted to the samples of MBNR. *Chaetomium mollicellum, C.*

echinulata, M. fragilis, M. varians, S. racemosum and T. harzianum are reported as new host findings.

Overall, a total of 41fungal species belonging to 22 genera were isolated from the spoiled samples of the carrot, Beet root, sweet potato and corm (elephant foot yam) from five districts (Table-5). Among the 22 genera, *Fusarium* sp. were found to be most dominant ones responsible for extensive damage of tuber vegetables in the local market of Telangana districts and followed by *Aspergillus* species. The samples of underground vegetables showed a high degree of fungal association and it was maximum in the samples of MBNR and next followed by those found in R.R district (fig.1). Out of 41 fungal species, 20 fungi such as *A. niger, A. terreus, A. fumigatus, F. solani, F. oxysporum, F. oxysporum. f.batatus, F. moniliformae, G. candidum, M. phaseolina, Mycelia sterilia* (black), *P. funiculosum, P. decumbens, R. arrhizus, R. oryzae, R. stolonifer, Rhizoctonia solani, Rhizoctonia spp., S. rolfsii, S. sclerotiorum and S.* recemosum were appeared predominantly in all five districts.

Fuasirium sp. were found to be most dominant fungi and next followed by *Aspergillus* sp.(Table 5).Among the all *Fuasirium* sp., *Fusarium solani* was the most common and frequently isolated fungus associated with all four tuber vegetables in all five districts.(Table 1-4). Eight fungi namely,*Byssochlamys nivea, Cunnighamella echinulata, Chaetomium mollicellum, Monilina fructicola, Monodictys fluctuata, Trichoderma harzianum and Trichothecium roseum* were recorded as new fungal species for the first time from the Telangana region (Table 5).The study also clearly indicated that the loss of tuber vegetables during storage is due to predominance of fungi.

Under the environment of this study, carrot had highest number of fungal species while in the sweet potato least number of fungi were recorded. Among the four tuber vegetables carrot showed high number of fungi due to its high sugar content and nutrients (Odebode and Unachulwu, 1997; Obetta *et al.*, 2011). Least frequency of fungi on sweet potato is thought to be due to its high phenol content and wound cork formation (Bweimer and Harter, 1921; Madhukar and Reddy, 1991; Amusa *et al*., 2006 and Sarkar, 2009). Phenols are transported from healthy part of sweet potato to infection site of sweet potato. This could give resistance of the host towards pathogens (Madhukar and Reddy, 1991; Amusa *et al*., 2006 and Sarkar, 2009).

Fusarium species were reported to be most dominant fungi and followed by *Aspergillus* species. *Among the Fusarium species, Fusarium solani* was the most frequently isolated fungus and it was commonly associated with the all four root vegetables in all five districts of Telangana than other fungi. This might be due to either strong soil borne nature of the fungus or its high amount of conidia and chlamido spores in the market atmosphere and suitable environmental conditions for its growth in Telangana markets.

Highest frequency of fungi was recorded in Mahabubnagar, followed by Ranga Reddy. This might be owing to improper storage conditions and lack of knowledge about post-harvest handling techniques to the farmers and vegetable venders at field and markets, respectively. MBNR is poor district at an economical and educational level. People don't have awareness of post-harvest technology to keep vegetables fresh. This might be one of the reasons for having highest fungi in MBNR.

Table.1 Occurrence and distribution of Fungal isolates from the post-harvest samples of rotten carrot in Mahabubnagar (MBNR), Nalgonda (NLG), Nizamabad (NZB), Karimnagar (KMNR) and Ranga reddy (RR) districts of Telangana

S.NO	Fungi	MBNR	NLG	NZB	KNR	R.R
1	***Alternaria radicina*** Meir Drech. & Eddy	+	-	-	-	-
2	*Aspergillus flavus* Link	+	-	+	-	-
3	*Aspergillus niger*van Tieghem	+	+	+	+	+
4	*Aspergillus terreus* Thom	-	-	+	-	+
5	***Fusarium culmorum*** (W.G. Smith) Saccardo	+	-	+	-	-
6	***Fusarium oxysporum*** Schl. ex Fr.	+	+	+	+	+
7	*Fusarium solani* (Martius) Sacc.	+	+	+	+	+
8	*Geotrichum candidum* Link	+	-	-	-	+
9	*Macrophomina phaseolina**** (Tassi) Goid.	+	+	+	-	+
10	**Monilia fructicola* (Winter) Honey	+	-	-	-	+
11	***Mucor varians*** Povah	+	-	-	+	+
12	**Rhizopus arrhizus* A. Fischer	+	+	+	+	+
13	*Rhizopus oryzae* Went & Prins. Geerl.	+	-	+	+	+
14	***Rhizopus stolonifer*** Ehr. ex Fr.	+	-	-	-	+
15	***Rhizoctonia carotae*** Rader.	+	+	-	-	+
16	***Rhizoctonia solani*** Kuhn	+	+	+	+	+
17	*Rhizoctonia* sp.	+	+	+	+	+
18	***Sclerotinia minor*** Jagger	+	-	+	-	+
19	***Sclerotinia sclerotiorum*** (Lib.) Bary	+	+	+	+	+
20	*Sclerotium rolfsii* Sacc.	+	+	+	+	+
21	***Syncephalastrum racemosum*** Cohn ex J. Schrot.	+	-	-	-	+
22	***Trichoderma harzianum*** Rifai	+	-	-	-	-
23	*** Trichothecium roseum*** Link	+	_	-	-	+
24	Mycelia sterilia (black)	+	+	+	+	+
	Total	**23**	**12**	**15**	**11**	**20**

*** = New host records**

MBNR = Mahabubnagar; **NLG** = Nalgonda; **NZB** = Nizamabad; **KNR** = Karimnagar;**RR** = Ranga Reddy district.(**-**) = Absent(**+**)= present

Table.2 Occurrence and distribution of Fungal isolates from the post-harvest rotten samples of rotten beet root in Mahabubnagar (MBNR), Nalgonda (NLG), Nizamabad (NZB), Karimnagar (KMNR) and Ranga reddy (RR) districts of Telangana

S. No	Fungi	MBNR	NLG	NZB	KNR	RR
1	*Aspergillus flavus* Link	-	-	+	-	-
2	***Aspergillus fumigatus* (Fresenius)	**+**	**+**	**+**	**+**	**+**
3	*Aspergillus niger* van Tieghem	+	+	+	-	+
4	*Fusarium dimerum* (Penzig)	-	-	-	+	+
5	*Fusarium equiseti* (Corda) Saccardo	+	-	-	+	+
6	*Fusarium moniliforme* Sheldon	**+**	**+**	**+**	**+**	**+**
7	*Fusarium oxysporum* Schl. ex Fr.	**+**	**+**	**+**	**+**	**+**
8	**Fusarium solani* (Martius) Sacc.	**+**	**+**	**+**	**+**	**+**
9	*Geotrichum candidum* Link	+	-	-	-	+
10	***Mucor varians* Povah	+	-	-	-	-
11	*Penicillium funiculosum* (Thom)	**+**	**+**	**+**	**+**	**+**
12	*Rhizopus arrhizus* Fischer	**+**	**+**	**+**	**+**	**+**
13	***Rhizopus stolonifer* Ehr. ex Fr.	**+**	**+**	**+**	**+**	**+**
14	*Sclerotium rolfsii* Sacc.(*Athelia*)	**+**	**+**	**+**	**+**	**+**
15	***Syncephalastrum racemosum* Cohn ex J. Schrot.	+	-	+	-	+
16	***Trichoderma harzianum* Rifai	+	-	-	-	+
17	***Trichothecium roseum* Link	+	-	-	-	+
18	Mycelia sterilia (white)	+	-	+	+	+
	Total	**16**	**8**	**12**	**11**	**16**

*** = New host records**(New fungi on carrot from Telangana region).

MBNR = Mahabubnagar; **NLG** = Nalgonda; **NZB** = Nizamabad; **KNR** = Karimnagar; **RR** = Ranga Reddy district.(**-)** = Absent(**+)**= present

Table.3 Occurrence and distribution of fungal isolates fromthe post-harvest samples of rotten sweet potato inMahabubnagar (MBNR), Nalgonda (NLG), Nizamabad (NZB), Karimnagar (KMNR) and Ranga reddy (RR) districts of Telangana

S. NO	Fungi	MBNR	NLG	NZB	KNR	RR
1	*Aspergillus flavus* Link	+	-	+	-	+
2	*Aspergillus terreus* Thom	+	+	+	+	+
3	*Botryodiplodia theobromae* Pat.	+	+	-	-	+
4	*Byssoclamys nivea* Westling	+	-	-	-	-
5	*Fusarium moniliforme* Sheldon	+	+	-	-	+
6	*Fusarium oxysporum. f. batatus* (Schl. ex Fr.) e. Anyd. Et Hans.	+	+	+	+	+
7	*Fusarium pallidoroseum* (Cooke) Sacc.	-	-	+	+	-
8	*Fusarium solani* (Martius) Sacc.	+	+	+	+	+
9	***Macrophomina phaseolina* (Tassi) Goid.**	-	+	+	-	+
10	***Monodictys fluctuata* (Tandon & Bilgrami)**	+	-	-	-	+
11	*Mucor varians* Povah	+	-	-	-	+
12	*Penicillium decumbens* Thom	+	+	+	+	+
13	*Rhizopus oryzae* Fischer	+	+	+	+	+
14	*Thielaviopsis paradoxa* (De Seynes) Hohn. (*Ceratocystis paradoxa*)*****(Dade) C. Moreau	+	+	-	+	+
15	***** Mycelia sterilia(black*)*	+	-	-	+	+
	Total	**13**	**9**	**8**	**8**	**13**

*** = New host records**

MBNR = Mahabubnagar; **NLG** = Nalgonda; **NZB** = Nizamabad; **KNR** = Karimnagar; **RR** = Ranga Reddy district.(**-)** = Absent(**+)**= present

Table.4 Occurrence and distribution of fungal isolates from the post-harvest samples of rotten corm in Mahabubnagar (MBNR), Nalgonda (NLG), Nizamabad (NZB), Karimnagar (KMNR) and Ranga reddy (RR) districts of Telangana

S. No	Fungus	MBNR	NLG	NZB	KNR	RR
1	*Alternaria radicina* Meir Drech. & Eddy	+	-	-	-	-
2	*Aspergillus flavus* Link	+	-	-	+	+
3	*Aspergillus niger* van Tieghem	+	+	+	+	+
4	*Botryodiplodia theobromae* Pat.	+	+	-	-	+
5	***Chaetomium mollicellum*** L.M. Ames	+	+	-	-	+
6	***Cunninghamella echinulata*** Thaxter	+	-	-	-	+
7	*Fusarium moniliforme*Sheldon	+	+	+	+	+
8	*Fusarium oxysporum*Schl. ex Fr.	+	+	+	+	+
9	*Fusarium solani*(Mart.) Sacc.	+	+	+	+	+
10	*Geotrichum candidum*Link	+	+	+	+	+
11	*Macrophomina phaseolina*(Tassi) Goid.	+	+	+	+	+
12	***Mucor fragilis*** Bainier	-	-	-	+	+
13	***Mucor varians*** Povah	+	-	-	+	+
14	*Penicillium decumbens* Thom	+	-	+	-	-
15	*Rhizopus arrhizus*Fischer	+	+	+	+	+
16	*Rhizoctonia solani* Kuhn	+	+	-	+	+
17	*Sclerotinia sclerotiorum*(Lib.) Bary	+	+	+	+	+
18	*Sclerotium rolfsii* Sacc.	+	+	+	+	+
19	*Syncephalastrum racemosum*** Cohn ex J. Schrot.	+	+	+	+	+
20	***Trichoderma harzianum*** Rifai	+	-	+	+	-
21	Mycelia sterilia (white)	+	+	-	-	+
	Total	**20**	**14**	**12**	**15**	**18**

***= New host records**

MBNR = Mahabubnagar; **NLG** = Nalgonda; **NZB** = Nizamabad; **KNR** = Karimnagar; **RR** = Ranga Reddy district.

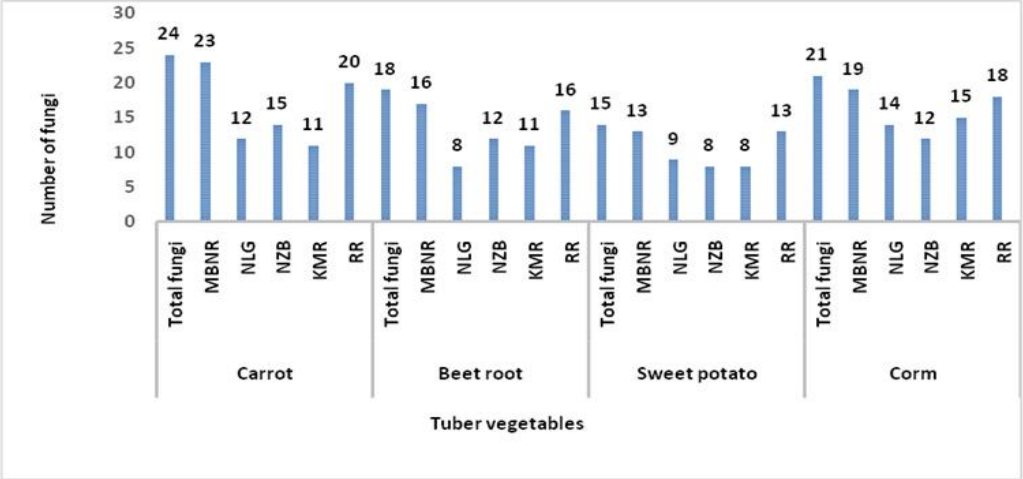
- = absent+= present

Table.5 Total number of various fungal species belonging to 23 genera in four underground vegetables collected from five districts of Telangana

Numbering of Genera	species	Numbering of species
1. *Aspergillus*Sp.	*A. niger*	4
	A. flavus	
	A. terreus	
	A.fumigatus	
2.*Alternaria* Sp.	*A. radiciana*	1
3.*Botryodiplodia* Sp.	*B. theobromae*	1
4.*Byssochlamys* Sp.	*B. nivea* *	1
		1
5.*Thielaviopsis* Sp.	*C.paradoxa*	1
6.*Cunnighamella* Sp.	*C. echinulata* *	1
7.*Chaetomium* Sp.	*C. mollicellum* *	1
8.*Fusarium* Sp.	*F. solani*	8
	F. oxysporum	
	F. oxysporum.f.batatus	
	F. culmorum	
	F. equisetum	
	F. moniliformae	
	F. dimerum.	
	F. pellidoroseum	
9.*Geotrichum* Sp.	*G. candidum*	1
10.*Monilina* Sp.	*M. fructicola**	1
11.*Mucor* Sp.	*M. fragilis*	2
	M. varians	
12.*Monodictys* Sp.	*M. fluctuata* *	1
13.*Macrophomina* Sp.	*M. phaseolina.*	1
14.*Mycelia* Sp.	*M. sterilia Black*	2
	M. sterilia white	
15.*Penicillium* Sp.	*P. funiculosum*	2
	P. decumbens	
16.*Rhizopus* Sp.	*R. arrhizus*	3
	R. oryzae	
	R. stolonifer	
17.*Rhizoctonia* Sp.	*R. carotae*	3
	R. soloni	
	Rhizoctonia like sp.	
18.*Sclerotium* Sp.	*S. rolfsii*	1
19.*Syncephalastrum* Sp.	*S. recemosum*	1
20.*Sclerotina* Sp.	*S. sclerotiorum*	2
	S. miner	
21.*Trichoderma* Sp.	*T. harzianum* *	1
22.*Trichothecium* Sp.	*T. roseum* *	1
	TOTAL	41

***= New fungi were identified for the first time from Telangana region**

Fig.1 Number of fungi recorded from post-harvest samples of rotten carrot, beet root, sweet potato and corm collectedfrom MBNR, NLG, NZB, KMR and R.R districts of Telangana



Of the 41 fungi, *F. solani* appeared throughout sampled areas in Telangana as well as in all four root vegetables. Therefore, *Fusarium solani* was the most frequently isolated fungus than other fungi. This could be due to either strong soil borne nature of the fungus and its high production of conidia and chlamidospores or suitable environmental conditions of Telangana markets for its growth. Similar finding are reported by Thakur in 1966. He surveyed Delhi Markets for fungal diseases of fruits and vegetables and found *Fusarium* Spp., and *Rhizopus arrhizus* to be the major pathogens and *Aspergillus* spp., and *Penicillium* to be minor pathogens.

The results of this study are in agreement with the findings of other researchers (Usharani, 1982) encountered that pre and post -harvest diseases of some underground vegetables and its associated fungi during storage in the surroundings of Hyderabad. The pre-dominance of these fungi which cause severe deterioration of produce is due to poor storage conditions, high moisture and other related factors. The poor post-harvest technology in the transport system and markets has supported high disease incidence by fungal pathogens. In conclusion, the aim of this work was to isolate and identify the specific fungi associated with rotten root vegetables from five districts of Telangana. This study has provided useful information about the incidence of fungi associated with tuber vegetables in the district local markets of Telangana State, India and feasibility of post-harvest loss. Therefore, urgent attention is required to implement post-harvest handling technology in order to increase fresh vegetable supply and national economy.

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How to cite this article:

Brunda Devi, K., Pavan Kumar Pindi, D.S.R. Rajender Singh and Bhadraiah, B. 2016. Study on Fungi Associated with Tuber Vegetables during Storage in Markets of Telangana State, India. *Int.J.Curr.Microbiol.App.Sci.* 5(12): 919-929.
doi: http://dx.doi.org/10.20546/ijcmas.2016.512.100