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Studies on certain aspects of root surface fungi

II. Succession of fungi on decomposing Pennisetum typhoides (Burm. f.) Stapf et Hubb. **

R. S. KANAUJIA *

Department of Botany, University of Gorakhpur
Gorakhpur (U. P.), India

Kanaujia R. S.: *Studies on certain aspects of root surface fungi. II. Succession of fungi on decomposing Pennisetum typhoides (Burm. f.) Staff et Hubb.*, Acta Mycol. 17: 27-40, 1981.

Sixty seven fungal species from the nonrhizosphere (NR), rhizopshere (RS) and cortical (RPC) and steler (RPS) parts of rhizopshere of crown (RC), middle (RM) and distal (RD) regions of decomposing roots of *Pennisetum typhoides* Burm. f.) Stapf. et Hubb. were isolated during December to June, 1970-72. The number of fungal species gradually decreased from NR—RPS in horizontal and RC—RD in vertical regions. The fungal population was always higher in RS of different depths than in corresponding NR regions. The amino acids and sugar components of the roots showed a direct correlation with the fungal population. The amount of cellulose, hemicellulose and lignin components of roots gradually decreased from December to June. Root-washing collected from RC, RM and RD regions exhibited the presence of vanillic acid and 3-4 dihydroxy benzoic acid during March and April. It also exerted an adverse effect on the 10 rhizosphere fungi during this period. pH and moisture contents showed a poor correlation with the fungal population except during summer months. *Phycomycetes* with species of *Deuteromycetes* obtained in the first phase were followed by *Deuteromycetes* along with few *Ascomycetes* in the second phase. In the last *Deuteromycetes* with some sterile mycelia were isolated. Aspergilli were the most numerous throughout the present investigation.

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* Present address: Department of Botany, K. S. Saket Post-Graduate College (Awadh University), Faizabad (U. P.), India.

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INTRODUCTION

In the present paper the succession of fungi on above stated three root-regions of decomposing *P. typhoides* (Burm. f.) Stapf. et Hubb. has been studied. The fungal succession on decomposing roots in relation to amino acids, sugars, cellulose, hemicellulose and lignin components of roots, the liberation of phytotoxins, their effects on rhizosphere fungi and physico-chemical characters of the soil has been investigated.

MATERIALS AND METHODS

Pennisetum typhoides (Burm. f.) Stapf et Hubb., raised in the experimental plot situated on the campus of University of Gorakhpur, was selected in the present study. The first sampling of roots from crown (RC), middle (RM) and distal (RD) regions of plants and corresponding nonrhizosphere (NR) was completed on December 25, 1970 and again on the same date of 1971 when aerial parts of the plants were dead. The sampling was performed by method adopted by Kanaujia (1973). The subsequent samplings were made monthly till the roots were completely decomposed in the month of June. The isolation of mycoflora of NR, RS and cortical (RPS) and steler portions of rhizoplane was done using the method described by Kanaujia (1973). The fungal population per g dry soil for NR and per g soil and root for RS regions was calculated.

The amino acids and sugars present in the root extracts (prepared from the part of roots sampled every time) of RC, RM and RD regions of root were detected by unidirectional paper chromatography (Smith 1960a, 1960b) and calorimetrically (Paeach, Tracey 1955). The cellulose, hemicellulose and lignin components of the roots of the above three depths were separately estimated (Peach et Tracey 1955) and amounts were expressed as percentage of the initial dry weight of the roots.

The washings of decomposing roots from RC, RM and RD regions were collected (Kanaujia 1973) on respective sampling dates and their effect on 10 rhizosphere fungi (*Rhizopus nigricans, Trichoderma viride, Aspergillus flavus, A. aculeatus, A. terreus A. sydowi, A. flavipes, Chaetomium apiculatum, Monilia sitophila* and *Fusarium nivale*) was examined by the hanging drop method. The detection of phytotoxins in the root-washing was done by unidirectional paper chromatography (Smith 1960c; Hathway 1960).

The moisture content and pH of nonrhizosphere soil from correspond-

ing RC, RM and RD regions was determined by methods of Piper (1944).

RESULTS

Sixty seven fungal species comprising 10 spp. of *Phycomycetes*, 4 of *Ascomycetes*, 46 of *Deuteromycetes*, one of mycelia sterilia and 6 of sterile colonies were isolated from RC, RM and RD zones of NR, RS, RPC and RPS of roots during December to June of 1970-1971 and 1971--1972 (Table 2).

Horizontal distribution of fungi

Fifty eight, 49, 33 and 30 fungal species were recorded from NR, RS, RPC and RPS regions of roots respectively. Eight, 4, 41, 1 and 4 fungi

Table 1

Fungi isolated from the soil of Pennisetum typhoides

Fungi	Root regions							Total
	horizontal				wertical			
	NR	RS	RPC	RPS	RC	RM	RD	
PHYCOMYCETES								
Rhizopus	2	3	1	1	3	2	1	3
Mucor	3	2	1	1	2	3	3	3
Other spp.	3	2	1		3	1	4	4
ASCOMYCETES								
Chaetomium	2	1	1	1	2	2	2	2
Other spp.	2	1			1	1	2	2
DEUTEROMYCETES								
Aspergillus	11	11	8	7	11	10	11	14
Penicillium	6	4	3	2	6	5	5	6
Cladosporium	3	3	2	2	3	3	3	3
Curvularia	3	3	1	1	3	3	3	3
Fusarium	4	4	5	5	5	5	5	5
Other spp.	14	11	4	4	12	9	11	15
MYCELIA STERILIA								
Rhizoctonia solani	1		1	1	1		1	1
STERILE COLONIES	4	4	5	5	6	6	4	6
Total	58	49	33	30	57	51	52	67

NR - nonrhizosphere, RS - rhizosphere, RPC - cortical, RPS - steler, RC - crown, RM - middle, RD - distal

of *Phycomycetes*, *Ascomycetes*, *Deuteromycetes*, mycelia sterilia and sterile colonies respectively from NR; 7, 2, 36 and 4 species of *Phycomycetes*, *Ascomycetes*, *Deuteromycetes* and sterile colonies respectively from RS; 3 *Phycomycetes*, 1 each of *Ascomycetes*, and *Mycelia sterilia*, 23 *Deuteromycetes* and 5 sterile colonies from cortical part of rhizoplane were isolated. The number of fungi belonging to different groups in steler portions of rhizoplane was similar to that of cortical one except one *Phycomycetes* which was higher (Table 1). Fourteen, 5 and 1 species were confined to NR, RS and RPC regions respectively. Thus, 44 out of

Table 2
Distribution of fungi in different regions of decomposing Pennisetum typhoides root

Species	Root regions											
	crown				middle				distal			
	NR	RS	RPC	RPS	NR	RS	RPC	RPS	NR	RS	RPC	RPS
Absidia spinosa Lendn.	+				+	+						
Rhizopus oryzae Went. et Prins.Geerl.	+	+										
R. nigricans Ehrenb.	+	+	+	+	+	+	+	+	+	+	+	+
Mucor hiemalis Wehm.	+	+	+	+	+	+	+	+	+	+	+	+
M. racemosus Fres.									+			
Zygorhynhus heterogamus /Vuill/ Vuill.	+	+			+	+			+			
Choanephora cucurbitarum /Berk.et Rav./Thaxt.			+									
Cunninghamella echinulata /Thaxt./ Thaxt.	+	+				+			+	+	+	
Pythium ultimum Trow.					+							
Chaetomium apiculatum B.C.Lodha	+				+				+			
C. globosum Kunze	+	+	+	+	+	+	+	+	+		+	
Lophotrichus sp.									+			
Pheotrichum sp.	+	+			+				+			
Phoma hibernica Grimms, O'Con.et Cumm.	+	+	+	+	+	+	+	+	+	+	+	+
P. humicola Gilman et Abbolt	+	+	+	+	+	+	+	+	+	+	+	+
Monilia sitophila Mont. et Sacc.	+					+						
Trichoderma viride Pers. et Fr.	+	+	+	+	+	+	+	+	+	+	+	+
Aspergillus aculeatus Lizuka	+	+	+	+	+	+	+	+	+	+	+	+
A. carneus /v.Tiegh./ Bloch.	+											
A. flavipes Berk. et Br.		+								+		
A. flavus Link	+	+	+	+	+	+	+	+	+	+	+	+
A. fumigatus Fres.	+	+	+	+	+	+	+	+	+	+	+	
A. sp.									+			
A. nidulans /Eid./ Wint.	+	+	+		+	+	+		+	+	+	
A. niger v. Tiegh.	+	+	+	+	+	+	+	+	+	+	+	+
A. niger v. Tiegh. /2/						+						
A. ochraceous Wilhelm	+		+	+	+		+	+	+	+	+	
A. sydowi /Bain. et Sart./ Thom					+				+			
A. tanarii Kita		+										
A. terreus Thom	+	+	+	+	+	+	+	+	+	+	+	
A. ustus /Bain./ Thom et Church	+	+	+		+	+	+		+	+	+	+
Penicillium chrysogenum Thom	+	+	+	+	+	+	+	+	+	+	+	+
P. humicola Oud.	+	+			+	+		+	+	+		+
P. lanosum Westl.	+											
P. nigricans /Bain./ Thom	+	+				+			+	+		
P. notatum Westl.	+				+				+		+	
P. spiculisporum Lehm.		+	+		+	+			+	+		
Cladosporium epiphyllum /Pers./ Martius	+	+	+	+	+	+	+	+	+	+	+	+
C. herbarum Link ex Fr.	+	+	+	+	+	+	+	+	+	+	+	+
C. sp.	+	+				+				+		
Gliocladium fimbriatum Gilm. et Abb.									+	+		
G. roseum Link		+										
Humicola fusco-atra Traen									+	+		
Verticillium terrestre /Link/ Lindau									+			
Paecilomyces fusisporus Saksena	+	+			+	+			+	+		
P. varioti Bain.	+				+				+			
Stachybotrys atra Cords	+	+										
Curvularia lunata /Wakker/	+	+		+	+		+		+	+	+	+
C. palescens Boedijn	+	+			+				+	+		
C. tetramera /McKinney/ Boedijn	+				+				+	+		
Alternaria alternata Fr.	+	+	+		+	+	+	+	+	+	+	+
Helminthosporium sativum Pammel, Kirg. et Bakke		+			+					+		
Pestalotia sp.	+				+							
Myrothecium roridum Tode ex Fr.									+			
Fusarium avenaceum /Fr./ Sacc.			+	+	+		+	+			+	+
F. moniliforme Sheld	+	+	+	+	+	+			+	+		
F. nivale /Fr./ Ces.	+	+	+	+	+	+	+	+	+	+	+	+
F. oxysporum Schlecht.em.Snyder et Huds.	+	+	+				+	+	+	+	+	+
F. roseum Link		+	+			+	+	+			+	
Rhizoctonia solani Kühn.	+		+								+	+
White sterile colonies /W$_1$/	+	+	+	+	+	+	+	+	+	+	+	+
White sterile colonies /W$_2$/			+	+		+						
Creamy sterile colonies	+				+				+			
Black sterile colonies	+	+	+	+	+	+	+		+	+	+	+
Brown sterile colonies				+			+	+				
Grey sterile colonies	+	+	+		+	+			+	+	+	+
Total	46	40	38	23	42	34	26	23	46	37	28	22

58 species from NR could reach the RS region. This number was reduced to 32 in RPC and 30 in Steler regions. The overall succession of fungi from NR → RS, RS → RPC and RPC → RPS was 58 → 44, 49 → → 32, and 33 → 30 respectively (Table 1). Out of 67 fungi isolated in

Table 3
Distribution of dominant fungi in horizontal and vertical different regions of decomposing Pennisetum typhoides roots

Species	Root regions						
	horizontal				vertical		
	NR	RS	RPC	RPS	RC	RM	RD
Rhizopus nigricans	+				+		
Mucor hiemelis				+	+		
Aspergillus aculeatus		+				+	
A. flavus	+	+	+	+	+	+	+
A. niger	+	+	+		+	+	+
A. fumigatus	+				+		+
A. terreus			+			+	
Penicillium chrysogenum	+		+	+	+		+
Cladosporium herbarum	+	+	+	+	+	+	+
C. epiphyllum	+	+	+	+	+	+	+
Fusarium avenaceum				+			+
F. nivale	+	+	+	+	+	+	+
F. oxysporum				+		+	
White sterile cols/Wl/	+	+	+	+	+	+	+
Black sterile Cols.				+			+

/Explanation - see table 1/

the present study, 12 were commonly distributed in all the root regions and nonrhizosphere soil (Table 2). Fifteen fungal isolates (Table 3) were found to be dominantly associated with different root regions and nonrhizosphere soil.

The fungal population (present in one of dry soil in NR and per g dry soil and root in RS) exhibited a regular pattern. In the NR region the population was always lesser than in RS. In the RS region fungal propagules per g dry soil were always greater than in per g dry root (Fig. 1).

In NR region the highest fungal population was recorded in December. It decreased gradually till June when the lowest population was noticed in this region.

In the RS region, the population exhibited a trend similar to NR, except that sudden decrease in the population was noticed in March (RM and RD) and April (RC, RM and RD) in the zones indicated in the brackets (Fig. 1).

Vertical distributions of mycoflora

Fifty seven, 51 and 52 fungal species were recorded from all the 3 root regions and NR of crown, middle and distal zones respectively. Eight *Phycomycetes*, 3 *Ascomycetes*, 40 *Deuteromycetes*, 1 *Mycelia sterilia* and 6 sterile colonies from the crown region; 6, 3, 3, 5 and 6 species of *Phycomycetes, Ascomycetes, Deuteromycetes* and sterile colonies re-

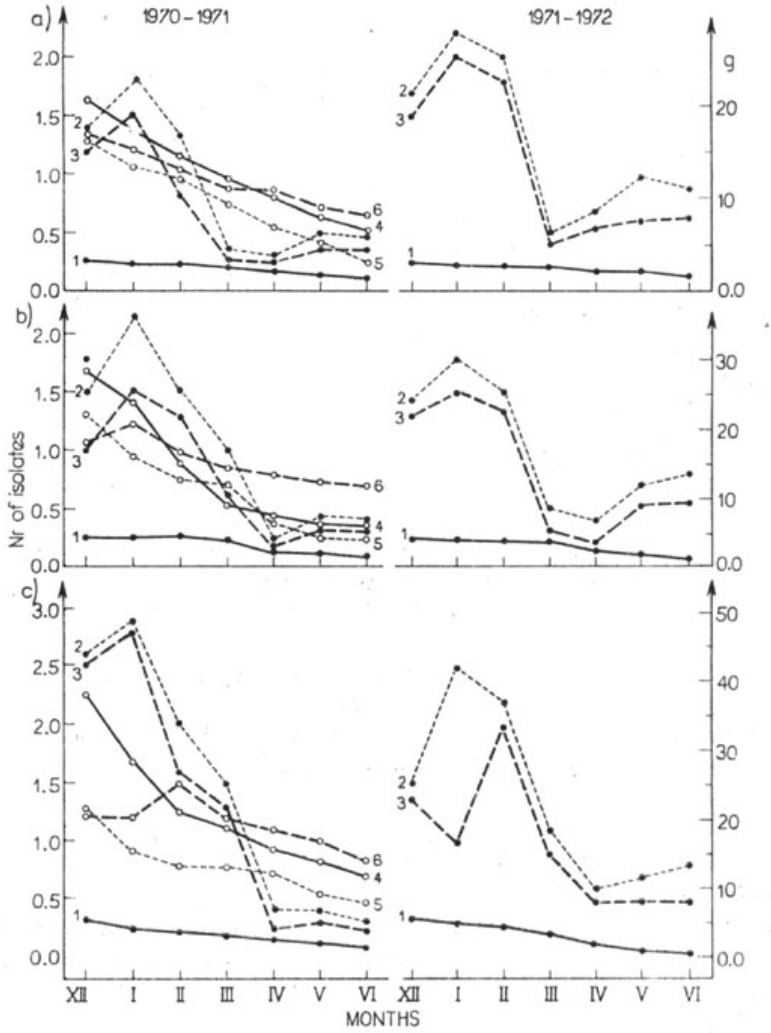

Fig. 1. Celluloses, hemicelluloses and lignins of roots and fungal population of crown, middle and distal regions of nonrhizosphere and rhizosphere of *Pennisetum typhoides*

a — distal zone, *b* — middle zone, *c* — crown zone; *1* — nonrhizosphere (× 10^5) g dry soil; *2* — rhizosphere (× 10^8) g dry soil; *3* — rhizosphere (× 10^6) g dry root; *4* — cellulose, *5* — hemicellulose and *6* — lignin, (initial dry wt. of root)

spectively from middle region; and 8 spp. of *Phycomycetes*, 4 of *Ascomycetes*. 38 of *Deuteromycetes*, one of *Mycelia sterilia* and 4 of sterile colonies from distal region were isolated. Aspergilli followed by *Penicillia* and *Fusaria* were the most numerous in the present study (Table 1). Forty two fungi were commonly present in all the 3 vertical zones, whereas 7, 3 and 5 were solely confined to RC, RM and RD regions respectively (Table 2). Out of 15 dominant fungal isolates, 10, 9, 10 were observed in RC, RM and RD regions respectively (Table 3).

With few exceptions, the distributional pattern of number of fungal species in different root regions at different stages of decomposition exhibited the trend normally reported by many workers (S r i v a s t a v a 1969; K a n a u j i a 1973).

The fungal population away from the root influence exhibited following trend: during December to March the population was highest in the upper horizon (RC) and lowest in the distal one whereas from April to June it exceeded in the distal region (Fig. 1). The population at root surface during December to March was maximum in crown region and afterwards it was maximum in the distal region. A low population was found in the middle and distal regions in March and in all the three vertical regions in April of both the years (Fig. 1).

Amino acids

Fifteen amino acids (Table 4) were chromatogrammed in the root extracts from the three depths. Alanine, methionine, valine, iso-leucine and threonine were frequently isolated whereas the remaining amino acids were of less common. The number of amino acids generally decreased gradually from December to June. The amount of individual amino acids differed in different sets. The free amino acid content (mg/2 g fresh roots) gradually decreased in 3 depths from beginning to the total decomposition of the roots (Table 4).

Sugars

The sugars (Table 4) were detected chromatographically from December till June. Glucose and xylose were present in all the root regions at different stages of decomposition of root. Few sugars, hewever, were of restricted distribution. The amount and number of sugars showed a pattern similar to that of amino acids.

Cellulose, hemicellulose and lignin

The amount of cellulose, hemicellulose and lignin were generally

Table 4

Amino acids/sugars in the root extracts of crown /RC/, middle /RM/ and distal /RD/ regions of decomposing P. typhoides root in different months

Root regions		Amico acids/Sugars																No.of acids/ sugars	Amount of acids/sugars /ug/2g fresh root/
		Alanine / Arabitose	Arginine / Deoxyribose	Cystein / Glucose	Glutamic Acid / Lactose	Glycine / Mannose	Histidine / Rhamnose	Iso-leucine / Ribose	Leucine / Sucrose	Lysine / Xylose	Methionine / Unidentified sugars	Proline	Serine	Threonine	Tryptophane	Valine			
December 1970 /pre decomp/	RC	75	175	25/+	25		85/+		80	-/+				50	90	100		7/3	705/875
	RM	50	90	-/+			50/+	75	210	-/+	50				80			7/3	600/530
	RD	105	110	125/+	80		50/+	-/+	120	-/+	55			100	25	90		10/4	860/970
January 1971 /partial dec./	RC	50		-/+		-/+	-/+	90/+	87	-/+	80			35		70		6/5	412/630
	RM			-/+		110/+	-/+	50	70	60/+		25	40			T		7/4	355/450
	RD		30	-/+		100/+	-/+	90	110	100/+	-/+		60	45		30		8/5	565/732
February	RC	45	75	-/+	T		-/+	50/+		T/+	50							6/4	220/500
	RM		70	-/+	T			35		45/+	T						T	6/2	150/275
	RD	88	T/+	-/+			-/+	60	-/+	50/+	25					25		6/5	248/520
March /semi dec./	RC	30		60/+	-/+	T		-/+	-/+	T/+	40						T	7/5	130/220
	RM	T		-/+				-/+		25/+	T		T				T	5/3	25/125
	RD	50	-/+	25/+		25			-/+	40/+	T		T				T	7/4	140/370
April	RC			-/+			-/+	25	T	-/+	25			25		25		5/3	100/200
	RM			-/+			-/+	T		-/+	T			30		T		4/3	30/100
	RD	-/+		-/+			-/+	40		-/+	T			40		T		4/4	80/250
May /Dec./	RC			-/+				25		-/+	25			25				3/2	50/170
	RM			-/+				T										2/1	T/80
	RD			-/+				T		-/+	T			25				3/2	25/T
June	RC			-/+				T		-/+				25				2/2	25/40
	RM			-/+				T						T				2/1	T/15
	RD			-/+				T		-/+	T			T				3/2	T/T

T - present in traces

highest in the month of December and exhibited a decreasing tendency in the succeding months. The cellulose and hemicellulose showed more rapid degradation than lignin (Fig. 1).

Effect of washing of decomposed roots on the germination of fungi

Nine rhizosphere and 1 nonrhizosphere fungus germinated up to varying degree in the washing of roots decomposed for different time. A fradual increase in the germination of spores of majority of test fungi in the root washing of all the 3 vertical depths was observed up to February. During March washing of RM and RD regions of root and in April washing of all the 3 regions appreciably decreased the germination of all the test fungi. In succeeding months (May and June) the germination of *Chaetomium apiculatum* and *Monilia sitophila* however, was all the times lower than the control (Table 5).

Release of phyto-toxins by decomposing roots

Root washings from RC, RM and RD regions were found to certain phytotoxins. Vanillic acid was commonly detected by roots of RM and

Table 5

Fungitoxic property /expressed as percentage of spore germination/ of root washings from crown /RC/, middle /RM/ and distal /RD/regions of decomposing P. typhoides roots in soil

Root washings		A. nigricans	T. viride	A. flavus	A. aculeatus	A. terreus	A. sydowi	A. flavipes	C. apiculatum	Monilia sitophila	P. nivale
December	RC	70	75	67	59	70	53	60	17	36	100
	RM	60	69	68	58	67	49	66	10	40	93
	RD	76	80	72	62	76	58	59	20	50	100
	Control	60	67	65	56	60	40	47	37	67	80
January	RC	74	78	73	68	73	56	63	23	47	100
	RM	64	72	70	67	74	52	60	18	49	95
	RD	83	79	79	70	79	62	47	24	50	100
	Control	55	63	60	53	61	45	30	36	59	81
February	RC	76	79	80	74	78	63	59	25	47	100
	RM	66	67	73	72	74	57	64	17	53	100
	RD	89	92	86	76	80	70	50	25	52	100
	Control	51	51	60	60	60	43	33	60	57	80
March	RC	72	75	83	78	79	60	55	10	40	100
	RM	43	55	48	43	50	32	30	4	38	63
	RD	35	49	32	47	45	30	24	7	20	66
	Control	50	63	61	61	65	40	35	35	60	85
April	RC	40	36	49	45	26	17	23	8	30	57
	RM	28	19	36	18	17	12	17	4	40	45
	RD	36	23	37	29	29	26	24	5	28	53
	Control	55	55	63	63	60	41	48	43	63	80
May	RC	51	57	63	67	69	52	38	12	45	89
	RM	52	55	60	56	55	46	48	10	20	85
	RD	58	59	67	69	72	73	46	16	34	86
	Control	50	50	62	60	63	42	33	41	61	83
June	RC	58	63	66	70	75	56	55	17	47	100
	RM	60	60	65	63	66	49	60	16	66	100
	RD	67	73	70	79	80	75	50	19	50	100
	Control	53	50	65	60	60	43	40	43	63	80

RD regions both in March and April, and 3-4 dihydroxy benzoic acid in RM and RC regions during March and April respectively were detected (Fig. 2).

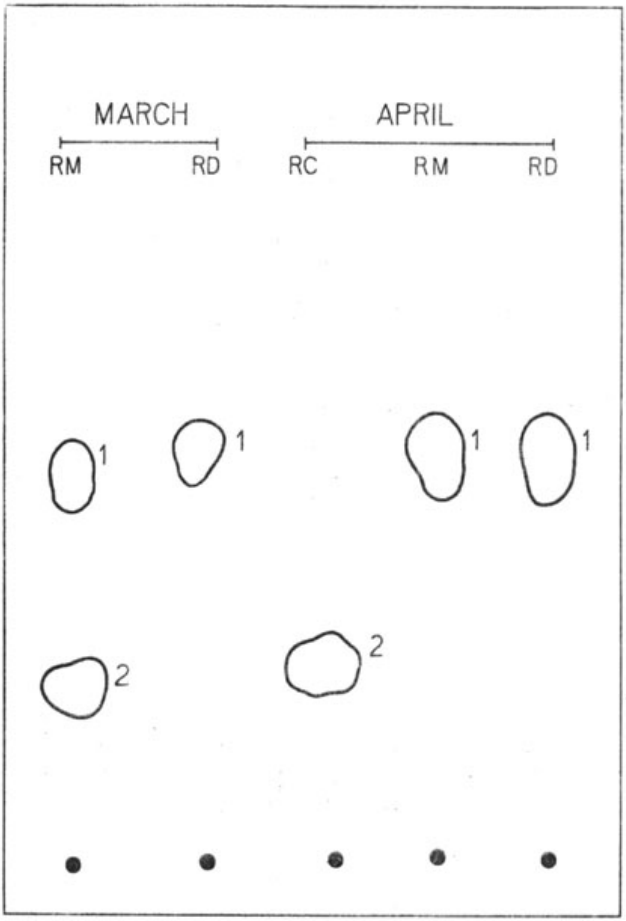

Fig. 2. Detection of phytotoxins (1 — vanillic acid, 2 — 3, 4-dihydroxybenzoic acid) in the washings of decomposing roots of Pennisetum typhoides in the crown (RC), middle (RM), and distal (RD) regions

pH and moisture content of the soil

The pH and moisture content of different vertical regions of root at different stages of decomposition varied to a little extent. (Fig. 3).

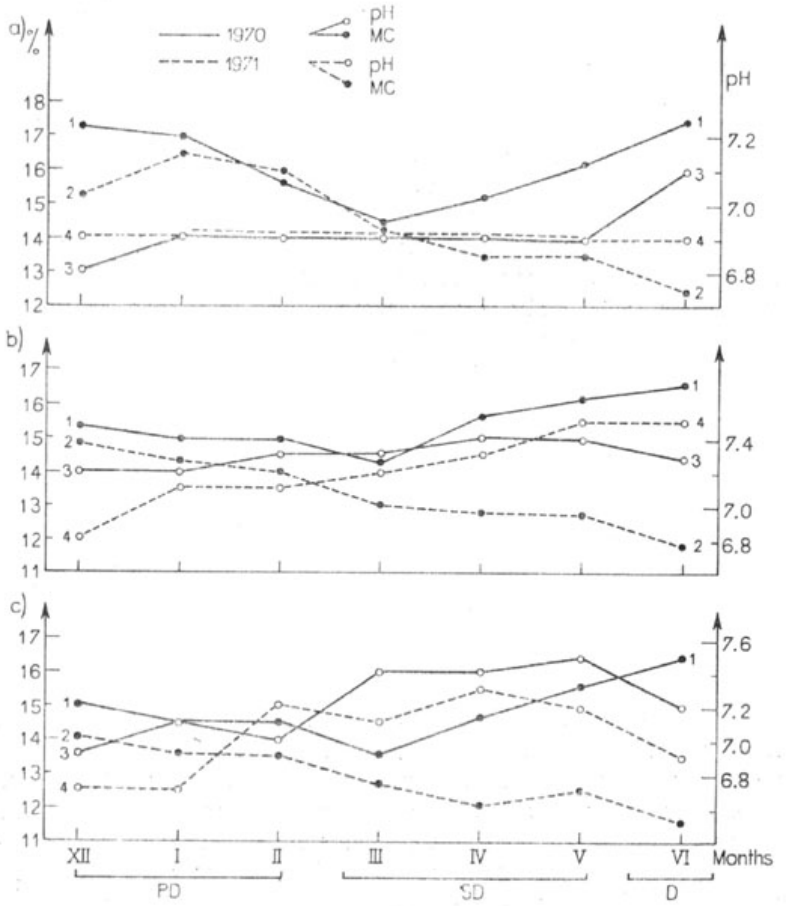

Fig. 3. Moisture content (MC in %) and pH of crown (*c*), middle (*b*) and distal (*a*) regions of *Pennisetum typhoides* plot
1 — MC 1970-71, *2* — MC 1971-72, *3* — pH 1970-71, *4* — pH 1971-72

DISCUSSION

A greater number of fungal species was recorded from nonrhizosphere of all the 3 vertical regions than corresponding root surfaces of rhizosphere and the number of species in the cortical part of the roots was always greater than steler one of the rhizoplane (Table 1). On the other hand, the fungal population at root surface was every time greater than NR (Fig. 1).

The soil is a unique assemblage of various micro- and macroorganisms

like fungi, bacteria, actinomycetes, algae, protozoans, nematodes and other living and non-living entities both in active and passive phases (Garrett 1963). Fungi, which are show a wide range of nutritional requirement are more abundant in soils (Cochrane 1958). The rhizosphere region though nutritionally richer is a selective medium when not all organisms can grow. Thus, quality of fungi in the rhizosphere region of root is always accepted to be lesser than the corresponding NR one. Moreover, due to competition which is more intense in between species with similar nutritional requirements, out of a large number of fungi present in NR only certain forms having high saprophytic ability are able to reach the RS region (Garrett 1963) and this explains the isolation of less fungi in RS than NR in the present study.

Many workers have reported a lower number of fungal species at root surface than away from it (Bhat 1966; Gylenberg 1957; Kanaujia 1973; Mishra, Kanaujia 1974; Srivastava 1969; Subba-Rao, Baily 1961; Vidal, Vinosa 1965).

The fungal population at the root surface always greater than in NR (Fig. 1). The root surface is nutritionally richer than the NR region due to decomposition of root tissues (Table 4) which provide a variety of nutrients like amino acids, sugars, organic acids and other breakdown products of roots to fungi and resulted in the higher population in this region.

The number of fungal species was higher in cortical part of the rhizoplane region than in the steler one. The cortical part is composed of comparatively soft tissues as compared to steler regions. Soft tissues are likely to be decomposed earlier than hard ones by microorganisms (Garrett 1963). The cortical part being softer and situated ou twards provides comparatively more free surface and is, therefore, easily approachable to by fungi than intact inner steler and thus, there are more fungi in the cortical part than in the steler one (Tables 1, 2).

Many species were commonly distributed in different horizontal root regions; few were confined in their occurrence; some appeared earlier and persisted for a short duration and vice-versa. The common substrate variations in quality and quantity of amino acids and sugars (Table 4) accounted for their varying distributional patterns. The restricted nature of some of the species in different root regions may be ascribed to the selective behaviour of roots and their components which is further confirmed by spore germination studies of some of the fungi in root washing (Table 5).

From december to march the highest population was recorded in the crown region (Fig. 1). Most of the roots in crown region at this stage being quite older provide sloughed-off materials for microbial co-

lonization. Simultaneously few newly formed stilt roots in association with older living roots probably added certain amount of root exudates for the microbes. Thus, due to combined effect of dead sloughed-off root tissues and root exudates, the nutritional level in this region at this stage was raised which accounted for higher fungal population (Fig. 1). Considerably low population in the middle and distal regions during march and in all the regions in april may be ascribed to the liberation of phytotoxins by decomposing root tissues (Fig. 2). This has further been confirmed with the spore germination studies of some rhizosphere fungi in the root washings where lowering of the germination of various test organisms was recorded (Table 5).

The higher fungal population in the upper horizon has been reported by many workers (Cobbs 1932; Dwivedi 1966; Dwivedi, Dwivedi 1971; Kanaujia 1973; Mishra, Kanaujia 1972; Saksena 1969; Srivastava 1969; Thornton 1956). Thornton (1956) attributed lesser micropopulation at lower depth due to decreased organic matter. During hot summer months higher fungal population in lower depths may be ascribed to the suitable temperature and moisture status of the sublayers (Fig. 3).

On a virgin substrate during the course of normal fungal succession, the fungi which appear first are those which utilize most simple form of nutrients. These are called "sugar fungi — loving fungi". Most of the phycomycetes fall in this group. The second which follow the sugar fungi are hemicellulose and cellulose decomposers. These constitute species of *Ascomycetes* and few *Deuteromycetes*, and in the last fungi appearing, are lignin decomposers which comprise species of *Basidiomycetes* and some *Deuteromycetes*. The above schematic pattern of fungal succession has been proposed by Garrett (1963). In the present study, however, *Phycomycetes* along with several *Deuteromycetes* appeared in the first phase. These were followed many species of *Deuteromycetes* along with few *Ascomycetes*; and in the last phase, the species of second category of Garrett were recorded. The simultaneous appearance of *Deuteromycetes* along with *Phycomycetes* in the beginning, their dominance in the second and third phases may possibly be due to their wide range of nutritional liking (Cochrane 1958). Sterile mycelia were prevalent at the stage when the decomposition of the root was approaching to completion. The decreased nutritional status possibly led to the sterility of many pre-existing forms at this stage.

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REFERENCES

Bhat S., 1966, Age as a factor in the rhizosphere mycoflora of leguminous plants. Thesis, B. H. U., Varanasi.

Cobbs M. J., 1932, A quantitative population of a hemlock and a deciduos forest soil. Soil Sci. 33: 325-345.

Cochrane V. W., 1958, Physiology of Fungi, pp. 524. J. Wiley and Sons, INC, New York. Repr. Toppan Print. Co. Japan.

Dwivedi R. S., 1966, Ecology of soil fungi of some grasslands of Varanasi. II. Trop. Ecol., 7: 84-99.

Dwivedi R. S., Dwivedi, Rajpati, 1971, Ecology of soil fungi of a sal forest with emphasis on soil fungistasis. Plant and Soil 34: 33-42.

Garrett S. D., 1951, Ecological groups of soil fungi. A survey of substrate relationships. New Phytol. 50: 149-166.

Garret S. D., 1963, Soil Fungi and Soil Fertility, pp. 165. Mac-Millan Co., New York.

Hathway D. E., 1960, Plant phenols and tannius. [In:] Chromatographic and Electrophorelic Techniques. 1: 308-354. ed., I. Smith, London, W. Heinmann Medical Books.

Kanaujia R. S., 1973, Studies on succession of fungi on rootregions of *Pennisetum typhoides* (Burm f.) Stapf et Hubb., Thesis, Univ. Gorakhpur, India.

Kanaujia R. S., (Unpubl.), Studies on certain aspects of root surface fungi. I. (Communic. to Anales de Edafol. Agrobiol., Spain).

Mishra R. R., Kanaujia R. S., 1972, Certain ecological aspects of soil fungi. III. Proc. Nat. Acad. Sci., 42-B (P. II): 131-140.

Mishra R. R. and Kanaujia R. S., 1974, Investigations into rhizosphere mycoflora. VIII. Technology 10: 66-69.

Peach K., Tracey M. V., 1955, Modern Methods of Plant Analysis. Berlin. Springer Verl.

Piper C. S., 1966, Soil and Plant Analysis. Bombay. Hans Public.

Saksena R. K., 1969, Some recent advances in the study of fungal root diseases. Indian phytopathol. 22: 1-17.

Smith I., 1960a, Amino acids, amides and related compounds. [In:] 1: 82-142, ed. I. Smith. W. Heinmann Medical Books, London.

Smith I., 1960b, Sugars and related compounds. Ibid. 1: 246-260.

Smith I., 1960c, Phenolic acids. Ibid. 1: 291-307.

Srivastava V. B., 1969, Investigations into rhizosphere microflora of certain crop plants. Thesis, Univ. Gorakhpur, India.

Subba Rao N. S., Baily D. L., 1961, Rhizosphere studies in relation to varietal resistance or susceptibility. Canad. J. Bot., 39: 1747-1753.

Thornton R. H., 1956, Fungi occurring in mixed oak wood and healthy soil profiles, Trans. Brit. Mycol. Soc., 39: 485-495.

Vidal G., Vinola L., 1965, Etude de la mycoflorae de la rhizosphere de tois leguminoses, Ann. Pasteur, 108: 535-540.