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Diversity of Arbuscular Mycorrhizal Fungi (AMF) on the Coastal Saline Soils of the West Coast of Kerala, Southern India

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Abstract: There is a rich diversity of arbuscular mycorrhizal (AM) fungi, which are associated with the *Ipomoea pes-carpae* and *Phyla nodiflora.* They grow in coastal saline soils of the five districts of the west coast of Kerala, Southern India. Their diversity was stuided in the four different cultivation seasons viz., south-west monsoon, North-east monsoon, summer and late summer. Soil and root samples were analysed for rhizosphere edaphic features, spore density, root colorization, species richess and diversity of AM fungi. The survey revealed the occurrence of 35 species of AM fungi belonging to six genera viz., *Acaulospora, Entrophospora, Glomus, Gigaspora, Sclerocystis* and *Scutellospora.* Members of the Glomaceae family dominated (51.4%) followed by Gigasporaceae (28.6%) and Acaulosporaceae (20.0%). The number of AM fungal species recovered per plant from *I. pes-caprae* ranged from 1 to 22 whereas in *p. nodiflora* it ranged from 1 to 12.Species richness were highest during summer and late summer seasons for both plants and thay were significantly correlated with soil pH, calcium, phosphorous and percent of root colorization.

Key words: *Ipomoea pes-carpae* · *Phyla nodiflora* · AM fungi · Monsoon and summer seasons

INTRODUCTION

AM fungi play a vital role in primary and secondary succession of plant species, especially in low nutrient soil ecosystems found in costal sand dunes. Increased nutrient supply, salinity tolerance, reduced abiotic stresses and formation of wind-resistent aggregates are the major benefits derived from AM fungal association with these plants [1-2].

The distribution of AM Fungi in different ecological regions and their relations to soil properties and native plants have been investigated by several researchers [3-7] Relatively large populations of these fungi have been reported in some saline soils [8,9].

Ipomoea pes-carpae (L.) R. Br. (Convolvulaceae) is a dominant and widely distributed stoloniferous creeping sand binder in tropical sand dunes. *Ipomoea pes-caprae* and *Phyla nodiflora* were found on the coastal saline soils of different study localities in the west coast of Kerala, Southern India. Measuring the biodiversity of AM fungi associated with these two plant species helps to understand the ecology of the habitat and to develop the conservation strategies. The present study deals with the colonization, species richness and diversity of AM fungi associated with *I. Pes-caprae* and *Phyla nodiflora* in relation to the rhizosphere edaphic features during the monsoon and summer seasons in five localities on the west coast of Kerala.

MATERIALS AND METHODS

Sampling Area: AM fungi associated *Ipomoea pes-caprae* and *Phyla nodiflora* were collected from 5 different coastal saline soil localities in five districts along the west coast of Kerala, Southern India during the four major seasons viz., South-west monsoon (June-August), North-east monsoon (September-November), Summer (December-February) and late summer (March-May).

The sampling area characterized with little variations in climatic parameters among the seasons. The atmospheric temperature normally ranged from 28 to 32°C (82 to 90°F) on the plains but dropped to about 20°C (68°F) in the high lands during the study time. The localities experienced a rich annual rainfall which was around 2600 mm. Ninety per cent of this precipitation was during the two monsoons, south west (about 60%) and north-east monsoons (about 30%).

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Sampling: Roots and rhizosphere soil samples (5 replicates from each study site) were collected from all the 25 study localities in the five districts of the West Coast of Kerala. In each locality, an area of 1000 m^2 was chosen for sample collection. Five plants 10-15 m apart were selected for sampling. From each test plant, feeder roots of 2 mm diameter were collected. About 1000 g of soil sample from the rhizosphere of each plant at a depth of 15-30 cm was collected in poly ethylene bags and stored at 5°C before processing. The root samples were washed thoroughly to remove the adhered soil particles and then cut into several small segments and fixed in FAA in the field itself and then differentially stained with 0.05% trypan blue in lactophenol [10].

Determination of Soil-edaphic Characteristics: Rhizosphere soil samples of both plants were collected separately from each study site. A portion of the soil was analysed for soil texture, pH, EC_{se}, organic matter, moisture, N, P, K, Ca, Na and Cl with the help of standard methods [11,12,13]. From the remaining soil sample, 100 g was used to estimate AM fungal spore number per sample bag.

Colonization and Spore Density: Colonization of AM fungi was assessed by staining the root pieces in 0.05% tryphan blue [10]. The percentage of root colonization of both test plants was estimated [14]. The spore density in 100g of air-dried rhizosphere soil was assessed by using wet-sieving and decanting technique [15] as modified by the floatation-adhesion technique [16].

Different species of AM fungal spores were also stored separately in Ringer's solution for further studies and mass multiplication. The spores and sporocarps were identified using the synoptic keys [17-18].

Statistical Analysis: Character differences among the twenty-five rhizosphere edaphic samples were studied by employing independent sample t-test. The test was also performed to understand the differences in the colonization, spore density and species richness of the twenty-five localities in relation to the four different seasons. Variations in AM fungal species richness and spore density in relation to pH, organic carbon, sodium, calcium and phosphorus were determined by Karl Pearson's Correlation Analysis [19].

From the data obtained, the spore density and richness for each sampled site were worked out based on the equation proposed by Whittaker [20]. The diversity of AM fungi in the twenty-five localities was studied with the help of Simpson's and Shannon index [21]. Paired t-test was performed to assess the differences in diversity among the 25 localities [22].

RESULTS

Rhizosphere Edaphic Features: The physico-chemical characteristics of the soils of 25 different study localities indicated that the soils were neither totally neutral nor highly alkaline (pH 7.4 – 8.8) with a low to moderate high salinity. The ionic analysis of the soils indicated that sodium and chloride ions were more when salinity increases. Soil texture analysis indicated that the west coast of Kerala had mostly fine textured sandy and sandy loam soils. The available nitrogen content of the soils irrespective of the study localities was invariably high (47.92 mg g^{-1}). The soils were nutrient-deficient particularly with low organic carbon (0.12 – 0.67%) low phosphorus levels (16.5 – 53.62 mg g^{-1}) and moderate to high level of potassium (10.41 – 62.63 mg g^{-1}). The rhizosphere moisture content was highest during monsoon season (2.87 – 4.29%) while in summer (0.47 – 0.69%) it was low. The calcium content (75.63 – 176.64 mg g^{-1}) was maximum during the monsoon season. The organic carbon (0.12 – 0.65%) and chloride (72.12 – 176.28 mg g^{-1}) attained peaks during summer and late summer seasons (Table 2). Sodium content (26.2 – 180.9 mg g^{-1}) was very high during south-west and north-east monsoon seasons (Table 1), while potassium (12.41 – 22.25 mg g^{-1}) was less during summer and late summer seasons (Table 2).

Colonization and Spore Density: Both the plants studied tested positive for AM fungal colonization in the roots during all the four seasons. The percentage colonization of AM fungi in the roots however differed from locality to locality but there was no definite trend perceivable in AM colonization between monsoon seasons. Per cent root colonization in *I. pes-caprae* ranged from 10.1 – 49.5% during south-west monsoon, 16.5 – 66.2% in north-east monsoon, 15.0 – 94.5% summer season and 20.2 – 98.5% in late summer season whereas the per cent root colonization in *P. nodiflora* ranged from 10.5 – 58.5% in south-west monsoon, 32.4 – 65.4% in north-east monsoon, 38.5 – 78.3% in summer season and 42.4- 94.6% in late summer season. In general, the per cent root colonization was as low as 10.1 and 10.5% in test plants of *I. pes-caprae* and *P. nodiflora* respectively which

Table 1: Edaphic characteristics of rhizosphere soils of *Ipomoea pes-caprae* and *Phyla nodiflora* on coastal saline soils of west coast of Kerala during south west and north east monsoon seasons (n = 5; mean value)

							Macronutrients (mg g^{-1})			Micronutrients (mg g^{-1})		
District	Location	General soil texture	pH	Organic matter (%)	Moisture (%)	EC_{se}	N	P	K	Ca	Cl	Na
Alappuzha	Tottapalli	Sandy loam	7.65	0.36	3.06	0.10	38.58	35.99	62.63	113.02	77.13	38.51
	Ambalapuzha	Sandy	8.24	0.42	3.42	0.10	24.24	24.25	11.66	168.38	74.97	33.80
	Punnapra	Sandy	7.92	0.37	3.17	0.12	24.55	31.90	12.51	136.49	86.09	33.40
	Alappuzha beach	Sandy loam	7.85	0.27	3.47	0.10	30.16	33.70	15.64	138.39	88.75	34.70
	Chertala	Sandy loam	8.34	0.39	3.06	0.20	14.77	36.31	16.61	140.52	90.96	36.60
Kannur	Tellicherry	Sandy	8.35	0.26	4.15	0.25	14.93	36.35	20.25	144.94	88.95	36.30
	Payyambalam beach	Sandy loam	7.65	0.58	3.16	0.20	17.96	30.25	12.72	134.32	104.26	37.40
	Azhikkod	Laterite	7.96	0.64	2.87	0.30	37.56	28.96	12.94	160.37	87.19	38.60
	Mattul	Laterite	8.24	0.65	2.97	0.20	23.56	35.62	11.64	161.04	67.66	33.38
	Payangati	Sandy loam	8.35	0.62	2.92	0.10	29.16	23.20	11.64	182.64	66.13	33.72
Kollam	Paravur	Sandy loam	7.86	0.67	3.45	0.20	34.53	22.26	16.91	146.82	85.42	33.20
	Mundakkal	Sandy loam	7.94	0.64	3.18	0.20	35.88	35.84	15.64	81.63	106.16	33.50
	Tangasseri	Sandy loam	7.82	0.27	2.79	0.20	30.12	34.85	10.41	136.11	98.08	26.20
	Kanunagappalli	Sandy loam	7.84	0.22	3.74	0.10	13.92	33.26	12.81	168.25	98.07	36.40
	Clappana	Sandy loam	7.88	0.32	3.78	0.10	13.77	53.62	11.62	162.32	90.73	63.10
Malappuram	Ponnani	Sandy loam	8.34	0.44	3.65	0.20	44.05	28.91	11.84	164.95	70.34	80.90
	Purathur	Sandy loam	8.35	0.27	3.25	0.20	43.43	25.45	11.10	142.92	80.25	63.40
	Koottayi	Sandy loam	8.46	0.42	4.15	0.30	43.95	25.42	12.64	152.70	82.57	70.10
	Tanur	Sandy loam	8.25	0.32	4.29	0.20	47.92	33.58	12.76	108.25	86.24	32.90
	Parappanangadi	Sandy	8.34	0.37	4.15	0.10	44.53	24.25	13.60	136.26	92.58	26.60
Thiruvananthapuram	Puvar	Sandy loam	7.86	0.34	3.78	0.10	44.56	25.26	16.64	134.25	70.28	36.40
	Vizhinjam	Sandy loam	7.94	0.42	3.74	0.10	30.17	23.14	14.60	148.64	68.49	34.50
	Kovalam	Sandy loam	7.92	0.22	3.65	0.20	19.90	20.50	14.14	132.25	72.58	38.20
	Veli	Sandy loam	7.64	0.14	3.62	0.10	25.12	19.30	12.10	138.26	76.24	33.80
	Varkala	Sandy loam	7.85	0.16	3.75	0.10	14.93	18.60	12.13	118.13	70.44	35.30

Table 2: Edaphic characteristics of rhizosphere soils of *Ipomoea pes-caprae* and *Phyla nodiflora* on coastal saline soils of west coast of Kerala during summer and late summer seasons (n = 5; mean value)

							Macronutrients (mg g^{-1})			Micronutrients (mg g^{-1})		
District	Location	General soil texture	pH	Organic matter (%)	Moisture (%)	EC_{se}	N	P	K	Ca	Cl	Na
Alappuzha	Tottapalli	Sandy loam	7.8	0.34	0.65	0.10	35.56	33.99	14.63	107.01	96.73	44.52
	Ambalapuzha	Sandy	8.2	0.40	0.47	0.10	21.24	22.24	13.69	162.39	76.33	40.80
	Punnapra	Laterite	7.9	0.35	0.54	0.12	21.56	29.80	14.52	142.49	102.06	40.30
	Alappuzha beach	Sandy loam	7.8	0.25	0.59	0.10	27.16	31.70	17.65	132.38	112.14	41.70
	Chertala	Sandy loam	7.8	0.37	0.52	0.20	11.76	34.31	18.62	134.52	112.82	42.60
Kannur	Tellicherry	Sandy	8.2	0.24	0.63	0.25	12.92	34.35	22.25	138.94	94.96	43.20
	Payyambalam0beach	Sandy loam	7.8	0.56	0.57	0.20	15.96	28.24	14.72	140.32	110.27	43.40
	Azhikkod	Laterite	7.9	0.62	0.47	0.30	35.56	26.95	14.95	154.37	93.19	45.60
	Mattul	Laterite	8.1	0.63	0.62	0.20	21.56	33.62	13.65	167.04	73.66	40.38
	Payangati	Sandy loam	8.4	0.60	0.48	0.10	27.16	21.20	13.64	176.64	72.12	40.72
Kollam	Paravur	Sandy loam	7.8	0.65	0.54	0.20	32.52	20.25	18.92	152.83	91.42	39.20
	Mundakkal	Sandy loam	7.9	0.62	0.52	0.20	33.88	33.84	17.65	75.63	112.16	39.50
	Tangasseri	Sandy loam	7.6	0.25	0.63	0.20	28.12	32.85	12.41	142.11	104.06	32.20
	Kanunagappalli	Sandy loam	7.6	0.20	0.49	0.10	11.92	31.25	14.82	162.25	104.08	42.40
	Clappana	Sandy loam	7.8	0.30	0.48	0.10	11.76	51.62	13.62	168.32	96.73	70.10
Malappuram	Ponnani	Sandy loam	8.8	0.42	0.52	0.20	42.04	26.92	13.84	158.95	76.34	86.90
	Purathur	Sandy loam	8.8	0.25	0.62	0.20	44.42	23.45	13.12	148.92	166.24	170.20
	Koottayi	Sandy loam	8.4	0.40	0.64	0.30	41.96	23.42	14.65	146.71	168.58	177.10
	Tanur	Sandy loam	8.8	0.30	0.48	0.20	45.92	31.56	14.79	114.25	155.24	138.90
	Parappanangadi	Sandy	8.8	0.35	0.49	0.10	42.52	22.24	15.62	130.25	148.58	132.60
Thiruvananthapuram	Puvar	Sandy loam	7.8	0.32	0.54	0.10	21.56	23.25	18.65	140.25	176.28	182.40
	Vizhinjam	Sandy loam	7.6	0.40	0.52	0.10	27.16	21.12	16.62	142.64	72.48	41.70
	Kovalam	Sandy loam	7.8	0.20	0.62	0.20	16.8	18.50	16.15	138.25	78.58	44.20
	Veli	Sandy loam	7.4	0.12	0.69	0.10	22.12	17.20	14.12	132.25	82.25	40.80
	Varkala	Sandy loam	7.4	0.14	0.62	0.10	11.92	16.50	14.14	124.12	76.45	42.40

Table 3: Seasonal variations in AMF colonization and spore density of *Ipomoea pes-caprae* in coastal saline soils of west coast of Kerala (mean, n = 5 ± S.D)

		South west monsoon (June – August)		North east monsoon (September – November		Summer (December – February)		Late Summer (March – May)	
District	Location	Number of spores / 100 g soil	AMF colonization (%)	Number of spores / 100 g soil	AMF colonization (%)	Number of spores / 100 g soil	AMF colonization (%)	Number of spores / 100 g soil	AMF colonization (%)
Alappuzha	Tottapalli	140 ± 2.2	18.6 ± 1.4	180 ± 2.6	35.2 ± 1.8	482 ± 11.2	69.5 ± 11.4	580 ± 13.2	78.2 ± 11.4
	Ambalapuzha	45 ± 1.2	14.2 ± 1.2	65 ± 1.8	24.5 ± 2.8	180 ± 8.2	38.5 ± 8.6	240 ± 11.8	42.5 ± 8.6
	Punnapra	110 ± 4.8	42.2 ± 2.4	170 ± 5.2	50.6 ± 2.4	280 ± 10.2	52.2 ± 10.2	320 ± 12.6	68.9 ± 11.2
	Alappuzha beach	86 ± 6.2	38.2 ± 1.8	98 ± 6.4	46.6 ± 2.8	186 ± 10.8	58.8 ± 10.2	348 ± 12.8	62.8 ± 11.2
	Chertala	112 ± 5.2	49.5 ± 2.4	162 ± 5.4	59.5 ± 2.4	420 ± 12.2	69.5 ± 11.2	495 ± 13.2	72.6 ± 11.4
Kannur	Tellicherry	52 ± 3.2	22.5 ± 1.8	89 ± 4.8	26.4 ± 1.8	98 ± 9.2	32.5 ± 8.2	142 ± 10.8	38.5 ± 10.4
	Payyambalam0beach	86 ± 6.2	40.2 ± 2.8	102 ± 6.4	60.2 ± 3.2	410 ± 11.8	72.2 ± 10.4	485 ± 13.2	74.2 ± 11.4
	Azhikkod	84 ± 6.2	38.6 ± 1.8	110 ± 6.2	46.4 ± 7.2	210 ± 10.2	58.6 ± 9.2	285 ± 12.4	64.5 ± 11.2
	Mattul	40 ± 3.8	28.2 ± 1.4	95 ± 3.9	34.5 ± 3.2	92 ± 6.8	38.5 ± 6.2	112 ± 11.2	43.6 ± 10.8
	Payangati	54 ± 5.2	13.5 ± 1.2	162 ± 5.6	18.4 ± 1.2	46 ± 6.2	23.5 ± 6.2	66 ± 6.8	26.2 ± 6.4
Kollam	Paravur	120 ± 6.2	36.8 ± 2.4	180 ± 6.8	43.4 ± 2.4	320 ± 10.2	56.8 ± 9.0	356 ± 10.2	66.8 ± 9.2
	Mundakkal	95 ± 6.2	26.5 ± 1.2	125 ± 6.8	32.6 ± 2.8	210 ± 9.8	46.8 ± 8.2	280 ± 10.4	52.2 ± 10.8
	Tangasseri	110 ± 6.2	42.2 ± 2.6	145 ± 5.2	58.5 ± 3.2	310 ± 11.8	62.2 ± 10.2	392 ± 12.6	68.2 ± 11.2
	Kanunagappalli	86 ± 5.2	43.2 ± 2.8	116 ± 4.8	56.4 ± 2.8	316 ± 11.8	62.2 ± 11.2	386 ± 12.8	67.2 ± 11.2
	Clappana	120 ± 6.2	28.4 ± 1.4	165 ± 5.8	38.4 ± 3.2	420 ± 13.2	64.4 ± 10.2	480 ± 13.2	68.2 ± 11.2
Malappuram	Ponnani	28 ± 2.8	10.1 ± 0.8	32 ± 2.4	16.5 ± 1.2	36 ± 6.8	22.0 ± 6.2	38 ± 8.4	26.2 ± 6.4
	Purathur	18 ± 2.4	20.2 ± 1.2	40 ± 2.2	24.0 ± 1.2	38 ± 8.4	20.0 ± 5.8	42 ± 8.2	22.2 ± 6.4
	Koottayi	45 ± 6.2	22.2 ± 1.2	52 ± 6.4	26.5 ± 1.2	52 ± 9.2	22.0 ± 6.4	56 ± 9.6	28.5 ± 6.4
	Tanur	12 ± 1.2	22.5 ± 1.2	18 ± 1.2	24.5 ± 1.2	28 ± 6.5	25.5 ± 6.2	38 ± 6.4	29.8 ± 6.2
	Parappanangadi	25 ± 3.2	10.5 ± 0.8	19 ± 1.2	18.6 ± 1.4	35 ± 6.2	15.0 ± 5.2	45 ± 6.0	20.2 ± 5.4
Thiruvananthapuram	Puvar	120 ± 3.4	32.5 ± 1.6	145 ± 3.8	42.5 ± 2.2	420 ± 12.2	62.5 ± 9.8	540 ± 12.8	69.2 ± 10.2
	Vizhinjam	125 ± 6.2	36.5 ± 1.6	180 ± 6.2	62.5 ± 3.8	520 ± 13.2	72.5 ± 10.2	692 ± 13.6	78.5 ± 11.2
	Kovalam	210 ± 6.4	38.2 ± 1.8	245 ± 6.8	64.5 ± 3.8	610 ± 13.4	72.5 ± 11.4	685 ± 13.4	78.2 ± 11.4
	Veli	170 ± 6.2	40.5 ± 2.2	210 ± 6.8	60.8 ± 3.2	670 ± 13.2	78.5 ± 10.2	764 ± 13.6	82.5 ± 11.4
	Varkala	180 ± 6.2	42.5 ± 2.4	260 ± 7.2	66.2 ± 3.8	820 ± 14.2	94.5 ± 10.6	852 ± 14.8	98.5 ± 11.6

Table 4: Seasonal variations in AMF colonization and spore density of *Phyla nodiflora* in coastal saline soils of west coast of Kerala (mean, n = 5 ± S.D)

		South west monsoon (June – August)		North east monsoon (September – November		Summer (December – February)		Late Summer (March – May)	
District	Location	Number of spores / 100 g soil	AMF colonization (%)	Number of spores / 100 g soil	AMF colonization (%)	Number of spores / 100 g soil	AMF colonization (%)	Number of spores / 100 g soil	AMF colonization (%)
Alappuzha	Tottapalli	165 ± 6.2	28.6 ± 1.2	210 ± 10.4	56.5 ± 6.2	285 ± 12.4	64.5 ± 6.2	382 ± 14.4	84.5 ± 10.1
	Ambalapuzha	48 ± 2.8	12.4 ± 0.8	92 ± 10.2	38.5 ± 5.8	112 ± 10.2	49.5 ± 6.2	202 ± 14.29	69.6 ± 6.3
	Punnapra	112 ± 4.8	28.2 ± 1.4	198 ± 10.2	49.5 ± 6.5	145 ± 12.3	59.5 ± 8.5	295 ± 14.30	79.5 ± 8.4
	Alappuzha beach	92 ± 6.8	19.5 ± 1.2	148 ± 9.2	48.2 ± 6.8	142 ± 10.2	58.2 ± 7.2	312 ± 15.25	78.2 ± 7.2
	Chertala	112 ± 8.2	38.5 ± 4.8	198 ± 9.2	52.4 ± 6.5	262 ± 10.1	62.4 ± 8.5	345 ± 15.6	82.4 ± 8.6
Kannur	Tellicherry	65 ± 6.8	18.5 ± 2.2	85 ± 6.2	38 ± 5.2	114 ± 6.2	42.2 ± 6.2	192 ± 10.11	62.2 ± 6.3
	Payyambalam0beach	92 ± 9.2	38.5 ± 5.2	148 ± 10.2	52.4 ± 6.6	222 ± 12.2	60.4 ± 8.6	285 ± 14.30	80.4 ± 8.5
	Azhikkod	78 ± 6.2	26.4 ± 3.6	138 ± 12.2	58.2 ± 8.5	235 ± 12.2	62.5 ± 8.5	260 ± 15.19	82.5 ± 8.4
	Mattul	42 ± 5.8	10.5 ± 1.2	86 ± 6.2	36.4 ± 5.8	114 ± 8.2	42.4 ± 6.2	160 ± 9.25	42.4 ± 7.3
	Payangati	54 ± 5.6	12.5 ± 1.4	90 ± 5.8	32.5 ± 4.2	110 ± 6.2	38.5 ± 4.2	180 ± 10.13	58.5 ± 5.1
Kollam	Paravur	110 ± 8.4	39.5 ± 3.8	190 ± 12.2	52.4 ± 6.8	280 ± 12.4	60.4 ± 8.5	420 ± 14.30	80.5 ± 9.5
	Mundakkal	112 ± 8.2	24.6 ± 4.2	195 ± 10.2	48.4 ± 6.2	245 ± 12.2	54.2 ± 7.2	310 ± 15.18	74.2 ± 7.3
	Tangasseri	114 ± 6.8	38.5 ± 6.2	188 ± 12.2	52.5 ± 6.8	262 ± 13.2	58.5 ± 7.8	340 ± 14.31	78.5 ± 8.8
	Kanunagappalli	96 ± 5.8	32.5 ± 6.2	185 ± 12.2	48.2 ± 7.8	222 ± 12.2	56.2 ± 7.8	282 ± 15.3	76.2 ± 8.9
	Clappana	124 ± 10.2	46.0 ± 5.8	195 ± 12.8	52.6 ± 6.8	245 ± 14.2	58.4 ± 8.2	295 ± 15.19	78.4 ± 9.1
Malappuram	Ponnani	46 ± 5.2	18.5 ± 3.2	92 ± 6.2	38.2 ± 4.8	124 ± 8.2	48.4 ± 5.8	206 ± 9.16	68.4 ± 6.7
	Purathur	48 ± 2.8	15.5 ± 3.2	86 ± 6.2	33.5 ± 3.2	114 ± 6.2	43.2 ± 6.2	180 ± 10.2	63.2 ± 6.3
	Koottayi	65 ± 6.2	19.5 ± 1.8	95 ± 8.4	48.0 ± 6.2	135 ± 8.2	52.4 ± 7.2	205 ± 10.12	72.4 ± 8.2
	Tanur	48 ± 3.8	16.5 ± 1.2	76 ± 6.2	36.5 ± 6.2	142 ± 8.2	46.5 ± 6.4	210 ± 9.25	66.5 ± 7.4
	Parappanangadi	28 ± 3.2	14.5 ± 1.2	68 ± 8.2	32.4 ± 6.2	122 ± 8.2	48.2 ± 6.5	190 ± 10.12	68.2 ± 7.5
Thiruvananthapuram	Puvar	112 ± 4.8	42.5 ± 3.2	180 ± 8.2	52.4 ± 6.8	220 ± 10.2	61.2 ± 8.4	445 ± 14.20	81.3 ± 9.4
	Vizhinjam	120 ± 6.2	40.5 ± 3.8	195 ± 12.2	50.5 ± 8.2	205 ± 12.2	60.5 ± 8.2	420 ± 14.32	80.5 ± 9.3
	Kovalam	110 ± 5.8	48.5 ± 4.2	210 ± 14.2	58.4 ± 10.8	285 ± 14.2	62.4 ± 12.8	485 ± 15.18	82.5 ± 13.7
	Veli	210 ± 9.2	49.6 ± 4.4	310 ± 14.2	59.6 ± 10.2	365 ± 14.8	69.5 ± 12.2	540 ± 16.2	92.2 ± 13.8
	Varkala	210 ± 12.2	58.5 ± 5.2	312 ± 14.2	68.4 ± 10.5	380 ± 14.4	78.3 ± 12.0	560 ± 17.8	94.6 ± 14.5

were collected from Malappuram study localities and Kannur study localities during south-west monsoon, it was as high as 98.5 and 94.6% in both plants collected from Varkala in Thiruvananthapuram District during the late summer season (Table 3 and 4).

The spore densities of AM fungi in the rhizosphere soils of the samples are given in Tables 3 and 4. The number of AM fungal spores in the rhizosphere soils differed according to locality. Spore density in root-zone soils of *I. pes-caprae* ranged from 12.0-210 in

Table 5: Correlation analysis of AM fungal factors and rhizosphere edaphic factors of *Ipomoea pes-caprae* on the saline soils of west coast of Kerala

Parameters			Correlation coefficient*
AM colonization	Vs	Organic matter	-0.2545
	Vs	Soil pH	0.5265
	Vs	Calcium	0.5360
	Vs	Sodium	-0.3378
	Vs	Phosphorus	0.4458
Species richness	Vs	Organic matter	-0.2643
	Vs	Soil pH	0.5325
	Vs	Calcium	0.5280
	Vs	Sodium	-0.3268
	Vs	Phosphorus	0.2648
	Vs	Colonization	0.3325
Spore density	Vs	Organic matter	-0.2585
	Vs	Soil pH	0.5142
	Vs	Calcium	0.3812
	Vs	Sodium	-0.2874
	Vs	Phosphorus	0.3462
	Vs	Colonization	0.3248

* C.V. (2-tail), 0.05 = ± 0.2540

Table 6: Correlation analysis of AM fungal factors and rhizosphere edaphic factors of *Phyla nodiflora* on the saline soils of west coast of Kerala

Parameters			Correlation coefficient*
AM colonization	Vs	Organic matter	-0.2446
	Vs	Soil pH	0.5145
	Vs	Calcium	0.5280
	Vs	Sodium	-0.3268
	Vs	Phosphorus	0.4362
Species richness	Vs	Organic matter	-0.2545
	Vs	Soil pH	0.5312
	Vs	Calcium	0.5145
	Vs	Sodium	-0.3264
	Vs	Phosphorus	0.2632
	Vs	Colonization	0.3264
Spore density	Vs	Organic matter	-0.2642
	Vs	Soil pH	0.5125
	Vs	Calcium	0.3615
	Vs	Sodium	-0.2765
	Vs	Phosphorus	0.3458
	Vs	Colonization	0.3242

* C.V. (2-tail), 0.05 = ± 0.2540

the south-west monsoon, 19.0 – 260 in the north-east monsoon, 28.0 – 820 in the summer season and 38.0 – 852 in the late summer season whereas the spore density in root-zone soils of *Phyla nodiflora* ranged from 28.0 – 210 in the south-west monsoon, 76.0 – 312 in the north-east monsoon, 110 – 380 in the summer seasons and 160 – 560 in the late summer season. In general, the spore density was as low as 12.0 and 28.0 in the test plants of *I. pes-caprae* and *P. nodiflora* respectively which were collected from the Malappuram locality, whereas it was as high as 852 and 560 in both the species collected from Varkala in Thiruvananthapuram District during the late summer season (Tables 3 and 4).

Species Richness, Frequency Distribution and Host Specificity: A year's survey of *I. pes-caprae* and *P. nodiflora* revealed the occurrence of 35 species of AM fungi belonging to six genera viz., *Acaulospora, Entrophospora, Glomus, Gigaspora, Sclerocystis* and *Scutellospora*. Members of the family *Glomaceae* dominated (51.4%) followed by Gigasporaceae (28.6%) and Acaulosporaceae (20.0%). The number of AM fungal species recovered per plant of *I. pes-caprae* ranged from 1 to 22 whereas in *P. nodiflora* it ranged from 1 to 12. Species richness was the highest during the summer and late summer seasons for both the plants and it was significantly correlated with soil pH, Calcium, Phosphorus and percent root colonization (Tables 5 and 6).

Species richness was consistently greater in dry seasons and wet seasons. Significant differences were found in species richness between dry and wet seasons. Species richness and diversity were observable in Thiruvananthapuram and Alappuzha study localities. The Simpson diversity of AM fungi was higher in summer and late summer seasons than wet seasons. The Shannon diversity of AM fungi was the highest in the late summer season. The diversity indices and expected species were greater in the summer and late summer seasons than the south west and north-west monsoon seasons.

DISCUSSION

The present work was conducted with the study of colonization rates distribution, diversity, spore density and species richness of AMF associated with *I. pes-caprae* and *P. nodiflora* collected from the coastal saline rhizosphere soils of the West Coast of Kerala in relation to some physical and chemical properties of soils during four different seasons. *Ipomoea pes-caprae*, a pioneer mat- forming creeping strand species, shows wide distribution throughout the tropical beaches of the world. The AM fungal communities on tropical dunes have shown high levels of diversity, as measured by diversity indices.

The typical AM fungal invasion was seen in the roots of *Ipomoea pes-caprae* and *Phyla nodiflora*, the number of spores was higher in the rhizosphere than in the non-rhizosphere soils of these plants. This finding coincides with that of a earlier study by Beena *et al.* [23] who also noted the diversity and typical AM fungal

invasion associated with the dominant maritime strand plant species, *I. pes-caprae* done in the coastal sand dunes of the west coast of Karnataka state, India. The present study reports the impact of rhizosphere edaphic factors and disturbances on the species richness and diversity of AM fungi in 25 localities in the coastal saline soils during four different seasons. The diversity, AM fungal colonization and species richness were greater in *I. pes-caprae* than *P. nodiflora* irrespective of the season. The AM fungal species richness and spore density in both cases were strongly correlated with rhizosphere phosphorus, calcium and organic carbon. Among the twenty-five rhizosphere edaphic features like organic carbon, calcium and AM fungal root colonization showed significant differences between *I. pes-caprae* and *P. nodiflora* plants. Pooled data indicated that *Glomus geosporum* was the most dominant, followed by *Glomus aggregatum, Gigaspora margarita, Glomus microcarpum* and *Scutellospora heterogama*.

The seasonal formation of hyphae, arbuscules and vesicles observed in *I. pes-caprae* and *P. nodiflora* followed a pattern similar to those observed earlier in *Atriplex gardeneri* [24] and in *Phyla nodiflora* [25]. The present findings are in sharp contrast to the observation made earlier in a number of shrubs in North Western Mexico [26] which evidenced considerable fluctuations in the root colonization percentages with no evident seasonal pattern. This is because Lindsey [26] did not investigate the intraradical formation of the mycorrhizal structures at different periods of growth. High percentage of AMF colonization was observed during late summer. This is in agreement with the findings of Kannan [25]. In the present study, maximum spore number was observed in the late summer season. This seasonal pattern in spore numbers and AM colonization observed in the present study also agree with the similar findings recorded in *Atriplex gardeneri* [24], *Phyla nodiflora* [25]and in some mangroves [27].

CONCLUSION

The physico-chemical characteristics of the soils of the 25 different study localities indicated that the soils were neutral to alkaline and alkaline with a low to moderately high salinity. The soil was mostly fine textured-sandy or sandy loam. The available nitrogen was invariably high and the soils were deficient in nutrients with low level of organic carbon, phosphorus and moderate to high levels of Potassium. The Calcium and Sodium contents were very high during south-west and north-east monsoon seasons.

Glomus geosporum was an abundant species followed by *G. aggregatum* and *Gigaspora margarita* found in the rhizosphere soils of both plants collected from all the study localities. Species richness was highest during summer and late summer seasons and it was correlated with soil pH, calcium, phosphorus and % root colonization.

Glomus aggregatum, G. geosporum, Gigaspora margarita, Acaulospora scrobiculata and *Scutellospora heterogama* were isolated from the rhizosphere soils of both the species studied during all the four cultivation seasons. *A. denticulata, A. nicolsoni, A. spinosa* and *E. infrequens* were isolated only from rhizosphere soils of *I. pes-caprae* at Thiruvananthapuram study localities.Two species of *Sclerocystis* (*S. pakistanika* and *S. sinuosa*) were isolated from rhizosphere soils of *I. pes-caprae* from all the study localities during summer and late summer seasons.

Maximum percentage of root colonization was observed in both the species during summer and late summer seasons. *Glomus aggregatum* and *G. geosporum* showed highest colonization in the roots of *P. nodiflora* and *I. pes-caprae* respectively. Maximum spore number was observed in summer and late summer seasons. Spore density was strongly correlated with calcium, phosphorus and soil pH.

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