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Research Article

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Physico-Chemical Characteristics of Rodent Burrow Soil in Relation to the Survival of Rodent Fleas in Plague Endemic Areas of Kolar and Chittoor Districts in South India

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ABSTRACT

Rodent fleas are considered as principal vectors for plague transmission in rodent population and human. In total 744 rodent-fleas were collected from 1960 rodents from various placesof Kolar district of Karnataka (KA) andChittoor districtof Andhra Pradesh (A. P.), South India.Analysis done on 22 soil samples collected from various areas of both the districts.Soilsamples of two districts exhibited variation in texture and color. Most of the soil samples were found to be acidic in nature (pH range 4.5 to 6.5). 86% samples had less nitrogen content,23% samples had lesspotassium content and 9% samples had less phosphorous content. The organic carbon contentwas less in all places. However, 50% samples had high potassium content and 77% samples were high phosphorous content.Mainly two types of rodent fleas, Xenopsylla astia and X. cheopis were found in these areas. The percentage of female rodent fleasis generally considered as a good indicator for the fast growing population of rodent fleas.Breeding season for fleas mostly depended on climatic conditions like temperature below28oC and humidity above 70%. However, fleas can survive in shady areas athigher temperature. Wide diversity in soil characteristics and breeding of rodent fleas throughout the year reflected that other factors like optimum humidity,temperature and abundance of food inside the burrows as well as outsidewere also helpfulfor the survival and growth of rodent fleas.

Keywords: *Plague, Rodent fleas, Soil physical and chemical characteristics,Xenopsylla spp.*

INTRODUCTION

Plague is a most dreaded zoonotic disease and its pneumonic form spread very fast in human beings. It caused a heavy death toll throughout the world[7]. During 1898 to 1918, more than 25 million people died in Indian subcontinent alone. Natural cycle of plague occurs and remains in rodent population and continues mostly through the infected rodent flea bite. Rodent fleas are main vectors that is responsible for transmission from rodent to rodent and rodent to human being. The development of antibiotics such as streptomycin and sulphanomide after the Second World War, led to dramatic reduction in plague cases. This alsohadbeen attributed to the universal use of DDT in rural areas for mosquito control, and rodent fleas were sensitive to DDT at that time[3]. In India, plague mortality rate came down from 183 to 1.8 per thousand populations and finally reached to zero during 1967. The last case of plague was reported during 1966 in Mulbagal area of Kolar district, Karnataka, India. However, sporadic cases of plague were also reported after 1967 in Tangnu, Himachal Prades hand Attibele, Karnataka, India during 1966 and 1983, and in 1984 respectively. The sylvatic plague incidences were detected during routine plague surveillance by National Institute of Communicable Disease (NICD/NCDC), India in the tri-junction area of Karnataka, A. P. and Tamil Nadu. After a long quiescence period of 28 years, plague re-emerged in 1994 at Mamla village, Beed district, Maharashtra. Both types of plague (Bubonic and Pneumonic) cases were reported from Beed district of Maharashtra and Surat of Gujarat at that time. Again after 8 years of long

quiescence localized pneumonic plague outbreaks were reported from Hatkoti, Shimla, Himachal Pradeshand Dangud village, Uttarkashi,Uttarakhand in 2002 and 2004 respectively. All over the world, 26 countries had reported 53417 incidents of plagueand 4060 deaths (7.6%) to WHO, during 1987 to 2009. Though it is well known fact thatthe under reporting is always there due to various factorswhich are beyond the control of administration[3].

Table 1: Data on rodent fleas in Kolar (KA) area (2009-2010)

S. No	Period	Avg. max. Temp. ^{o}C	Avg. Min. Temp. ^{o}C	Avg Humidity (%)	Avg. Ppt. (mm)	No. of Rodents Collected	No. of Fleas Collected
1	Jan	33	10	60	2	105	64
2	Feb	37	11	52	4	87	30
3	Mar	38	10	46	20	0	0
4	Apr	38	18	54	82	51	15
5	May	38	15	64	122	66	14
6	Jun	38	14	74	112	50	12
7	Jul	37	11	77	139	50	5
8	Aug	38	9	79	148	23	8
9	Sep	33	11	76	188	31	6
10	Oct	39	12	78	202	65	14
11	Nov	33	12	73	62	82	21
12	Dec	32	12	68	17	100	26
Total						710	215

Balthazardand Bahmanyar[1] reported that plague is not localized but from time to time it shifts from one place to other due to the rodent migration and the vector too. The rodent fleas as main vectors are responsible for its continuity. Various biotic and abiotic factors are also responsible for the outbreaks of plague. The containment of plague was well done with vector control by use of DDT. But now the scenario has changed. In the beginning rodent fleas were very sensitive to DDT and now it has developed resistance[2]. This is posing as a threat and has generated a need to find other ways or means to contain the development of rodent fleas. High population growth, rapid transport system and fast development of various pesticides/insecticides and antibiotics and their uncontrolled uses in agriculture sector and in health sector will have some impact in almost all sphere of life and it might affect nature of plague vector. Therefore, there is a need for a fresh study on the biodiversity of plague vector in India particularly in plague endemic areas.

Soil is important to everyone directly or indirectly because it supports growth of not only plants but also micro flora which generates lot of valuable nutrients for the development of the plant cell. The quality of soil depends upon amount of nitrogen, potassium, phosphorus, organic and inorganic materials and water. Little information is available about the role of soil of rodent burrow where plague vector, plague micro-organism and rodents co-exist[9]. Therefore, an attempt was made to study the physico-chemical characters of the soil of rodent burrows with particular reference to both reservoir and plague vector.

MATERIALS AND METHODS

The study area was taken in Kolar district of Karnataka, bordering to Tamil Nadu and Andhra Pradesh and lies between 77° 21' to 78° 35' east longitude and 20° 46' to 130° 58' north latitude. This area is most significant because the last case of human plague was detected in Mulbagal area of Kolar district in 1966 [3]. The sero-positivity for plague in rodents was also detected in this district in the past. Sample of another area, Chittoor district of A. P. state, South India was taken for comparison. Recently the Kolar district was divided into two districts i.e. Kolar and Chikbalapur. Soil samples were collected from five taluks of plague endemic areasof Kolar district, Karnataka (Kolar, Srinivaspur, Mulbagal, Bangarpet and Malur) and four of Chittoor district, A.P. (Madanapalle, Punganur, Gangavaram and Palamner). The soil sampleswere collected from the burrow of the rodents. Temperature of inside soil and atmospheric temperature in these areas at the time of sample collection were also recorded.

Wild rodents were collected by digging and using wonder traps (live multiple catch trap) from the domestic and peri-domestic situations. Fleas were retrieved from captured live rodents, by combing and

then sucking with the help of flea suction apparatus.The fleas so collected were transferred to a larger test tubeand plugged with cotton. Fleas were preservedin small tubes containing 70% - 80%

Table 2: Data of rodent fleas in Chittoor (A. P.) area (2009-2010)

Sl.No	Period	Avg. Max. Temp. ^{o}C	Avg. Min. Temp. ^{o}C	Avg. Humidity(%)	Avg. Ppt. (mm)	No. of Rodents Collected	No. of Fleas Collected
1	Jan	35	12	74	21	95	39
2	Feb	40	13	72	15	110	77
3	Mar	39	18	71	23	148	85
4	Apr	43	18	72	24	115	45
5	May	45	20	65	53	100	30
6	Jun	43	19	63	87	110	40
7	Jul	40	20	65	109	87	34
8	Aug	40	21	69	137	125	48
9	Sep	39	20	72	134	81	28
10	Oct	37	18	80	336	70	31
11	Nov	39	18	81	374	127	43
12	Dec	39	17	77	152	82	29
Total						1250	529

alcohol and transported to laboratory for further processing. The fleas were processed for proper identification as per the standard method described by Iyengar[5].

The soil samples so collected were kept in double polythene bags and sealed at the time of collection to retain moisture contents intact. The samples were brought to the laboratory and further analysis was done for various parameters like the texture, moisture, nitrogen, potassium, phosphorous, pH and organic carbon contents of soil by the standard method described by Saxena[8].

RESULTS

The rodent fleas collected from the various places were processed and identified and the data generated is presented in the Table 1 and Table 2. The environmental data of these areas were also collected to generate the linkage, if any, for the proliferation of plague vector.

The texture of the soil samples were red dusty, dark black (hard and fine granules) and greyish black (very hard stone type) as shown in Table 3 to Table 5. The soil temperature was found more when compared to the atmospheric temperature in case of samples (S-10 to S-13 in Table 4) which were collected from the Mulbagal and Bangarpet area of Kolar.

The soil temperature was found more in comparison to atmospheric temperature for samples S-15 to S-17 in Table 5, which was collected from Madanapalle and Punganur area. The texture of the soil samples were (black) loose and wet, (black) fine granules and hard and (black) loose and humid. In other samples temperature variation was approximately 1oC - 2oC only.

Table 3: Physical characteristics of soil samples collected from Kolar city and adjoining areas (Aug-Sep 2012)

Sample No.	Places in KolarTaluk	Observation Time	Soil Humidity (%)	Atmospheric Temp. (^{o}C)	Soil Temp. (^{o}C)	Soil Color	Soil Texture
S-1	Shantinagar, Aruhalli	1.05 pm	6.167	35^{o}C	29 ^{o}C	Blackish Brown	Granules of 0.5-1 cm.
S-2	KG Mohalla 1st Cross, Kolar	1.10 pm	9.65	35 ^{o}C	31 ^{o}C	Brownish Black	Humid and powder form
S-3	Fish Market	1.15 pm	5.32	35 ^{o}C	38 ^{o}C	Light Brown	>0.5 cm sized granules

S-4	Antaragange, Field Area, Ti breeding soil	3.15 pm	0.668	38 ^{o}C	38 ^{o}C	Light Red	Sandy and fine granules
S-5	Antaragange, Park Area, Ti breeding soil	3.40 pm	1.262	32 ^{o}C	28 ^{o}C	Light Red	Fine granules
S-6	Arahally, Brick Work Factory	4.20 pm	2.00	35 ^{o}C	34 ^{o}C	Red	Dry powder like
S-7	Rehmat Nagar, BD Colony	4.35 pm	1.997	32 ^{o}C	34 ^{o}C	Light Brown Black	Sandy and fine granules

Table 4: Physical characteristics of soil samples collected from various taluks of Kolar dist. (Aug - Sep 2012)

Sample no.	Taluks ofKolar District		Observation Time	Soil Humidity (%)	Atmospheric Temp.^{o}C	Soil Temp.^{o}C	Soil Color	Soil Texture
S-8	Srinivaspura	Eukalyptus forest area	12.15 pm	9.283	34^{o}C	32^{o}C	Gray	Hard
S-9	Srinivaspura	Mulbagal road near pump house	12.20 pm	1.604	34^{o}C	34^{o}C	Reddish yellow	Dust
S-10	Mulbagal	Someswarpalya	2.40 pm	2.133	32^{o}C	36^{o}C	Black	Fine granules
S-11	Mulbagal	Kolar bypass road	2.50 pm	1.440	35^{o}C	36^{o}C	Red	Dust
S-12	Bangarpet	Bethmangala	4.20 pm	2.016	34^{o}C	38^{o}C	Dark black	Hard and fine granules
S-13	Bangarpet	Colar gold field (KGF)	4.55 pm	9.396	31^{o}C	35^{o}C	Grayish black	Very hard stone type
S-21	Mallur	Dry lake area	10.00 am	21.207	26^{o}C	24^{o}C	Black	Wet and soft
S-22	Mallur	KRM brick factory, Eukalyptus forest	10.36 am	14.841	28^{o}C	25^{o}C	Red	Hard fine granules and dust
Note: During collection of soil samples 21 and 22, night rain occurred								

The pH of soil was found to be in the range from 4.5 to 6.5 in these two plague endemic areas. Potassium contents were also high in Kolar district except Bangarpet and Malur taluks. In the plague endemic areas of Chittoor district, about 50% of the soil samples were also having low contents of potassium. Phosphorous contents were high in most of the soil samples tested except for the soil samples collected from the Mulbagal area. The organic carbon content was low in 13 of 15 (about 86%) soil samples collected from Kolar district, whereas in Chittoor district it was low in 4 of 7 (about 57%) soil samples. None of the soil samples were found to have higher content of organic carbon (Table 6 and Table 7).

DISCUSSION

The literature on the study of soil in the plague endemic areas of Kolar district (KA) and the adjoining areas of Chittoor district (A.P.) in relation to the impact of various physico-chemical and environmental factors on plague vector is scanty. During present study, it was observed that the status of the soil varied from loose to hard nature and color was varied from red to greyish and black. Soil temperature was found more as compared to the atmospheric temperature in the soil samples S-10 to S-13 which was collected from Mulbagal and Bangarpet area. Similar results were also observed in the soil samples S-15 to S-17 which was collected from Madanapalle and Punganur area of Chitoor district. Texture of the soil samples in Chittoor district was (black) loose and wet, (black) fine granules and hard, and (black) loose and humid.

Table 5: Physical characteristics of soil samples collected from various Taluks of Chittoordist. (Aug-Sep 2012)

SampleNo.	Taluks ofChittoor District		Observation Time	Soil Humidity (%)	Atmospheric Temp.	Soil Temp.	Soil Color	Soil Texture
S-14	Madanapalle	Bus stop pond area	12.25 pm	12.303	30^{o}C	28^{o}C	Black	Loose, soft and Wet

S-15	Madanapalle	Thattuarpalli, BalaGII Talkies	1.00 pm	8.461	30°C	33°C	Black	Loose, soft and Wet
S-16	Punganur	Agricultural field area	2.45 pm	6.363	33°C	35°C	Black	Fine granules and hard
S-17	Punganur	Gum Accasia field area	3.00 pm	7.719	33°C	35°C	Black	Loose and humid
S-18	Gangavaram	Indira Nagar	4.30 pm	4.628	35°C	35°C	Red	Humid, soft & fine granules
S-19	Gangavaram	Indira Nagar, near poultry firm	4.40 pm	3.941	31°C	30°C	Red	Sandy, humid & stone granules
S-20	Palamaner	Wet Land	4.50 pm	16.018	29°C	29°C	Black	Loose, humid & soft
Note: During collection of soil sample no. 16 to 20, light rain occurred								

The pH range of soil was found to be in the range from 4.5 to 6.5 in these two plague endemic areas. The variation in potassium, phosphorous, nitrogen and organic carbon contents were also found and it is also same as the findings of Roy *et al*.[6] in Kolar. The organic carbon contents were low in 13 of 15 samples (about 86%) collected from Kolar district, whereas in Chittoor district it was low in 4 of 7 samples (about 57%). Chemicals in soil may have impact on agricultural produce, but this might have not significant impact on rodent flea survival.

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Table 6: Chemical characteristics of soil samples collected from Kolar and Chittoor districts (Aug - Sep 2012)

Sample No.	Places		Soil pH	Nitrogen	Potassium	Phosphorous	Organic Carbon
S-1	Kolar	Shantinagar, Aruhalli	5.0	L1	H2	H1	L
S-2		KG Mohalla	5.0	M1	H2	H2	M
S-3		Fish Market	5.25	M1	H2	M2	M
S-4		Antaragange, Field	4.25	L1	H2	H1	L
S-5		Antaragange, Park	4.0	L1	H2	H1	L
S-6		Arahally, Brick Factory	6.5	L1	H2	H1	L
S-7		Rehmat Nagar	6.5	M1	H2	H1	L
S-8	Taluks of Kolar District	SrinivaspurKolar	5.0	L1	H1	M1	L
S-9		SrinivaspurKolar	5.0	L1	H1	M1	L
S-10		Mulbagal, Kolar	5.5	L1	H1	L2	L
S-11		Mulbagal, Kolar	6.0	L2	H1	L1	L
S-12		Bangarpet, Kolar	6.0	L1	M1	H2	L
S-13		KGF, Kolar Black hard soil	5.0	L1	L1	H2	L
S-14	Taluks of Chittor District	MadanapallyChittoor	5.0	L1	M1	H2	M
S-15		MadanapallyChittoor	5.0	L1	L1	H2	L
S-16		PunganurChittoor	5.0	L1	L1	H2	M
S-17		PunganurChittoor	6.0	L1	L2	H1	M
S-18		GangavaramChittoor	4.5	L2	M1	H2	L
S-19		GangavaramChittoor	4.5	L2	M1	H2	L
S-20		Palmner Wet land	5.0	L1	M2	H1	M
S-21	Taluksof Kolar	Malur Black soil, Kolar	6.5	L1	L1	H1	L
S-22		Malur Red Soil, Kolar	6.5	L1	L1	H1	L

The increase in soil temperature may not be favorable for rodent fleas and may be dependent on the nature of soil and direct exposure to sunlight and less intensity of wind flow in that area. It was also observed that rodent burrows were found in those areas where bushes were present which helped to

maintain the temperature more or less uniform nearing to 28°C. More over their burrows in such areas were about 1.5 to 2 feet down in the soil. So they feel comfortable in their burrows throughout the year. The rodents preferred to move out in search of food in the evening or night time. The rodent fleas which usually hide in the fur of the rodents to have blood meal were sensitive to higher temperatures so their number decreased in the summer season. However, their presence was observed throughout the year. This is because they also live in the burrow soil in association with rodents, where they lay eggs and emergence of adult fleas takes place. The humidity of about 70% and temperature of about 28°C were considered as the best for the propagation of rodent fleas. This was maintained in deep rodent burrow by the soil humidity which was ranged from 2-21% depending on the climatic conditions. It was also found that the rodent fleas of Dodra Kawar area (H. P.) were very sensitive to temperature variation. They were unable to withstand the extreme climatic condition of Kolar region.

Table 7: Approximate quantity of chemicals in high/medium/low in soil

Name of chemicals	Amount of available chemical in soil	Approx. quantity of available Chemical in Kg/Acre			
Nitrogen	Low (<100 Kg/Acre)	L1	<50 Kg/Acre	L2	50 – 99 Kg/Acre
	Medium (100 – 200 Kg/Acre)	M1	100 – 150 Kg/Acre	M2	151 – 200 Kg/Acre
	High (>200 Kg/Acre)	H1	201 – 300 Kg/Acre	H2	>300 Kg/Acre
Phosphorous	Low (<4 Kg/Acre)	L1	<1Kg/Acre	L2	1 – 3 Kg/Acre
	Medium (4 – 10 Kg/Acre)	M1	4 – 7 Kg/Acre	M2	8 – 10 Kg/Acre
	High (>10 Kg/Acre)	H1	11 – 15 Kg/Acre	H2	>15 Kg/Acre
Potassium	Low (<50 Kg/ Acre)	L1	<25 Kg/Acre	L2	25 – 49 Kg/Acre
	Medium (50 – 120 Kg/Acre)	M1	50 – 80 Kg/Acre	M2	81 – 120 Kg/Acre
	High (>120 Kg/Acre)	H1	121 – 150 Kg/Acre	H2	>150 Kg/Acre
Organic Carbon	Low	<0.5 %			
	Medium	0.5 – 0.75 %			
	High	>0.75 %			
Note: L1= Very low, L2= Low; M1= Very medium, M2= Medium; H1= Very high, H2= high					

The acidic nature of soil may have adverse impact on the survival of the plague microorganism. But this may activate the microorganism to go in the dormant phase. Plague bacilli was isolated from the soil of the abundant burrows even after a year or so. Though Sobey *et al* [10] concluded on the base laboratory breeding experiment that soil has no additional impact on breeding of rodent fleas, but it may not be holding well in the natural environment especially for the survival and propagation of flea progeny. Rodent flea larvae do need micro nutrients and traces of vitamins which are provided in the natural environment by the microflora of the soil and the dropping of the rodents.

Thus, it may be more appropriate to say that rodent needs safe place, conducive environment to live and easy approach to their meal which is provided by the soil. The rodent fleas may also need blood along with other conducive environmental conditions which may easily be available in the rodent burrow soil.

CONCLUSION

It was concluded that altogether 744 fleas were retrieved from 1960 rodents and mainly two types of rodent fleaswere found i.e. *Xenopsyllaastia*and *X. cheopis* in these areas of Kolar and Chitoor district. The soil in these places exhibited variation in texture,color, and moisture contents. The soil was acidic. The nitrogen and organic carbon contents were low in most of the places. The potassium and phosphorous contents were also found on the higher side except in fewtaluks. The diversity in the soil characteristics and the breeding of rodent fleas reflected that other factorssuch as optimum humidity,temperature and abundance of food in side their burrows as well as outside are responsible for the survival and propagation of rodent fleas.

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