FUNGAL DEGRADATION OF COTTON MATERIALS UNDER OUTDOOR WEATHERING AND IN SOIL BURIAL CONDITIONS

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The degradation of five types of cotton fabric and three types of cotton yarn and threads was studied during outdoor monsoon exposure, tropic room exposure and soil buried conditions. The susceptibility of different cotton materials was due to micronaire characteristics of the fibres and varying fungal activity. Highly twisted and mercerized yarn was more resistant. 20 to 25% soil moisture favoured maximum degradation. Thirty three fungi were isolated from exposed and soil buried cotton materials. Three species were encountered for the first time from cotton materials.

The climatic condition of India, being typically tropical is most conducive for the microbial degradation of cotton materials. Both raw and finished cotton are susceptible to fungal attack during exposed conditions in warm and humid environment[1]. In India some emphasis has been given on the protective treatments of cotton materials against micro-oragnisms. But it has been observed that the material which was given mildew-resistant treatments deteriorated badly after a short period of use. Keeping in view these facts and that cotton is staple industrial fibre for bulk production in India, a detailed investigation has been undertaken to study the pattern of fungal degradation of cotton materials under varied circumstances both in soil contact condition and above ground exposure conditions. These studies will correctly help in formulating adequate preventive/protective measures for evolving both physical and chemical applications for cotton textiles.

MATERIALS AND METHOD

Following cotton materials were taken for study.

Light Fabrics	(*i*) Cotton cambric, 170 gm per sq. meter, warp count 30^s
	(*ii*) Cotton dosooti, 237.5 gm per sq. meter, warp count 14^s.
Heavy Fabrics	(*iii*) Cotton duck canvas, 475 gm per sq. meter.
	(*iv*) Cotton light canvas, 542.5 gm. per sq. meter.
	(*v*) Cotton heavy canvas, 677.5 gm per sq. meter.
Yarn	(*vi*) Cotton grey yarn, two-ply, count 2.5^s.
Threads	(*vii*) Cotton thread sized three-ply, count 0.75^s.
	(*viii*) Cotton thread mercerized two-ply, count 40^s.

Test sample : In fabric the test pieces of size 29 cm. x 6 cm. were cut along warp. In yarn and threads the samples were 1.5 meter in length.

Outdoor Monsoon Exposure : The exposure of cotton materials was made through 15 June to 15 October, 1973 at Kanpur as per specification No. ISO/TC-38/SC-1/(1967), adapted by Sahgal and Agarwal[2]. Four samplings were made, each after 30 days. The exposed as well as unexposed (control) sample pieces were subjected to breaking strength and elongation-at-break tests[3]. Wheather data were also recorded continuously at the exposure site.

Tropic Room Exposure : The ideal tropical conditions characterized by high temperature and humidity followed by nocturnal condensation were simulated in a Tropic Room maintained at Defence Materials & Stores Research & Development Establishment, Kanpur on the principles given by Smith[4]. The cotton materials were exposed in Tropic Room through 15 June 1973 to 15 January, 1974. Seven samplings were made, each after 30 days. The samples were subjected to breaking strength and elongation-at-break tests[3].

Soil Burial Test : The cotton materials were subjected to soil burial test as per ISI specification no. IS/ 1389-1959 taking different soil moisture contents in the soil ranging from 5%, 10%, 15%, 20%, to 30%. The test pieces were incubated in Tropic Room. Random sampling was done after 3, 5, 7 and 9 days in case of light fabric, yarn/threads and after 7, 14, 21 and 28 days in case of heavy fabrics. The harvested samples were subjected to breaking strength test.

Isolation of fungi : The fungi were isolated from exposed and soil buried cotton samples[5] using Potato dextrose agar, Thortons agar, Waksman agar and Czapek-Dox agar media. The cellulolytic activity of the fungal isolates was determined on China-blue-Aurin-Cellulose agar[6].

RESULTS

Outdoor Monsoon Exposure : The climatic data at the exposure site are given in Table 1.

TABLE 1

CLIMATIC DATA AT THE EXPOSURE SITE

Month	Max. temp (°C)	Min. temp (°C)	Relative humidity (%)
June	39.9	28.7	54
July	33.7	26.6	61
August	32.1	25.8	86
September	32.7	24.9	81
October	32.7	19.6	69
November	28.9	12.3	66
December	24.3	8.5	78
January	22.8	8.6	80

The rate of degradation of cotton materials in outdoor monsoon exposure have been expressed (Table 2) in terms of percentage loss in breaking strength and elongation-at-break as compared to control. On statistical analysis the retained breaking strength and elongation revealed significant variations in different samples. All the values were significantly superior to control. The loss in breaking strength and elongation showed a progressive increase with the increase in the duration of exposure. Among the light fabrics maximum loss in breaking strength was observed in dosooti followed by cambric but the pattern of loss in elongation was reverse. Among the heavy fabrics, duck cotton showed higher losses in breaking strength and elongation in early period of exposure. The heavy canvas which was resistant during early exposure period showed greater loss on prolonged exposure. The susceptibility of yarn and threads in decreasing order was grey yarn—sized thread—mercerized thread.

TABLE 2

LOSS IN BREAKING STRENGTH (BS) AND ELONGATION-AT-BREAK (EL) OF COTTON MATERIALS IN MONSOON OUTDOOR EXPOSURE (15 JUNE TO 15 OCTOBER 1973)

Cotton material	Exposure days							
	30		60		90		120	
	BS	EL	BS	EL	BS	EL	BS	EL
Cambric	2.8	5.0	12.8	22.5	22.3	36.0	42.6	40.0
Dosooti	8.9	0.0	24.0	7.1	37.0	12.5	48.4	24.0
Duck Cotton	6.5	5.8	10.8	19.7	19.4	52.5	26.1	54.0
Light canvas	4.6	5.8	8.2	10.5	30.2	33.8	34.4	73.0
Heavy canvas	4.5	5.5	12.0	13.4	30.2	36.6	35.6	72.3
Grey yarn	27.3	19.0	59.0	26.2	60.0	78.2	80.0	89.8
Sized thread	27.3	3.0	57.5	26.5	59.5	68.7	68.9	79.1
Mercerized thread	10.9	5.9	39.0	24.6	58.0	73.5	65.9	77.4
Control (unexposed)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The values are highly significant at 0.05 probability level.

It was also evident that in heavy fabrics, yarn and threads the breaking strength and elongation showed similar trend but these properties were inversely related in case of light fabrics.

Tropic Room Exposure : The rate and pattern of degradation of cotton materials was studied under controlled tropical exposure conditions for 210 days. The data of breaking strength and elongation showed significant variations in different samples. (Table 3). The pattern of loss in breaking strength and elongation of fabrics was almost similar to that observed in monsoon outdoor exposure. Among the yarn/threads, sized thread showed maximum loss in breaking strength till 120 days after which grey yarn became highly susceptible till last sampling. But the loss in elongation in grey yarn was higher than that of sized thread. Mercerized thread comparatively showed minimum loss both in breaking strength and elongation.

TABLE 3

LOSS IN BREAKING STRENGTH (BS) AND ELONGATION AT-BREAK (EL) OF COTTON MATERIALS DURING 'TROPIC ROOM' EXPOSURE FROM 15 JUNE, 1973 TO 15 JANUARY, 1974. (AV. TEMP. 25.9± 4° C; R.H. 93±4%)

Cotton Materials	Exposure days													
	30		60		90		120		150		180		210	
	BS	EL	BS	EL	BS	EL	BS	EL	BS	EL	BS	EL	BS	EL
Cambric	5.6	5.0	26.1	28.5	34.5	38.5	55.9	81.0 a	81.1 a	82.5 a	90.0	88.5	100	100
Dosooti	11.8	16.0	38.2	35.0	53.1	63.2	67.6	71.5	78.5	77.5	86.6	86.4 a	92.6	87.5 a
Duck cotton	7.5	16.0 a	32.4	18.6 a	51.3	33.0 b	58.4	35.5 b	75.9 c	44.1	80.0 c	47.1 d	84.8 c	48.3 d
Light canvas	9.0	6.3	16.7	7.5	46.0	32.5	56.1	25.5	65.4	42.5	75.4	40.5	84.3	50.0
Heavy canvas	8.2	6.8 a	14.7	6.6 a	43.0	23.7 b	49.8	23.7 b	60.7	31.7	70.4	40.7	80.0	52.0
Grey yarn	23.2	11.6	34.8	21.2	71.8	40.0	77.8	48.0	91.1 a	61.2 b	94.6 a	63.6 b	98.5	78.0
Sized thread	37.8	3.0	48.0	16.0	60.1	24.0	71.3	52.6	79.6	66.3 a	85.0	71.3 a	96.0	100
Mercerized thread	5.8	3.8 a	41.5	8.5 a	60.0	22.8	70.0	61.0	80.7 b	72.2 c	84.3 b	74.8 c	89.1	87.7
Control (unexposed)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Values in each horizontal column followed by the same letter are not significantly different at the 0.05 probability level.

Soil Burial ; The rate of degradation of cotton materials in soil burial conditions was studied under different soil moisture contents (Fig. 1—3; and Table 4). The data of retained reaking strength were highly significant at 0.05 probability level It was observed that at 5% soil moisture the loss in breaking strength

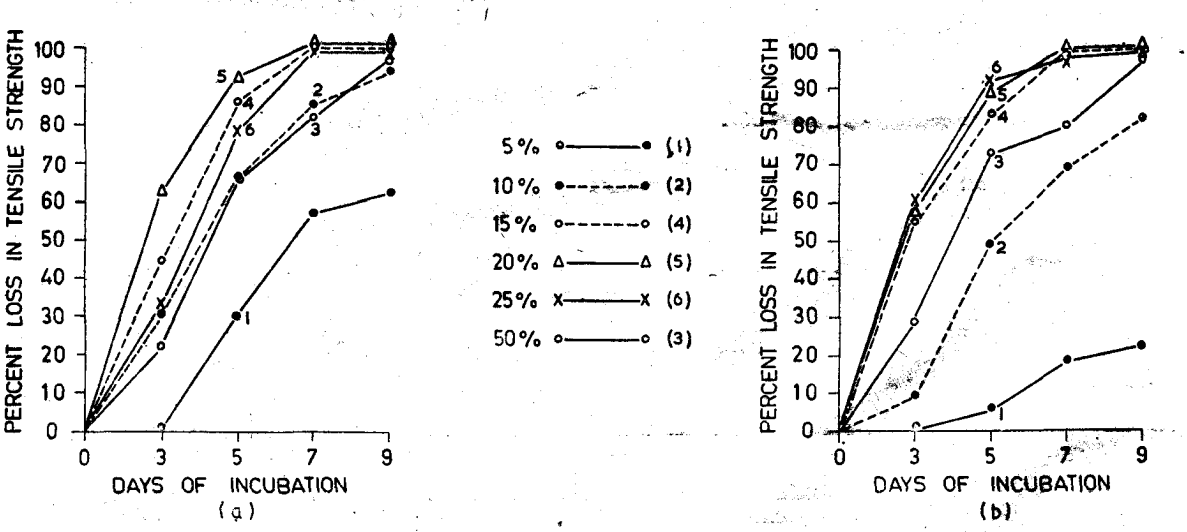

Fig. 1—Rate of fungal degradation of light cotton fabrics in soil under different moisture contents; (a)=cambric and (b)=Dosooti

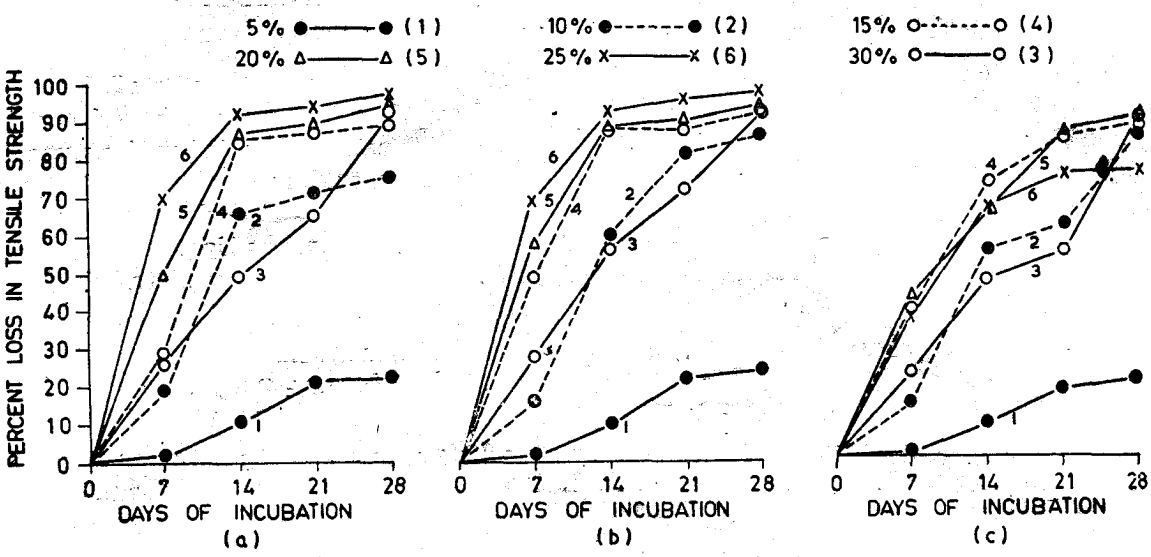

Fig. 2– Rate of fungal degradation of heavy cotton fabrics in soil under different moisture contents; (a)=Duck cotton, (b)=light canvas and (c)=Heavy canvas.

TABLE 4

PERCENT LOSS IN BREAKING STRENGTH OF COTTON MATERIALS IN SOIL BURIAL TEST; AV. TEMP. 25.9± 4°C, R.H. 93± 4%

Soil moisture (%)	Samplings	Percent loss in breaking strength to control							
		Cambric	Dosooti	Duck cotton	Light canvas	Heavy canvas	Grey yarn	Sized thread	Mercerized thread
5	I	0.0	0.0	1.9	14.1	0.6	0.6	0.4	1.1
	II	29.8	5.0	10.9	20.2a	9.2	9.5	1.4	6.0
	III	56.6	17.8	20.8a	21.5a	18.4a	16.7	2.7	12.0
	IV	62.5	22.4	22.1a	24.1a	21.0a	29.6	5.0	18.0
10	I	29.8	8.7	18.5	30.0	14.4	48.6	34.8	4.8
	II	66.0	49.2	66.3	80.0	54.4	57.5	61.9	24.0
	III	85.5	69.1	71.3	80.8	62.1	72.3	69.0	71.0
	IV	94.0	82.1	75.3	85.9	85.8	78.4	73.3	83.0
15	I	40.0	55.3	29.4	48.6	39.0	57.8	36.0	65.0
	II	86.4	82.5	85.1b	87.5	72.8	70.3	58.4	74.6
	III	100	100	87.6b,c	88.0	85.0b	85.1	93.2	78.2
	IV	100	100	88.7c	92.0	89.0b	100	96.0	90.3
20	I	63.8	58.5	49.8	77.1	43.0	49.0	69.5	72.3
	II	93.7	89.4	87.1d	89.8b	65.4	77.4	80.1	79.4
	III	100	100	89.4d	89.7b	86.0c	90.4	96.2	84.4
	IV	100	100	93.8	93.8	89.6c	100	100	100
25	I	32.7	60.2	69.7	68.8	38.1	17.4	48.9	47.2
	II	78.6	91.9	92.3e	92.2c	65.9	75.6	76.3	55.3
	III	100	98.4a	94.3e,f	94.4c	75.2d	100	100	86.0
	IV	100	100a	97.3 f	97.3	76.0d	100	100	100
30	I	22.0	28.1	25.7	28.2	22.1	14.0	22.2	13.2a
	II	66.6	73.2	48.9	56.3	47.2	54.0	51.4	13.0a
	III	82.3	79.6	64.9	71.8	54.6	83.7	93.3	61.4
	IV	97.3	100	92.4	92.2	98.1	90.4	96.0	74.6
Control (unexposed)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Values in each vertical column followed by the same letter are not significantly different at 0.05 probability level.

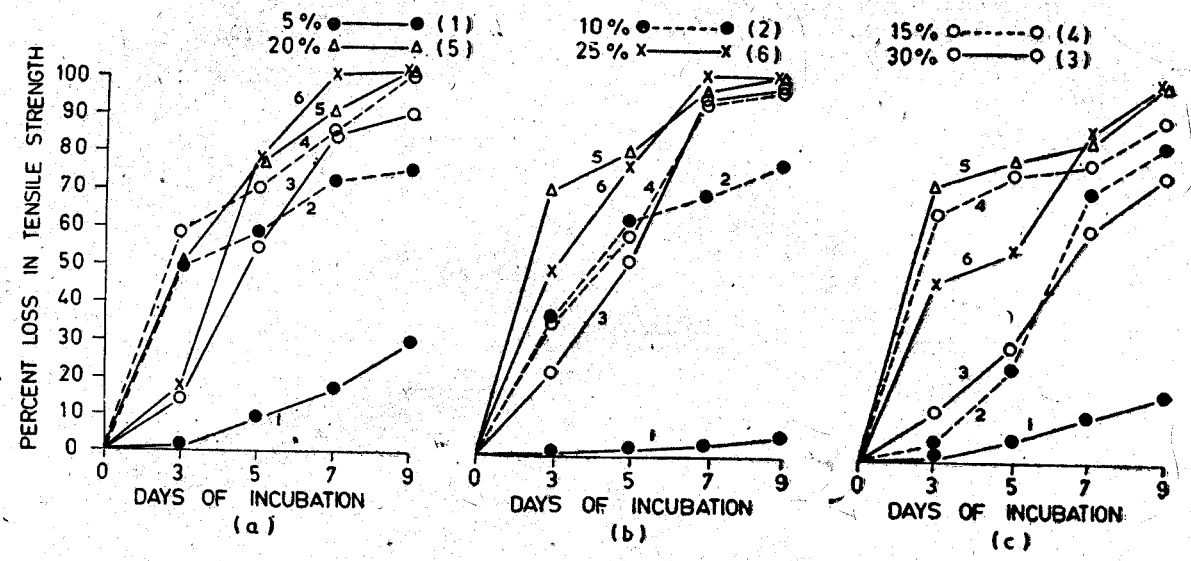

Fig. 3—Rate of fungal degradation of cotton yarn threads in soil under different moisture contents; (a)=Grey yarn, (b)=Sized thread and (c)=Mercerized thread.

was minimum. There was a gradual increase in percent loss in breaking strength of the cotton materials with the increasing moisture content of the soil upto a optimum level, after which it decreased with further increase in the moisture content in the soil (Fig. 1—3). The statistical analysis has shown following pattern of gradual increase in loss of strength of cotton materials (Table 5—values in the same bar did not differ significantly) :

TABLE 5

LOSS IN BREAKING TRENGTH OF COTTON MATERIAL SUNDER SOIL

Cotton material	Loss in breaking strength in increasing order under different soil moistures					
Cambric	5	30	10	15	25	20
Dosooti	5	10	30	15	20	25
Duck cotton	5	10	30	15	20	25
Light canvas	5	30	10	15	20	25
Heavy canvas	5	30	10	25	15	20
Grey yarn	5	30	10	25	15	20
Sized thread	5	10	30	15	25	20
Mercerized thread	5	30	10	25	15	20

The soil moisture optima causing maximum loss in the breaking strength of the cotton materials ranged between 20—25%.

It was also observed that mean values of loss in breaking strength of cotton materials increased with the prolongation of incubation period. The interaction between soil moisture and incubation period was well marked. The loss in breaking strength in different soil moistures varied with the period of incubation (Fig. 1—3).—The susceptibility of cotton materials in decreasing order was found as under :

Cambric—Dosooti

Light canvas—Duck-cotton—Heavy canvas

Grey yarn —sized thread—Mercerized thread.

Fung : 33 species of fungi were isolated from the exposed and soil buried cotton materials. These were* :

1. *Rhizopus nigricans*
2. *Cunninghamella echinulata*
3. *Chaetomium globosum*
4. *Phoma* sp.
5. *Trichoderma viride*
6. *Aspergillus flavus*
7. *A. fumigatus*
8. *A. nidulans*
9. *A. niger*
10. *A. oryzae*
11. *A. sparsus*
12. *A. sydowi*
13. *A. terreus*
14. *A. terricola*
15. *Penicillium thomii*
16. *Penicillium* sp.
17. *Penicillum* sp.
18. *Paecilomyces varioti*
19. *Botrytis cinerea*
20. *Pullularia pullulans*
21. *Stachybotrys atra*
22. *Humicola* sp.
23. *Memnoniella echinata*
24. *Cladosporium herbarum*
25. *Curvularia lunata*
26. *C. pallescens*
27. *Helminthosporium* sp.
28. *Alternaria tenuis*
29. *Fusarium chlamydosporum*
30. *F. moniliforme*
31. *F. roseum*
32. *Myrothecium verrucaria*
33. *Grey sterile fungus* (unidentified).

* Fungi in serial 4, 14, 16, 20–23, 27, 32, 33 were restricted to fabrics.
Fungi in serial 11 was restricted to yarn and threads.
Fungi in serial 3-5, 7, 10, 13, 15, 19, 21-32 were cellulolytic.
Fungi in serial 14, 15, 19 were encountered for the first time from cotton materials.

DISCUSSION

The microbial activity in Indian climatic conditions is usually uppermost and the degradation of susceptible cotton materials is intensive and widespread. The micro-organisms concerned in degradation of cellulosic materials are mainly bacteria and fungi but widespread microbial deterioration in the tropics is predominantly due to fungal attack[7]. Particularly during monsoon both soil and atmosphere are replete with fungal spores but the pattern of fungal attack on cotton materials is determined by the interaction between the cellulolytic activity of the fungi and climatic effect. Under constant state of wetting and drying during monsoon, the cotton materials respond more rapidly to degradation by fungi.

The susceptibility of different cotton materials to fungal deterioration is due to their physical characteristics such as nature, texture, count (fineness), weight, compactness and twisting of yarns, weave and also due to varying fungal activities in outdoor monsoon weathering and in soil burial conditions. It is concluded that the light-weight cotton fabrics made from twisted and/or mercerized yarns are more resistant to fungal attack than the heavy weight fabrics made from non-twisted grey yarns. The susceptibility of yarn and threads is also due to the nature, thickness, spinning, mercerization and application of sizing materials. The susceptibility of grey cotton fibres may be also due to the fact that it contains all the essential nutrients required for the growth of fungi as suggested by Fargher[8]. The chemical treatment (mercerization) however washes the nutritional components of the grey fibres resulting in their resistance to fungal attack[9]. This explains the resistance in mercerized yarn and fabrics. In relatively thick and closely woven fabric the rate of drying is slow so that the moisture is retained in the fabric for a long period and this is conducive to fungal degradation.

The rate of degradation of cotton materials studied under controlled and simulated tropical climatic conditions consistently for seven months gives an additional information on the pattern of degradation in continuous and consistent tropical conditions which may or may not be uniformly available in nature. In general it has supported the data of monsoon outdoor exposure.

The moisture content of the soil has played an important role in the degradation of cotton materials. The soil moisture enhances the growth and activity of fungi as long as there is no water-logging[10—12]. The optimum activity of fungi at 20—25% soil moisture resulted in maximum loss in strength. Further increase in moisture above 25% possibly reduced aeration and resulted in high multiplication of facultative anaerobic organisms and this in turn disfavoured the growth of fungi. Similar observations have been made by Waksman and others[13]. Behaviour of different cellulose decomposers at different moisture levels is reported to be different[14]. This interpretation along with the variations in the physical characteristics of the cotton materials are the reasons for getting different optima of soil moisture level for maximum degradation.

The degradation of cotton materials in the soil is more rapid and intense than in outdoor exposure. This observation has also been supported by Tweedie and Baylay[15] while working on vegetable fibres. It may be due to the fact that large number of fungi of every nutritional taste inhabiting the most ideal growth conditions in the soil colonize the substrate and decompose it vigorously in presence of suitable moisture and temperature.

In most of cotton materials loss of breaking strength is more than that of elongation. These findings are also corroborated by Lee and Finkner[16]. However in heavy fabrics as well as in yarn/threads a reverse correlation between breaking strength and elongation losses has been observed. The elongation property of cotton materials is also related to the physical characteristics of the fibres. The elongation property is of considerable importance in relating the elongation behaviour of different morphological components of the cotton fibres.

Fungi encountered on cotton materials differ in their property of destroying cellulose. Due to higher cellulolytic activity the fungi belonging to Fungi Imperfecti group play a major role in the degradation of cotton materials.

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REFERENCES

1. MARSH, P.B. & BOLLENBACHER, K., *Text. Res. J.*, **19** (1949), 313.
2. SAHGAL, D.D. & AGARWAL, P.N., *Labdev J. Sci. Tech.*, **5** (1967), 175.
3. SRIVASTAVA, K.C. & NIGAM, S.S., *Labdev J. Sci. Tech.*, **12B(1)**, (1974), 1.
4. SMITH, G., *Endeavour*, **5** (1946), 110.
5. SEN GUPTA, S.R., NIGAM, S.S. & SAXENA, B.B.L., *Proc. Ind. Acad. Sci.*, **29(5) B**, (1949), 205.
6. SANBORN, J.R., *J. Bact.*, **12** (1926), 1.
7. NIGAM, S.S., AGARWAL, P.N. & TANDON, R.N., *Labdev J. Sci. Tech.* **10B(1)**, (1972), 1.
8. FARGHER, R.G., *J. Soc. Dyers, Colourists*, **61** (1945), 118.
9. BARGHOORN, E.S., Micro. Ser. Rep. 4 : US. Army Quar. Mas. Res. & Dev. (1946).
10. WAID, J.S., 'The growth of fungi, an international symposium', (Liverpool Univ. Press), 1960, p. 71.
11. PUGH, G.J.F. 'Ecology of fungi in developing coastal soils and soil organisms' (Netherlands), 1963.
12. MISRA, R.R. & KANAUJIYA, R.S., *Proc. Natl, Acad. Sci. India*, **42B** (1972), 131.
13. WAKSMAN, S.A., *Soil Sci.*, **14** (1922), 32.
14. GARRET, S.D., Soil fungi and soil fertility' (Pergamon Press, N.Y.) 1963, p. 65.
15. TWEEDIE, A.S. & BAYLAY, C.H., *Amer. Dyestuff. Reptr.*, **33** (1944) 373.
16. LEE, J.S. & FINKNER, M.D., *Text. Res. J.*, **38** (1968), 1044.