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# STUDIES ON THE PHYSIOLOGY OF HIGHER FUNGI : VI. EFFECT OF TEMPERATURE, LIGHT AND HYDROGEN-ION CONCENTRATIONS ON VEGETATIVE GROWTH OF SOME SPECIES OF *FOMES* AND *GANODERMA*

By

NIRMALENDU SAMAJPATI and SACHINDRANATH BANERJEE

*Department of Botany, University of Calcutta, Calcutta, India*

The present study has been undertaken to provide information about the role of different environmental factors on the rate of vegetative growth of *Fomes senex* Nees & Mont., F. *fastuosus* Lev., F. *durissimus* (Lloyd), *Ganoderma applanatum* (Pers.) Pat., *G. lucidum* (Leyss.) Karst, and *G. colossus* (Fr.) Bres.. Glucose-casein hydrolysate medium has been used as basal medium. It has been found that 30 °C. is the optimum temperature for all the species of test-fungi except F. *fastuosus* where it is 25°C. In case of light, alternate light and darkness has maximum stimulatory effect on the rate of growth of all the fungi. Next comes, blue range (435-800 mμ) of different spectral ranges of continuous light. It has been noticed that all the test-fungi are acid-loving. The optimum pH for the growth of all the three species of *Ganoderma* is 6.0. In case of two species of *Fomes* (F. *senex* and F. *durissimus*) it is 5.0 while for F. *fastuosus* it is 4.0. A possible explanation of the diversity shown by the test-fungi in response to their different environmental factors have been discussed.

## Introduction

In the present investigation the role of three environmental factors on the rate of vegetative growth of six species of basidiomycetes have been recorded. The fungi, under study, belong to two allied genera, viz., *Fomes* and *Ganoderma*, of the family Polyporaceae. Of each genus, three allied species, common in West Bengal have been selected and these are *Fomes senex* Ness & Mont., F. *fastuosus* Lev , F. *durissimus* Lloyd, *Ganoderma applanatum* (Pers.) Pat , *G. lucidum* (Leyss.) Karst., and *G. colossus* (Fr.) Bres. They are chiefly lignicolous fungi but sometimes also attack living trees, particularly the basal region of the tree trunks. These fungi are widely distributed throughout the plains and hills of India.

The present investigation deals with the effect of three environmental factors on the rate of vegetative growth of the test-fungi, viz. temperature, light and hydrogen-ion concentration. Temperature has a direct or

indirect effect on almost all cellular activities. The influence of light on fungal growth has so far attracted very little attention of the scientists. The effects of light on fungi have so far been broadly divided into (a) *morphogenetic effect*, in which light induced or inhibits the formation of a stucture, and (b) *non-morphogenetic effect*, in which light plays its role on the rate of vegetative growth and in the synthesis of compounds, and in the directive movement of the vegetative body. It is known that different grades of hydrogen-ion concentration of a substratum exert considerable influence on the rate of growth of fungi. Fungi have been found to tolerate a wide range of this grade.

The relation of temperature to growth of wood-rotting fungi have been extensively studied by Humphrey and Siggers (1933), Cartwright and Findlay (1934), Campbell (1938), Snell (1922, 1923, 1928) Fritz (1923), Walpert (1924), and others.

It has been shown by Humphrey and Siggers (1933), and Cartwright and Findlay (1934) that the temperature-growth-curve tends to become more symmetrical as the optimum becomes lower but fungi with optimum temperature of 22 to 24°C. or less often have a much less skewed curve. It has been reported that all the low-temperature fungi, however, do not show this type of growth. Snell (1922, 1923, 1928) has determined the rates of growth of a number of wood-rotting fungi under various temperature conditions and used the data in a key for distiguishing various species in culture. Fritz (1923) also has studied the rates of growth of some wood-rotting fungi in culture along with other characters at different temperatures. Walpert (1924) after studying the influence of temperature on eight species of basidiomycetes has placed them into three groups, viz., low temperature (upto 25°C.), intermediate temperature group (upto 30°C) and high temperature group (35°C and above) on the basis of optimum temperature. Mounce (1929) has reported that *Fomes pinicola* grew well at temperature ranging from 8°C to 35°C., with an optimum temperature of about 27°C. to 29°C. Lindgreen (1933) has studied the effect of temperature on rates of decay in wood and of mycelial growth in culture for three wood-rootting fungi. He has concluded that optimum temperature for both *Lenzites sepiaria* and *Polystictus versicolor* is the same but in case of *Lentinus triginus*, the decay has been maximum at 27°C., while the maximum mycelial development has been found between 32 and 35°C. Humphrey and Siggers (1933) also have classified the wood-rotting fungi into three groups depending on their optimum range of temperature viz., (i) low-temperature-group (20° to 24°C.), (ii) intermediate-temperature-group (24° to 32°C.), and (iii) high-temperature-group (above 32°C.). Cartwright and Findlay (1934) have shown that temperature requirements within the family, Thelephoraceae, Polyporaceae and Agaricaceae vary between species even within the same genus. Campbell

(1938) has studied the cultural characteristics of thirty-one species of *Fomes* in which growth in culture at different temperature has been recorded and included the data thus obtained in a key to species of *Fomes* in culture proposed by him. It has been found that *Poria vaporaria* and *Schizophyllum communne* have brought about most rapid decay at 2° to 3°C. below the optimum temperature in culture. Banerjee and Bakshi (1945) have studied the effect of temperature on four species of *Polyporus*, one species of *Polystictus* and one species of *Merulius* in India and concluded that the mycelial growth of all the fungi seem to be best at 33°C., and also the pigmentation has been intensed at the same temperature. Rennerfelt and Paris (1953) have observed that *Polyporus (Fomes) annosus* can grow well at 20° to 32°C. Mizumoto (1956) also has studied four species of *Lenzites* and concluded that the optimum temperature for mycelial growth and decay of test blocks have been 26° to 28°C. for *L. abietina* and 32° to 34°C. for other three species. Etheridge (1957) has determined that the maximum temperature for growth on *malt-agar* is 5°C. lower for butt-rotting fungi than for the trunk-rotting group (20° and 25° C. respectively). Lombard, Davidson and Lowe (1960) have determined that the optimum as well as killing temperature in *Poria ambiosa* and *Fomes ulmarius*. Ward (1964) has reported the formation of stromalike structures in culture by low-temperature-basidiomycetes. Nandi (1964) has also reported that *Lentinus praerigidus* exhibit a typical skewed-temperature-growth-curve and placed it under intermediate temperature group after Humphrey and Siggers (1933).

Most of the reports on the effects on light on basidiomycetes deal with the vegetative growth rather than with the reproduction. Buller (1905) has reported that light is essential for the formation of pileus of *Lentinus lepideus*. He also has noted that *Polyporus squamosus* in darkness develope black stag-horn like sterile stroma with each branch having a white tip in place of a stipitate pileus. The formation of a normal pileus in this case is entirely conditioned by the presence of day light. It has been noted that germ-tubes of uredespores of *Puccinia rhamni* are negetively phototropic and mentioed that similar reaction with those of *P. elopirse* has early been recorded. Long and Harsch (1918) has worked out the influence of light on a number of Polypores. They allow direct sunlight to reach the young cultures for one to two hours, but later the amount of direct sunlight is decreased by light screens. This checked the mycelial growth and intesified the colours of the aerial mats. Fritz (1923) has carried on her investigations with several species of *Fomes* in complete darkness and in her opinion their diagonastic characters become well manifiested even in the abscence of light. Bose (1930) has studied the influence of light on twelve species of Polyporaceae and concluded that diffuse light of the

laboratory induce the formtion of basidiocarps, but the vegetative growth is rather poor. Borriss (1934) has reported inhibition of growth by light in some basidiomycetes. He has found that if the haplophasic mycelia of *Coprinus lagopus* are exposed to light from darkness, inhibition start after a lag period. Benerjee and Bakshi (1945) have studied the effect of light on six species of basidiomycetes and concluded that in the presence of light the vegetative hyphae become more compact due to early condensation and more rich and varied colouration is produced than those in darkness. Gettkandt (1954) has reported inhibition of growth by light in the germ-tudes of uredospores of *Puccinia triticina*. Nandi (1964) has concluded that *Lentinus praerigidus* grow well in complete darkness or in alternate light and darkness, while it is unable to tolerate continuous light.

The references on the effects of light on the growth of fungi are given in the critical reviews by Banbury (1959), Carlile (1965) and recently by Page (1965)

A critical review of literature on the effect of hydrogen-ion concentration on the growth of different basidiomycetous fungi will show that the majority of them grow well in grades of pH towards the acidic side although some of them preffered to grow well in grades of pH on the alkaline side.

Meachum (1918) has studied the pH requirements of four species of Polypores and concluded that their optimum pH for growth is 3.0. Webb (1922) has reported that *Lenzites saepiaria* grow well within the pH-range of 2.8 to 7.4. Walpert (1924) has studied eight species of basidiomycetous fungi and report that they grow well within the pH range of 2.5 to 7.6. It has been demonstrated by Melin (1924) that optimum pH for four species of *Boletus* is 5.0. Weis and Nielson (1927) has reported that most favourable pH for the growth of *Fomes annosus* is 4.0. Montgomery (1936) has recorded 6.0 to 7.0 as the optimum range for the growth of *Fomes fraxineus*. It has also been reported that optimum pH for the growth of *Merulius confluens* is 4.0. It has been found that optimum pH for the growth of *Stereum gausapatum*, *Coprinus* spp., are 2.0 to 8.2 and 4.8 to 6.9, respectively. Lindeberg (1944) has revealed that calcium-ion in culture is effective in overcoming the initial toxic effect of an initial pH of 3.3. In culture the larger basidiomycetes fail to grow at an initial pH above 7.0 and they are ingeneral restricted to acidic environment (Lindberg, 1944 ; Norkrans, 1950). It has been seen that some species of fleshy basidiomycetes require alkaline condition for their growth. Robbins (1950) has reported that pH requirement for the growth of *Fomes lignosus* is 7.5. It has been reported that optimum pH range for the growth of *Fomes annosus* is 2.9 to 7.0 while according to Etheridge (1955) it is 4.6 to 4.7.

## Materials And Methods

For the present investigation six species of basidiomycetes, viz., *Fomes senex* Nees & Mont., *F. fastuosus* Lev., *F. durissimus* Lloyd, *Ganoderma applanatum* (Pers.) Pat., *G. lucidum* (Leyss.) Karst., *G. colossus* (Fr.) Bres. have been collected from Calcutta and suburbs. From the context of each of the fresh basidiocarp, tissue cultures have been made following the method proposed by Dugger *et al.* (1917). These tissue culture are subcultured at regular intervals and maintained as stock cultures for further study.

Glucose-casein hydrolysate medimm (Leonian and Lilly, 1945) has been selected as basal medium for the present investigation as it has been recommended as a well balanced medium by Lilly and Barnett (1949). The composition of the medium is as follows : Glucose, 25 gm.; Casein hydrolysate, 2 gm.; $MgSO_4$, $7H_2O$, 0.5 gm.; $KH_2PO_4$, 1.0gm ; Fumaric acid, 1.32 gm.; $Na_2CO_3$, 1.12 gm.; Fe as sulphate, 0.2 mg,; Zn as sulphate, 0.2 mg.; Mn as sulphate, 0.1 mg.; and distilled water to make the volume 1000 ml.

Pyrex Erlenmeyer flasks are used as culture vessels. In each of the required number of flasks, 25 ml. of the basal medium is taken. They were then plugged and sterilised at 15 lbs. pressure. for 15 minutes. Experimental flasks are inoculated according to the method of Lindeberg (1944), modified by Norkrans (1953). After inoculation, all the flasks are incubated (stationary) at 30°C. in darkness. Sufficient flasks are incubated to provide five replicates for each treatment for 20 days. The length of the incubation period necessary for optimum growth for each treatment is predetermined by running a series of experiments.

Every fourth-day, five replicates of each treatement are harvested five times and the contents are filtered through a tared filter paper (Whatman No. 1), using a Buchner funnel. The residual mycelia are washed with distilled water to remove any trace of the medium and then dried at 60°C., in an oven for 24 hrs. After drying they are kept in closed vaccuum dessicator, cooled, and later weighed in a chemical balance (Sartorius).

The quantitative data thus obtained on individual test nutrients are based on the average dry weight of mycelia produced in a test medium of five flasks. In all the experiments, the *p*H of the medium for optimum growth for each fungus is maintained by N/15 phosphate buffer.

In case of temperature, sufficient numbers of culture vessels are inoculated to have five replicates of each treatment during each harvesting and they are incubated at different temperatures. The different temperature used are 15°, 20°, 25°, 30°, 35°, and 40°C.

The culture vessels are inoculated as usual with the test-fungi and incubated as usual. The light source is a big projection glass chamber illuminated internally by three day-light flourescent tubes (Osram, 80 Watt). Each treatment box has a clear glass plate as the base and is painted dark black internally. The lid of the box is light-tight but with a light-tight ventillator. At the base below the glass plate there is neutral density filter. A light-tight shutter is mounted between the glass plate and neutral density filter. The culture flasks are accomodated in each treatment box. These boxes are then placed upon the projection chamber and the cultures are differently illuminated from below by using Ilford's Standard Spectrum light filters (2″×2″). The intensity of light of the treatment boxes is 2100 lux. The different types of light are continuous light, alternate light and darkness, red light (610-750 $m\mu$), blue light (435-800 $m\mu$), green light (500-560 $m\mu$), orange light (595-610 $m\mu$), and complete darkness.

The normal basal medium is neutralised and then by addition of N/15 phosphate buffer solution, the following grades of *p*H are prepared in the experimental culture vessels and they are sterilised by passing the entire medium through a IG-5 filter (Jena) and inoculated as usual before incubating at optimum source of temperature and light. The grades of *p*H used are 3.0, 4.0, 5.0, 6.0, 6.5, 7.0, 8.0, 9.0, and 10.0. The other necessary experimental procedures are as usual as stated before.

## Results

The experimental results reveals that all the test-fungi show a wide diversity in their reponses against the environmental factors, e.g. light and temperature and hydrogen-ion concentrations. It further reveals that all the above factors role on the vegetative growth of the test-fungi is again controlled by the incubation periods of the test-fungi.

(i) *Temperature*—The results obtained during the experimental periods have been given in Tables 1—3.

Table 1. *Data (mean) showing the effect of different temperature on the rate of vegetative growth (mg./25 ml.) of three species of* Fomes *and Ganoderma at different incubation periods.*

Fungus (F) X Temperature (T)

| Fungus Temperature | G. applanatum | G. lucidum | G. colossus | F. senex | F. fastuosus | F. durissimuss | T. means |
|---|---|---|---|---|---|---|---|
| 15 | 66.4 | 67.6 | 68.3 | 34.0 | 36.8 | 40.5 | 52.3 |
| 20 | 82.5 | 83.4 | 84.3 | 78.6 | 77.0 | 80.3 | 81.0 |
| 25 | 132.0 | 132.3 | 134.3 | 93.9 | 111.1 | 99.7 | 115.6 |
| 30 | 298.4 | 299.8 | 301.4 | 105.3 | 101.1 | 119.5 | 203.1 |
| 35 | 101.9 | 88.9 | 95.2 | 89.3 | 87.3 | 90.5 | 92.2 |
| 40 | 40.3 | 40.2 | 36.9 | 65.6 | 57.3 | 66.0 | 51.1 |
| F-means | 120.3 | 118.7 | 120.1 | 77.8 | 78.7 | 82.6 | |

S. Em for F = ±0.00038
S. Em for T = ±0.00038
S Em. for F X T = ±0.00095
C. D. at 5% of P for F-and T—0.00105
C. D. at 5% of P for F X T—0.00265

Table 2. *Data (mean) showing the effect of incubation periods on the rate of vegetative growth (mg./25ml.)of three species of* Fomes *and Ganoderma at different temperatures.*

Fungus (F) X Incubation Periods (I)

| Fungus Incubation Period | G. applanatum | G. lucidum | G. colossus | F. senex | F. fastuosus | F. durissimuss | I-means |
|---|---|---|---|---|---|---|---|
| 4 days | 109.8 | 108.7 | 110.6 | 72.8 | 72.2 | 76.0 | 91.7 |
| 8 days | 115.5 | 114.4 | 115.9 | 75.1 | 75.4 | 79.4 | 95.9 |
| 12 days | 119.8 | 119.1 | 120.3 | 77.6 | 80.1 | 82.0 | 09.9 |
| 16 days | 125.7 | 123.3 | 124.5 | 81.7 | 83.5 | 86.2 | 104.2 |
| 20 days | 130.4 | 128.0 | 129.1 | 86.6 | 88.3 | 91.4 | 109.9 |
| F-means | 120.3 | 118.7 | 120.1 | 77.8 | 78.7 | 82.6 | |

S. Em for I = ±0.00034
S. Em for F X I = ±0.00087
C. D. at 5% of P for I—0.000945
C. D. at 5% of P for F X I—0.00241

Table 3. *Data (mean) showing the effect of different temperature on the incubation periods of vegetative growth (mg./25ml.) of three species of* Fomes *and Ganoderma.*

Temperature (T) X Incubation period (I)

| Incubation period / Temperature | 4 days | 8 days | 12 days | 16 days | 20 days | T means |
|---|---|---|---|---|---|---|
| 15 | 46.6 | 49.1 | 52.5 | 54.4 | 58.2 | 52.3 |
| 20 | 75.1 | 78.2 | 81.0 | 84 0 | 86.9 | 81.0 |
| 25 | 107.8 | 114.3 | 119.3 | 123.0 | 128.4 | 115.6 |
| 30 | 189.3 | 199.2 | 204.4 | 203.2 | 223.9 | 203.6 |
| 35 | 86.0 | 88.6 | 91.4 | 95.9 | 99.1 | 92.2 |
| 40 | 45.2 | 48.2 | 50.9 | 54.0 | 57.4 | 51.1 |
| Incubation period means | 91.7 | 95.9 | 99.9 | 104.2 | 109.9 | |

S. Em for T X I ±0.00087 C. D. at 5% of T X I—0.00241

From the fore-going tables (Tables 1—3), it will be evident that for all the test-fungi, the optimum temperature for vegetative growth is 30°C., while that in case of *Fomes fastuosus* is 25°C. The minimum and maximum temperature for growth of all the test-fungi, however, are the same in all cases, which is 15°C and 40°C. respectively.

(ii) *Light*—The results obtained during the experimental periods are given in Tables 4—6.

Table 4. *Data (mean) showing the effect of various sources and nuture of light on the vegetative growth (mg /25ml.) of three species of* Fomes *and* Ganoderma *at different incubation period.*

Fungus (F) X Light (T)

| Fungus / Light | G. applanatum | G. lucidum | G. colossus | F. senex | F. fastuosus | F. durissimus | T means |
|---|---|---|---|---|---|---|---|
| Continuous light | 300.0 | 310.4 | 308.9 | 115.2 | 122.0 | 134.2 | 215.1 |
| Alternate light & darkness | 311.7 | 316.3 | 320.5 | 127.0 | 129.0 | 138.0 | 223.7 |
| Darkness | 306.3 | 313.5 | 315.0 | 119.4 | 125.7 | 136.2 | 219.3 |
| Blue | 301.4 | 309.5 | 308.1 | 113.7 | 120.2 | 129.7 | 213.8 |
| Red | 294.9 | 303.7 | 305.2 | 108.1 | 115.8 | 124.1 | 208.6 |
| Green | 296.3 | 307.2 | 306.2 | 111.6 | 116.9 | 126.4 | 210.8 |
| Orange | 289.3 | 302.7 | 303.3 | 106.6 | 113.8 | 121.5 | 206.2 |
| Control (Diffused light) | 298.5 | 299.8 | 301.6 | 105.5 | 112.6 | 119.6 | 206.3 |
| F means | 299.8 | 307.9 | 308.6 | 113.4 | 119.5 | 128.7 | |

S. Em for F=±0.0004 C. D. for F at 5% of P—0.001112
S. Em for T=±0.0005 C. D. for T at 5% of P—0.001390
S. Em for FXT=±0.0012 C. D. for FXT at 5% of P—0.003337

Table 5. *Data (mean) showing the effect of incubation periods on the vegetative growth (mg./25ml ) of three species of Fomes and Ganoderma in the presence of various sources and nature of light.*

Fungus (F) X Incubation periods (I)

| Fungus / Incubation Period | G. applanatum | G. lucidum | G. colossus | F. senex | F. festuosus | F. dusissimuss | I means |
|---|---|---|---|---|---|---|---|
| 4 days | 275.0 | 286.0 | 285.0 | 102.7 | 108.2 | 115.6 | 191.8 |
| 8 days | 290.0 | 295.0 | 298.0 | 199.7 | 115.3 | 123.2 | 205.0 |
| 12 days | 300.0 | 908.0 | 309.0 | 113.8 | 120.3 | 129 0 | 213.6 |
| 16 days | 311.0 | 319.0 | 388.0 | 117.9 | 115.2 | 134 8 | 221.4 |
| 20 days | 320.0 | 328.0 | 330.0 | 112.9 | 128.5 | 140.9 | 228.7 |
| F means | 299 8 | 307.9 | 308.6 | 113.4 | 189 5 | 128.7 | |

S. Em for I= ±0.0004 C. D. for I at 5% of P—0.001112
S. Em for FXI= ±0.0009 C. D. for FXI at 5% of P—0.002502

Table 6. *Data (mean) showing the effect of interaction of the various sources and nature of light and different incubation periods on the vegetative growth (mg/25ml.) of three species of* Fomes *and* Ganoderma.

Light (T) X Incubation periods (I)

| Incubation Periods / Light | 4 days | 8 days | 12 days | 16 days | 20 days | T mean |
|---|---|---|---|---|---|---|
| Continuous light | 198.4 | 207.3 | 215.4 | 223.3 | 531.0 | 215.1 |
| Alternate light & darkness | 203.1 | 214 7 | 225.7 | 233.2 | 241.8 | 223.7 |
| Darkness | 200.6 | 210.9 | 219.7 | 228.1 | 237.2 | 219.3 |
| Blue | 157.2 | 206.7 | 514.1 | 221.9 | 229.0 | 213.8 |
| Red | 191.6 | 201.9 | 209.5 | 216.1 | 223.2 | 208.6 |
| Green | 194.0 | 204.1 | 210.8 | 219.2 | 226.0 | 210.8 |
| Orange | 189.5 | 199.3 | 207.3 | 213.8 | 220.9 | 206.2 |
| Control (Diffused light) | 191.3 | 199.4 | 206-4 | 213.5 | 220.7 | 206.3 |
| I means | 191.18 | 205.6 | 213.6 | 221.4 | 228.7 | |

S. Em for TXI= ±0.0011 C. D. for TXI at 5% of P—0003059

From the fore-going tables, it is evident that for all the test-fungi the optimum source for vegetative growth is alternate light and darkness and the orange light has a maximum inhibitory effect on growth of all the test-fungi.

(iii) *Hydrogen-ion concentrations*—The results obtained during the experimental periods are given in Tables 7—9.

Tables 7, *Data (mean) showing the effect of different hydrogen-ion concentration on the vegetative growth (mg./25 ml.) of three species of Fomes and Ganoderma at different incubation periods.*

Fungus (F) X Hydrogen-ion Concentration (T)

| Fungus Hydrogen-ion concentration | G. applanatum | G. lucidum | G. colossus | F. senex | F. fastuosus | F, durissimus | T means |
|---|---|---|---|---|---|---|---|
| 10.0 | 32.3 | 36.1 | 38.4 | 24.6 | 24.9 | 26.0 | 30.4 |
| 9.0 | 70.3 | 58.7 | 88.8 | 41.9 | 54.9 | 55.3 | 61.6 |
| 8.0 | 102.3 | 80.1 | 117.1 | 55.2 | 67.1 | 65.8 | 81.2 |
| 7.0 | 182.1 | 105.1 | 211.7 | 74.3 | 89.6 | 86.2 | 115.6 |
| 6.5 | 279.1 | 148.3 | 85.7 | 96.1 | 98.5 | 108.7 | 186.0 |
| 6.0 | 298.4 | 301.3 | 309.1 | 106.1 | 113.2 | 121.2 | 206.9 |
| 5.0 | 231.9 | 158.8 | 125.1 | 88.9 | 93.6 | 85.6 | 130.6 |
| 4.0 | 183.1 | 96.3 | 78.6 | 56.1 | 56.3 | 56.6 | 87.8 |
| 3.0 | 105.9 | 35.7 | 35.2 | 23.8 | 36.3 | 36.7 | 45.6 |
| Fungus means | 152.4 | 113.4 | 142.6 | 63.3 | 70.4 | 71.3 | |

S. Em for Fungus (F)= ±0.0007 C. D. for F at 5% of P – 0.001946
S. Em for pH (T)= ±0.0083 C. D. for T at 5% of P – 0.002308
S. Em for the body FXT – 'F' not significant

Table 8. *Data (mean) showing the effect of different incubation period on the vegetative growth (mg./ml.) of the test-fungi at different hydrogen-ion concentrations.*

Fungus (F) X Incubations periods (I)

| Fungus Incubation periods | G. applanatum | G. lucidum | G. colossus | F. senex | F. fastuous | F. durissimus | I means |
|---|---|---|---|---|---|---|---|
| 4 days | 145.4 | 102.4 | 133.5 | 58.7 | 64.5 | 65.7 | 98.5 |
| 8 days | 152.3 | 107.7 | 138.3 | 61.1 | 67.1 | 68.1 | 99.1 |
| 12 days | 158.3 | 112.5 | 143.0 | 62.9 | 70.2 | 71.1 | 103.0 |
| 16 days | 164.5 | 131.6 | 147.3 | 65.5 | 72.7 | 71.8 | 108.6 |
| 20 days | 171.8 | 124.5 | 151.4 | 68.4 | 76.0 | 77.9 | 111.6 |
| F mean | 152.4 | 113.4 | 142.6 | 63.3 | 70.4 | 71.3 | |

S. Em for Incubation periods (I)= ±0.00463 C. D. for the I at 5% of P—0.001752
S. Em for the body F X I —'F' test not significant

It is evident from the experimental results that the optimum *pH* for growth of all the three species of *Ganoderma* is 4. 2. In case of *Fomes senex* and *Fomes durissimus*, the optimum *pH* is 5. 0, while that in case of *Fomes fastuosus* is 4. 0.

Table 9. *Data (mean) showing the effect of interatction of hydrogen-ion concentration and incubation period on the vegetative growth of three species of* Fomes *and* Ganoderma.

Hydrogen-ion concentration (T) X Incubation period (1)

| Incubation period Hydrogen-ion conc. (pH) | 4 days | 8 days | 12 days | 16 days | 20 days | T-means |
|---|---|---|---|---|---|---|
| 10.0 | 24.2 | 28.1 | 30.6 | 31.2 | 34.6 | 30.4 |
| 9.0 | 49.6 | 57.1 | 55.8 | 69.8 | 75.8 | 61.6 |
| 8.0 | 72.0 | 76.1 | 82.4 | 86.6 | 89.1 | 81.2 |
| 7.0 | 100.6 | 106.8 | 114.8 | 125.8 | 130.1 | 115.6 |
| 6.5 | 168.6 | 174.6 | 177.1 | 187.8 | 195.1 | 186.0 |
| 6.0 | 188.1 | 198.6 | 207.2 | 218.8 | 221.8 | 206.9 |
| 5.0 | 110.8 | 119.8 | 129.4 | 142.6 | 148.4 | 130.6 |
| 4.0 | 74.6 | 71.4 | 86.6 | 98.2 | 101.4 | 87.8 |
| 3.0 | 29.7 | 35.4 | 46.2 | 54.6 | 61.6 | 45.6 |
| I-means | 98.5 | 99.1 | 103.0 | 108.6 | 111.6 | |

S. Em for the body of T X I='F' test not significant

## Discussion

A study on the responses exhibited by six species of basidiomycetes, vix., *Fomes senex*, *Fomes fastuosus*, *Fomes durissismus*, *Ganoderma applanatum*, *Ganoderma lucidum* and *Ganoderma colossus*, under different and uniformly controlled environmental and nutritional conditions, makes it possible to discuss in a general way some of the salient features regarding the relation that exists between these fungi and the environments, both physical and chemical. The present investigation confirms the findings of other workers in that the test-fungi under consideration differ widely among themselves in these respects.

After evaluating the role of temperature on vegetative growth of the test-fungi, it has been found that all the three afore-said species of *Ganoderma*, F. *durissimus* and F. *senex* have maximum yield at 30°C, while in case of F. *fastuosus* it is at its best at 25°C. The temperature growth curves obtained

for all the fungi are found to be almost symmetrical rather than of the skewed type. Following Walpert (1924). *Fomes fastuosus* should be included in the low-temperature group (upto 25°C.) while rest of the fungi in the intermediate temperature group (upto 30°C.). The trunk-rotting group (25°C.) of Etheridge (1957) is more or less similar to low temperature group of Walpert(1924). Humphrey and Siggers(1933) include three other species of *Fomes* in the low-temperature-group (20°C. to 24°C.), *Ganoderma applanatum* with other six species of *Fomes* in the intermediate temperature group (24°C. to 32°C.) and G. *lucidum* in the high temperature group (about 32°C.). Cartwight and Findlay (1934) have stated that the optimum temperature for growth of *Ganoderma applanatum* lies at 30°C. but in case of two other species of *Fomes*, it lies at 23°C. and 25°C. respectively. Basing on the available data obtained in the present investigation, it can be stated that the present findings support the view of Walpert (1924) and Etheridge (1657) in case of F. *fastuosus*, and Humphrey and Siggers (1933) and Cartwright and Findlay (1634) in case of *Ganoderma applanatum*. It, however, differs with Humphrey and Siggers (1933) in case of G. *lucidum* in that its optimum temperature has been found to be 30°C. *Fomes fastuosus* has been seperated from two closely allied species, viz, *F. durissimus* and F. *senex* on the basis of optimum temperature for growth, which is 25°C. in case of F. *fastuous* and 30°C. in case of the other two species. The influence of temperature, however, becomes more evident as a result of its effect on the many complex chemical and physical processes induced in vegetative growth. The many different effects of temperature on reproduction indicate the complexity of the vegetative phases and suggest that temperature may influence a number of metabolic processes, any one of which may be limiting under particular circumstances. This effect of temperature may be direct on some metabolic step or it may be indirect. Further critical investigations are necessary before any general interpretation on the effect of temperature is made.

After studying the effects of different sources of light on the growth of all the test-fungi, it has been noticed that the optimum light source for growth is alternate light (500-650 m$\mu$) and darkness while orange light (595-610 m$\mu$) has maximum inhibitory effect. Fritz (1923) has reported that in complete darkness the diagonostics characters of some species of *Fomes* are well manifested. Borriss (1934) has noticed that day light inhibits the growth of some basidiomycetes. The present study fully supports Borriss in that light has definite inhibitory effect on the growth of all the test-fungi. The effect of different spectral range of light further reveals that all the ranges have similar inhibitory effects. Of these, blue light (433-800 m$\mu$) has minimum and orange light has maximum effects when compared to the effects in alternate light and darkness and

continuous darkness. Uptil now most of the work on induction and stimulation on growth of fungi by visible light has been at best semi-quantitative. The maximum stimulatory effect of alternnte light and darkness can be explained on the basis of two metabolic reactions which are influenced by light. The first reaction is enhanced in the presence of continuous light but inhibited in the presence of continuous darkness and the second reaction is enhanced in the presence of continuous darkness but inhibited in the presence of continuous light. So both the reactions in alternating periods of light and darkness are required. The available data on the action spectrum indicate fairely consistently that the effective wavelength is in the blue region of the spectrum (Borriss, 1934, Medelin, 1956) which is close to the peak of action spectrum of phototropism. Most of the data so far available on the photoreceptors in fungi, have been, however, found to be of carotenoid nature. It has been found that action spectrum of phototropism has a maximum at about 430-500 mμ (this is also limited by the spectral range of blue light) and carotenoid, being found in fungi is absorbed maximally in the same region of the spectrum. However, the nature of the photoreceptors in fungi which may be a flavin or flavoprotein or a carotenoid (β-carotene) compound need further detailed investigation to reveal its chemical nature and role in the photoreception mechanism. At present all the responses of light that have been studied in detail probably involve synthesis of the wall materials. How light induces this changes is still unknow. If it can be shown by further extensive research that ATP is responsible for providing the energy for wall synthesis, a link between the reception of light energy and visible response in growth will be possible to establish in future, Further investigations in this line are in progress in order to establish this relationship, that possibly exists between the photoreception mechanism and the chemical mediator.

The tolerence of hydrogen-ion concentration by the test-fungi reveals that all of them are acid loving. The optimum pH for all the three species of *Ganoderma* is near abont 6.0 while that in case of two specics of *Fomes* (*F. senex* and *F. durissimus*) is 5.0 and in case of *F. fastuosus* it is 4.0.

The alkaline range of pH for higher fungi have also been reported. It has been found that all the test-fungi under consideration have grown well within the range of pH of 3.0 and 7.0. Records show that the optimum pH for the growth of *Fomes* sp. varies widely in different species (Meachum, 1918 ; Montgomry, 1939 ; Robbins, 1950 ; Rennerfelt and Paris, 1953 ; Weis and Nielson, 1927 and Etheridge, 1957). This diversity in the nature of optimum pH requirement for growth of different species of *Fomes* have also been noticed in the present investigation.

The evidences so far obtained show convincingly that *pH* is an environmental factor of enormous consequences in modifying their metabolic activity. These effects are always intricately correlated. As a secondary feature it is apparent that each species may differ in the limits of their *pH* range. The underlying reasons for this, lie upon the isoelectric point of the constituent proteins of the different species. It is know that *pH* may act in several ways such as influencing enzyne action, altering metal solubilities, modifying surface reactions, or preventing or facilitating the entry of vitamins and organic acids or minerals into the hyphae. A great deal of work is, therefore, needed to elucidate the mechanism of the effect of *pH* but it is an established fact that *pH* is a critical factor in vegetative growth of the fungi.

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