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An analysis of the succession of fungi on dung

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Four animals were kept in cages and were fed their different diets. The fungi tested for the cellulolytic activity and dry weight of mycelial production showed variable nature.

INTRODUCTION

Harper and Webster (1964) experimentally analysed the succession of rabbit pellets and felt that, although it has been interpreted as a nutritional sequence, based on the physiology and nutrition of the different groups of fungi concerned and on the nutrient content of the component organic materials at the various stages of decay, the causal factors bringing about the succession were not fully investigated. They attempted to isolate and study the effects of some important ecological factors on growth and sporulation of a range these fungi and their results were found relevant to the timing of the succession. During the investigation they also felt the necessity of biochemical analysis of decomposing dung at varying intervals, so that the loss of sugars, celluloses and lignins could be followed and the relationship of this to nitrogen utilization could be investigated.

In the light of the above facts, it was proposed to study the succession of fungi on dung of two mammals and two birds the analysis of dung to estimate total soluble sugars, hemicelluloses, celluloses, lignins, total nitrogen, organic nitrogen, nitrate nitrogen and pH at different stages of its decay; and to perform the experiments on the antagonistic effect of bacteria on fungi, cellulolytic activity of some fungi, viability of fungal spores in the alimentary canal of these four animals and the germination of spores of different fungi.

MATERIALS AND METHODS

During the present study four animals (rabbit, rat, fowl, pigeon) were kept in cages in the Animal House of Gorakhpur University (U. P.). They were fed different foods keeping in view their natural requirements. Rabbits were fed on carrots, grasses and leaves of radish and cabbage. Rats were given water soaked grain seeds, flour of cereals (wheat, barley, oat) and pieces of bread. Pigeons were fed upon cereals (oat, maize, barley, rice) ragi and cotyledons of pea, mistard, lenties and *Vicia*. Fowls were given normal poultry fead (W.F.P. maize 33.5%; local maize 1.75%; rice polish 10%; wheat bram 20%; milo 5%; fish meal 4%; G.N. cake 15%; bone meal 1.5%; calcium 3%; hard grit 1% common salt 0.5%; and mollases 5%) supplied by Animal Husbandry Department, Gorakhpur. The animals were given tap water in washed glassware. The cages and food and drink containers were washed periodically to avoid contamination. About 12 hours before sampling the cage was sterilized with alcohol to minimise contamination. Health of caged animals remained normal during experimentation.

Fresh pellets of rabbit and rat, and droppings of fowl and pigeon were collected from their cages with halp of sterilized apatulas, and were kept in sterilized bottles; 10 pellets or droppings were then transferred to Petridish moist chambers devised by Keyworth (1951). This method allowed the filter paper to remain wet for a long time and when needed more sterilized water was added from the sides. After 24 hours of incubation the samples were examined under the high power lens for any fruiting body and observations were made daily up to 50 days. Different dung samples were incubated five times and the average of readings was taken into consideration.

Specific diagnosis of *Chaetomia* revealed the presence of certain variants within a species which were given separate designations to distinguish them from typical species.

During the experimentation, the pellets of mammals and droppings of birds were distributed in 10 Petri dish moist chambers at the rate of 10 per chamber and each pellet of dropping was considered as a unit of study. The frequency of each species was calculated by the formula given below:

$$\%\ \text{frequency: } \frac{\text{number of pellets or droppings on which species occurred}}{\text{total number of pellets or droppings studied}} \times 100$$

The calculated frequency of species is given in Tables 1 - 4. A total of the incidence of different groups of fungi on the dung of these four animals represented the number of fungi (Table 5). The successional pattern of fungi on dung of animals

was reflected from the appearance and disappearance of a particular species on the substrate (Table 6).

The chemical analysis of dung was done at intervals of 17.34 and 50 days designated as stage 'I', 'II' and 'III' respectively. Analysis of fresh dung (zero stage) served as control. The dung samples were taken, oven dried for 48 hours at 80°C and ground into powder. These were then analysed for total soluble sugars, hemicelluloses, celluloses, lignins, total nitrogen, organic nitrogen and nitrate nitrogen. pH of fresh dung and that at the three stages was determined in original state prior to its dryness. The data on the chemical analysis of dung samples at different stages are expressed in terms of initial dry weight of fresh dung (Table 7). Total soluble sugars were determined by anthrone sulphuric acid method of Loewas; hemicelluloses and celluloses were estimated by the method of Wise, Murphy and D'Addieco; and determination of lignins was done by the method of Klason (Paech, Tracey 1955). Estimation of total nitrogen, and organic nitrogen was done by the method used by Cotton (1945), and nitrate nitrogen was determined by the method of Sprengeles (1946). pH of dung at different stages, was determined by preparing the suspension in double distilled water (1:5 dung water ratio) and measuring by Leeds and Northrup electric pH meter.

The antagonistic effect of five bacteria viz., *Proteus vulgaris* isolated from rabbit dung, *Pseudomonas pyocyaneous* from fowl dung, *Alcaligenes fecalis* from pigeon dung, *Escherichia coli* from rabbit and pigeon dung and *Klebsiella* sp. from rabbit, rat and fowl dung was experimentally observed on 11 fungi of different classes. The tests were performed in sterilized Petri dishes (7 cm.dia. and 2 cm height) containing potato dextrose agar and the method employed was done by Mathur (1968); (Table 8).

Ten fungi which generally appeared late on incubated dung were selected for study for their ability to utilize celluloses. Their cellulolytic activity was measured by the method devised by Reese and Lavinson (1952) and used by Hoog (1966); (Table 9).

To study retention of viability of fungal spores in alimentary canal, all the four animals in cages were starved for 24 hours and fed upon their respective autoclaved food contiouosly for five days. The dung obtained after 5th day feeding was incubated to observe the presence of fungi, if any. After five days of continuous feeding, they were again fed upon the same autoclaved foot but containing spores of the fungi which were isolated from the dung of respective animal. The dung obtained from such animals was incubated and examined for colonization by the fungi. In the next series, a mixture of spores of all the above mentioned fungi was mixed with the autoclaved food and the dung obtained was incubated to observe the growth of fungi (Table 10).

For the study, latent period of spore germination, rate of germ tube extension and percentage germination of 17 species colonizing dung at different times during succession were under taken. The well known hanging drop method was employed and the slides were observed continuously for 12 hrs and then at intervals of one hour for 24 hrs. In order to determine the rate of germ tube growth, the length of germ tube was measured as every observation time with the help of ocular micrometer and the growth (M/hr) was calculated (Table 11).

RESULTS

A total number of 56 fungal species were isolated from dung (Table 5). The number of all fungi nearly the same on the dung of rabbit and rat while a myxomycete was noticed on rabbit dung only. On fowl and pigeon dung also, the number of *Phycomycetes*, *Ascomycetes*, *Deuteromycetes* and *Mycelia sterilia* was nearly the same but a single *Basidiomycetes* was isolated from fowl dung only. It is also evident that the *Phycomycetes* were larger in number on mammalian dung than on avian dung. The number of *Ascomycetes*, *Basidiomycetes*, *Deuteromycetes* and *Mycelia sterilia* was nearly the same on the dung of both classes of animals. A myxomycete was recorded from one mammalian (rabbit) dung and none from avian dung.

Among the *Phycomycetes Thamnidium elegans* showed tha lowest frequency (2%) and *Pilobolus crystallinus* exhibited the highest (98%) on the rabbit dung but on rat dung the species with lowest frequency (3%) was *Mucor* sp. I, and *Mucor hiemalis* had the highest frequency (98%). *Absidia spinosa* and *Mucor heterosporus* were common to both the dung with 18% and 11% frequency of the former and 11% and 9% of the latter in rabbit and rat respectively. The frequency in remaining species ranged from 3 - 89% on rabbit and 6 - 11% on rat dungs. Among the *Ascomycetes*, *Chaetomium globosum* I had the lowest frequency (5%) and *C. atrobrunneum* III the highest frequency (55%) on rabbit dung but on rat dung these two species showed reversed frequency, *C. atrobrunneum* III haeving the lowest (3%) and *C. globosum* I the highest (39%). The frequency of other species on rabbit dung ranged from 6 - 15% and on rat dung from 5 - 6%. *Coprinus heptemerus*, the only basidiomycete, showed 14% and 10% frequency on the dung of rabbit and rat respectively. Of the *Deuteromycetes*, *Aspergillus* sp. exhibited the lowest frequency (3%) on rabbit dung and *Memnoniella echinata* the highest (46%), which had the highest frequency (24%) on rat dung also. *Penicillium nigricans* showed the minimum frequency (5%) on the rat dung. The only other *Deuteromycete* (*Fusarium sporotrichoides*) on rabbit dung had 5% frequency. On rat dung the frequency of the remaining species ranged between 6 - 7%. White sterile mycelium occurred with 3% and 5% frequency on the dung of rabbit and

rat respectively. A myxomycete (*Dictyostelium mucoroides*), isolated from rabbit dung only showed 10% frequency (Tables 1, 2).

Only one species of *Phycomycetes* could be observed on the dung of fowl and pigeon, and it showed 3% and 6% frequency respectively (Tables 3, 4). Among the *Ascomycetes*, *Chaetomium globosum* II showed the lowest frequency (3%) and *C. globosum* IV the highest (28%) on the fowl dung while *C. atrobrunneum* I showed the highest (20%) and *Kernia nitida* the lowest (4%) frequency on pigeon dung. The only other species were *Chaetomium* sp. (18%), *Gelasinospora calospora* (6%) and *Phaeotrichum . ircinatum* (8%). The first two being on the fowl dung and the last one on the pigeon dung. *Coprinus* sp. was the only basidiomycete present on fowl dung with 3% frequency. Among *Deuteromycetes*, *Stachybotrys atra* appeared to be least frequent (6%) on fowl dung while *Cephaliophora irregularis* showed the maximum frequency (88%) on this as well as on pigeon dung (95%). *Stysanus medius* had the lowest frequency (4%) on pigeon dung. *Aspergillus flavus*, *Cephaliophora irregularis*, *Fusarium sporotrichoides* and *Stachybotrys atra* were common to both the avian dungs. The frequencies of these forms were 44%, 88%, 13%, and 6% respectively on fowl and 70%, 95%, 7% and 6% on pigeon excreta. Black sterile mycelium, recorded only on fowl dung showed 15% frequency. White sterile mycelium, however, was common to both and exhibited the same (12%) frequency.

No appreciable difference in the timing of appearance and disappear nce and disappearance of a particular class of fungi on the dung of different animals, although, members of different classes appear and disappear at different intervals (Table 6). It appears that the *Phycomycetes* were first to fruit and they began to appear on the 3rd day of incubation. Some of these (*Mucor* sp. III, *Pilaira anomala*, *Pilobolus crystallinus* and *Thamnidium elegans*) appeared early and persisted for a short time. Others were to appear early and persisting for a long time. All the *Ascomycetes* encountered appeared late but persisted for a long time. The *Basidiomycetes* were represented by *Coprinus heptemerus* and *Coprinus* sp. These species could maintainual them selves only for a short time. Among *Deuteromycetes* a few species like *Aspergillus flavus*, *Cephaliophora irregularis* and *Fusarium sporotrichoides* (on fowl and pigeon), appeared early and persisted for a long time. The remaining *Deuteromycetous* forms on the other hand, made the their appearance late and persisted for a comparatively longer time. Among the sterile mycelial forms, white sterile mycelium n rabbit and pigeon dungs appeared early and remained for a long time. But on rat and fowl dungs the white sterile mycelium behaved differently, appearing late and persisting for a longer period. The black sterile myce ium on rat and fowl dungs also behaved like white sterile mycelium. *Dictyostelium mucoroides*, a myxomycete appeared early and persisted for a long time on the rabbit dung only.

The amount of soluble sugars in dung samples varied with different animals, it being maximum in pigeon dung followed by rabbit, rat and fowl. There was a decrease in amount in stage 'I' while no sugar was detected in stages 'II' and 'III'. The maximum amount of hemicelluloses was present in the dung of fowl followed by rabbit, rat and pigeon while celluloses and lignins were maximum in their amounts in rabbit followed by rabbit, rat and pigeon while celluloses and lignins were maximum in their amounts in rabbit followed by fowl, rat and pigeon dungs. The amount of hemicelluloses, celluloses and lignins gradually decreased with the time but were present till after stage 'III'. The rate of decrease in their amounts was rapid during stage 'II' as compared to stages 'I' and 'III' (Table 7). The maximum amount of total nitrogen and organic nitrogen was present in dung of pigeon followed by rat, rabbit, and fowl but nitrate nitrogen was maximum in pigeon followed by rat, fowl and rabbit. The amount of total nitrogen gradually decreased with the time up to stage 'II', after which these showed slight decrease in their amounts. The rate of increase in amount of total nitrogen and organic nitrogen was rapid during stage 'II' as compared to stage 'I'. In contrast, the amount of nitrate nitrogen decreased gradually up to stage 'I' after which there was a sharp decline including stage 'II'. During stage 'III', the decrease in amount was slight. At '0' stage, pH of rabbit and rat dung was higher than the dung of fowl and pigeon. It decreased correspondingly during stage 'I'. In stage 'II' there was a considerable rise in pH value which was nearly the same in excreta of all the animals. In stage 'III', however, there was again a decline in pH value which remained nearly the same in excreta of all the animals (Table 7).

Of the eleven fungi tested, only six were affected by the bacterial growth (Table 8). Four species *Chaetomium* and *Sordaria fimicola* were not affected at all. Growth of *Cephaliophora irregularis* was slightly inhibited by only two bacteria (*Alcaligenes fecalia, Pseudomonas pyocyaneous*). One species of *Chaetomium* (*C. atrobrunneum* III) was inhibited by all the five bacteria. *Mucor hiemalis* and *Helicostylum piriforme* showed quite a large inhibition zone by all the five bacteria followed by *Absidia spinosa* and *Fusarium sporotrichoides*. Of the five bacteria, *Alcaligenes fecalia* and *Pseudomonas pyocyaneous* were most antagonistic, *Escherichia coli* and *Klebsiella* sp. less so and *Proteus vulgaris* generally the least.

All the fungi tested were found to utilize varying quantities of celluloses (Table 9). *Chaetomium atrobrunneum* I, II and III, *C. globosum* IV and *C. gracile* showed high cellulolytic activity and high dry weight production; *Memnoniella echinata* showed high cellulolytic activity and low mycelial production; *Sordaria fimicola* and *Myrothecium verrucaria* exhibited low cellulolytic activity with high mycelial production. *Chaetomium erraticum* II and *Penicillium nigricans*, on the other hand, showed low cellulolytic activity with low mycelial dry weight production.

Only those fungi which had been isolated from the dung of a particular animal survived in the alimentary canal of that animal (Table 10). The fungi which were isolated from the dung of a particular animal did not survive in the alimentary canal of other animals.

Among five *Phycomycetes* tested, *Helicostylum piriforme*, *Pilaira anomala* and *Pilobolus crystallinus* showed prolonged latent period of spore germination, low rate of germ tube extension and low percentage of spore germination (Table 11). The remaining two (*Mucor hiemalis* and *Mucor* sp. III) showed short latent period in germination of spores, high rate of germtube extension and greater percentage of spore germination. Among *Ascomycetes*, *Chaetomium atrobrunneum* I and III exhibited ahost latent period of spore germination with low rate of germ tube extension and spore germination; *Chaetomium* sp. and *Sordaria fimicola* exhibited short latent period, higher rate of germ tube extension and high rate of germination; *Chaetomium globosum* IV, *C. atrobrunneum* II and *Gelasinospora calospora* exhibited longer latent period of spore germination with slow rate of germ tube growth and average to high rate of spore germination. Two *Basidiomycetous* fungi exhibited high latent period of spore germination, low growth rate and low percentage of germination. The three *Deuteromycetes* showed short latent period of spore germination high growth rate of germ tune and high percentage of spore germination.

DISCUSSION

Nature and anvironmental conditions of the microhabitat affect selectively the microorganisms that can enter into competition for substrate (G a r r e t t 1963: 116). S a c c a r d o and M a r c h a l (1885) reported greater number of fungal species from herbivores than that on carnivore dungs and reptilian dung yielded the least number of species. In present study, the dung of mammals, rabbit and rat, yielded the larger number of fungi than that of birds, fowl and pigeon (Table 5).

The composition of natural communities is not haphazard and each microbial species and genus has certain distributional pattern which is determined by the physiological responses of population to the environment into which it is introduced. Success of a fungus in the colonization of any particular substrate is conditioned by its competitive saprophytic ability, its inoculum potentoal and environmental condition including the population of competing fungi and other soil microorganisms (G a r r e t t 1963; 120). In this study, *Phycomycetes* were larger in number on mammalian than on avian dungs (Table 5). Their lesser number on bird dungs is attributed to high bacterial content. These dungs are in semisolid state with high water content which favour bacterial multiplication. Occurrence of *Pilaira anomala* and *Pilobolus crystallinus* on

Table 1

Frequency /%/ of species on rabbit dung incubated for 50 days

Species	1–2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17–18	19	20	21	22	23	24–25	26–27	28	29	30–32	33–34	35	36	37	38	39–41	42–50
	Days of incubation																																
P Absidia spinosa Lendner	–	–	15	17	18	18	18	18	18	18	18	18	18	18	18	18	18	18	10	10	2	–	–	–	–	–	–	–	–	–	–	–	–
Helicostylum piriforme Bain.	–	–	1	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mucor heterosporus Fischer	–	9	11	11	11	11	11	11	11	11	11	11	11	11	11	11	7	3	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pilaira anomala Van Tieghem	–	89	89	89	89	89	89	38	7	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pilobolus crystallinus /Tode/ Van Tiegh.	–	98	98	98	98	98	98	98	98	98	40	10	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Thamnidium elegans Link	–	–	2	2	2	2	2	2	2	2	2	2	2	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
A Chaetomium atrobrunneum I Ames	–	–	–	–	–	–	–	–	2	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
C. atrobrunneum III	–	–	–	–	–	–	–	–	28	28	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
C. erraticum II	–	–	–	–	–	–	–	3	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
C. globosum I Kunze.	–	–	–	–	–	–	–	–	–	–	–	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
C. undulatum Bain.	–	–	–	–	–	–	–	–	2	2	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Sordaria fimicola /Rab./Ces.et Not.	–	–	–	–	–	–	–	3	5	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
B Coprinus heptemerus Fr.	–	–	–	–	–	–	–	–	–	–	10	10	14	14	14	14	14	8	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
D Aspergillus sp.	–	–	–	–	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	–	–	–	–	–	–	–	–
Fusarium sporotrichoides Sherb.	–	–	–	–	–	–	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1	–	–	–	–	–	–	–	–	–	–
Memnoniella echinata /Riv./ Gall.	–	–	–	–	–	–	18	23	28	28	28	43	46	46	46	46	46	46	46	46	46	46	46	46	46	46	38	35	35	21	21	6	–
MS White	–	–	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	–	–	–	–	–	–	–	–
MY Dictyostelium mucoroides Bref.	–	–	2	3	-5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	7	4	4	1	–	–

P – Phycomycetes; A – Ascomycetes; B – Basidiomycetes; D – Deuteromycetes; MS – Mycelia sterilia; MY – Myxomycetes

Table 2

Frequency /%/ of species on rat dung incubated for 50 days

Species	Days of incubation																														
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24-25	26-29	30	31	32	33-35	36-37	38-39	40-42	43	44-50
P Absidia spinosa Lendn.	6	9	10	11	11	11	11	11	11	11	11	11	11	11	11	11	11	8	7	6	6	3	-	-	-	-	-	-	-	-	-	-
Circinella muscae /Sor./ Berl.et Toni	-	-	4	5	6	6	6	6	6	6	6	6	6	5	3	3	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mucor heterosporus Fisch.	8	9	9	9	9	9	9	9	9	9	9	9	9	6	6	4	3	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-
M. hiemalis Wehm.	95	98	98	98	98	98	98	98	98	98	98	98	91	80	60	44	18	18	-	-	-	-	-	-	-	-	-	-	-	-	8	-
Mucor sp. I	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A Chaetomium atrobrunneum II Ames	-	-	-	-	-	-	-	3	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
C. atrobrunneum III	-	-	-	-	-	-	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
C. globosum I Kunze.	-	-	-	-	12	28	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
C. gracile Udag.	-	-	-	-	-	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
B Coprinus heptemerus Fr.	-	-	-	-	-	-	-	-	-	-	3	9	10	10	10	10	10	10	6	4	1	-	-	-	-	-	-	-	-	-	-	-
D Aspergillus flavus Link ex Fr.	-	-	-	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	3	-	-	-	-	-	-	-	-	-
A. ustus /Bain./ Thom et Church	-	-	-	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	2	-	-	-	-	-	-	-
Memnoniella echinata /Riv./ Gall.	-	-	-	-	-	3	3	12	17	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	22	22	20	12	8	6	-	-
Myrothecium verrucaria /A.et S./ Ditm.ex Fr.	-	-	-	-	2	3	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	5	5	3	-	-	-	-	-	-
Penicillium nigricans Bain. ex Thom.	-	-	-	-	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1	1	-	-	-	-	-	-	-	-
MS White	-	-	-	3	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	2	-	-	-	-

P - Phycomycetes; A - Ascomycetes; B - Basidiomycetes; D - Deuteromycetes; MS - Mycelia sterilia

Table 3

Frequency /%/ of species on fowl droppings incubated for 50 days

Species	Days of incubation																														
	3	4	5	6	7	8	9	10	11	12	13-20	21	22	23	24	25	26	27	28	29	30	31	32	33-35	36	37	38	39	40	41	42	43-50
PHYCOMYCETES																																
Mucor sp. III	3	3	3	3	3	3	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ASCOMYCETES																																
Chaetomium globosum Kunze. II	-	-	-	-	-	-	1	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
C. globosum IV	-	-	-	-	5	15	23	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Chaetomium sp.	-	-	-	-	-	6	8	11	17	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Gelasinospora calospora /Mouton/ C.et M.Moreau	-	-	-	-	-	-	-	3	3	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
BASIDIOMYCETES																																
Coprinus sp.	-	-	-	-	-	-	-	-	1	3	3	2	2	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DEUTEROMYCETES																																
Aspergillus flavus Link ex Fr.	-	17	32	44	44	44	44	44	44	44	44	32	28	12	8	7	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cephaliophora irregularis Thaxter	-	22	84	88	88	88	88	88	88	88	88	88	88	88	75	75	25	20	9	7	5	-	-	-	-	-	-	-	-	-	-	-
Fusarium sporotrichoides Sherb.	-	8	11	13	13	13	13	13	13	13	13	11	11	11	6	6	6	6	6	6	6	6	6	6	6	6	5	3	3	1	1	-
Stachybotrys atra Corda	-	-	-	-	-	-	-	-	-	1	6	6	6	6	6	6																
MYCELIA STERILIA																																
Black	-	-	-	-	-	8	12	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	18	18	60	60	8	6	6	5	-	-
White	-	-	-	9	10	12	12	12	12	12	12	12	12	12	12	12	12	12	9	7	7	2	1	-	-	-	-	-	-	-	-	-

Table 4

Frequency /%/ of species on pigeon droppings incubated for 50 days

Species	Days of incubation																								
	3	4	5	6-7	8	9	10	11-14	15-16	17-20	21	22	23	24	25	26	27	28	29	30	31	32	33-37	38	39-50
P Mucor sp. III	1	4	5	6	6	6	6	6	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A Chaetomium atrobrunneum I Ames	-	-	-	-	7	7	18	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Kernia nitida /Sacc./ Neiuwe	-	-	-	-	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Phaeotrichum circinatum Cain	-	-	-	-	1	1	5	6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
D Aspergillus flavus Link ex Fr.	26	62	65	70	70	70	70	70	70	70	70	70	70	70	70	64	64	49	49	19	14	4	1	-	-
Cephaliophora irregularis Thaxter	59	89	95	95	95	95	95	95	95	95	77	77	53	53	15	8	-	-	-	-	-	-	-	-	-
Fusarium sporotrichoides Sherb.	-	4	7	7	7	7	7	7	7	7	7	6	6	2	2	-	-	-	-	-	-	-	-	-	-
Stachybotrys atra Corda	-	-	-	-	-	-	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	3	-
Stysanus medius Sacc.	-	-	-	-	-	-	4	4	4	4	4	4	4	4	4	-	-	-	-	-	-	-	-	-	-
MS White	-	8	9	12	12	12	12	12	12	12	12	12	12	12	12	7	5	3	-	-	-	-	-	-	-

P - Phycomycetes; A - Ascomycetes; D - Deuteromycetes; MS - Mycelia sterilia

Table 5
Number of fungi on excreta of four animals

Fungal classes	Mammalian dungs		Total	Bird droppings		Total	$\sum$
	rabbit	rat		fowl	pigeon		
Phycomycetes	6	5	11	1	1	2	13
Ascomycetes	6	4	10	4	3	7	17
Basidiomycetes	1	1	2	1	-	1	3
Deuteromycetes	3	5	8	4	5	9	17
Mycelia sterilia	1	1	2	2	1	3	5
Myxomycetes	1	-	1	-	-	-	1
Total	18	16	34	12	10	22	

rabbit dung only may be ascribed to certain hormonal substances necessary for their growth and reportedly present in the dung of herbivores (Hesseltine et al. 1953; Neiland 1957). The number of *Ascomycetes*, *Basidiomycetes*, *Deuteromycetes* and *Mycelia sterilia* on mammalian and avian dungs was found to be nearly the same (Table 5). This may be due to similar ingradients in the dung of these animals. Dungs of rabbit and rat supported an equal number of species, so did the dungs of fowl and pigeon between themselves. The number recorded from classes as a whole, however, differed with each other. The similarity between the members of the same class can be attributed to the similar physical and chemical nature of the dung. Occurrence of a *Myxomycetes* on rabbit dung only may be due to the conditions favourable for its growth and plasmodia formation.

The results (Tables 1-4) show that in spite of nearly the same estimated amount of sugars (Table 7) in the dung of four animals, the relative frequency of *Phycomycetes* in birds was low as compared to mammals. This was due to higher bacterial content and high rate of their multiplication in the dung of the former. High frequency of *Pilaira anomala* and *Pilobolus crystallinus* on rabbit dung (Table 1) is possibly due to the discharge of reproductive structures in the form of sporangia on the herbage easten by the rabbit. The spores then come out with the excreta and germinate producing fruiting bodies abundantly (Buller 1958: 167). *Mucor hiemalis* showed high frequency on rat dung probably due to its high inoculum potential. *Aspergillus flavus* however, showed very high frequency on bird dungs. This may be attributed to the ability of this fungus to secrete antibacterial substance (Bush, Goth 1943). *Cephaliophora irregularis* also showed high frequency which might be due to the inability of bacteria to have any antagonistic effect on its growth (Table 8). *Ascomycetes* being predominantly cellulolytic, their similar relative frequency may be correlated with corresponding amount of celluloses in their excreta (Tables 1-4, 7). Parkinson and

Table 6

Appearance and persistence of species on excreta of four animals

	Species	Appearance /days/	Decline /days/	Persistence /days/
P	Absidia spinosa	Ra 4th; R 3rd	Ra 21st; R 20th	Ra 23rd; R 26th
	Circinella muscae	R 5th	R 16 th	R 20th
	Helicostyllum piriforme	Ra 4th	Ra 21st	Ra 21st
	Mucor heterosporus	Ra 3rd; R 3rd	Ra 19th; R 16th	Ra 21st; R 21st
	M. hiemalis	R 3rd	R 15th	R 20th
	Mucor sp. I	R 3rd	R 19th	R 20th
	Mucor sp. III	F 3rd; P 3rd	F 10th; P 15th	F 10th; P 16th
	Pilaira anomala	Ra 3rd	Ra 9th	Ra 11th
	Pilobolus crystalinus	Ra 3rd	Ra 12th	Ra 14th
	Thamnidium elegans	Ra 4th	Ra 16th	Ra 16th
A	Chaetomium atrobrunneum I	Ra 10th; P 8th	-	Ra 50th; P 50th
	C. atrobrunneum II	R 10th	-	R 50th
	C. atrobrunneum III	Ra 10th; R 9th	-	Ra 50th; R 50th
	C. erraticum II	Ra 9 th	-	Ra 50th
	C. globosum I	Ra 13th; R 7th	-	Ra 50th; R 50th
	C. globosum II	F 9th	-	F 50 th
	C. globosum IV	F 7th	-	F 50 th
	C. gracile	R 8th	-	R 50th
	C. undulatum	Ra 10th	-	Ra 50th
	Chaetomium sp.	F 8th	-	F 50th
	Gelasinospora calospora	F 10th	-	F 50th
	Kernia nitida	P 8th	-	P 50th
	Phaeotrichum circinatum	P 8th	-	P 50th
	Sordaria fimicola	Ra 9th	-	Ra 50th
B	Coprinus heptemerus	Ra 12th; R 13th	Ra 20th; R 21st	Ra 21st; R 23rd
	Coprinus sp.	F 11th	F 21st	F 24th
D	Aspergillus flavus	R 5th;F 4th;P 3rd	R26th;F21st;P26th	R29th;F27th;P36th
	A. ustus	R 6th	R 31st	R 31st
	Aspergillus sp.	Ra 6th	Ra 28th	Ra 29th
	Cephaliophora irregularis	F 4th; P 3rd	F 24th; P 21st	F 30th; P 26th
	Fusarium sporotrichoides	Ra 8th;F 4th;P4th	Ra26th;F21st;P22nd	Ra27th;F27th;P25th
	Memnoniella echinata	Ra 8th; R 8th	Ra 33rd; R 31st	Ra 41st; R 43rd
	Myrothecium verrucaria	R 7th	R 30th	R 32nd
	Penicillium nigricans	R 6th	R 26th	R 30th
	Stachybotrys atra	F 12th;P 10th	F,P 38th	F 42nd; P 38th
	Stysanus medius	P 10th	P 24th	P 25th
MS	Black	F 8th	F 34th	F 40th
	White	Ra,P 4th; R,F 6th	Ra 29th, R 36th, F 28th, P 26th	Ra 29th, R 37th, F 33rd, P 28th
MY	Dictyostelium mucoroides	Ra 4th	Ra 35th	Ra 39th

P - Phycomycetes; A - Ascomycetes; B - Basidiomycetes;

D - Deuteromycetes; MS Mycelia sterilia; MY - Myxomycetes

Ra - rabbit; R - rat; F - fowl; P - pigeon

Table 7

Amount of different fractions/100 g of dry dung

Different fractions	Dung samples of different stages															
	0				I				II				III			
	R	Ra	F	P	R	Ra	F	P	R	Ra	F	P	R	Ra	F	P
Total soluble sugars	5.76	5.20	4.76	5.86	4.11	4.30	4.03	4.52	-	-	-	-	-	-	-	-
Hemicelluloses	20.86	18.04	28.08	11.63	16.10	12.93	23.81	8.69	8.48	6.12	8.80	4.04	8.14	5.65	8.08	4.02
Celluloses	47.66	40.93	42.90	40.15	39.38	32.66	33.53	30.44	19.29	15.29	18.27	13.32	18.84	15.10	18.04	13.17
Lignins	7.23	4.15	6.32	3.27	6.14	3.34	4.99	2.64	4.27	1.95	3.31	1.43	3.75	1.83	2.19	1.41
Total nitrogen	0.66	0.69	0.61	0.72	0.68	0.71	0.64	0.74	1.35	1.40	1.03	1.43	1.33	1.38	0.74	1.43
Organic nitrogen	0.42	0.44	0.40	0.48	0.55	0.60	0.52	0.64	0.58	0.60	0.54	0.66	0.55	0.56	0.52	0.62
Nitratenitrogen	.0042	.0048	.0044	.0057	.0040	.0044	.0042	.0044	.0010	.0017	.0013	.0019	.0010	.0011	.0010	0.015
pH	6.8	6.8	6.4	6.6	5.7	5.8	5.4	5.6	7.2	7.4	7.6	7.5	7.0	7.2	7.1	7.1

R - Rabbit; Ra - Rat; F - Fowl; P - Pigeon

Table 8

Inhibition zone /in mm/ in fungi produced by bacteria

Test fungi	Bacterial isolates				
	Alcaligenes fecalis	Escherichia coli	Klebsiella sp.	Proteus vulgaris	Pseudomonas pyocyaneous
Absidia spinosa	11.0	11.0	11.0	8.0	11.5
Helicostylum piriforme	16.0	14.0	14.0	13.0	16.0
Mucor hiemalis	17.0	15.0	15.0	13.0	17.0
Chaetomium atrobrunneum I	-	-	-	-	-
C. atrobrunneum II	-	-	-	—	-
C. atrobrunneum III	3.0	3.0	1.5	2.5	4.0
C. globosum IV	-	-	-	- -	-
Chaetomium sp.	-	-	-	-	-
Sordaria fimicola	-	-	-	-	-
Cephaliophora irregularis	2.0	-	-	-	1.5
Fusarium sporotrichoides	9.0	7.0	6.5	5.0	10.5

Table 9

Amount of celluloses utilized and mycelium produced by some fungi

Fungi	Amount of celluloses utilised /%/	Dry weight of mycelium /mg/
Chaetomium atrobrunneum I	7.3	186.0
C. atrobrunneum II	11.3	295.0
C. atrobrunneum III	8.4	201.0
C. erraticum II	5.9	126.0
C. globosum IV	8.0	159.0
C. gracile	9.6	254.0
Sordaria fimicola	5.3	161.0
Memnoniella echinata	12.5	122.0
Myrothecium verrucaria	4.5	205.0
Penicillium nigricans	2.2	8.3

Table 10

Frequency /%/ of spores passed through alimentary canal of animals

Spore of fungi	Original dung source	Animal dung			
		Rabbit	Rat	Fowl	Pigeon
Mucor hiemalis	Rat	-	100	-	-
Pilobolus crystallinus	Rabbit	100	-	-	-
Chaetomium atrobrunneum III	Rabbit and Rat	100	100	-	-
Chaetomium sp.	Fowl	-	-	100	-
Phaeotrichum circinatum	Pigeon	-	-	-	100
Cephaliophora irregularis	Fowl and Pigeon	-	-	100	100

Kendrick (1960) have stated that the low mineral content in a substrate may retard the formation of fruit bodies of certain fungi, thus confining them to their sterile conditions. The high relative frequency of *Mycelia sterilia* on bird dungs may be accounted for by this phenomenon. Similar relative frequency of nearly all classes of fungi on the excreta of animals of the same group (mammals or birds) may be due to the similarity in the physical and chemical composition of their dungs.

Chemical analysis of all the dungs revealed the highest amount of soluble sugars at 'zero' stage which decreased at stage 'I' and got completely depleted at stage 'I'. *Phycomycetes*, which are also known as 'sugar-fungi', grew luxuriantly during the early stage of decomposition coiciding with the larger amount of sugars and disappeared completely at stage 'II' where no sugar remained. Nicholson et al.; (1966) have also atrributed a large population of

Table 11

Latent period of spore germination, rate of germ tube extension and percentage germination of some fungi

Fungi	Observations		
	latend period of spore germination (in hrs)	rate of germ tube extension (M/hr)	germination (%)
P Helicostylum piriforme	12.0	19.1	30.0
Mucor hiemalis	5.0	45.2	100.0
Mucor sp. III	4.5	29.3	100.0
Pilaira anomala	12.0	13.0	33.0
Pilobolus crystallinus	9.0	16.6	40.0
A Chaetomium atrobrunneum I	4.0	28.5	66.6
C. atrobrunneum II	9.0	31.6	85.7
C. atrobrunneum III	3.0	32.8	60.0
C. globosum IV	9.0	24.6	50.0
Chaetomium sp.	4.5	44.1	75.0
Gelasinospora calospora	12.0	21.6	50.0
Sordaria fimicola	4.0	53.0	77.7
B Coprinus heptemerus	6.0	20.7	20.0
Coprinus sp.	9.0	21.5	40.0
D Aspergillus flavus	3.5	78.1	100.0
Cephaliophora irregularis	2.5	67.0	100.0
Fusarium sporotrichoides	2.5	49.3	100.0

P – Phycomycetes; A – Ascomycetes; B – Basidiomycetes; D – Deuteromycetes

bacteria and *Phycomycetes* to the presence of readily available nutrient in the dung during the early stage of decomposition. Hemicelluloses and celluloses are the major constituents of dung. In the present investigation, rate of decomposition of hemicelluloses and celiuloses of different stages was not uniform. A small decrease in their amount during 'I' stage appears to be connected with the utilization by small number of *Ascomycetes* which appeared and were not overgrown by *Phycomycetes* at this stage. Stage 'II' showed a rapid decrease of these substances probably due to the increasing number of *Ascomycetes* and *Deuteromycetes* which being cellulolytic freely utilized the hemicelluloses and celluloses without any competition with the *Phycomycetes*. In stage 'II'. Their amount was nearly the same as in stage 'II' and so was the number of these fungi. Among various ingradients of natural organic materials, lignins are most resistant to the action of fungi and bacteria (W a k s m a n 1926). *Basidiomycetes* including *Coprinus* spp. have capacity to degrade lignins (F r i e s 1953). The rate of decomposition of lignins was rapid during 'II' stage. The rapid

decomposition at this stage corresponded to the presence of *Basidiomycetes* (Table 7). During stage 'III', the small decrease in amount of lignins was due to slow growth of mycelium in the substratum where present, though their fruiting bodies might have disappeared. Amount of total nitrogen and organic nitrogen showed an increase in the 'II' stage and then become constant. It may be recalled that *Phycomycetes* appeared forst but most of them soon disapeared leaving their remains in dung itself enriching its nitrogen content. Later on, the number of fungi increased to a large extent and the amount of nitrogenous compounds utilized balanced the amount of nitrogenous compounds synthesized. The amount of total nitrogen, therefore, was constant in later stages. A decrease in nitrate nitrogen may be due to its utilization by the increasing number of fungi at stage 'II'.

The sequential appearance of fungi on dung of these four animals was nearly the same. The *Phycomycetes* made their appearance first being closely followed by *Deuteromycetes*, *Ascomycetes* and *Basidiomycetes*. *Mycelia sterilia* and *Myxomycetes*, though lesser in numbers, appeared early and late but both persisted for a much longer time (Table 6). This pattern of succession of fungi agrees with observations of Harper and Webster (1964) on pellets of rabbit. Burges (1939, 1958) and Garrett (1951) have elaborated the concept of ecological groups of fungi based on their substrate relationships. They pointed out an apparent correlation between the decomposition of progressively complex carbon sources and the taxonomic disposition of the species. During the decomposition of manures, composts and plant litters, sugars, starches and proteins are first to be utilized followed by hemicelluloses and celluloses. Lignins usually disappear in the last phase of decomposition. Early appearance of *Mucor* sp. III, *Pilaira anomala*, *Pilobolus crystallinus* and *Thamnidium elegans* is due to their rapid spore germination, high growth rate, short time taken in necessary developmental processes in fruit body formation and ability to utilize the soluble part of the substrate quickly. The short persistence of these fungi is possibly due to competition between fungi and bacteria for food because bacteria have been found to be more active in decomposition during the first two weeks when *Phycomycetes* are present (Carter 1958; Nicholson et al. 1966). The early appearance and long persistence of *Absidia spinosa*, *Circinella muscae*, *Helicostylum piriforme*, *Mucor heterosporus*, *M. hiemalis* and *Mucor* sp. I may be ascribed to their ability to grow even on nutritionally deficient substrate. The late appearance and long persistence is evident in all the *Ascomycetes*. Their late appearance may be due to long time taken in their fruit body formation (Griffin 1972: 40; Harper, Webster 1964) and long persistence is possibly due to the avaibility of hemicelluloses and celluloses for a longer time in the substrate (Table 7). The fruit bodies of *Basidiomycetes* appeared very late

during succession and disappeared after a short duration. Their late appearance may be associated with very slow growth rate of these forms (B u r g e s 1960; G r i f f i n 1972: 39). They are able to persist for a short duration only as their fruiting bodies are very delicate and decay soon after maturation. The behaviour of most of the *Deuteromycetes* was similar to *Ascomycetes* in their appearance and persistence. Various reasons advanced for the behaviour of *Ascomycetes* also hold good for *Deuteromycetes*. *Mycelia sterilia* appearing either early or late in succession persisted for a long time. Generally, these sterile forms are members of *Basidiomycetes* and are supposed to be similar to them in exploitation of the substratum (A l e x o p o u l o s 1952: 318). A myxomycete appeared early probably due to the availability of bacterial cells as the source of food (R a p e r 1951). Its persistence for long time suggests its ability to utilize cellulose also.

Antagonism between two organisms results due to competition for available nutrients, creation of conditions by one organism which may be injurious to the other, direct parasitism of one upon other, competition for available space and production of specific substances which have capacity of lysing or dissolving the cells of other organisms (W a k s m a n 1961: 114). In present investigation, three *Phycomycetes*, (*Absidia spinosa*, *Helicostylum priforme*, *Mucor hiemalis*) were antagonised by all bacterial isolates. Among *Deuteromycetes*, *Fusarium sporotrichoides* was also affected but *Cephaliophora irregularis* was affected to some extent only by two bacteria. All *Chaetomia* except *C. atrobrunneum* III were not at all affected (Table 8). C. are known to produce antibacterial substances. Thus, it may be considered that the fungi which produce antibacterial substances are less susceptible to this kind of bacterial action (B r i a n 1960). Among the bacteria employed *Alcaligenes fecalis* and *Pseudomonas pyocyaneus* were more effective, *Escherichia coli* and *Klebsiella* sp. less and *Proteus vulgaris* the least possibly indicating a certain amount of specificity in antibiosis (V a s u d e v a, C h a k r a v a r t h i 1954).

Regarding the cellulolytic activity and dry weight production of mycelia, the fungi tested showed variable nature. Higher cellulolytic ability can be attributed to high activity of cellulolytic enzymes and higher dry weight production to greater utilization of assimilatory substrates. Fungi which show high cellulolytic activity together with high dry weight of mycelia production may have higher enzymic activity and better utilization of substrate while the reverse may be true for those having lower cellulolytic activity and lower mycelial production. *Memnoniella echinata*, which has high cellulolytic activity and low mycelial production must be having higher enzymic activity but be unable to make full use of the substrate. The reasons for low cellulolytic activity and high mycelial production in *Sordaria fimicola* and *Myrothecium verrucaria* is obscure (Table 9).

Spores of *Mucor hiemalis*, *Pilobolus crystallinus*, *Chaetomium atrobrunneum*

III, *Chaetomium* sp., *Phaeotrichum circinatum* and *Cephaliophora irregularis*, detected in the excreta of animals after feeding on autoclaved food mixed with them, shows that these spores are eapable of surviving in their elimentary canals. The retention of viability of fungal spores in the alimentary canal of rabbit has also been shown through feeding experiments by Salmon and Messes (1902), Janczewski (1871) and Harper and Webster (1964).

The latent period of germination, rate of germ tune extension and percentage germination of spores are three criteria to be considered in the study of spore germination (Tomkins 1932). In the present study, two *Phycomycetes* (Mucor sp. III, *M. hiemalis*), showed short latent period of spore germination, high rate of germ tune ectension and high percentage of spore germination which corresponded with early fruiting and high frequency occurrence of these species during succession (Table 11). Three *Deuteromycetes* (*Aspergillus ustus*, *Cephaliophora irregularis*, *Fusarium sporotrichoides*) behaved similarly during succession studies. Long latent period of spore germination, slow growth rate and low percentage of germination of spores of *Basidiomycetes* like *Coprinus* sp. and *C. heptemerus* corresponded with their rare occurrence and late appearance. In three *Phycomycetes* (*Helicostylum pririforme*, *Pilaira anomala*, *Pilobolus crystallinus*) and all the *Ascomycetes*, there appeared no correlation between these and observed successional pattern which was probably due to random variability or physiological geterogeneity of spores causing spread in time of germination (Harper, Webster 1964). Webster (1970) has pointed out several possible causes for the dormancy of spores, one or more of which might affect their germination and consequent appearance of fruiting bodies.

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