*Chapter V*

# BIOPOLLUTION OF ENVIRONMENTS DURING AGRICULTURAL PRACTICES

## INTRODUCTION

Dust particles are typical of agricultural working environments. The agricultural dust is composed mainly of organic particles, including fungal spores and hyphal fragments, derived from the parasitic and saprophytic fungi growing on vegetation in the field. Machanical disturbances involved in various agricultural practices, *i.e.* harvesting, threshing, shredding, weeding, manure broadcasting, mowing etc. are sufficient enough to enhance spore liberation from the hay, grains or other plant materials at a faster rate. These results in an increased airborne fungal load to which the farmers are exposed during the operations.

It is a common observation that the respiratory troubles among the farm workers are related to the various agricultural operations resulting in heavy exposure to fungal spores. Besides, dissemination of various plant pathogens are also enhanced by such operations.

Investigations were therefore, initiated to study the effect of threshing operations on the mycoflora of the farm air in "Aman" and "Boro" varieties of paddy and wheat. Experiments were also carried out during harvesting of pea (a green vegetable) and during mechanical shedding of leaves from jute stalks.

## MATERIALS AND METHODS

Air was sampled as usual with the exposure plate method (Uddin and Chakraverty 1995 and 1996). Exposures were taken during threshing of wheat and, "Boro" and "Aman" varieties of paddy in 1992. The petriplates containing 2% malt extract agar, fortified with streptomycin (40 µg / ml) and sodium deoxycholate (0.08%), were exposed for 30 seconds, in the respective sites during the crop seasons. Exposures were made before, during and after the threshing operations, maintaining a time gap of 30 min in between the three sets of exposures. Streptomycin was used to inhibit the bacterial growth and sodium deoxycholate for restricting the fungal colonies, which are innumerable, particularly in the plates exposed during threshing operations. On the date of sampling, consecutively two sets of exposures were taken before, during and after the threshing operations for the

respective crops (each set, composed of 5 petriplates). The exposed plates were incubated at 28$^{o}$C and the resulting colonies were recorded and identified. The mean of two observations were then calculated and compared. The meteorological data for the days concerned were also recorded.

In the next year (1993) the samples were taken on 4th April, 9th May and 12th December during the threshings of wheat, and "Boro" and "Aman" varieties of paddy respectively and studied as earlier.

A similar experiment was also performed on 10th November 1992 while harvesting of pea (a green vegetable) was continued in the field.

Just after harvesting of jute, the cut plants were stacked on the field for 10 to 14 days for undergoing rotting of leaves prior to retting. On the date of retting the stems were threshed by the farmers to cast off the half decayed leaves. Air samples were taken for 30 seconds at the time of threshing and half an hour before and after the threshing of the jute stalks.

In 1995, at the end of crop seasons of paddy ("Aman" variety), wheat and "Boro" variety of paddy, during threshing operations of these grains another type of investigation was initiated with the aim to detect the fungal spore concentration in air at the site of threshing and, 10 m and 20 m away from the site. A set of five petriplates was exposed for 30 s on the site and at the two distant places simultaneously while threshing was continued.

## STATISTICAL ANALYSIS

In these experiments, suppose there are $l$ similarly classified populations at threshing period, where $l = 3$ i.e. before, during and after. Let $k$ be the number of classes in each population and $p_{ij}$ be the proportion of the $j$ th population in the $i$ th class ($i = 1, 2, ....k$ and $j = 1, 2, 3, ..... l$).

When $p_{ij}$ are unknown it has been decided if the $I$ populations of fungal spores' distribution may be supposed to be identical or homogeneous. In the other words, one would like to test the following null hypothesis,

$$H_o : p_{i1} = p_{i2} = \ldots\ldots = p_{iI} \quad \text{for each } i$$

Let a random sample of size $n_j$ be drawn from the $j$ th population ($j$ = 1, 2, ..... $I$), the drawings being mutually independent, and let the number of members of this sample which belong to the $i$ th class be $f_{ij}$. We have then

$$\sum_{i=1}^{k} f_{ij} = n_j.$$

In the present set up, for each $j$

$$\sum_{i=1}^{k} \frac{(f_{ij} - n_j p_{ij})^2}{n_j p_{ij}} \text{ is distributed as approximately a } \chi^2 \text{ with } df = k\text{-}1.$$

Hence,

$$\sum_{j=1}^{I} \sum_{i=1}^{k} \frac{(f_{ij} - n_j p_{ij})^2}{n_j p_{ij}} = \sum_{i=1}^{k} \sum_{j=1}^{I} \frac{(f_{ij} - n_j p_{ij})^2}{n_j p_{ij}},$$

being the sum of $I$ independent $\chi^2$'s each with $df = k$-1, is itself a $\chi^2$ with $df = (k\text{-}1)I$. Under the null hypothesis, the statistic

$$\sum_{i} \sum_{j} \frac{(f_{ij} - n_j p_i 0)^2}{n_j p_i 0} \text{ follows approximately a } \chi^2 \text{ distribution with } (k\text{-}1)I \text{ degrees}$$

of freedom, where $p_i 0$ is the common value of $p_{ij}$ for all $j$. This statistic could be used to test $H_o$ [where $H_o = p_{i1} = p_{i2} = \ldots\ldots = p_{iI}$ ] if $p_i 0$ were known quantities. Suppose we replace each $p_i 0$ by its estimator - an unbiased estimator being the sample proportion - obtained by combining all samples, viz.

$$p_i0 = \sum_j f_{ij} / \sum_j n_j = f_{i0} / n,$$

where $f_{i0} = \sum_j f_{ij}$ and $n = \sum_j n_j$. Then the frequency $\chi^2$ takes the form :

$$\sum_i \sum_j \frac{(f_{ij} - n_j f_{i0} / n)^2}{n_j f_{i0} / n} = n \sum_i \sum_j \frac{f_{ij}^2}{f_{i0} n_j} - n.$$

Since $p_{i0}$'s are replaced by their sample estimates, the number of degrees of freedom will get reduced by *(k-1)* (and not by k, since when *k*-1 proportions are estimated, the remaining one is automatically determined by virtue of the property and the sum of all proportions is unity).

The hypothesis $H_o$ will, therefore, be rejected or accepted according as

$$n \left( \sum_i \sum_j \frac{f_{ij}^2}{f_{i0} n_j} - 1 \right)$$

exceeds $\chi^2_{\alpha,\,(k-1)\,(l-1)}$ or not, where $\chi^2_{\alpha,\,(k-1)\,(l-1)}$ denotes $\alpha$ percent critical value, i.e., the upper $\alpha$-point of the $\chi^2$ distribution with

$$df = (k-1)\, l - (k-1) = (k-1)\,(l-1).$$

## RESULTS

The total colony forming units (CFUs) in the three sets of exposures of the crops concerned were counted and compared. An immediate increase in the total airspora was observed during threshing and harvesting operations.

In 1992, in case of wheat (threshed on 1st April 1992) the concentration rose to 13.9 fold during threshing, came down to 6 times after the operation. In "Boro" variety of paddy (7th May 1992), the increase reached up to 139.5 times during threshing, reduced to 10.1 times after the operation. In case of "Aman" variety of paddy (15th December 1992), the rise was 61.2 times, reduced to 8.8 times in the post exposure plates.

The different fungal types encountered during threshing of wheat grains are represented in **Table 28**. During threshing, *Alternaria* spp. chiefly represented by *A. tenuissima* scored the highest, reaching 54.43% to the total catch, followed by *Drechslera* sp. (19.32%), *Cladosporium herbarum* (17.22%) and *Penicillium* spp. (3.89%). In the pre-threshing exposures *Aspergillus* spp. were the dominant types; of which *A. parasiticus* was found in more than a half of the total catch (52.86%), followed by *Alternaria tenuissima* (17.86%), *Drechslera* (15.72%) and *Penicillium* (7.86%). In the post-threshing exposures, *Alternaria tenuissima* was the dominant type (48.29%) followed by *Cladosporium herbarum* (18.38%) and *Drechslera* (15.26%). A few colonies of yeast was observed during threshing and post-threshing exposures.

In "Boro" variety of paddy **(Table 29)**, during threshing operation, the dominant genus was *Alternaria*, represented by *A. humicola* (51.53%) and *A. tenuissima* (25.92%). A number of species of *Curvularia* and *Penicillium* contributed a much to the airspora. In pre-threshing exposures, apart from *Alternaria humicola* and *A. tenuissima, Aspergillus* represented by *A. parasiticus* and *A. niger,* and *Penicillium* were observed in significant numbers. In the post-threshing exposures, *Alternaria humicola* and *A. tenuissima* contributed 42.15% and 41.38% to the total catch respectively. Yeast colonies were observed during and after the operations.

In "Aman" variety of paddy (**Table 30**), *Helminthosporium oryzae* was the dominant fungus which accounted for 45.92% of the total catch during threshing. It was also observed in the pre- and post-threshing exposures in significant numbers. Significant number of *Cladosporium* spp. was also observed in all the three sets of exposures. Yeast colonies contributed 21.43, 12.6 and 21.76% to the total catch in pre-, during and post-threshing exposures respectively.

In the next year *i.e.*1993, during wheat threshing (threshed on 4th April 1993), spore level was found to increase about 23 fold and was declined into 40.3 times after the

**Table 28.** Total mean CFUs and percentage occurrence of fungi, before, during and after threshing operations in wheat in 1992

| Sl. No. | Fungal types | Before | | During | | After | |
|---|---|---|---|---|---|---|---|
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Aspergillus parasiticus* | 74 | 52.86 | - | - | - | - |
| | *A. ochraceous* | 1 | 0.72 | - | - | - | - |
| | *A. candidus* | 2 | 1.43 | 1 | 0.05 | - | - |
| | *A. niger* | - | - | 10 | 0.52 | - | - |
| | *Aspergillus* spp. | - | - | 21 | 1.08 | - | - |
| 2. | *Penicillium* spp. | 11 | 7.86 | 76 | 3.89 | 5 | 1.56 |
| 3. | *Cladosporium herbarum* | 1 | 0.72 | 336 | 17.22 | 59 | 18.38 |
| 4. | *Alternaria* spp. | 2 | 1.43 | - | - | - | - |
| | *A. tenuissima* | 25 | 17.86 | 1062 | 54.43 | 155 | 48.29 |
| 5. | *Drechslera* spp. | 22 | 15.72 | 377 | 19.32 | 49 | 15.26 |
| 6. | *Curvularia* spp. | - | - | 3 | 0.15 | 12 | 3.74 |
| | *C. interseminata* | 1 | 0.72 | - | - | - | - |
| | *C. geniculata* | 1 | 0.72 | - | - | - | - |
| 7. | Yeast | - | - | 30 | 1.54 | 13 | 4.05 |
| 8. | *Trichoderma lignorum* | - | - | 7 | 0.36 | - | - |
| | *T. koningi* | - | - | - | - | 5 | 1.56 |
| 9. | *Fusarium* spp. | - | - | - | - | 4 | 1.25 |
| 10. | *Cephalosporium* sp. | - | - | - | - | 1 | 0.31 |
| 11. | *Diplodia* sp. | - | - | - | - | 1 | 0.31 |
| 12. | *Verticillium* sp. | - | - | - | - | 1 | 0.31 |
| 13. | *Brachysporium* sp. | - | - | - | - | 1 | 0.31 |
| 14. | "Sterile form" | - | - | - | - | 1 | 0.31 |
| 15. | "Unidentified" types | - | - | 28 | 1.44 | 14 | 4.36 |
| | Total | 140 | 100% | 1951 | 100% | 321 | 100% |

**Table 29.** Total mean CFUs and percentage occurrence of different fungal types, before, during and after the threshing operations in "Boro" variety of paddy in 1992

| Sl. No. | Fungal types | Before | | During | | After | |
|---|---|---|---|---|---|---|---|
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Aspergillus* sp. | - | - | 1 | 0.04 | - | - |
| | *A. parasiticus* | 2 | 10.53 | - | - | - | - |
| | *A. niger* | 1 | 5.26 | 5 | 0.19 | - | - |
| | *A. ochraceous* | - | - | 1 | 0.04 | - | - |
| 2. | *Penicillium* spp. | 2 | 10.53 | 112 | 4.22 | 8 | 3.07 |
| 3. | *Cladosporium herbarum* | - | - | 51 | 1.92 | 3 | 1.15 |
| 4. | *Alternaria humicola* | 5 | 26.32 | 1366 | 51.53 | 110 | 42.15 |
| | *A. tenuissima* | 7 | 36.84 | 687 | 25.92 | 108 | 41.38 |
| 5. | *Helminthosporium* sp. | - | - | 19 | 0.72 | - | - |
| 6. | *Curvularia* spp. | - | - | 20 | 0.75 | 1 | 0.38 |
| | *C. lunata* | - | - | 132 | 4.98 | 10 | 3.83 |
| | *C. geniculata* | - | - | 15 | 0.56 | 1 | 0.38 |
| | *C. pallescens* | - | - | 12 | 0.45 | 2 | 0.77 |
| | *C. subulata* | - | - | 14 | 0.53 | - | - |
| 7. | *Stemphylium* sp. | - | - | 3 | 0.11 | 1 | 0.38 |
| 8. | *Brachysporium* sp. | - | - | 1 | 0.04 | - | - |
| 9. | *Cephalosporium* spp. | - | - | 24 | 0.90 | 1 | 0.38 |
| 10. | *Fusidium* sp. | - | - | 52 | 1.96 | 2 | 0.77 |
| 11. | Yeast | - | - | 73 | 2.75 | 11 | 4.22 |
| 12. | *Trichothecium roseum* | - | - | 2 | 0.08 | - | - |
| 13. | *Cordana* sp. | - | - | 1 | 0.04 | - | - |
| 14. | *Fusarium* sp. | 1 | 5.26 | 1 | 0.04 | - | - |
| 15. | *Tetraccosporium paxianum* | - | - | 1 | 0.04 | - | - |
| 16. | *Sclerotium* sp. | - | - | 1 | 0.04 | - | - |
| 17. | *Sporidesmium* sp. | - | - | - | - | 1 | 0.38 |
| 18. | "Sterile forms" | - | - | 49 | 1.85 | 1 | 0.38 |
| 19. | "Unidentified" types | 1 | 5.26 | 8 | 0.30 | 1 | 0.38 |
| | Total | 19 | 100% | 2651 | 100% | 261 | 100% |

**Table 30.** Total mean CFUs and percentage occurrence of different fungal types, before, during and after threshing operations in "Aman" variety of paddy in 1992

| Sl. No. | Fungal types | Before | | During | | After | |
|---|---|---|---|---|---|---|---|
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Aspergillus* spp. | 1 | 3.57 | 2 | 0.12 | 1 | 0.52 |
| | *A. parasiticus* | 2 | 7.14 | - | - | - | - |
| 2. | *Penicillium* spp. | - | - | 107 | 6.24 | 7 | 3.63 |
| 3. | *Cladosporium* sp. | - | - | 89 | 5.19 | 10 | 5.18 |
| | *C. herbarum* | 2 | 7.14 | 312 | 18.20 | 31 | 16.06 |
| 4. | *Alternaria* spp. | - | - | 7 | 0.40 | - | - |
| | *A. humicola* | - | - | 13 | 0.76 | - | - |
| | *A. tenuissima* | - | - | 19 | 1.10 | 1 | 0.52 |
| 5. | *Helminthosporium oryzae* | 2 | 7.14 | 787 | 45.92 | 24 | 12.44 |
| 6. | *Curvularia* sp. | - | - | - | - | 2 | 1.04 |
| | *C. pallescens* | 1 | 3.57 | 1 | 0.06 | 4 | 2.07 |
| | *C. lunata* | - | - | 27 | 1.58 | 9 | 4.66 |
| 7. | Yeast | 6 | 21.43 | 216 | 12.60 | 42 | 21.76 |
| 8. | *Cephalosporium* spp. | 1 | 3.57 | 21 | 1.23 | 1 | 0.52 |
| | *C. humicola* | - | - | 21 | 1.23 | 8 | 4.15 |
| 9. | *Fusidium viride* | 2 | 7.14 | 14 | 0.82 | 1 | 0.52 |
| 10. | *Nigrospora sphaerica* | 2 | 7.14 | - | - | - | - |
| 11. | *Geotrichum candidum* | 1 | 3.57 | 1 | 0.06 | - | - |
| 12. | *Trichoderma* sp. | - | - | 1 | 0.06 | 1 | 0.52 |
| | *T. lignorum* | - | - | 11 | 0.64 | - | - |
| 13. | *Sclerotium* sp. | - | - | 2 | 0.12 | - | - |
| 14. | *Spicaria* sp. | - | - | 6 | 0.35 | - | - |
| 15. | *Epicoccum purpurascens* | - | - | 9 | 0.53 | - | - |
| 16. | *Chaetomium* sp. | - | - | - | - | 2 | 1.04 |
| 17. | "White sterile forms" | 1 | 3.57 | - | - | 6 | 3.10 |
| | "Brown " " " | 5 | 17.86 | 40 | 2.33 | 36 | 18.65 |
| 18. | "Unidentified" types | 2 | 7.14 | 8 | 0.47 | 7 | 3.63 |
| | Total | 28 | 100% | 1714 | 100% | 193 | 100% |

operation (**Table 31**). In the pre-threshing period, *Alternaria* (24.62%), *Penicillium* (29.23%) *Aspergillus* (25.4%) and *Cladosporium* (13.85%) were dominated. While threshing was continued *Alternaria* spp. (viz. *A. tenuissima*, *A. humicola* and *A. tenuis*) were increased heavily (77.45%) followed by *Drechslera* (10.49%). *Aspergillus*, *Penicillium* and *Cladosporium* were found to decline during threshing. A number of fungal spores of various organisms were deposited but in very lower amount. In post-exposure plates, *Alternaria* count was well maintained (31.08%) and in contrast to "during threshing" *Cladosporium*, *Penicillium* and *Aspergillus* again reappeared. A number of other fungi were found to appear during the operation.

With "Boro" variety of paddy (9th May 1993), spectacularly very high rise (116 times) in spore count was recorded during threshing operation (**Table 32**); followed by 9.76 times decline. Prior to the threshing, the airspora was comprised of *Aspergillus* spp. represented by *A. niger* (25%) and *A. parasiticus* (6.25%), *Alternaria humicola* (25%), *A. tenuissima* (6.25%), yeasts (18.75%), *Penicillium* (12.5%) and *Curvularia pallescens* (6.25%). *Alternaria humicola* (40.78%) and *A. tenuissima* (25.46%) accounted for the high rise in spore load during threshing operation. While *Penicillium* maintained its concentration, *Aspergillus*, yeast and *Curvularia* were found to decline during threshing. Nevertheless, a number of genera appeared at that time, of which *Trichoderma lignorum* (6.69%), *Cephalosporium* spp. (5.23%), *Fusidium viride* (2.16%), *Cladosporium herbarum* (2.1%) and "sterile forms" (3.29%) were significant. *Penicillium*, *Aspergillus* and yeast count was found to increase in the post-threshing exposures.

**Table 33** represents the mean CFUs and percentage occurrence of fungal types as measured during threshing of "Aman" variety of paddy on 12 December 1993. Total CFUs increased 49.58 fold during threshing and was decreased 42 times after half an hour of threshing. The tremendous rise in spore count during threshing was chiefly due to *Helminthosporium oryzae* (28.59%), *Cladosporium* (14.50%), yeast (10.9%), *Arthrobotrys superba* (9.27%), *Penicillium* (7.72%), *Fusarium* (5.84%), *Trichoderma lignorum* (4.88%)

**Table 31.** Total mean CFUs and percentage occurrence of fungi found before, during and after threshing operations in wheat in 1993

| Sl. No. | Fungal types | Before | | During | | After | |
|---|---|---|---|---|---|---|---|
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Aspergillus* spp. | 1 | 0.77 | 6 | 0.20 | - | - |
| | *A. parasiticus* | 4 | 3.08 | 5 | 0.17 | 1 | 1.35 |
| | *A. ochraceous* | 6 | 4.62 | 3 | 0.10 | 1 | 1.35 |
| | *A. candidus* | 2 | 1.54 | 6 | 0.20 | - | - |
| | *A. terreus* | 5 | 3.85 | 3 | 0.10 | 2 | 2.70 |
| | *A. sydowii* | 5 | 3.85 | - | - | 3 | 4.05 |
| | *A. niger* | 6 | 4.62 | 7 | 0.23 | 6 | 8.10 |
| | *A. fumigatus* | 1 | 0.77 | 1 | 0.03 | - | - |
| | *A. flavus* | 3 | 2.30 | - | - | - | - |
| | *A. nidulans* | - | - | - | - | 1 | 1.35 |
| 2. | *Penicillium* spp. | 24 | 18.46 | 72 | 2.42 | 13 | 17.57 |
| | *P. tardum* | 10 | 7.69 | - | - | 3 | 4.05 |
| | *P. miczynskii* | 1 | 0.77 | - | - | - | - |
| | *P. islandicum* | 1 | 0.77 | 14 | 0.47 | - | - |
| | *P. funiculosum* | 2 | 1.54 | - | - | 1 | 1.35 |
| 3. | *Cladosporium herbarum* | 17 | 13.07 | 124 | 4.16 | 15 | 20.27 |
| | *C. cladosporioides* | 1 | 0.77 | - | - | - | - |
| 4. | *Alternaria tenuissima* | 22 | 16.92 | 1330 | 44.57 | 15 | 20.27 |
| | *A. humicola* | 10 | 7.69 | 981 | 32.88 | 8 | 10.81 |
| | *A. tenuis* | - | - | 4 | 0.13 | - | - |
| 5. | *Drechslera* spp. | 3 | 2.30 | 313 | 10.49 | 1 | 1.35 |
| 6. | Yeast | 2 | 1.54 | 24 | 0.80 | 1 | 1.35 |
| 7. | *Cephalosporium* spp. | 2 | 1.54 | 25 | 0.83 | - | - |
| 8. | *Stemphylium* sp. | - | - | 3 | 0.10 | - | - |
| 9. | *Curvularia lunata* | - | - | 10 | 0.34 | - | - |
| | *C. pallescens* | - | - | 1 | 0.03 | - | - |
| 10. | *Epicoccum purpurascens* | - | - | 2 | 0.07 | - | - |
| 11. | *Arthrobotrys superba* | - | - | 1 | 0.03 | - | - |
| 12. | *Spicaria sylvatica* | - | - | 3 | 0.10 | - | - |
| | *S. divaricata* | - | - | 1 | 0.03 | - | - |
| 13. | *Humicola grisea* | - | - | 1 | 0.03 | - | - |
| 14. | *Trichoderma* sp. | - | - | 3 | 0.10 | - | - |
| 15. | *Brachysporium* sp. | - | - | 1 | 0.03 | - | - |
| 16. | "Unidentified" types | - | - | 2 | 0.07 | - | - |
| 17. | White sterile forms | 2 | 1.54 | 3 | 0.10 | 1 | 1.35 |
| | Brown " " | - | - | 35 | 1.17 | 2 | 2.70 |
| | Total | 130 | 100% | 2984 | 100% | 74 | 100% |

**Table 32.** Total mean CFUs and percentage occurrence of fungal organisms before, during and after threshing operations in "Boro" variety of paddy threshed on 9 May 1993

| Sl. No. | Fungal types | Before | | During | | After | |
|---|---|---|---|---|---|---|---|
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Aspergillus niger* | 4 | 25.00 | 4 | 0.22 | 40 | 21.05 |
| | *A. parasiticus* | 1 | 6.25 | 5 | 0.27 | 5 | 2.63 |
| | *A. flavus* | - | - | 3 | 0.16 | - | - |
| | *A. terreus* | - | - | 6 | 0.32 | 4 | 2.10 |
| | *A. ochraceous* | - | - | - | - | 2 | 1.05 |
| | *A. luchuensis* | - | - | - | - | 2 | 1.05 |
| | *A. sydowii* | - | - | - | - | 7 | 3.68 |
| 2. | *Penicillium* spp. | 1 | 6.25 | 93 | 5.02 | 61 | 32.10 |
| | *P. funiculosum* | 1 | 6.25 | 5 | 0.27 | 2 | 1.05 |
| 3. | *Alternaria humicola* | 4 | 25.00 | 756 | 40.78 | 15 | 7.89 |
| | *A. tenuissima* | 1 | 6.25 | 472 | 25.46 | 9 | 4.74 |
| 4. | Yeast | 3 | 18.75 | 116 | 6.26 | 30 | 15.79 |
| 5. | *Curvularia lunata* | - | - | 14 | 0.76 | - | - |
| | *C. pallescens* | 1 | 6.25 | 6 | 0.32 | - | - |
| 6. | *Cladosporium herbarum* | - | - | 39 | 2.10 | 2 | 1.05 |
| 7. | *Trichoderma lignorum* | - | - | 124 | 6.69 | - | - |
| 8. | *Cephalosporium* spp. | - | - | 26 | 1.40 | 2 | 1.05 |
| | *C. humicola* | - | - | 71 | 3.83 | 1 | 0.53 |
| 9. | *Fusidium viride* | - | - | 40 | 2.16 | - | - |
| 10. | *Arthrobotrys superba* | - | - | 2 | 0.10 | - | - |
| 11. | *Stemphylium* sp. | - | - | 2 | 0.10 | - | - |
| 12. | *Nigrospora sphaerica* | - | - | 1 | 0.05 | - | - |
| 13. | *Verticillium* sp. | - | - | - | - | 5 | 2.63 |
| 14. | "Unidentified" types | - | - | 8 | 0.43 | 1 | 0.53 |
| 15. | White sterile forms | - | - | 1 | 0.05 | 1 | 0.53 |
| | Brown sterile forms | - | - | 60 | 3.24 | 1 | 0.53 |
| | Total | 16 | 100% | 1854 | 100% | 190 | 100% |

**Table 33.** Total mean CFUs and percentage occurrence of fungal isolates on before, during and after threshing operations in "Aman" variety of paddy in 1993

| Sl. No. | Fungal types | Before | | During | | After | |
|---|---|---|---|---|---|---|---|
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Cladosporium herbarum* | 13 | 22.80 | 330 | 11.68 | 9 | 13.24 |
| | *C. cladosporioides* | 2 | 3.50 | 80 | 2.83 | 4 | 5.88 |
| 2. | *Penicillium* spp. | 5 | 8.77 | 214 | 7.57 | 7 | 10.29 |
| | *P. funiculosum* | 1 | 1.75 | 4 | 0.14 | 3 | 4.42 |
| | *P. miczynskii* | 1 | 1.75 | - | - | - | - |
| | *P. islandicum* | - | - | - | - | 1 | 1.47 |
| 3. | *Aspergillus* spp. | - | - | 14 | 0.50 | 1 | 1.47 |
| | *A. sydowii* | 3 | 5.26 | 55 | 1.95 | 10 | 14.70 |
| | *A. niger* | 1 | 1.75 | 1 | 0.04 | - | - |
| | *A. flavus* | 2 | 3.50 | 7 | 0.25 | 1 | 1.47 |
| | *A. ochraceous* | - | - | 1 | 0.04 | - | - |
| | *A. parasiticus* | - | - | 10 | 0.35 | 1 | 1.47 |
| 4. | *Fusarium* spp. | 4 | 7.02 | 165 | 5.84 | 1 | 1.47 |
| 5. | *Helminthosporium oryzae* | 3 | 5.26 | 808 | 28.59 | 3 | 4.42 |
| 6. | *Curvularia lunata* | 2 | 3.50 | 18 | 0.64 | - | - |
| | *C. pallescens* | 1 | 1.75 | 9 | 0.32 | - | - |
| 7. | Yeast | 4 | 7.02 | 308 | 10.90 | 16 | 23.53 |
| 8. | *Arthrobotrys superba* | 1 | 1.75 | 262 | 9.27 | - | - |
| 9. | *Fusidium viride* | 1 | 1.75 | 123 | 4.35 | 3 | 4.42 |
| 10. | *Brachysporium* sp. | 1 | 1.75 | - | - | - | - |
| 11. | *Humicola fuscoatra* | 1 | 1.75 | 12 | 0.43 | - | - |
| 12. | *Pestalotia truncata* | 2 | 3.50 | 5 | 0.18 | - | - |
| 13. | *Verticillium* sp. | 1 | 1.75 | - | - | 1 | 1.47 |
| 14. | *Trichoderma lignorum* | 1 | 1.75 | 138 | 4.88 | - | - |
| 15. | *Cephalosporium* spp. | - | - | 71 | 2.51 | - | - |
| | *C. humicola* | - | - | 30 | 1.06 | - | - |
| 16. | *Nigrospora oryzae* | - | - | 18 | 0.64 | - | - |
| | *N. sphaerica* | - | - | 7 | 0.25 | - | - |
| 17. | *Mucor* spp. | - | - | 34 | 1.20 | - | - |
| 18. | *Spicaria sylvatica* | - | - | 7 | 0.25 | - | - |
| 19. | *Chaetomium* sp. | - | - | 1 | 0.04 | - | - |
| 20. | *Cercospora* sp. | - | - | 1 | 0.04 | - | - |
| 21. | *Sclerotium rolfsii* | - | - | 2 | 0.07 | - | - |
| 22. | "Unidentified" types | - | - | 11 | 0.39 | 1 | 1.47 |
| 23. | White sterile forms | 3 | 5.26 | 51 | 1.80 | 3 | 4.42 |
| | Brown " " | 4 | 7.02 | 29 | 1.03 | 3 | 4.42 |
| | Total | 57 | 100% | 2826 | 100% | 68 | 100% |

and *Fusidium viride* (4.35%). *Cladosporium*, *Penicillium*, *Fusarium* and *Aspergillus* were found to be present in appreciable amount in the air prior to threshing. Other forms such as *H. oryzae, Arthrobotrys superba, Fusidium viride, T. lignorum* were already observed before threshing in very low level, increased remarkably during threshing operations. *Penicillium* (16.18%), *Aspergillus* (19.12%) and yeast (23.53%) deposit on petriplates were found to increase after threshing; on the other hand, *Fusarium* and *H. oryzae* declined contributing 1.47% and 4.42% respectively. *Cladosporium* count was maintained in post exposure samples.

A local increase (13.4 fold) in spore load at harvesting time was recorded in case of *Pisum sativum* (**Table 34**) in comparison with the half an hour before harvesting operation in the standing crop. A fall of 8.7 times was found after the completion of harvesting. Just prior to harvesting the airspora components were *Penicillium*, *Cephalosporium*, *Cunninghamella*, *Aspergillus*, *Curvularia pallescens*, *Cladosporium herbarum*, yeast and *Blakeslea* in the order of preponderance. During and at post-harvesting period an increment in fungal types was recorded. During harvesting the airspora was rich with *Cladosporium* (54.13%) and *Penicillium* (27.83%); followed by *Trichoderma lignorum* (4.42%), sterile forms (3.65%), *Aspergillus* (2.69%) and *Alternaria* (2.3%). After half an hour of harvesting *Cladosporium* count was much reduced and *T. lignorum* disappeared; on the contrary, *Penicillium* (36.67%), *Aspergillus* (30%), *Cunninghamella* (8.33%) and sterile forms (8.33%) persisted.

In 1991, on 11th August during threshing of jute stalks (**Table 35**) to shed the leaves, an increase in total CFUs in the air up to 39.4 fold was observed followed by a decline (13.4 times) after the operation. Various species of *Aspergillus*, *Penicillium, Fusarium*, *Trichoderma lignorum, Mucor* and *Rhizopus* disseminated in huge amounts as dust accounted for such increment in total CFUs. These were also found to be present in the air before the start of threshing. At the post operation exposures, *Penicillium* spp. predominated in the air followed by *Aspergillus* while others either settled or dispersed.

**Table 34.** Fungal spore load in the air during pea vegetable harvesting, and before and after the operation, harvested on 11 November 1992

| Sl. No. | Fungal types | Before | | During | | After | |
|---|---|---|---|---|---|---|---|
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Cladosporium herbarum* | 1 | 2.56 | 259 | 49.72 | 3 | 5.00 |
| | *C. cladosporioides* | - | - | 23 | 4.42 | - | - |
| 2. | *Penicillium* spp. | 8 | 20.51 | 48 | 9.22 | - | - |
| | *P. tardum* | 9 | 23.07 | 74 | 14.20 | 13 | 21.67 |
| | *P. funiculosum* | 1 | 2.56 | 1 | 0.19 | - | - |
| | *P. miczynskii* | - | - | 22 | 4.22 | 9 | 15.00 |
| 3. | *Aspergillus* sp. | - | - | - | - | 2 | 3.33 |
| | *A. candidus* | 1 | 2.56 | - | - | - | - |
| | *A. luchuensis* | 1 | 2.56 | 2 | 0.38 | - | - |
| | *A. sydowii* | 1 | 2.56 | - | - | 11 | 18.33 |
| | *A. parasiticus* | - | - | 12 | 2.30 | 1 | 1.67 |
| | *A. niger* | - | - | - | - | 1 | 1.67 |
| | *A. ochraceous* | - | - | - | - | 2 | 3.33 |
| | *A. fumigatus* | - | - | - | - | 1 | 1.67 |
| 4. | *Curvularia* sp. | - | - | 2 | 0.38 | - | - |
| | *C. lunata* | - | - | 3 | 0.58 | 1 | 1.67 |
| | *C. pallescens* | 3 | 7.69 | 2 | 0.38 | - | - |
| 5. | *Cephalosporium* spp. | 5 | 12.82 | 2 | 0.38 | 2 | 3.33 |
| 6. | Yeast | 1 | 2.56 | 4 | 0.77 | 1 | 1.67 |
| 7. | *Trichoderma lignorum* | - | - | 23 | 4.42 | - | - |
| 8. | *Cunninghamella* sp. | 7 | 17.95 | - | - | 5 | 8.33 |
| 9. | *Blakeslea* sp. | 1 | 2.56 | - | - | - | - |
| 10. | *Spicaria* sp. | - | - | 3 | 0.58 | - | - |
| 11. | *Fusarium* spp. | - | - | 5 | 0.96 | - | - |
| 12. | *Alternaria brassicae* | - | - | 5 | 0.96 | - | - |
| | *A. tenuissima* | - | - | 7 | 1.34 | - | - |
| 13. | *Cercospora arachidicola* | - | - | - | - | 1 | 1.67 |
| 14. | "Unidentified" types | - | - | 5 | 0.96 | 2 | 3.33 |
| 15. | White sterile forms | - | - | 2 | 0.38 | 3 | 5.00 |
| | Brown " " | - | - | 14 | 2.68 | 2 | 3.33 |
| | Yellow " " | - | - | 3 | 0.58 | - | - |
| | Total | 39 | 100% | 521 | 100% | 60 | 100% |

**Table 35.** Fungal spore load in the air during jute threshing on 11 Aug. 1991 as compared to before and after

| Sl. No. | Fungal types | Before | | During | | After | |
|---|---|---|---|---|---|---|---|
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Aspergillus* spp. | - | - | 40 | 3.50 | 4 | 4.70 |
| | *A. niger* | 3 | 10.35 | 332 | 29.07 | 16 | 18.83 |
| | *A. fumigatus* | - | - | 108 | 9.46 | 3 | 3.53 |
| | *A. parasiticus* | 1 | 3.45 | 40 | 3.50 | - | - |
| | *A. flavus* | - | - | 6 | 0.53 | - | - |
| | *A. ochraceous* | - | - | - | - | 1 | 1.18 |
| 2. | *Penicillium* spp. | 6 | 20.69 | 349 | 30.56 | 52 | 61.18 |
| | *P. islandicum* | 1 | 3.45 | 2 | 0.18 | - | - |
| 3. | *Cephalosporium* spp. | 2 | 6.89 | 20 | 1.75 | 1 | 1.18 |
| | *C. humicola* | - | - | 5 | 0.44 | - | - |
| 4. | *Fusarium* spp. | 7 | 24.14 | 63 | 5.52 | 2 | 2.35 |
| 5. | *Rhizopus nigricans* | 1 | 3.45 | 17 | 1.49 | - | - |
| 6. | *Trichoderma lignorum* | 3 | 10.35 | 68 | 5.95 | - | - |
| 7. | *Spicaria* sp. | - | - | 8 | 0.70 | 2 | 2.35 |
| 8. | *Mucor* spp. | - | - | 31 | 2.72 | 1 | 1.18 |
| 9. | *Cladosporium herbarum* | - | - | 2 | 0.18 | - | - |
| 10. | *Curvularia* spp. | - | - | 4 | 0.35 | - | - |
| | *C. lunata* | 1 | 3.45 | 13 | 1.14 | - | - |
| 11. | *Helminthosporium* sp. | - | - | 4 | 0.35 | - | - |
| 12. | *Humicola grisea* | - | - | 1 | 0.09 | - | - |
| 13. | *Dendrographium* sp. | - | - | 3 | 0.26 | - | - |
| 14. | *Macrophomina phaseolina* | - | - | 4 | 0.35 | - | - |
| 15. | *Chaetomium* sp. | - | - | - | - | 1 | 1.18 |
| 16. | Unidentified isolates | - | - | 6 | 0.53 | - | - |
| 17. | Sterile forms (White) | 3 | 10.35 | 2 | 0.18 | - | - |
| | " " (Brown) | 1 | 3.45 | 14 | 1.23 | 2 | 2.35 |
| | Total | 29 | 100% | 1142 | 100% | 85 | 100% |

On 11th August 1992, the high count during the mechanical defoliation of jute (**Table 36**) was mainly due to *Aspergillus* and *Penicillium* which accounted for 67.37% and 20.37%. *Cephalosporium* (4.96%), yeasts (2.26%), *Macrophomina phaseolina* (1.74%) and *T. lignorum* (1.29%) also contributed to some extent. In pre- and post-threshing plates *Penicillium* was extraordinarily high *i.e.*, 54.39% and 87% respectively.

**Table 37** represents the data of fungal spore load in the air as per distance observed during threshing of "Aman" variety of paddy on 2nd January 1995. On the spot of threshing the spore deposit in 30 seconds was 3122 in number, while at 10 m and 20 m away from the site the spore deposit was counted as 2060 and 466 respectively showing a simultaneous dispersion and settling down of spores. The high spore release as dust during threshing at the site was due to *Helminthosporium oryzae* (39.66%), *Cladosporium* spp. (26.62%), yeast (11.98%), *Nigrospora* spp. (3.69%) and *Curvularia* (3.24%) which were also found to be present in significant numbers at 10 m and 20 m distant places. The percentage occurrence was increased at distant places in cases of fungal organisms bearing smaller and lighter spores *viz. Fusidium viride*, *Penicillium*, *T. lignorum*, *Cladosporium*, *Aspergillus*, *Epicoccum purpurascens* and *Fusarium* (up to 10 m). These spores thus showed the capability of quick dispersion to distant places where they get deposited.

During wheat threshing on 1st April 1995 (**Table 38**), from the site of threshing (2347 CFUs), the spore deposit decreased to 1.8 times at 10 m (1322 CFUs) followed by further 2.6 times decline (507 CFUs) at 20 m. Counts of *Alternaria* (57.05%), *Drechslera* (17.21%) and *Cladosporium* (14.06%) were the highest at the threshing site; of which according to distance *Alternaria* (49.62% and 44.57%) and *Drechslera* (12.93% and 7.49%) were declined while *Cladosporium* count was found to be increased with distance *i.e.* at 10 m (19.66%) and at 20 m (17.95%). A linear relationship in increment of count frequency was recorded in cases of yeast (2.08 to 3.33 to 7.49%), *Aspergillus* (1.83 to 3.93 to 5.33%), *Penicillium* (3.15 to 5.44 to 5.52%) and in *Curvularia* (1.74 to 2.27 to 4.93%).

**Table 36.** Fungal spore load in the air, before, during and after the jute threshing on Aug. 11, 1992

| Sl. No. | Fungal types | Before | | During | | After | |
|---|---|---|---|---|---|---|---|
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Aspergillus* spp. | 3 | 5.26 | 61 | 3.93 | 3 | 2.44 |
| | *A. parasiticus* | 1 | 1.75 | 260 | 16.76 | 1 | 0.82 |
| | *A. fumigatus* | 2 | 3.50 | 681 | 43.90 | - | - |
| | *A. niger* | - | - | 12 | 0.77 | 2 | 1.63 |
| | *A. ochraceous* | - | - | 16 | 1.03 | - | - |
| | *A. candidus* | - | - | 5 | 0.32 | - | - |
| | *A. terreus* | - | - | 7 | 0.45 | 4 | 3.25 |
| | *A. sydowii* | - | - | 3 | 0.19 | - | - |
| 2. | *Penicillium* spp. | 31 | 54.39 | 310 | 19.99 | 100 | 81.30 |
| | *P. islandicum* | - | - | 4 | 0.26 | - | - |
| | *P. miczynskii* | - | - | 1 | 0.06 | 4 | 3.25 |
| | *P. funiculosum* | - | - | 1 | 0.06 | 3 | 2.44 |
| 3. | *Fusarium* spp. | 3 | 5.26 | 5 | 0.32 | - | - |
| 4. | *Trichoderma lignorum* | 7 | 12.28 | 20 | 1.29 | 3 | 2.44 |
| 5. | *Thielavia terricola* | 1 | 1.75 | - | - | - | - |
| 6. | *Geotrichum candidum* | 4 | 7.02 | - | - | - | - |
| 7. | *Cladosporium* sp. | 1 | 1.75 | - | - | 1 | 0.82 |
| 8. | *Verticillium* sp. | 1 | 1.75 | - | - | 1 | 0.82 |
| 9. | *Macrophomina phaseolina* | - | - | 27 | 1.74 | - | - |
| 10. | *Cephalosporium* spp. | - | - | 77 | 4.96 | - | - |
| 11. | Yeast | - | - | 35 | 2.26 | - | - |
| 12. | *Curvularia lunata* | - | - | 5 | 0.32 | - | - |
| 13. | *Alternaria* spp. | - | - | 10 | 0.65 | - | - |
| | *A. tenuis* | - | - | 2 | 0.13 | - | - |
| 14. | *Cercospora* sp. | - | - | 3 | 0.19 | - | - |
| 15. | *Helminthosporium oryzae* | - | - | 2 | 0.13 | - | - |
| 16. | Sterile forms (White) | 3 | 5.26 | - | - | 1 | 0.82 |
| | Sterile forms (Brown) | - | - | 4 | 0.26 | - | - |
| | Total | 57 | 100% | 1551 | 100% | 123 | 100% |

**Table 37.** Air fungal flora during paddy (Aman variety) threshing and their deposition on the site of threshing and 10 and 20 metre away from the site measured on 2nd January 1995

| Sl. No. | Fungal types | DISTANCE FROM THE THRESHING SITE | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 m | | 10 m | | 20 m | |
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Cladosporium herbarum* | 675 | 21.62 | 752 | 36.50 | 174 | 37.34 |
| | *C. cladosporioides* | 155 | 4.96 | 141 | 6.84 | 52 | 11.16 |
| 2. | *Helminthosporium oryzae* | 1238 | 39.66 | 568 | 27.57 | 72 | 15.45 |
| 3. | Yeast | 374 | 11.98 | 139 | 6.75 | 42 | 9.02 |
| 4. | *Epicoccum purpurascens* | 69 | 2.21 | 64 | 3.10 | 11 | 2.36 |
| 5. | *Penicillium* spp. | 14 | 0.45 | 21 | 1.02 | 4 | 0.86 |
| | *P. islandicum* | - | - | - | - | 2 | 0.43 |
| 6. | *Nigrospora sphaerica* | 52 | 1.67 | 11 | 0.54 | 4 | 0.86 |
| | *N. oryzae* | 63 | 2.02 | 9 | 0.44 | 4 | 0.86 |
| 7. | *Trichoderma lignorum* | 50 | 1.60 | 62 | 3.00 | 7 | 1.50 |
| 8. | *Curvularia lunata* | 101 | 3.24 | 40 | 1.94 | 5 | 1.07 |
| | *C. pallescens* | - | - | 6 | 0.29 | 1 | 0.22 |
| 9. | *Fusidium viride* | 83 | 2.66 | 103 | 5.00 | 40 | 8.58 |
| 10. | *Arthrobotrys superba* | 43 | 1.38 | 8 | 0.39 | 7 | 1.50 |
| 11. | *Fusarium* spp. | 46 | 1.47 | 44 | 2.14 | 3 | 0.64 |
| 12. | *Pestalotia truncata* | 14 | 0.45 | 1 | 0.05 | - | - |
| 13. | *Alternaria humicola* | 11 | 0.35 | 4 | 0.19 | 2 | 0.43 |
| 14. | *Cephalosporium* spp. | 6 | 0.19 | 5 | 0.24 | 5 | 1.07 |
| | *C. humicola* | 4 | 0.13 | 1 | 0.05 | - | - |
| 15. | *Aspergillus* sp. | - | - | - | - | 2 | 0.43 |
| | *A. luchuensis* | 2 | 0.06 | - | - | 5 | 1.07 |
| | *A. niger* | - | - | 9 | 0.44 | - | - |
| | *A. fumigatus* | - | - | - | - | 4 | 0.86 |
| | *A. sydowii* | - | - | - | - | 3 | 0.64 |
| 16. | *Humicola fuscoatra* | 8 | 0.26 | - | - | - | - |
| 17. | *Mucor* sp. | - | - | 2 | 0.10 | - | - |
| 18. | *Papularia sphaerosperma* | - | - | - | - | 1 | 0.22 |
| 19. | *Brachysporium* sp. | - | - | - | - | 1 | 0.22 |
| 20. | "Unidentified" types | 2 | 0.06 | - | - | 4 | 0.86 |
| 21. | White sterile forms | 20 | 0.64 | 5 | 0.24 | 5 | 1.07 |
| | Brown " " | 92 | 2.95 | 65 | 3.16 | 6 | 1.29 |
| | Total | 3122 | 100% | 2060 | 100% | 466 | 100% |

**Table 38.** Air fungal load during threshing operations in wheat at the site of threshing and 10 and 20 metre away, threshed on 1st April 1995

| Sl. No. | Fungal types | DISTANCE FROM THE THRESHING SITE | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 m | | 10 m | | 20 m | |
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Aspergillus* spp. | 11 | 0.47 | 15 | 1.13 | 5 | 0.98 |
| | *A. ochraceous* | 7 | 0.29 | 6 | 0.45 | - | - |
| | *A. parasiticus* | 10 | 0.43 | 14 | 1.06 | 8 | 1.58 |
| | *A. terreus* | 1 | 0.04 | - | - | 4 | 0.79 |
| | *A. flavus* | 3 | 0.13 | - | - | 2 | 0.39 |
| | *A. fumigatus* | - | - | 3 | 0.23 | 7 | 1.38 |
| | *A. niger* | 7 | 0.29 | 13 | 0.98 | - | - |
| | *A. candidus* | 4 | 0.17 | 1 | 0.07 | 1 | 0.19 |
| 2. | *Penicillium* spp. | 61 | 2.60 | 68 | 5.14 | 26 | 5.13 |
| | *P. islandicum* | 7 | 0.29 | - | - | 2 | 0.39 |
| | *P. miczynskii* | 6 | 0.25 | 4 | 0.30 | - | - |
| 3. | *Cladosporium herbarum* | 289 | 12.31 | 233 | 17.62 | 81 | 15.97 |
| | *C. cladosporioides* | 41 | 1.75 | 27 | 2.04 | 10 | 1.97 |
| 4. | *Drechslera* spp. | 404 | 17.21 | 171 | 12.93 | 38 | 7.49 |
| 5. | Yeast | 49 | 2.08 | 44 | 3.33 | 38 | 7.49 |
| 6. | *Alternaria* spp. | 24 | 1.02 | 21 | 1.59 | 3 | 0.59 |
| | *A. tenuissima* | 927 | 39.49 | 424 | 32.07 | 175 | 34.51 |
| | *A. humicola* | 388 | 16.53 | 211 | 15.96 | 48 | 9.47 |
| 7. | *Curvularia lunata* | 21 | 0.89 | 19 | 1.44 | 11 | 2.17 |
| | *C. geniculata* | 8 | 0.34 | - | - | - | - |
| | *C. pallescens* | 12 | 0.51 | 7 | 0.53 | 13 | 2.56 |
| | *C. tuberculata* | - | - | 4 | 0.30 | 1 | 0.19 |
| 8. | *Cephalosporium* spp. | 9 | 0.38 | 10 | 0.76 | - | - |
| 9. | *Trichoderma lignorum* | 7 | 0.29 | - | - | 4 | 0.79 |
| 10. | *Humicola fuscoatra* | 2 | 0.08 | - | - | 1 | 0.19 |
| | *H. grisea* | - | - | - | - | 1 | 0.19 |
| 11. | *Epicoccum purpurascens* | - | - | 7 | 0.53 | - | - |
| 12. | *Stemphylium* spp. | 6 | 0.25 | - | - | 10 | 1.97 |
| 13. | *Mucor* sp. | - | - | 4 | 0.30 | 1 | 0.19 |
| 14. | *Spicaria sylvatica* | 1 | 0.04 | 5 | 0.38 | 2 | 0.39 |
| 15. | *Pestalotia truncata* | 1 | 0.04 | - | - | - | - |
| 16. | *Fusarium* sp. | 3 | 0.13 | 1 | 0.07 | 8 | 1.58 |
| 17. | Unidentified types | 4 | 0.17 | 1 | 0.07 | - | - |
| 18. | White sterile forms | 3 | 0.13 | - | - | 3 | 0.59 |
| | Brown sterile forms | 31 | 1.32 | 9 | 0.68 | 4 | 0.79 |
| | Total | 2347 | 100% | 1322 | 100% | 507 | 100% |

The spore deposition pattern with respect to distance, in "Boro" variety of paddy threshing was represented in **Table 39**. The spore deposit within 30 s in five petriplates during threshing was 1249, 655 and 446 CFUs at the site, and 10 and 20 m away from the site respectively. A number of *Aspergillus* species were identified which chiefly accounted for huge spore count at the site contributing 48.92% to the total catch. These species were also predominant or even increased at 10 m (62.90%) and at 20 m (70.18%) away from the site. *Penicillium* count was also very high in all the three places of sampling. Yeast and *Alternaria* concentrations were significant at the threshing site but their count was lower with the rise in distance.

The meteorological records *viz.* temperature, relative humidity and rainfall, on the dates of air sampling are shown in **Table 40**.

For statistical analysis, Pearson $\chi^2$ test was performed for all the three types of grain threshing in each year, pea harvesting and jute threshing. It is found from the analyses that the composition of fungal count (for total and every fungus count) is significantly different for the three sets of exposures taken. The *P* values are very low, indicating that the null hypothesis of independence of fungal composition and threshing / harvesting stage is rejected at very low level of significance.

## DISCUSSION

The enormous rise in the airspora during threshing of paddy and wheat grains, and jute stalks in both the years under study was due to the mechanical disturbances of source materials. The paddy (both "Aman" and "Boro") and wheat plants are harvested at senescence stage and after sun drying these are threshed to collect the grains. As a result, threshing operation cause the enormous release of spores and hyphal fragments from the shoots of respective plants (Uddin and Chakraverty 1994). This phenomenon of sudden increase during various agricultural practices *i.e.* harvesting, threshing, mowing, shredding, handling etc. has been observed by a number of workers.

**Table 39.** Air fungal load during threshing operations in "Boro" variety of paddy at the site of threshing and, 10 and 20 metre away, threshed on 9th May 1995

| Sl. No. | Fungal types | DISTANCE FROM THE THRESHING SITE | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 m | | 10 m | | 20 m | |
| | | Total CFUs | % | Total CFUs | % | Total CFUs | % |
| 1. | *Penicillium* spp. | 260 | 20.82 | 180 | 27.48 | 53 | 11.88 |
| | *P. islandicum* | 20 | 1.60 | 3 | 0.46 | 5 | 1.12 |
| | *P. funiculosum* | 1 | 0.08 | - | - | 2 | 0.48 |
| 2. | *Aspergillus* spp. | 154 | 12.33 | 10 | 1.53 | 17 | 3.82 |
| | *A. niger* | 70 | 5.60 | 47 | 7.18 | 48 | 10.76 |
| | *A. fumigatus* | 38 | 3.04 | 12 | 1.83 | 11 | 2.47 |
| | *A. sydowii* | 302 | 24.18 | 322 | 49.16 | 217 | 48.65 |
| | *A. candidus* | 6 | 0.48 | 3 | 0.46 | 2 | 0.48 |
| | *A. parasiticus* | 11 | 0.88 | 3 | 0.46 | 3 | 0.64 |
| | *A. flavus* | 13 | 1.04 | 9 | 1.37 | 11 | 2.47 |
| | *A. luchuensis* | 3 | 0.24 | 3 | 0.46 | - | - |
| | *A. terreus* | 9 | 0.72 | 2 | 0.30 | 2 | 0.48 |
| | *A. oryzae* | 5 | 0.40 | 1 | 0.15 | 1 | 0.23 |
| | *A. ochraceous* | - | - | - | - | 1 | 0.23 |
| 3. | *Trichoderma lignorum* | 9 | 0.72 | - | - | - | - |
| 4. | *Cephalosporium* spp. | 8 | 0.64 | 2 | 0.30 | 5 | 1.12 |
| | *C. humicola* | 2 | 0.16 | - | - | - | - |
| 5. | Yeast | 190 | 15.22 | 38 | 5.80 | 40 | 8.97 |
| 6. | *Alternaria* spp. | 11 | 0.88 | - | - | - | - |
| | *A. humicola* | 58 | 4.65 | 3 | 0.46 | 9 | 2.02 |
| | *A. tenuissima* | 54 | 4.33 | 7 | 1.07 | 4 | 0.89 |
| 7. | *Curvularia lunata* | 7 | 0.56 | - | - | 1 | 0.23 |
| 8. | *Cladosporium herbarum* | 4 | 0.32 | - | - | 1 | 0.23 |
| 9. | *Spicaria sylvatica* | - | - | 1 | 0.15 | - | - |
| 10. | *Geotrichum candidum* | - | - | - | - | 2 | 0.48 |
| 11. | "Unidentified" types | - | - | - | - | 3 | 0.64 |
| 12. | White sterile forms | - | - | 6 | 0.92 | 4 | 0.89 |
| | Brown sterile forms | 14 | 1.12 | 3 | 0.46 | 4 | 0.89 |
| | Total | 1249 | 100% | 655 | 100% | 446 | 100% |

**Table 40.** Meteorological variables on the dates of agricultural practices

| DATE | CROP THRESHED/ HARVESTED | TEMPERATURE (°C) | | RELATIVE HUMIDITY (%) | | RAINFALL (mm) TOTAL |
|---|---|---|---|---|---|---|
| | | MAX | MIN | MAX | MIN | |
| April 1, 1992 | Wheat Threshing | 35.5 | 23.6 | 59 | 31 | 0.0 |
| May 7, 1992 | Paddy ("Boro" variety) Threshing | 35.6 | 24.6 | 80 | 30 | 0.6 |
| December 15, 1992 | Paddy ("Aman" variety) Threshing | 26.0 | 12.6 | 83 | 42 | 0.0 |
| April 4, 1993 | Wheat Threshing | 36.3 | 24.6 | 77 | 35 | 0.0 |
| May 9, 1993 | Paddy ("Boro" variety) Threshing | 35.4 | 26.8 | 83 | 61 | 0.0 |
| December 12, 1993 | Paddy ("Aman" variety) Threshing | 27.2 | 13.9 | 89 | 54 | 0.0 |
| November 11, 1992 | Pea Harvesting | 30.3 | 17.9 | 80 | 48 | 0.0 |
| August 11, 1991 | Jute Threshing | 34.2 | 27.6 | 89 | 72 | 0.0 |
| August 11, 1992 | Jute Threshing | 33.5 | 27.0 | 85 | 66 | 0.0 |
| January 2, 1995 | Paddy ("Aman" variety) Threshing | 24.4 | 14.8 | 87 | 57 | 0.0 |
| April 1, 1995 | Wheat Threshing | 36.0 | 25.6 | 76 | 53 | 0.0 |
| May 9, 1995 | Paddy ("Boro" variety) Threshing | 38.2 | 27.8 | 83 | 62 | 0.0 |

Sreeramulu and Ramalingam (1964), and Atluri *et al.* (1988a) observed similar rise during harvesting in paddy fields. In "Aman" variety of paddy, during threshing, the high count was due to *Helminthosporium oryzae* and *Cladosporium* in both the seasons. Since this variety is threshed in winter the low temperature (Table 40) favoured the growth of *Cladosporium*, along with the pathogenic *H. oryzae*. *Sreeramulu* and *Ramalingam* (1964) similarly recorded high counts of *Cladosporium* and *H. oryzae* during harvesting of paddy crop. In "Boro" variety of paddy threshed in early May (*i.e.* summer), *Alternaria humicola* and *Alternaria tenuissima* accounted for the high concentration of spores in the air during threshing; being not similar with the "Aman" variety of paddy. Atluri *et al.* (1988a) recorded that *Arthrobotrys*, *Cochliobolus miyabeanus*, *Drechslera* and *Ustilaginoidea virens* were greatly elevated on the day of harvesting as compared to pre and post harvesting period. The effect of threshing of paddy on the fungal airspora was observed by Seshavataram (1965) by gravity slide method, where *Ustilaginoidea virens*, *Neovossia* sp., *Helminthosporium* sp. and *Nigrospora* sp. were the major constituents of the spore load.

Fungi associated with the crop plants were greatly differ from crop to crop, which were again affected by the climatic parameters. Besides "Boro" and "Aman" varieties of paddy as mentioned earlier, wheat crop was associated highly with *Alternaria tenuissima*, *A. humicola*, *Drechslera* and *Cladosporium* which were observed to come out during threshing operations in early April of the year. In early winter (Table 40) during harvesting of a green vegetable i.e. *Pisum sativum*, the operation has resulted an immediate rise, mainly due to *Cladosporium*, *Penicillium* and *Trichoderma lignorum*. The jute stalks were threshed in rainy season and during this operation the air contaminants were huge amount of *Aspergillus*, *Penicillium*, *Trichoderma lignorum*, *Cephalosporium* and *Fusarium*. *Aspergillus* and *Penicillium* were reported to be the most predominant fungi during monsoon (Agashe *et al.* 1992, Uddin and Chakraverty 1995) and also *Fusarium* (Uddin and Chakraverty 1995).

As in the present harvesting and threshing operations, Pawsey and Heath (1964) recorded a similar rise due to grass mowing. Dransfield (1966) observed spore showers of

*Cladosporium*, *Penicillium* and *Aspergillus* during grass cutting by manual operation. Kotimaa *et al.* (1978) and Johansen (1992) recorded increased spore concentrations of *Cladosporium* sp. during threshing, grinding and handling of hay. Buttner and Stetzenbach (1993) have shown that human activity in the room resulted in retrieval of higher concentrations of airborne spores.

The present study to detect variation in spore concentration with distance from the source site showed that there was huge amount of spore load at the threshing site of the respective crop. These spores were dispersed to distant places through the air where these were sedimented. It has been found that the larger and heavier spores *e.g. H. oryzae*, *Alternaria*, *Drechslera* were sedimented quickly around the threshing site while small sized light spores *e.g. Penicillium*, *Aspergillus*, *Cladosporium* were dispersed readily to long distances and take time for sedimentation.

It can therefore be concluded that a few types of fungi *viz. Alternaria tenuissima*, *A. humicola*, *Helminthosporium oryzae*, *Cladosporium* spp., *Drechslera* sp., *Aspergillus* spp., *Penicillium* spp. and yeasts were the major constituents of the spore load in varying sequences in the crops concerned. These variations in sequence was due to the respective crops i.e. related with host specificity and also due to different crop seasons with different weather conditions (Table 40); since wheat and "Boro" varieties of paddy threshings were done in summer (April-May); threshing of "Aman" variety of paddy and harvesting of pea were done in winter (November-December); and the jute stalks were threshed in August i.e. in rainy season as in West Bengal there are three major seasons in the year (Uddin and Chakraverty 1996).

It was also observed that in the airspora studies on various crops under study (*viz.* paddy, wheat, jute, mustard and potato), there was a sudden rise in spore count during harvesting of the respective crop which was due to the human activities in the existing crop.

The immediate rises in spore load in the air during threshing, harvesting and other agricultural processings are liable to cause health hazards to the farmers and even to the cattles as they are exposed to huge amount of spore dust during the operations, since a number of reports are available regarding the ailments caused by fungi. *Cladosporium* was reported to be a most important allergenic fungal component (Edmonds 1979). Different species of *Aspergillus* was reported to cause aspergillosis (Fromtling and Shadomy 1986) and other fungi to cause many types of health problems (Platt *et al.* 1989, Strachan *et al.* 1990) including allergic symptoms (Ebner and Haselwandter 1992).