DISCUSSION

The present investigation, in relation to general airspora studies over the Bajra fields was carried out for two kharif seasons (i.e. first kharif season from 26\textsuperscript{th} June to 4\textsuperscript{th} September, 2013 and second season from 28\textsuperscript{th} June to 22 September, 2014) and also for continuous volumetric Tilak Air sampler, in order to study the correlation between airborne microbial components, weather parameters, growth stages of the crop and their subsequent effects on disease incidence on the crop. All the trapped airborne fungi have been included under spore types “Hyphal fragments, insect parts, protozoan cyst, pollengrains, plant parts are included under the other types” group. The investigation period of first season was from 1\textsuperscript{st} July to 30\textsuperscript{th} September, 2013 and of second season was from 1\textsuperscript{st} July to 30\textsuperscript{th} September, 2014.

The total airspora tapped in first kharif season i.e. 2013 was 518070/m\textsuperscript{3} of air while in second kharif season i.e. 2014 was 572880/m\textsuperscript{3} of air. This difference between the spore counts was due to available different meteorological condition in 2013 and 2014. The meteorological data of both seasons revealed that during second kharif season i.e. in 2014 more frequent raining (1029 mm) was there. The high percentage humidity and low temperature favours more spore count in 2014, while in the first season comparatively a less occasional raining (435.7 mm), less percentage humidity and high temperature leads to decrease spore count in 2012.

In 2014 the maximum temperature recorded was 34.0\textdegree C and minimum temperature recorded was 17.2\textdegree C. The average temperature was 25.6\textdegree C. The maximum
percentage humidity recorded was 100% and minimum percentage humidity was recorded 45%. The average percentage humidity was 72.5%.

In 2013 the maximum temperature recorded was 35.50°C and minimum temperature was recorded as 16°C. The average temperature was 25.75°C. The maximum percentage humidity recorded 100% and minimum percentage humidity was recorded 30%. The average percentage humidity was 65%. It clearly indicates the varied meteorological condition in 2013 and 2014 with respect to raining, temperature, percentage humidity leads to more spore count i.e. 572880/m3 in the second season i.e. 2013 than 2014.

In all, on an average during the period of the present investigation 76 types of airborne components were reported, of which 42 types belonged to Deuteromycotina, 20 to Ascomycotina, 4 to Basidiomycotina and 4 to Zygomycotina, 1 Myxomycotina 5 to other types.

During the first and second kharif seasons i.e. 20th June 24th September, 2013 to 28th June 22nd September, 2014, Deuteromycotina contributed with highest percentage (66.60% and 66.84%) to the total airspora followed by Basidiomycotina (8.43% and 11.08%), other types (9.74 and 10.19%), Ascomycotina (11.71 and 8.44%), Zygomycotina (3.13 and 3.06) and Myxomycotina (0.39% and 0.37%). So in two kharif seasons it was evident that the group Deuteromycotina dominated the total airspora.

The airborne components like *Cladosporium*, hyphal fragments, *Helminthosporium, Nigrospora, Alternaria*, smut spores, *Curvularia, Periconia*, contributed significantly to the total airspora in all the seasons i.e. two kharif seasons.
From group Zygomycotina, four spore types were recorded. The spores of *Albugo* were encountered in the months of July, August and September, 2013 and 2014 during first kharif and second kharif season. Weeds like Amaranhtus sp., Portulaca sp., Achyranthus sp., occurring in the cultivated fields must have served as a host where from the spore discharge might have taken pace in the ambient air over the fieldsof bajra field.

*Cunninghamella* recorded 0.55% and 0.38%to the total airspora was in first and second season respectively.

*Rhizopus* sp.is very common saprophyte and facultative parasite.The *Rhizopus* is a commonly occurring fungus on ripened fruits and vegetables in this area. *Rhizopus* contributed during first kharif season only (Table I-A). It exhibit “day spora” pattern. Among the group Zygomycotina, *Rhizopus* spores were reported in maximum number during first kharif season only. Hyde and Williams (1949), Kramer et.al. (1959, 1960), Kamal and Mishra (1977) also reco0rded spores of *Rhizopus* with significant concentration. Moderately high temperature (25\(^0\)C to 35\(^0\)C), high relative humidity favoured spore release of *Rhizopus*. In general, the source for airborne spores of *Rhizopus* was dead and decaying plant parts in and around the fields. However, the occurrence of the members of Zygomycotina was low in the airspora. This may be due to aquatic, semiaquatic, soil inhabitants, nature of fungus and however there is not special mechanism for their spore dispersal. In general, the members of Zygomycotina appeared in the atmosphere during the months from July to August, when there were rains, which obviously was the prerequisite in including them to release spores in to the air. Artificial irrigation might have been main parameter in inducting them to release their spores in air.
From the group Ascomycotina about 20 ascospores types were trapped and identified during the period of investigation. The group Ascomycotina stood second in the order of dominance, contributed 11.71% and 8.44% during two kharif seasons. *Pringshemia, Sordaria, Claviceps, Massarina, Parodiella, Stigmina* etc. occurred very rarely and their contribution to the total airspora in two kharif season where as ascospores types like *Chaetomium, Didymosphaeria, Leptosphaeria*, etc. occurred abundantly during kharif season. The spores of *Passerienella* occurred only in kharif season. *Didymosphaeria, Hypoxylon, Leptosphaeria, Melanospora, Pleospora, Sporomia*, etc. were the common airspora types occurred in both the kharif seasons. Ascospores of *Pringsheimia* were restricted to only one kharif (2012). The spores of *Chaetomium, Didymosphaeria, Passerinella, Pleospora, Pringshemia, Sordaria*, etc. showed their dependence upon the occurrence rainfall and occurred immediately after the outbreak of rainfall.

The presence of Ascospores in the ambient during the period of investigation revealed that there was abundance of parasitic and saprophytic members of Ascomycotina in and around the trapping site. From among the group Ascomycotina, *Leptosphaeria* was found to be dominant (12964/m3 and 10094/m3 of air) and contributed 2.50% and 1.77% to the total airspora catches. *Leptosphaeria* was collected on the dead plant twigs in saprophytic from abundantly in and around the field must have served as a source for boosting up its concentration in air over bajra fields. Total concentration and contribution of ascospores to the total airspora was 60728/m3 and
48384/m3 of air and 11.08% and 8.44% during both kharif seasons. *Sordaria* and *Sporomia* were found to be common during loving fungi of this region.

In most of the members of the Ascomycotina, spores are actively discharged for further transport through air currents. In general, the turbidity of the cells is essential in the process of spore liberation in fungi. However many of the spores of Ascomycotina showed their active spore discharge immediately after rainfall, as has already been reported by Ingold (1965). According to Wilcoxionet.a. (1967), the temperature may play a role in affecting the release of ascospores. *Chaetomium, Didymosphaeria, Leptosphaeria, Pleospora, Hypoxylon*, etc. were the dominant spore types. As a matter of fact, almost all of them occurred very frequently in the ambient air. Their incidence in the air was focused to be dependent upon immediately after the rainfall. Similar observations were made by Ingold (1965), Ramakrishna Reddy (1987), Malabade (1990), Kavishwar (1991), Bhadane (1991), Jayaswal (1993), Pawar (1998) and Garje (2000)

The obtained data clearly revealed that most of the ascospores required congenial conditions and precipitation as prerequisite for the release in the air. Many members of Ascomycotina showed active spore discharge mechanism (Ingold, 1965) stated that there has been a very little rainfall or only 2 mm leads to abundant release of airspora. Majority of the spores are released in the first three hours after rains. The ascospores of Didymosphaeria contributed 1.71% and 1.63% to the total airspora (Table I-A). The highest spore concentration (224/m3 and 280/m3) was recorded on 18th September, 2009 and 6th September, 2010 during two kharif seasons.
The spores of Chaetomium contributed 0.71% and 0.61% during two kharif seasons. The spores of Leptosphaeria, Pleospora, Didymosphaeria, Hypoxylon etc. also occurred with high concentration. The members like Leptosphaeria, Pleospora, Hysterium, Sporomia etc. discharged their ascospores into the atmosphere even long after the rains. Similar observations were made by Patil(1983), Patil(1985), Rao (1987), Jayaswal (1993). However, the ascospores of Chaetomium, Didymosphaeria, Pleospora, Hypoxylon etc. were observed during dry period and in less humid conditions. The present findings clearly revealed the importance and impact of rainfall, temperature and relative humidity on the ascospores release of some Ascomycotina members.

Massarina, Pringsheimia and Claviceps ascospores occurred very irregularly with feeble concentration. It may be due to non-availability of suitable substratum for their growth and sporulation in and around the trapping the external climate factors which greatly affected the development of reproductive structure, they appeared to be the prime determinants in long term periodic fluctuation like annual cycle of airborne catches.

The spores of Basidiomycotina contributed 8.43 and 11.08% to the total airspora during first and second kharif seasons 2013 and 2014. The analysis of total types of trapped spores of mycosporophyte clearly indicated that the spores of Basidiomycotina, however, dominated the amount of microbial population. From the group Basidiomycotina, Basidiospores (coloured and hyaline), rust spores and smut spores are reported in both kharif seasons.
Comparative analysis of epidemiology of different diseases of bajra showed that the moderate temperature, moderately high humid conditions, artificial irrigation and growth stages of crop favoured in inciting the disease to bajra crop. Under such congenial conditions, the concentration of pathogenic spores in air was found to be maximum.

During the period of present investigation, incidence of rust spores (uredospores) was noted throughout. However, there was a record of moderate incidence of rust disease on crop. Moderately low temperature and moderately high humid conditions were found very much congenial for increasing the concentration of rust spores in the ambient air over the crop of bajra. Contribution of uredospores to the airspora was found to be 5.13% and 6.37% in two kharif seasons. The highest spore catches of urediniospores 12838/m3 and 16730/m3 of air was in the months of September, 2013 and July 2014. The highest spore catches (448/m3 and 2800/m3 of air) was recorded on 3rd September, 2013 and 22nd July, 2014 in two kharif seasons.

Rust disease caused by Puccinia graminis Schew was observed in sporadic form on the lower leaves of bajra crop. However, there was very mild incidence of rust disease during the period of investigation. Rust spores (uredosposre) also played a significant role in inciting serious allergic disorders. The role of uredospores in inciting various types of allergy has been pointed out by earlier workers like Durham(1942), 1946), Baruah and Chettia (1960), Agarwal and Shivpuri (1974), Brown and Jackson (1978), Pawar (1998), Banswadkar (2002) etc.

Basidiospores (coloured and hyaline) were trapped in high concentration. The maximum concentration (4690/m3 and 7560/m3 of air) was recorded in the month of
September, 2013 and September, 2014 during two kharif seasons. From the obtained results, it is evident that there was a definite correlation between increased concentration of Basidiospores in the atmosphere with the rainfall, moderate temperature and high relative humidity. The members of Agaricales and Polyporales occurring in and around field might have served as the source for high concentration of coloured and hyaline Basidiospores.

Smut spores contributed 0.86% and 1.22% in two kharif seasons (Table I-A). The spores were recorded throughout the period of investigation. Their maximum concentration (2170/m3 and 1974/m3 of air) was recorded in the month of August, 2013 and 2014 during two kharif seasons. The smut spores were usually occurred in clumps comprising 5-50 spores. However, their occurrence was continuous with some fluctuation in concentration. From the above recorded observation it could be concluded that the occurrence of smut spores was mainly confined to dry period. Rees (1964) also reported smut spores in dry period. It became very difficult to trace out the exact source of smut spores in and around the trapping site. However, there was a variety of grasses there across the demarcated boundaries of fields, which were found infected by smut disease, eventually this smut have served as a source for abundant release of spores in the air over crop field.

The group Dueteromycets was well dominated by as many as 42 spore types during the period of investigation. The Deuteromycotina contributed 66.60% and 66.84% in two kharif seasons. The most regularly occurring spore type which contributed in a considerable number was Cladosporium. Alternaria, Curvularia. Nigrospora,
Amongst all the types, *Cladosporium* (22.01% and 20.57%), *Alternaria* (3.90% and 9.67%), *Curvularia* (5.98% and 4.22%), *Nigrospora* (4.30% and 3.49%), *Helminthosporium* (3.70% and 2.179%), *Periconia* (3.36% and 2.79%), were most dominant spore types in air in both kharif seasons. All of these spore types therefore, have been called as “airspora dominants”.

The maximum concentration of *Cladosporium, Nigrospora, Alternaria, Periconia, Helminthosporium*, etc. in the air was simply because of their saprobic habit, their high degree of vegetative reproduction by fragmentation, budding etc., asexual reproduction by developing conidia directly on conidiophores exogenously and also having capacity of high fruiting with passive spore liberation. The gentle wind currents, natural or mechanical disturbance have been found directly or indirectly involved in liberating enormous amount of spore load in the air. Gregory (1961) also stated that the mist-pick up mechanism was rather more effective in the dispersal of *Cladosporium* spores. The obtained results are in agreement with the statement of Gregory (1961).

The dominance of the spores of *Cladosporium* may be regarded as a universal dominant, because earlier workers from India and abroad also reported this spore type as the dominant type. Its allergenic importance is well known. It is one of the major components of airborne microbes causing atmospheric biopollution. In air, *Cladosporium* spores showed their clumps and hence called “conidial units of dispersal”. The high frequency of occurrence and predominance during wet and dry period was observed by Cammack (1955). He also stated that variation in the number of spores found dependent largely on availability of host as well as climatic factors. Reddy (1970)
recorded *Cladosporium* as the dominant spore type and observed in maximum numbers in all months with its seasonal maximum occurring in the period between November and January. Thus, it can be concluded that the maximum concentration of *Cladosporium* spores could be correlate with the flowering and seed forming stages in both seasons. The rain preceding days, irrigation in the season and leaf shedding might have served as pre-requisites for the copies growth and dispersal of spores in the atmosphere.

*Alternaria* spores occurred regularly and contributed 3.90% and 9.67% during two kharif seasons. The highest spore catch (20230/m3 and 55412/m3 of air) was recorded on 8th September, 2013 and 18th September 2014 during two kharif seasons. Weather parameters might have helped to the spore formation, liberation causing subsequent increase in conidial load in the air over sunflower crop field.

The spores of *Helminthosporium* contributed 3.70% and 2.17% during two kharif seasons. The highest daily mean concentration 462/m3 and 854/m3 of air was recorded on 16th September, 2013 and 9th September, 2014 when there was a record of 34.30°C and 27.5°C temperature, 80% and 91.0% relative humidity, 0.0 mm, 1.0 mm rainfall. The spores of *Helminthosporium* did not show significant prevalence during two kharif seasons though there were congenial conditions. Due to non-availability of suitable substrate the spores might have occurred with poor concentration. Similar observation was also made by Jayaswal (1993), Shukla (1971) isolated these spores in less concentration from the culture exposed in the forest.

In general, the other spore types belonging to group Deuteromycotina like*Nigrospora, Periconia, Pseudotorula, Torula, Cercospora, Drechslera, Curvularia*
etc. showed their high incidence in air in all the seasons. The spores of *Heterosporium*, *Stigmina*, *Harknessia*, *Tetraploa*, *Haplosporella* and *Fusarium* etc., belonging to the group of Deuteromycotina preferably occurred in day time, hence they have been included under ‘day spora’ group. However, these groups showed irregular recurrence throughout the period of investigation. This may be due to non-availability of the suitable host substratum and congenial weather parameters for their development and discharge.

In addition to the above spore types, few other fungal spore types contributed in very insignificant numbers in the air over bajra crop fields. Frequent irrigation resulted in boosting the local humid condition. Which in subsequent course of time helped in sprouting various weeds which incidentally became host for pathogenic or non-pathogenic types. Availability of different hosts in abundance in the beginning of the investigation period resulted in setting the beginning of the investigation period resulted in setting the concentration not only of *Cladosporium* spores but also of *Helminthosporium, Curvularia, Epicoccum, Pithomyces, Torulla*, etc.

In addition to systematically classified spore group, “other types”, an artificially formed group, contributed 9.74% and 10.19% during first and second kharif seasons. The group being heterogeneous in composition comprised of hyphal fragments, insect arts, plant parts, pollen grains and protozoan cysts.

The occurrences of hyphal fragments were abundant during the period of investigation. They contributed 4.03% and 3.96% during two kharif seasons. However, in the present study hyphal fragments stood third in order of dominance. The maximum monthly concentration 20874/m3 and 22694/m3 of air was recorded in the months of
September, 2013 and August, 2014 during two kharif seasons, when there was a record of 25.7°C and 25.35°C average temperature and moderate relative humidity. Windy climate and harvesting operations in the field might have helped in increasing the incidence of fungal hyphae in the air over bajra fields. Pady and Kramer (1960), Pady and Gregory (1963), stated that viable fragments are not less important than viable spores.

Harvey (1970), while studying airspora of Kansas and Cardiff, emphasized the importance of hyphal fragments in the airspora. The role in survival and pathogenicity of hyphal fragments is found to be equally important as like viable fungal spores. Tilak (1982) reported these as important airborne materials and their inherent ability as propagates due to their viability. Abundance of hyphal fragments in air over the bajra fields was mainly confined to dry, hot and windy days. The seasonal variation of the hyphal fragments clearly revealed its close correlation with weather parameters such as temperature, relative humidity, rainfall.

The insect parts also contributed significantly during the period of investigation. They contributed 0.85% and 1.16% during two kharif seasons. Their incidence in the air was quite high during the flowering of the crop due to high wind velocity. Insect parts generally occur in open air after the death and also shedding of scales or wings often occurs when insects fly. Fienberg et.al. (1956) pointed out the role of insects and insect scales in Allergy. Tilak and Bhalke (1979), presented a report on seasonal variation of insect parts from Aurangabad. Tilak (1982), reported that the abundance of the insect parts is related with meteorological parameters, while high wind velocity also helps in discharging the insect parts in air forming a common components
of airspora. During the period of present investigation, high amount of pollen grains were trapped from air over bajra field, where in the pollen grains of bajra and grasses were significantly more in number. Besides the pollen grains of the members of Convolulaceae, Solanaceae, Portulaceae, Amaranthaceae, Leguminosae, Asteraceae, etc. were also caught, but their incidence in air was within the limit of contribution. Pollen grains contributed 2.22% and 2.2% during two kharif seasons. The maximum concentration 11466/m³ and 12698/m³ during two kharif seasons. It may be just due to the weed flora growing near the boundaries of fields. Pollen grains of grasses Parthenium, Xanthium, Cassia, Acacia, Amaranthus, etc. occurred with agreeable concentration and have already been proved as allergenic. Hamilton (1959) and Lacey (1962) reported that the locality and vegetation has an influence on the concentration categories of pollen incidence in the air.

In the present investigation protozoan cysts were also reported in two kharif seasons. They contributed 1.37% and 1.44% during two kharif season. Most of the protozoans are found in the form of cysts. Protozoans occurred in air in the form of cysts occurred maximum (3094/m³ of air) in concentration in the month of September, 2013 during second kharif season. the concentration protozoan cysts occurring in the air could be correlated with environmental parameters like relative humidity, moderate temperature and high wind velocity. Similar observations were also made by earlier workers like Bhalke (1981), Patil(1985), Jogdand(1987), Jagan Mohan Reddy (1989), Jayaswal(1993), Mahajan (1995) and Garje (2000).

Different types of plant parts were trapped in both the kharif seasons. Mostly uniseriate, multiseriate epidermal hairs and trichomes were trapped in both the
seasons. Their contribution to the total airspora was recorded as 1.27% and 1.41% during two kharif seasons. The maximum monthly concentration (3626/m3 and 4228/m3 of air) was recorded in the months of September, 2013 and 2014 during two kharif seasons when there was an average record of 25.7°C and 25.55°C temperature with moderate percentage of relative humidity. In most of the fields in adjoining area of the trapping site crop were already harvested, thrashed and subsequently this must have served as the source for the airborne epidermal hairs during this period of investigation.

During the period of present investigation, in both the kharif seasons 2013, the total airborne aeroplanktons were found to be adequately rich. Airborne biocomponents like Cladosporium, hyphal fragments, Alternaria, Helminthosporium, Curvularia, Nigrospora. Rust spores, Pollen grains, Basidiospores, Pseudotorula, Leptosphaeria, Torula. Periconia, Epicoccum, Didymosphaeria etc. showed their more concentration in the first kharif season i.e. 2013 whereas Cladosporium, Alternaria, Rust spores, Curvularia, Basidiospores, Helminthosporium, Nigrospora, Hyphal fragments, Pollen grains etc. showed their higher incidence in the second kharif seasons i.e. 2014 (Table I-A)

Even though role of temperature to certain extent was found insignificant so far as release of fungal spores in air is concerned, but atmospheric relative humidity, soil moisture and scattered rains brought about their direct impact on either increase or decrease in the spore concentration. It is also well established fact that there was continuous fluctuation in the atmospheric spore concentration along with the fluctuations in environmental parameters.
Human activities like weeding, inter-culturing, spraying, dusting, harvesting operation, transportation etc. also affected the composition and concentration of airspora. Fluctuation in the concentration of airspora composition has been found to be temporary and they differ from seasons to seasons. In India 9% airborne components belong to the group mycota. *Cladosporium* alone contributed nearly half to its number (Ramlingam, 1971).

In his general survey he recorded 60 types of airborne biocomponents and almost all of them were plant pathogenic, 6 as animal and human pathogenic, 11 as bio deteriorating agents and large numbers of them were allergenic.

The present aerobiological study has helped to understand the various components of airspora over bajra field at Ambajogai (Maharashtra). Bajra being the economically important cash crop. The farmer wishes to grow bajra in kharif season but due to various pathological diseases in the said season was stumbling block to grow this crop. Farmers earlier were growing this crop only in the rabbi season.

Author provided apt knowledge regarding the incidence of disease in the said season. On the demands of farmers and cultivators and on the basis of present studies also suggested certain controlling their crop from the incidence of diseases and to avoid damages due to heavy concentration of pathogenic spores noted in the present studies is of immense help to farmers and cultivators, as would serve the purpose of alarming them of likely occurrence of fungal diseases.
Hence the atmospheric microbial population in relation to phytopathology has an ample scope for further investigations. Such studies would bring forth many results like disease forecasting which ultimately would help in protecting the crop.