DISCUSSION

In the present investigations nine different pathogens were isolated from different types of leaf spots of sorghum at Kanpur (U.P.), where sorghum is grown as a commercial crop for fodder and grain purposes. Helminthosporium basaliense, H. rostratum, H. turcicum, H. bicolor, H. betanum, H. zevis, Curvularia lunata, Aspergillus sorghi and Ulocladium sorghi were identified on the basis of their symptomatological, cultural and morphological characters.

Six species of Helminthosporium were selected for comparative studies on physiological, nutritional as well as pathological (perpetuation & survival, host range, varietal reaction and control measures) aspects.

Pathogens require food and energy from substrates upon which they subsist in nature. In order to culture fungi in the laboratory, it is necessary to furnish in the medium the essential elements and compounds which they require for the synthesis of cell constituents and for the operation of life processes. On the basis of composition there are two general types of media, natural media which are composed
entirely of natural products and synthetic media, which are of known composition (Lilly and Barnett, 1951).

Natural media which contain more chemical compounds ordinarily not present in the synthetic media in general give better growth than synthetic media (Lilly and Barnett, 1951). No consistency was noticed in the utilization of these media by the six species of *Helmintosporium*. All the pathogens showed maximum growth on Richards and minimum growth on cornmeal. This could be due to the presence and release of certain enzymes which are probably liberated during the course of the incubation period (Sarbhey, 1959).

The best growth of all the species of *Helmintosporium* was obtained on Richards medium, followed by Czapek’s (Box) medium which is supported by Orillo (1954) for *H. maydis*, Misra and Roy (1965) for *H. turcicum*, Misra and Kunankami (1966) for *H. betränkera*, Hodge et al. (1969) for *H. nodulosum* and Misra and Misra (1971) for *H. hawaliense*.

Sporulation of *H. hawaliense*, *H. makrakos*, *H. betränkera* and *H. maydis* was found to be good to excellent on most of the media whereas rest of the species showed nil to fair sporulation. Czapek’s (Box) medium showed excellent sporulation for *H. hawaliense*, *H. betränkera* and *H. maydis* while fair for the remaining species. Richards’s and potato-dextrose media showed good to excellent sporulation for all except *H. turcicum* and *H. bicolor*. These results are quite in agreement with the findings of Misra and Roy (1965) for
Improvement of the medium can increase the growth of microorganisms. Ideally, the medium will assist the growth of microorganisms. The growth of microorganisms is affected by the concentration of the medium. If the concentration of the medium is too high, it can retard the growth of microorganisms. In general, the growth of microorganisms can be affected by the concentration of the medium. If the concentration is too low, it may not support the growth of microorganisms. On the other hand, if the concentration is too high, it may inhibit the growth of microorganisms.
of three isolates of H. aerobacterium differed with pH range of
6.0 to 8.2. They also reported best pH of 6.1-6.8 for growth
and separation (1958), respectively. H. aerobacterium
within a pH range of 5.0-7.0 with an optimum at pH 7.0.

It was also observed that all the six species shifted
reported that the best pH of 4.5, followed by 5.5 for
growth of H. aerobacterium. The best growth of H. aerobacterium
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Temperature affects growth, spore germination, reproduction and indeed all the activities of the organism. Not only the species within a genus differ widely, but strains or geographical isolates of the same species may respond differently. Growth increases directly with the temperature, an optimum range may be narrow or rather broad and there is a descending growth limit as the temperature becomes too high (Cochrane, 1958). In the present study also the growth of all the six species of *Helminthosporium* increased up to 30°C and there was gradual fall up to 40°C. At 50°C, no growth was recorded for any of the species except *H. hawaiiense* and *H. betramarensis*.

All the six species grew within the optimum temperature range of 25°C to 30°C. At 10°C and 40°C the growth of all the species was not satisfactory but there was no growth of *H. turcicum* at 40°C. The above results are in agreement with the findings of Misra and Misra (1971b) who observed the optimum temperature for growth of the two isolates of *H. rostratum* to be 30°C and other two isolated at 32°C but the growth rate at 40°C was very poor. It also confirmed the findings of Misra and Munankami (1966), for *H. betramarensis* and Misra and Chatterjee (1963) for *H. betramarensis*.

Misikado (1927) gave the limiting temperatures for growth of *H. turcicum* as about 5°C and 35°C, with an optimum for mycelial growth at 27°C-30°C. Rangaswamy and Pandurangam (1962) reported the maximum mycelial growth at 29°C. Misra
and Singh (1963) found the optimum temperature for growth of *B. turcicrum* between 25° to 30° C while the growth was completely suppressed at 40° C. Misra and Mishra (1971a) while working with four isolates of *B. turcicrum* reported best temperature for growth at 30° C and 25° C. Hishikado (1927) reported the minimum temperature for growth of *B. maydis* about 40°C, maximum 35°C and optimum 30°C. Orillo (1954); Singh and Singh (1956) recorded that *B. maydis* had optimum growth at 24° - 30° C. These findings have been confirmed by the present investigations.

The average dry weight of all the species at different temperatures differed significantly from each other. However, the growth on 25° and 30° C was significantly different in all the species except *B. hawaiense*. pH of the media at 40° to 55°C temperatures changed slightly towards alkalinity. The colour of the original medium was colourless which changed after the growth of all the species at 70° to 25° , 25° and 35°C except *B. turcicrum*, *B. bicolor* and *B. maydis*.

Sporulation of *B. hawaiense* and *B. betanorum* was excellent at 25°, 25° and 30° C while fair to good in case of *B. rostratum* and *B. maydis* and poor to fair by *B. turcicrum*. This confirms the findings of Hishikado (1927), Orillo (1954) and Kenneth (1953).

In studies on the effect of different media on spore germination of all the six *Helminthosporium* species 2% sucrose, 2% dextrose and sorghum leaf extract supported 100 per cent
germination of spores. These findings are similar to those obtained by Pali and Suryanarayana (1964) and Kapeer (1970) with *H. rostratum* and *Bremularia australiensis*, respectively.

Spores of the species under study began to germinate two hours after their placing in all the water media at 29\(^\circ\) + 1\(^\circ\). Similar results were reported by Miura and Shrivestava (1968 and 1969) for *H. tetragenora* and *H. rostratum*, respectively and Reddy and Bilgrami (1969) for *H. rostratum*, *H. hawaiicensis*, *H. tetragenora* and *H. maydis*.

Maximum spore germination of all the six species of *Helminthosporium* under study was obtained at 30\(^\circ\), the optimum being in the range of 20\(^\circ\) - 30\(^\circ\). The above results are in close agreement with the findings of Nishikado and Miyake (1925), Singh (1953) and Miura and Singh (1955) for *H. turcicum*; Miura and Munakata (1966) for *H. tetragenora*; Yu (1955) and Singh and Singh (1955) for *H. maydis*; Reddy and Bilgrami (1969) for *H. hawaiicensis* and *H. rostratum* and Kapeer (1970) for *Bremularia australiensis*.

In the nutritional requirements of fungi for growth and sporulation, the results of the present studies show that the pathogens were able to utilise carbon from different sources fairly well but were unable to grow in the complete absence of carbon source in the medium. In all cases the amount of mycelial growth produced on them showed much variation. Utilisation of carbon sources by fungi depends upon structural configuration of the compounds as well as the capacity
also obtains other realizations.

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and H. betramera and on peptone for H. nevdaig which is similar to the results of earlier workers with H. hazalicense (Reddy, 1970), H. rostratum (Tarr and Kafi, 1968 and Reddy, 1971), H. furciacum (Miera and Roy, 1965), H. oryzae (Miera and Mukherjee, 1962), H. betremora (Miera and Munenskani, 1966), H. australicense (Thind and Chand, 1968) and Prochlamora auro- kiniana (Subramanian and Tyagi, 1969). The results obtained in the present study are also in general agreement with the observations of Foster (1949) that "virtually all fungi grew faster and probably more abundantly with complex organic material as source of nitrogen than with inorganic nitrogen."

However, some of the above results are in contradic-
tion with Tarr and Kafi (1968) for H. hazalicense and H. rostrat-
tum, Rangaswami and Pandurangan (1962) for H. furciacum and
Miera and Munenskani (1966) for H. betremora.

In general, the pH levels of filtrates of different nitrogen compounds utilised by different species of Helminthospor-
porium drifted towards alkaline side. Similar results were
reported by Geyerse (1953) and Chandwani and Munjal (1963)
regarding utilization of nitrogen by H. gaminacia.

Sulphur is structurally important as the constituent
of proteins and has a metabolic significance in the prosthetic
(-SH) groups of some enzymes and co-enzymes (Bhargava and
Tandon, 1963). Sulphate sulphur (SO₄) is the most common source
of sulphur (Lilly and Barnett, 1951). Most of the sulphates
(Magnesium sulphate, Ferrous sulphate, Ammonium sulphate, Calcium sulphate and sodium sulphate) were used as sources of sulphur for the present pathogen. In general the best growth was shown on magnesium sulphate by all the species except E. harleyi which is supported by the findings of Agarwal (1956). It was observed that ammonium sulphate supported good growth of all the species except E. harleyi which agrees with the observations of Bliss and colleagues (1963). Presence of calcium sulphate supported good growth on ammonium sulphate as compared to control devoid of sulphur source. All the species had the minimum growth on magnesium sulphate. Inhibitory effect on magnesium sulphate formation and sporation was shown by all the species. Bhargava and Tandon (1959) reported that sulphur of ammonium nitrate and copper sulphate had inhibitory effect on growth and sporulation of organisms. It is evident from the present investigations that all the species were capable to grow to some extent even on copper sulphate. No growth or sporulation on ammonium sulphate and calcium sulphate but good on ferrous sulphate. It was significant to note that kind of sulphur source had influenced the production of spores to a great extent and there was no correlation of the pathogen under study which varied from all to none extent. However, E. harleyi and E. faecalis produced good amount of spores on ammonium sulphate and calcium sulphate but not on ferrous sulphate.
sources tried. All the species except *H. haemalicae* had no sporulation on manganese sulphate.

pH of the medium containing ammonium sulphate or manganese sulphate altered to acidity after the growth of the pathogen on them.

Another important element in all forms of life is phosphorus. It was observed that all the species under study showed highly significant differences for average dry weights of mycelium on different phosphorus compounds. In general dibasic potassium phosphate had the best growth in four species of *Helminthosporium* while on dibasic sodium phosphate for *H. turcicum* and *H. maydis*. All the species gave good growth on potassium dihydrogen phosphate, magnesium phosphate and sodium dihydrogen phosphate. Agarwal (1953b) also found the best growth on dibasic potassium phosphate for *Curvularia pennisetii*. Singh (1974) working with *C. lunata* reported that it produced good growth on potassium dihydrogen phosphate, sodium dihydrogen phosphate was also reported by Bhargava and Tandon (1953). These findings are quite in agreement with the results obtained in the present studies.

Phosphorus compounds play an important role in the functions of chemical transformation and energy transfer. Phosphorus was also found to be essential for the present organisms as there was poor growth on a basal medium (Richards) devoid of phosphorus source. It was also true for many fungi (Agarwal, 1953b, Srivastava 1950 and Tandon and Bhargava, 1950).
The reaction of the basal medium containing ammonium di-hydrogen phosphate was changed towards acidity by all the species except *H. rostratum* and *H. maydis* which showed a drift towards alkalinity. All the species in other treatments changed the reaction towards alkaline side.

Potassium di-hydrogen phosphate showed excellent sporulation of *H. hesperia*, *H. rostratum* and *H. betramera*. Magnesium phosphate supported fair sporulation for four species and excellent for *H. betramera* but nil sporulation was found by *H. bicolor*. The above findings are similar to the results of Singh (1974) for *G. lunata*. It was also found that all the six species except *H. betramera* did not produce spores in control devoid of phosphorus sources.

Despite the efforts of a large number of workers, no generalised and legitimate conclusions have yet been drawn regarding the nutritional response of fungi. In the past it had been reported that species or even strains exhibited extreme variations so far as their physiological behaviour is concerned (Panwar, 1972). Such observations have been confirmed when comparative studies on six species of *Helminthosporium* were undertaken.

Sorghum in Uttar Pradesh is usually grown as a kharif crop and rarely as a (summer) crop but not as a robi crop. Thus there is no continuity of the crop in the fields. In spite of this diseases appear in the new crop every year. Therefore, the only source of inoculum appears
to be the plant debris left in the fields. In order to find out the survival of the six species of Helminthosporium under laboratory conditions isolations were made from dried infected leaves of each type preserved separately in two folds of blotting paper up to 12 months. It was observed that all the species remained viable on infected leaves in the laboratory for one year. It was also noted that the plants grown on sterilized soil heavily infested with plant debris showed infection on lower leaves. Therefore, it was assumed that the plant debris lying in the field helps in the built up of the inoculum and spores so produced cause the infection on leaves which come in contact with the soil. It had been invariably observed in the field that the lower leaves were the first to get infected. The results of the present studies show that the primary infection of all the six pathogens occurred on leaves through plant debris buried in the soil.

In China, conidia of H. maydis remained viable for 8 months on maize leaves and for over a year on seeds kept in laboratory (Yu, 1933). Puranik and Suryanarayana (1966) reported that infected debris from previous crop was able to cause new infections in case of Gloeosporium sorghi. Gruet (1962) also found the infected plant debris as the source of infection of leaf spot disease of gladiolus caused by Curvularia trifolii f. sp. gladiolus. Marquez (1924) found that maize plants grown in soil infected with H. jurjcius took infection and the fungus survived in soil for several years.
Survival of *Curvularia lunata* in soil for 3 years or more was also recorded by Magie (1953). Tarr (1962) reported that *G. sorchi* persisted between crop seasons on infected crop residues in the soil. Rangaswami & Ethiraj (1963) recorded *H. turcicum* causing leaf blight of sorghum survived for a much shorter period in the host tissue in unsterile soil than when added to sterile soil in the host tissue or as spore suspension to sterile and unsterile soils. Chand and Suryanarayana (1967) while working with *H. australiense* reported that the pathogen could survive for six months and up to ten months on unsterilized and sterilized soil with infected debris, respectively. These observations tally with the present investigations.

The present investigations revealed that *H. bicolor* and *H. hawaiicense* were recovered from seeds but the other four species were not obtained. Thus it shows that *H. bicolor* and *H. hawaiicense* are internment seed borne while other species are not so which supports the findings of Bain and Edgarson (1943) and Bain (1950) for *Gloeocercospora sorchi* in glumes and seeds of sorghum. Tarr (1962) and Paramik and Suryanarayana (1966) while working with *Aecchyta sorchi* and *Gloeocercospora sorchi*, respectively reported that it was not isolated from seeds taken from diseased sorghum plants and did not produce diseased seedlings.
Secondary infection of all the six pathogens took place through the conidia produced as spots on freshly infected leaves. These get transmitted through the agency of air from the lower leaves to upper leaves and from one place to another.

Martin (1959) reported that high winds during flowering period increased the amount of infection by Curvularia lunata. Ascocysta morphi and Gloeosporium morphi spread by air and rain as reported by Singh et al. (1957) and Tarr (1962), respectively. These findings are closely similar to the results of the present investigations.

In host range studies fifteen graminaceous hosts were artificially inoculated with all the six pathogens separately. H. bauhniense infected eleven hosts, but could not infect Buchlaena mexicana, Pannicus niliacens, Paspalum sarchiculum and Setaria italica. H. rostratum produced the symptoms on ten hosts, but no infection in five hosts viz. Cynodon dactylon, Schinorhachis colomus, Buchlaena mexicana, Oryza sativa and Pannicus niliacens. H. buuscens produced infection on Buchlaena mexicana, Paspalum sarchiculum, Pannigaster typhoides, Sorghum halepense and Sorghum vulgare. Eight out of all the graminaceous hosts were found to be susceptible to H. bischofi. In case of H. tetraconus the lesions developed on the leaves of ten different hosts while there was no infection on Pectylecanium aestivale, Oryza sativa, Pannicus frumentaceus, Paspalum sarchiculum and Setaria
Italics. *H. maydis* did not infect *Peronosclerotium nephobium*, *Echinochloa colona*, *Musine indica*, *Musine soraceae* and *Panicum milloaceum* but it could do so on the remaining ten hosts.

Different graminaceous hosts susceptible to *H. maydis* were reported by Lefebvre and Johnson (1944), Young et al. (1947), Farris (1950), Sprague (1950), Kenneth (1956), Whitehead and Calvert (1959), Pal and Suryanarayana (1964), Bhosik (1965) and Misra and Mishra (1971b). *H. maydis* was found on various hosts as reported by Shaw (1924), Mitra (1923), Deighton (1935), Christoff and Christon (1935), Hughes (1932), Budge et al. (1935), Saccas (1954), Robert (1962) and Bhosik and Prasad (1970). The susceptibility to *H. maydis* was recorded on different graminaceous hosts by Nishikado & Miyake (1925), Nattrass (1937), Grillo (1940), Cuttell et al. (1954) and Singh and Singh (1956). These findings are similar to the results of the present species of *Helminthosporium*. These results indicate that all the species could attack a wide range of host.

Sixty five germ plases including Indian sorghum cultures, hybrid and local varieties growing in pots were screened for their reactions to all the six pathogens separately under laboratory conditions. All the germ plases were infected with one or more of the pathogens but there were differences in reaction. Out of them, cultures Vidalia 60-1, and Kafir A were immune to all the six species of *Helminthosporium* in this study, whereas varieties OSI-2, BP 53, M55-1, T2, T4 and Gwalior
12-2 were resistant. *H. hamalience* was much more pathogenic among all the six species, followed by *H. rostratum*, *H. marcius* and *H. tetramera* while *H. bicolor* and *H. hurcianus* were less pathogenic. Intensity of disease varied from culture to culture against all the pathogens under study.

Miara and Mishra (1974) reported that *H. rostratum* was susceptible to all the seventeen varieties of *Sorghum vulgare* except G.2, N-1, N-8, N-9, N-10 and N-11 which were less susceptible to the isolates of pathogen. Sundaram et al. (1966) reported that a total of 3748 world collection of sorghum were classified for reaction to *H. hurcianus*, as 1039 resistant, 1032 susceptible and 1678 intermediate. Miara and Mishra (1974) inoculated separately 39 varieties of *Sorghum vulgare* with four isolates of *H. hurcianus* and found that varieties G1, G2, PV9, SV34, T3, SV-245, A10, A423, GS2-1, I.S. No. 9379, NE 300, N6 and N11 were moderately resistant to all the isolates, whereas variety N2 was susceptible. These findings are quite in agreement with the results obtained during the present studies.

Ten fungicides representing various groups were tested in the laboratory for their toxicity to all the six species of *Helminthosporium*. It was obtained that Agroasan GH (0.2%), Captan (0.2%), Duster (0.1%) and Cepral (0.2%) completely inhibited the growth and germination of all the six species whereas Blue copper (0.2%) and Benlate (0.2%) were effective in inhibiting the growth of all the species except *H. rostratum*.
and *H. betranera*. There was also no germination of spores of *H. hawaiense*, *H. boricum* and *H. bicolor* in blue copper. The least percentage of spore germination as well as growth of all the species was found on Ziram, followed by Zineb Ciba and Dithane Z-78.

While evaluating the fungicides in laboratory, Kapoor and Tandon (1968) reported that Blitox, Copper Sandoz, Micop E-30, Supravit, Dithane Z-78, Capesan, Zenlate and Kirti copper could not check the growth of *H. rostratus* which supports the present findings.

Bagchi and Das (1968) reported that Captan 83% completely inhibited the growth of *Curvularia lunata*. Captan, Breston-60 and Du-ter have also been reported to be inhibitory to *H. nobilissimum* (Hodge and Shivana Dappa, 1968). These findings tally with the present results of all the six species of *Helminthosporium*.

Keil (1945) and Howard and Keil (1947) worked on the control of copper spot of bent grass (*Agrostis* sp.) caused by *S. sorshi* and found that Ziram at 1.5 lb/100 gallons gave good control for more than 40 days. Stoner (1950) and Schi et al. (1966) reported that Zineb @ 2 lb/100 gallons of water as eleven applications at 3-day intervals gave the best control for *H. boricum* and Zineb and Captan were more efficient in reducing the disease intensity, respectively. Mishra et al.
(1959) suggested that seed treatment with Agrosan GH and 
Gerosan dry at the rate of 2.5 g per kg of seed gave the 
control of the app. of Helminthosporium. The present investi-
gation indicated that effective fungicides viz. Du-ter (0.1%), 
Coprantal (0.2%) and Ziram (0.2%) were effective in reducing 
the disease intensity of all the species. Du-ter (48 hours) 
proved to be the best fungicides among all the fungicides tried. 
48 hours after inoculation proved to be the best period for 
spraying the fungicides as it helped in controlling the diseases. 
Ziram and Coprantal (7 days) gave poor control of leaf spot 
diseases of sorghum.

The present investigations clearly show that effective fungicides were able to control the disease only if they 
were applied within 48 hours of the association of the patho-
gens with the host. As it will be very difficult to know the 
exact time when the pathogen will reach the host, therefore, 
repeated applications of fungicides before any sign of infec-
tion in the crop will be needed for effective control.