VERTICAL MOVEMENT OF THE SPORES OF *METARHIZIUM* *ANISOPLIAE* (METSCH.) SOROKIN THROUGH SAND AND SOIL

by
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ABSTRACT

The purpose of this research was to determine whether spores of the green muscardine fungus, Metarhizium anisopliae (Metsch.) Sorokin would migrate through sand and soil by the action of water and a wetting agent under laboratory and field conditions. M. anisopliae is an entomogenous pathogen occurring naturally in soils and is widely used in experimental microbial control attempts. Knowledge of the migration of the spores of M. anisopliae could establish the fungus as an effective agent in controlling hard-to-reach soil inhabiting insect pests and encourage its use in the field as a biological control agent.

Laboratory trials consisted of placing a spore suspension of M. anisopliae on the surface of three types of sterile soils, i.e. coarse sand, sand-loam mixture, and soil of the Plainfield series which had been placed in plexiglas columns. This topical application was followed by 150ml of sterile distilled water. Samples of the soils were taken at 5cm intervals to a depth of 35cm. Spores were found to have traveled to an average depth of 30cm in the sand and Plainfield soil and 20cm in the sand-loam mixture. Unsterile Plainfield soil was placed in a stainless steel column and treated in the same manner as the sterile soils. In this soil, the spores migrated to a depth of 20cm.

The surface of eight one-quarter square meter field plots were sprayed with a spore suspension of *M. anisopliae*. At the end of two months, the fungus was found at a depth of 18cm. *M. anisopliae* had migrated to a depth of 30cm after four months. There was no evidence that *M. anisopliae* occurred naturally in the soils of the test area.

A bioassay was devised to determine virulence of the spores after traveling through the soils. The larvae of the greater wax moth (*Galleria mellonella*) were inoculated with spores of *M. anisopliae* which were obtained from the cultures of the laboratory and field trials. All the larvae died of green muscardine disease.

Based on an evaluation of past research and this investigation, it is believed that *M. anisopliae* has a high potential as a microbial control agent against soil-inhabiting insects especially in conjunction with a pest management system such as an integrated control program.

ACKNOWLEDGMENTS

I wish to thank Dr. Hans G. Schabel, my major professor and the members of my graduate committee, Dr. Robert Miller and Dr. Marvin Temp for having faith in me the last seven years. I also wish to thank my family for their understanding and patience when I ignored them with the excuse of study or work.

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INTRODUCTION

The use of entomogenous pathogens, i.e. various fungi, bacteria, viruses, etc. as a means of microbial control of noxious insects, is gaining appeal as more chemical pesticides are being removed from the market due to their harmful effects against non-target organisms and their general pollution of the biosphere.

Entomogenous fungi have long played a significant role in the history of insect pathology and are important in the dynamics and natural regulation of insect populations (Steinhaus 1956). Despite their potential, there are very few economically successful programs which utilize fungal pathogens in general pest control procedures. Many of the problems lie in the lack of specific documentation such as dosage requirements, timing of applications, host insect life cycle, and the introduction and survival of fungal pathogens under field conditions.

Metarhizium anisopliae (Metsch.) Sorokin, the causal agent of green muscardine disease, is presently the second most widely used entomogenous fungus in experimental microbial control attempts and is continuously being appraised for its role in reducing pest populations. The fungus has been researched thoroughly under laboratory conditions but knowledge of the fate of the spores after topical application in the field is lacking. There is little information on the dispersal of the spores of *M. anisopliae* in soil especially through the action of water. The present study was conducted to investigate this possibility that spores of M. anisopliae could migrate through sand or soil utilizing water as the transport medium. This could encourage its use in the field as a microbial control agent either by itself or in conjunction with an integrated pest management system.

M. anisopliae occurs naturally in the soil and attacks insects living in this environment. The fungus is particularly effective against the insect order Coleoptera (Urs and Govindu 1971). This order includes the white grub, Phyllophaga spp., which are serious pests in forest tree nurseries and plantations. These insects inhabit the soils of Central Wisconsin and are known to feed on the roots of red pine (Pinus resinosa) seedlings (Shenefelt and Simkover 1950). Red pine is extensively planted in soils which the grubs prefer and the insects have caused severe losses in forest tree nurseries in Central Wisconsin. In one instance, 60% of a new plantation of red pine were killed by white grubs in one year (Pers. Obs.).

Treatment with the soil insecticide Chlordane ® before planting the seedlings has proven successful (Speers and Schmiege 1971); however, the production of Chlordane ® has been suspended and no other method of reducing the grub population has since been developed. Since M. anisopliae is an effective agent against white grubs, biological con-

control of this pest utilizing the fungus as a microbial insecticide was considered to be an alternative that would be more ecologically acceptable than chemical control.

If *M. anisopliae* was found to migrate through the soil profile with the action of water and then reach areas which white grubs inhabit, the fungus could in essence become an effective means of controlling this pest in forest nurseries and plantations.

LITERATURE REVIEW

History

M. anisopliae was first recorded as an insect pathogen in Russia in 1879 by Metschnikoff on the wheat cockchafer, *Anisoplia austriaca*, Herbst. The fungus belongs to the form-class Deuteromycetes, form-order Moniliales with a taxonomic position near *Penicillium*. The genus has been included in the Xerosporae because the spores of the fungus are dry and powdery (Wakefield and Bisby 1941). Names first ascribed to the fungus included *Entomophthora anisopliae*, Metsch.; *Oospora destructor*, Delacroix; and *Penicillium anisopliae*, Vuillemin (Rockwood 1950). In 1883, Sorokin described the fungus further and elected the genus *Metarhizium*, thus the final combination became *Metarhizium anisopliae* (Metsch.) Sorokin (Latch 1965).

The first attempts at using *M. anisopliae* as a biological control agent was by Krassilstschik in 1884 who mass-produced the fungus on beer mash. The fungus was then applied to small areas and it was reported to have killed 50-80% of the sugar beet curculio, *Cleonus punctiventris* Germ. (Latch 1965). Subsequently, *M. anisopliae* has been widely tested as a control agent in reducing various pest populations.

The cosmopolitan *M. anisopliae* is known to be highly pathogenic to over 200 species of insects representing seven different orders with Coleoptera (Scarabaeidae and

Curculionidae) being the most common host order (Yendol and Roberts 1970). The fungus is capable of attacking insects at any stage of development; however, the larval stage is generally the most susceptible.

Description

M. anisopliae is comprised of two forms; a short-spored form (forma minor) with conidia 5-8µ long; and a long-spored form (forma major) with conidia 9-14µ long (Latch 1965). It is thought that conidial length varies with the culture media suggesting that the difference between the forms are physiological (Tullock 1976).

The conidia are one-celled, cylindrical to oval in shape, and usually truncate at both ends. Their color varies from light to dark olive green. The conidiophores are simple or branched and are closely compacted and individual chains of conidia are only distinguishable in the early stages of formation (Latch 1965).

Culture

M. anisopliae may easily be cultured on a wide variety of natural and synthetic media. Barnes et al. (1975) determined growth and sporulation of M. anisopliae on media containing various peptone sources. Latch (1965) described the appearance of fungal colonies grown on potato-dextrose agar (PDA) and media other than PDA. Roberts (1966) examined four media to determine the best source of spores for the production of toxic substances. Submerse and surface cultivation for large scale field use was described by Adamék (1965) and Latch (1975).

A selective medium which acts against bacterial growth and minimizes the development of other fungi was formulated by Veen and Ferron (1966). This medium has been successful in the isolation of *M. anisopliae* from soil. Another selective medium which has been designated as CCE agar has recently been tested for estimating populations of *Metarhizium* in soil without interference from competing fungi (Pereira *et al*. 1979).

Germination

Relative humidities higher than 90% were found to be necessary for the germination of spores of *M. anisopliae* with the best germination occurring at humidities of 100% and no germination occurring at relative humidities below 90% (Walstad *et al*. 1970).

Optimum temperatures for spore germination generally are considered to be from 25°-30°C. with the temperature range for normal growth being 10°-30°C. (Walstad *et al*. 1970). *M. anisopliae* is relatively thermophilic with spores unable to germinate at temperatures below 10°C. The thermal death point is 49°C. (Schaerffenberg 1964).

The influence of the hydrogen ion concentration shows that mycelial growth curves are fairly level in a range of pH 4.7-10 with the optimum pH being 6.9-7.4 (Vouk and Klas 1931).

Light appears to be detrimental to mycelial growth and the viability of the spores of M. anisopliae (Roberts 1977).

Spores of M. anisopliae generally do not germinate on unsterile soil, duff, or leaf litter but remain viable there for days or weeks (Walstad et al. 1970). The spores will often germinate readily upon contact with the unsterile body wall of an acceptable host. Under optimum conditions, germination commences after 15 hours with the appearance of germ tubes (Latch 1965).

Viability

The length of a spore's life is measured by its ability to germinate after a period of time. The survival of the spores of M. anisopliae over an extended period of time is affected by storage temperature. Spore viability dropped to virtually zero in less than four months when the spores were stored above 21°C., while spores held below 8°C. had an 80% survival rate after 12 months (Walstad et al. 1970). There was no germination or mycelial growth of spores after being stored for 11 months at room temperatures of 15°-24°C., whereas those spores stored at 4° and -15°C. germinated and had vigorous mycelial growth (Latch 1976). Subzero temperatures are suitable for long term storage and spore suspensions held at -20°C. can remain viable for up to four years (Roberts and Campbell 1977).

Spore viability is also affected by relative humidities and spores survive longer at high or low than at median humidities (Walstad et al. 1970). Maximum germination was retained when spores were stored at 8°C. and 75% relative humidity (Yendol and Hamlen 1973). Viability is also affected by light and spores survive longer in darkness than in light (Roberts and Campbell 1977).

Bell and Hamalle (1970) stated that conidia could survive and still be effective after 40 days in dry sand or soil. Infection of host insects dropped only 30-50% after two years in greenhouse experiments with M. anisopliae (Müller-Kögler 1976). Bell (1975) found that M. anisopliae was viable for six months when stored outside in a silica gel bag and concluded that if spore material is kept dry, it could survive temperature fluctuations and remain viable and pathogenic for at least one year.

Virulence

A high degree of virulence is important if the fungus is to be successful as a biological control agent. M. anisopliae is a facultative parasite and may be cultivated and raised for several generations on a variety of artificial media. If the parasitic phase of the life cycle is omitted there is some loss of virulence. Fox and Jaques (1958) found continued subculturing caused a decline in virulence which was indicated by failure of the inoculum to cause disease. Rockwood (1950), on the other hand, stated that virulence may be maintained in artificial substrates on approximately the same level through a number of generations and up to seven years. Latch (1965) reported that isolates grown on artificial media showed no change in virulence after six months but that after 11 months, virulence had dropped by 24%. At this time, it is not known how many generations *M. anisopliae* can be cultivated on artificial substrates without loss of virulence. Therefore artificial subcultures of *M. anisopliae* are routinely interrupted by passage through host insects to insure virulence.

Mode of Infection

M. anisopliae initiates infection orally or percutaneously by germinating spores which produce germ tubes that typically grow over the surface of the host insect (Schabel 1976 The germ tube produces clavate, terminal dilations called appressoria at varying intervals which have been confirmed as origins for the penetrating hyphae (Schabel 1978). The invasive hyphae enter the host tissues and ramify throughout the hemocoel. Schabel(1978) also found that on adult pales weevils (*Hylobius pales*) hyphae grew extensively within the procuticle with a distinct preference for the interlamellar spaces. After filling the host with mycelium, emergence hyphae, will under proper conditions, grow through the integument to eventually produce spores on the external surface of the host. In the early stages of infection, the insect shows general ill effects, cessation of feeding, weakness, and disorientation. Soft-bodied hosts tend to change color and the cuticle often shows dark melanotic spots.

Toxins

Two insecticidal substances have been isolated from filtrates of M. anisopliae. These toxins include the so-called destruxins A and B which are cyclic peptides. M. anisopliae is among those fungi which kill before extensive invasion of the organs takes place and it is thought that the production of toxic substances by the fungus is responsible. These toxins appear to be liberated into the host by intact hyphae and hyphal bodies. It has been suggested that M. anisopliae would prove to be more promising as a pathogen than as a source of toxins (Roberts 1965).

Soil Aspects

There is little information as to the persistence and mobility of M. anisopliae after it has been applied in the field. Latch and Falloon (1976) found little spread of the fungus from inoculated areas to adjacent areas and what migration occurred was probably from the infected host insects. Although the inoculum was only mixed into the top 10cm of soil, M. anisopliae spores were found to be present in material taken 20-30cm from the soil surface. The spores were presumed to have been washed down the soil profile by rain or through the activities of small organisms such as ants or millipedes. Burges (1950) and Hepple (1960) reported that fungi producing dry spores such as M. ani-

sopliae, have little likelihood of being washed to lower levels in soil.

Toxicity to Vertebrates

There are no current reports of allergic reactions or infections to vertebrates by *M. anisopliae*. Latch (1976) reported that animals which had been fed spores of *M. anisopliae* in their diet, showed no abnormal symptoms in their behavior and upon conclusion of the trial when the test animals were sacrificed and autopsied, no tissue or organic abnormalities were observed. Wasti *et al*. (1980) assessed the toxicity of *M. anisopliae* to birds and concluded that the fungus did not cause any mortality or abnormal behavior although he observed a small decline in body weight. Dosages were considerably higher than amounts normally used in programs in field trials and when extrapolated to man, were found to be greater than any possible exposure or contamination. *M. anisopliae* is considered neither toxic nor pathogenic to man or other warmblooded animals. However, as with any insecticide, microbial or chemical, proper precautions such as the use of protective clothing and face masks should be taken whenever the spores are handled.

MATERIALS AND METHODS

Fungus

A strain of _M_. _anisopliae_ was isolated from a pales weevil obtained in Orange County, North Carolina, which had died of green muscardine disease. A culture was grown on dextrose-peptone-yeast agar (DPY), prepared according to the specifications of Schaerffenberg (1964) (App.2). Live white grubs approximately three centimeters in length were obtained in late April from a newly plowed field in Wood County, Wisconsin. These grubs were inoculated by brushing spores of the North Carolina isolate onto the integument of the larvae. The grubs subsequently died of green muscardine disease and formed the characteristic external fungal tufts of growth associated with _M_. _anisopliae_. Hyphal tip transfers were made from the grubs to the DPY agar and the resultant sporulating cultures (Fig. 1) were verified to be _M_. _anisopliae_. Subcultures were placed in slant tubes and used within a ten month period.

Columns

Plexiglas Columns

Three plexiglas columns consisting of a back plate, two side plates, and a base plate all cemented together with epoxy glue were designed. Three one-quarter inch holes were drilled into the base plate to provide drainage. The front plate was constructed in such a manner that it would fit into the sides and base plates and yet be easily

Fig. 1. Typical growth and culture of Metarhizium anisopliae. This sample was obtained from field plot number 6 and placed on a selective medium then transferred to dextrose-peptone-yeast agar.

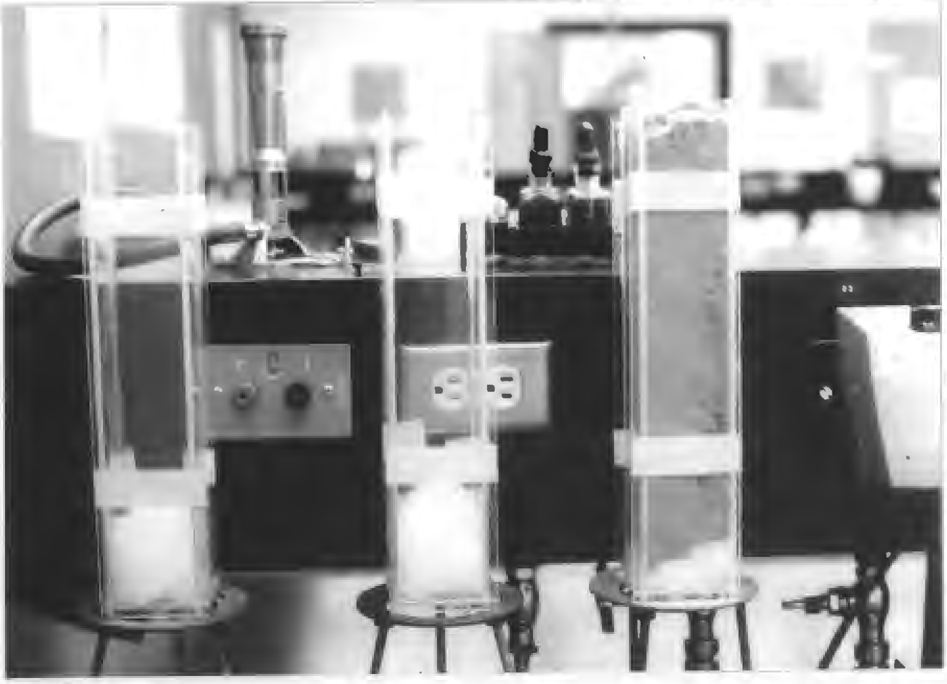

Fig. 2. The three columns constructed of plexiglas. The right column is filled with sand and each column has a bottom filter plug of fiberglas. The columns are held together with glue and masking tape.

removed. An entire column measured 6x6x35cm and was firmly held together with masking tape (Fig. 2). The columns were rinsed in 95% ethyl alcohol for sterilization. A plug of fiberglas soaked in the alcohol was fitted into the base of the column. Other sterilization procedures were not found to be necessary as the number of contaminating colonies on the culture plates was minimal and they were easily recognized and discarded. The soil sample used for each trial was first sterilized in an autoclave for 15 minutes and then placed in the column. No special precautions were taken to keep the columns of sand or soil aseptic.

Stainless steel column

The stainless steel column was constructed by bending a single piece of stainless steel to form the back and side panels. A base plate was welded to this three sided column and three one-quarter inch holes were drilled into the base plate to provide drainage. A front plate fitted snugly over the sides and base plates and the whole column was held firmly together with three rigid stainless steel bands and wing nuts (Fig. 3). The column measured 7x7x35cm and could be sterilized together with the soil in an autoclave. The construction of a steel column was necessary in order to obtain intact soil profiles from soil pits.

Soil

Three different types of soil were used: coarse sand, a sand-loam mixture, and soil classified in the Plainfield series. The latter consists of "deep extensively drained

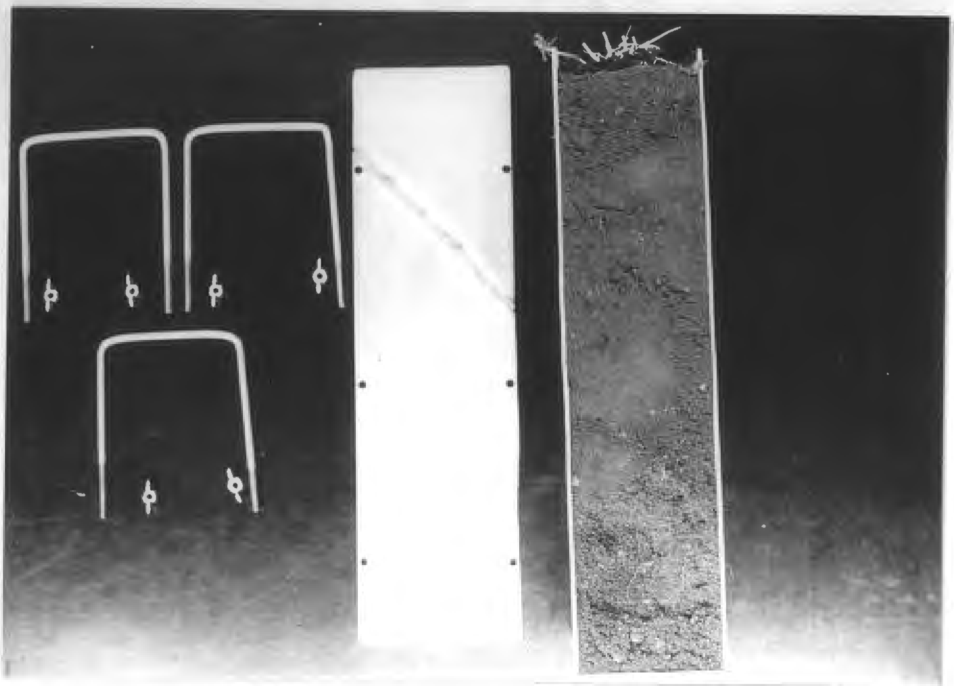

Fig. 3. Front view of the three sided column constructed of stainless steel and filled with a soil sample. To the left of the column, is the detachable front panel and its mounting hardware.

sandy soil on outwash plains" (USDA Soil Consv. Serv. 1977). These soil types are characteristic of soils found in Central Wisconsin the area of this research.

<u>Sand</u>

Sand was obtained from the substratum of a Plainfield type soil at a depth of five feet and consisted of a yellowish brown, single-grained, loose sand containing less than 95% quartz with an acidity of pH 5.9.

<u>Sand-loam mixture</u>

The sandy loam was obtained from the plow layer (soil ordinarily moved in tillage, about 5-8 inches in thickness) of a Plainfield type soil. The sand-loam mixture consisted of 50% coarse sand and 50% sandy loam. Both the sand and sand-loam mixture were sifted through a number 35 soil sieve to remove lumps and debris before sterilization and placement in the plexiglas columns.

Plainfield soil

The Plainfield soil was a typical Plainfield type soil having a profile which included an Ap, A1, B2, and C1 to C3 horizons. A soil pit was dug and a column of soil as undisturbed as possible to a depth of 35cm was obtained by pressing the stainless steel column against the profile thus forcing the soil into the column. This soil was sterilized intact in the steel column. Control trials were conducted in which the column of soil was not sterilized in order to determine if there were any antibiotic or fungistatic effects occurring.

Three replicates of each of the above soils were taken.

Administration of the Inoculum

After the columns had been filled with the corresponding type of soil, sufficient amounts of sterile distilled water (SDW) were allowed to flow through the columns to pack the soil and bring the soil to field capacity. This helped to prevent channels through which the spores might readily wash.

Spores of *M. anisopliae* were suspended in a .4% solution of the wetting agent polyoxyethylene sorbitan monolaurate (Tween 20 ®). A hemocytometer was used to calculate the spore suspension which contained an average of

$5\text{x}10^7$ spores per ml. A standard volume (2ml) of spore suspension was pipetted carefully over the surface of the soil after the column had drained of excess water. This was immediately followed by 150ml of SDW pipetted in 10ml increments. Both the spore suspension and the additional water were slowly poured on the surface of the soil to prevent disturbance of the upper layers of the soil. No standing water was allowed to accumulate on the surface of the soils.

Culturing Techniques

Samples of the drainage water were taken after the addition of 100ml of SDW and again after another additional 50ml of SDW. These samples were cultured to determine whether any spores had migrated completely through the column. When the column had stopped draining, it was placed in a horizontal position and the face plate carefully removed. The outer 1cm of soil was discarded to avoid those spores which might have traveled more rapidly down the smooth surface of the columns. A sterile probe was used to remove .005-.015 grams of soil from the center of the column. Three samples were removed at 5cm intervals throughout the length of the column and placed in sterile Petri dishes (Warcup 1950). The nutrient agar medium (DPY) was carefully poured over the samples and the plates were incubated at 25° C. for three days. An initial count was made of any colonies found to be present on the medium after the incubation period. Three replicates were made for each of the sterile soil types.

Samples of the non-sterile soil were taken at 5cm intervals and placed in sterile Petri plates. A selective medium for the isolation of *M. anisopliae* from soil prepared according to the specifications of Veen and Ferron (1966) was carefully poured over the sample. This medium eliminated many contaminants and slowed the growth of competitors thus allowing colonies of *M. anisopliae* to grow. Colonies of *M. anisopliae* were transferred through hyphal tips to the nutrient agar medium in order to confirm the actual presence of the fungus. The sporulating colonies were also examined microscopically for final verification that the fungus was *M. anisopliae*.

Field Procedure

Eight one-quarter square meter plots were prepared for the field trial. Four of these plots were scalped to the mineral soil (Fig. 4.) while the sod was left undisturbed on the other four plots (Fig. 5.). A plant water mister was used to spray each plot with 140ml of spore suspension containing an average of $6x10^7$ spores of *M. anisopliae* per ml. This topical application was immediatley followed by three liters of distilled water.

The eight plots remained exposed to the full radiation of the sun. Complete weather data were provided by the National Weather Service in Madison, Wisconsin situated ap-

Fig. 4. One of four plots one-quarter square meter in size and scalped to mineral soil.

Fig. 5. One of four plots one-quarter square meter in size and left undisturbed.

proximately 100 miles south of the test site (App. 1). The plots were located in a field which had been planted to red pine the preceding spring (Fig.6). The soil was of the Plainfield series and was from the same area from which the soil samples had been taken for the laboratory investigation.

Fig. 6. Location of the plots used in the field trials. The area had been planted to red pine (Pinus resinosa) the preceding spring. Flags indicate plots.

Two samples each were taken of each plot at two and four month intervals after the initial application of the spore suspension. The sample obtained two months after application of the spores was taken at 2cm intervals to a depth of 20cm. The second sampling four months after the initial application was taken at 5cm intervals to a depth of 30cm. A section of soil from the plots was removed to provide vertical access to a depth of 35cm. Two soil samples (.005-.015 g.) were removed with a sterile probe at each respective interval and placed on sterile Petri dishes. The selective medium formulated by Veen and Ferron (1966) was carefully poured over the soil samples and the samples were incubated at 25° C. until sporulation occurred. At this time, colonies which were thought to be *M. anisopliae* were transferred to the DPY agar and incubated to establish the identity of the fungus. Microscopic examination of the spores was also made to confirm this identity.

A control sampling was taken in the same area as the field trial to determine if *M. anisopliae* was occurring naturally in the soil. This sample was taken approximately 50 feet from the original plots to minimize any possible drift of spores from the prepared plots. A soil pit was dug and two samples each were obtained at 5cm intervals to a depth of 30cm. These samples were handled in the same manner as the samplings taken from the prepared plots.

Bioassay

A bioassay was devised to determine if the spores of *M. anisopliae* would lose their virulence while migrating through soil. Larvae of the greater wax moth were obtained from a live bait store for this portion of the research. Ten larvae were inoculated for each three samples and soil types. The spores were obtained from the cultures which had successfully produced colonies of *M. anisopliae* from the different soils and depths. A camel's hair brush was used to brush the spores onto the integument of the larvae. The brush was dipped into 95% ethyl alcohol to sterilize it between each application of spores onto a larva. Each group of larvae were placed on moistened filter paper fitted into a sterile Petri dish (Fig. 7). The larvae were then stored at room temperature and checked every 24 hours for signs of mycosis.

Fig. 7. Group of ten larvae of the greater wax moth (Galleria mellonella) inoculated with spores of M. anisopliae and placed on moistened filter paper in a sterile Petri plate.

A bioassay was also made of the positive cultures taken of the samples from the field plots, to determine if any inhibitory effects due to fungistasis would affect spore virulence.

A control group of ten larvae each were placed in ten sterile Petri dishes. These larvae were handled and kept in the same manner as the larvae which were inoculated with the spores of *M. anisopliae*.

RESULTS

Laboratory

Spores of M. anisopliae migrated downward through the columns of all three types of soils. Fig. 8 shows the variability of migration of spores in the three types of soil, i.e. coarse sand, sand-loam mixture, and Plainfield soil.

Composite soil type data

The rate of migration observed in the columns of sterile sand indicated a high retention of spores on the sand surface followed by a sharp decrease at the 5cm level. At 10cm the number of colonies had again increased to a level almost that found on the surface. The number of colonies then declined as the depth increased. No spores traveled completely through any of the columns of sterile sand.

The sterile sand-loam mixture as indicated in Fig.8 had a gradual decrease in the number of spores to the 5cm depth where an average of145 colonies per sample were plated out. By 10cm level, the number of spores had decreased sharply to less than 20 colonies per sample. Few spores traveled past the 20cm depth and no spores migrated completely through the columns of the sterile sand-loam mixture.

The sterile Plainfield soil (Fig. 8) showed a higher variability in its curve than the other two soil types.

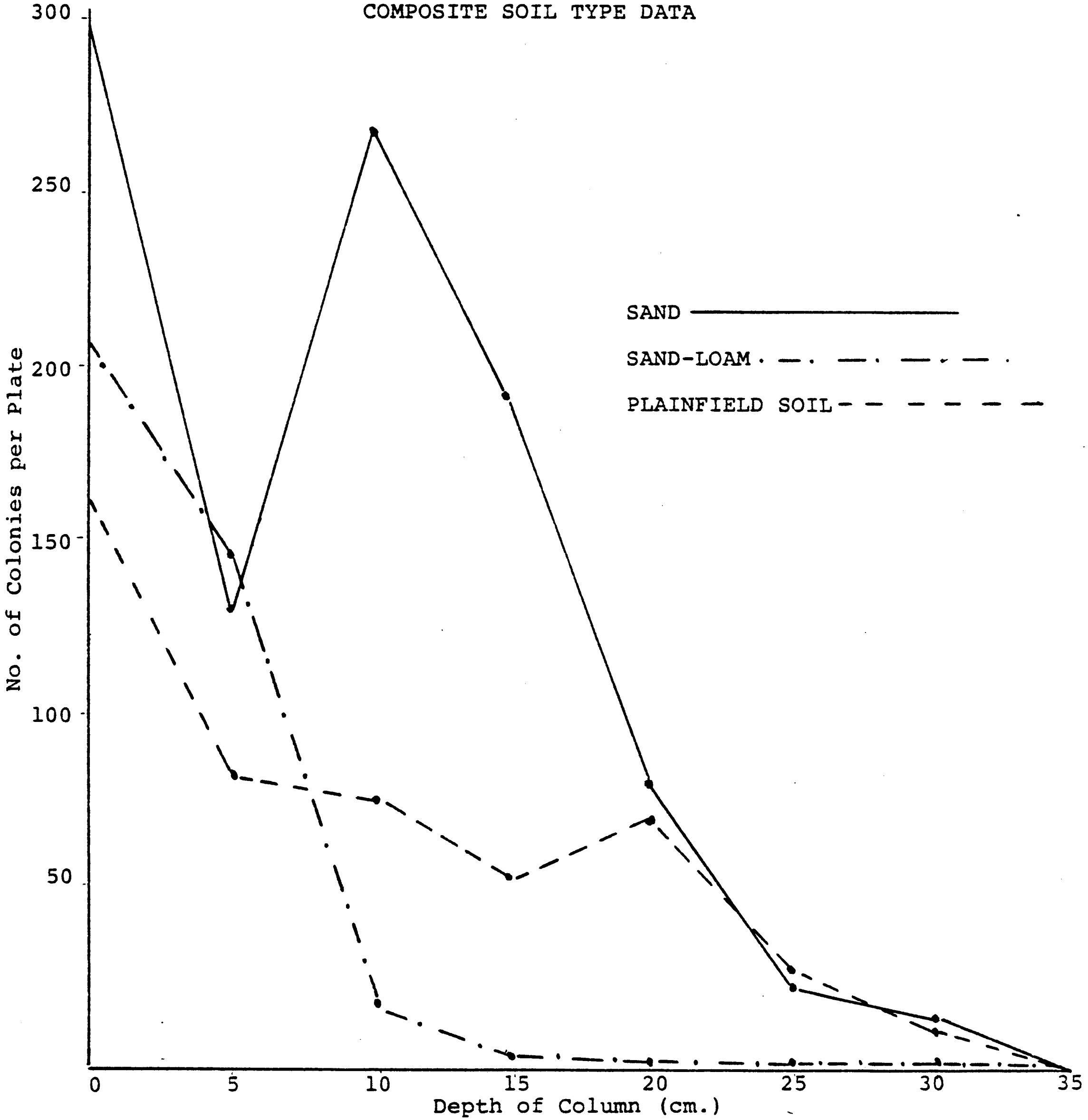

Fig. 8 Distribution of spores of Metarhizium anisopliae versus depth in columns of sterile sand, sand-loam mixture, and Plainfield soil after topical application of 2ml of spore suspension and 150ml of sterile distilled water. Each plotted value represents an average of nine replicates.

There was a drop in the number of spores at the 5cm depth similiar to the curve represented by the sterile sand. After 5cm the concentration of spores was relatively constant down to 20cm indicating spore migration through this depth. From the 20cm depth, the number of colonies decreased and approached zero by 35cm. No spores traveled completely through the columns of sterile Plainfield soil.

Sterile sand

Fig. 9 shows the migration of the spores of *M. anisopliae* versus column depth for the three columns of sterile sand. All three columns show a decrease in the number of colonies to 5cm followed by a sharp increase at 10cm. In columns A and C the number of spores declined after 10cm as depth increased approaching zero by 25cm. Column B however, maintained a constant concentration of colonies from 10cm through 15cm before declining and approaching zero at 35cm. Fig. 9 indicates the variability of the migration of spores between the three columns while Fig. 10,11,and 12 show the variability within Columns A, B, and C. Each set of graphs demonstrates the repeatability of the trials with the sterile sand and indicates the same general migration trend.

Sterile sand-loam mixture

Fig. 13 represents the concentration of colonies versus depth in the three columns of sterile sand-loam mixture. This graph shows the variability of migration of spores

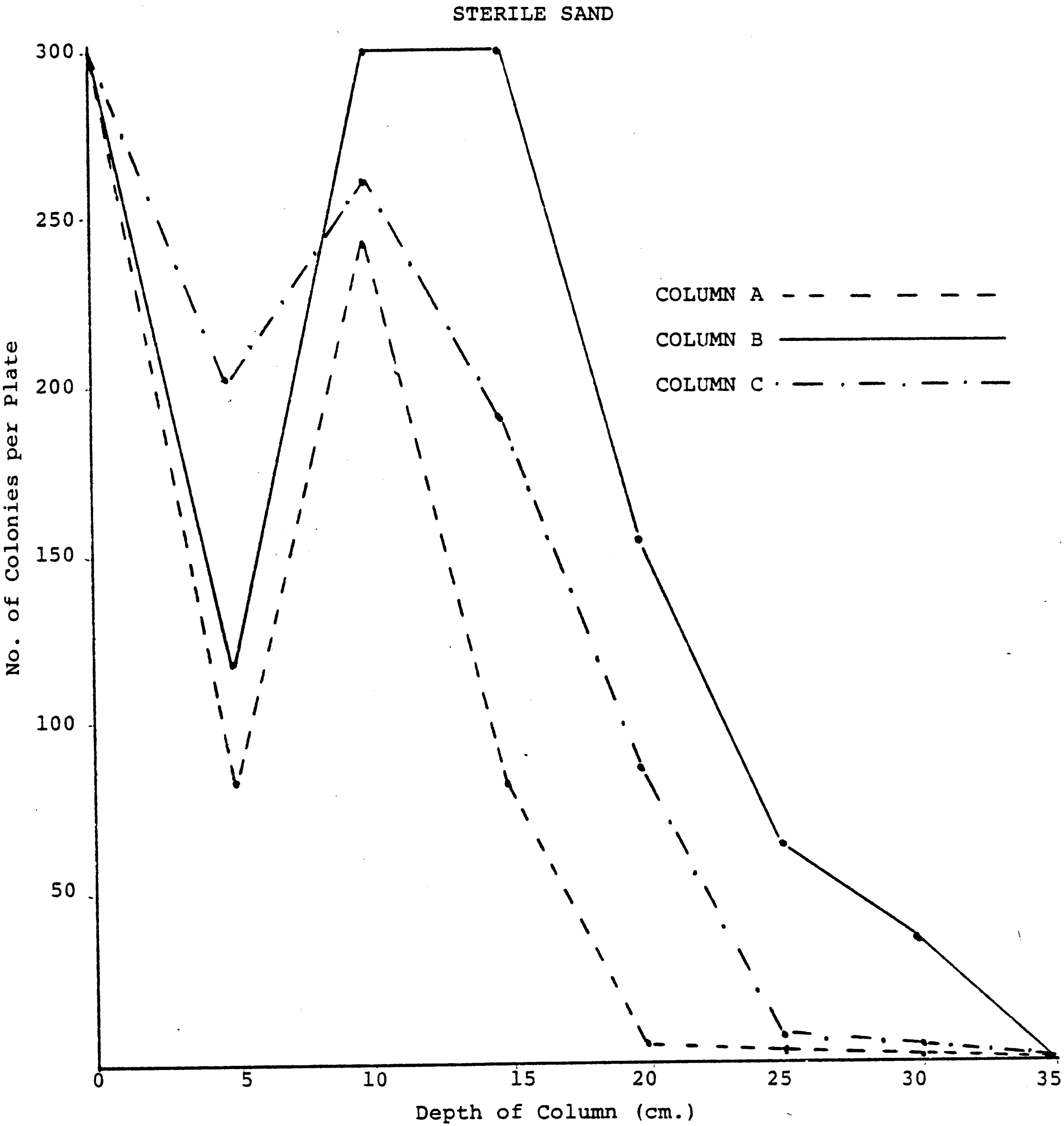

Fig. 9. Distribution of spores of Metarhizium anisopliae versus depth in three columns of sterile sand after topical application of 2ml of spore suspension and 150ml of sterile distilled water. Each plotted value represents an average of three replicates obtained from each column.

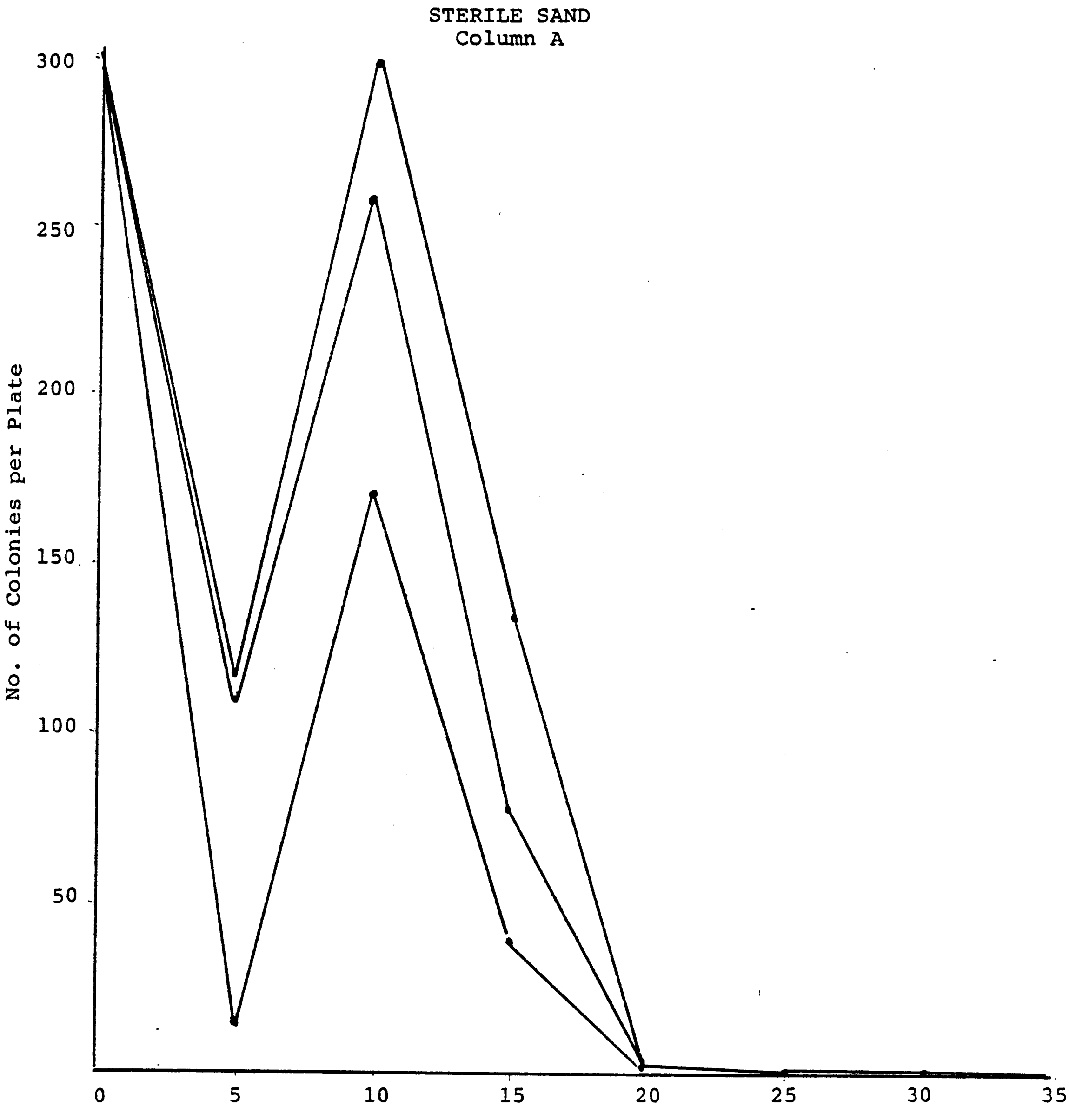

Fig. 10. Distribution of spores of <u>Metarhizium</u> <u>anisopliae</u> versus depth in Column A of the sterile sand after topical application of 2ml of spore suspension and 150ml of sterile distilled water.

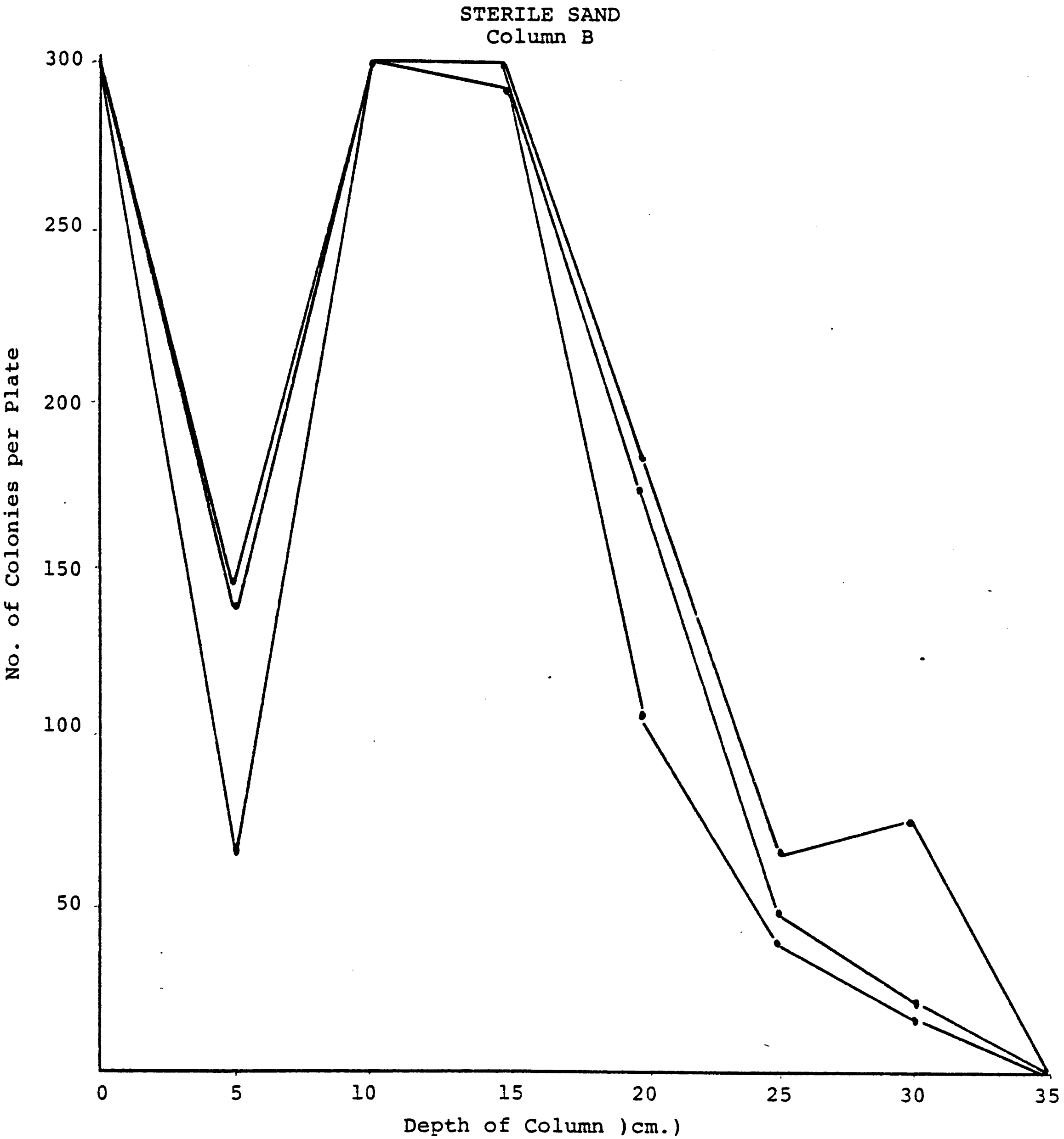

Fig. 11. Distribution of spores of <u>Metarhizium anisopliae</u> versus depth in Column B of sterile sand after topical application of 2ml of spore suspension and150ml of sterile distilled water.

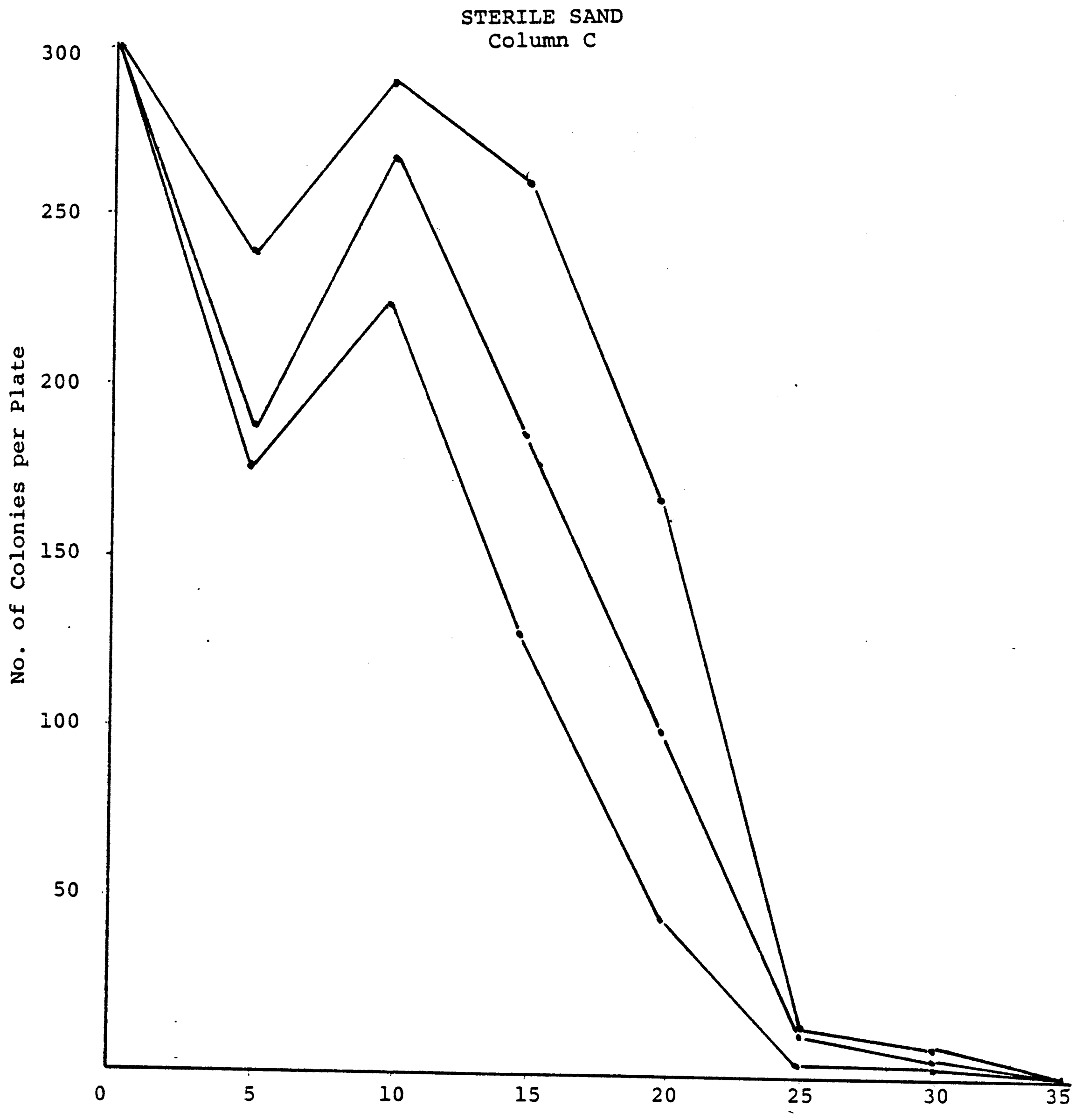

Fig. 12. Distribution of spores of Metarhizium anisopliae versus depth in Column C of sterile sand after topical application of 2ml of spore suspension and 150ml of sterile distilled water.

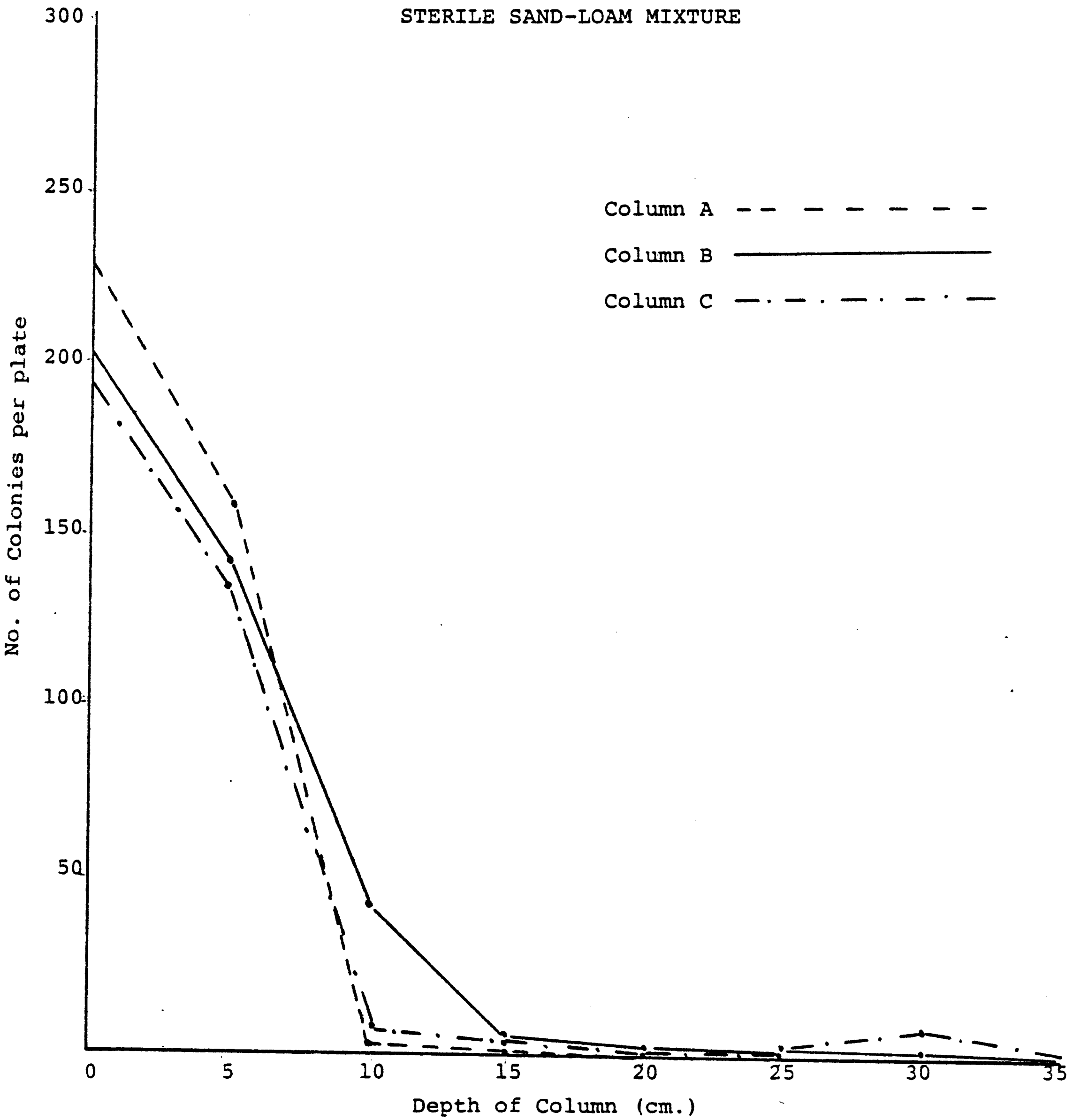

Fig. 13. Distribution of spores of Metarhizium anisopliae versus depth in three columns of sterile sand-loam mixture after topical application of 2ml of spore suspension and 150ml of sterile distilled water. Each plotted value represents an average of three replicates obtained from each column.

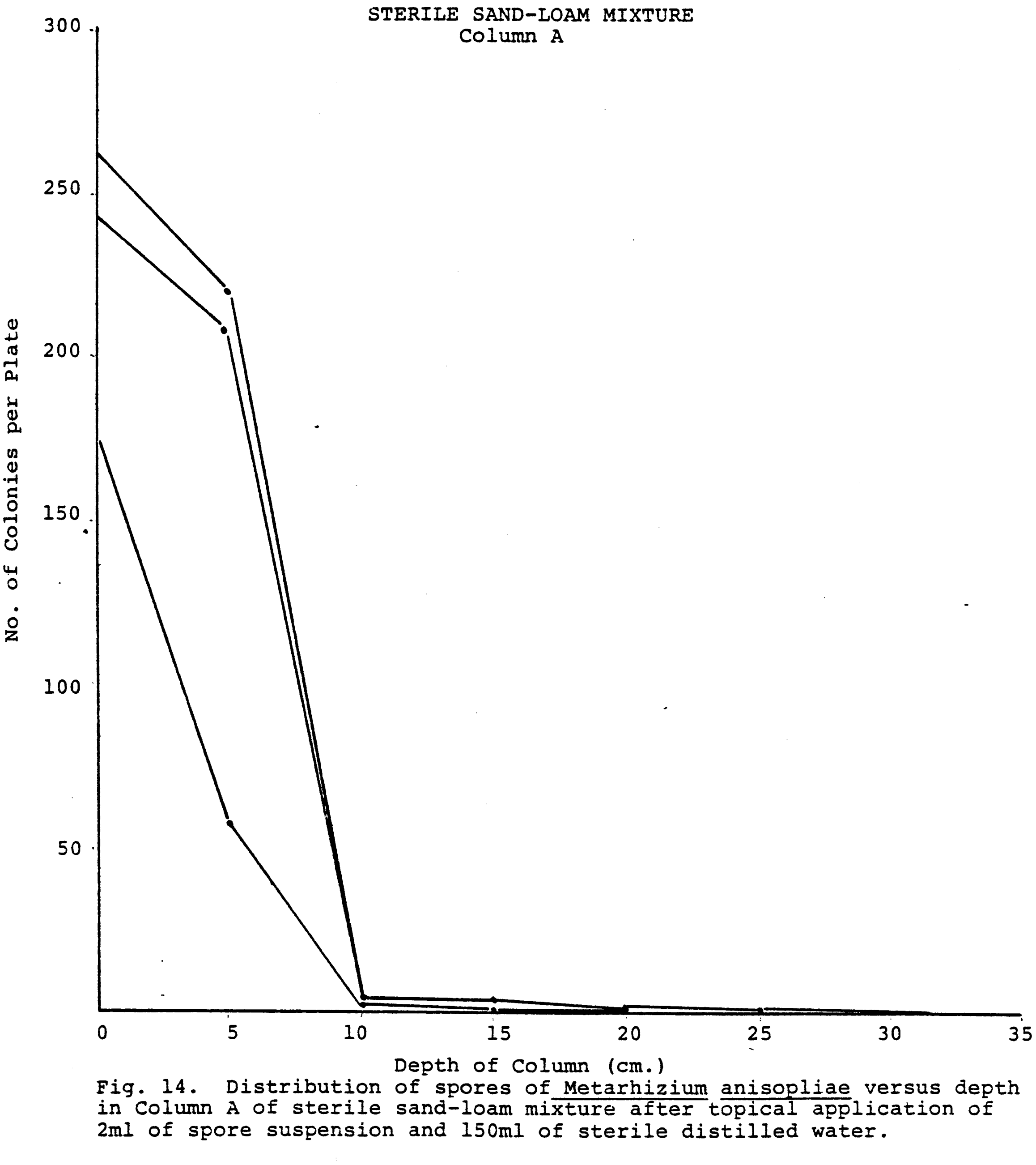

Fig. 14. Distribution of spores of <u>Metarhizium anisopliae</u> versus depth in Column A of sterile sand-loam mixture after topical application of 2ml of spore suspension and 150ml of sterile distilled water.

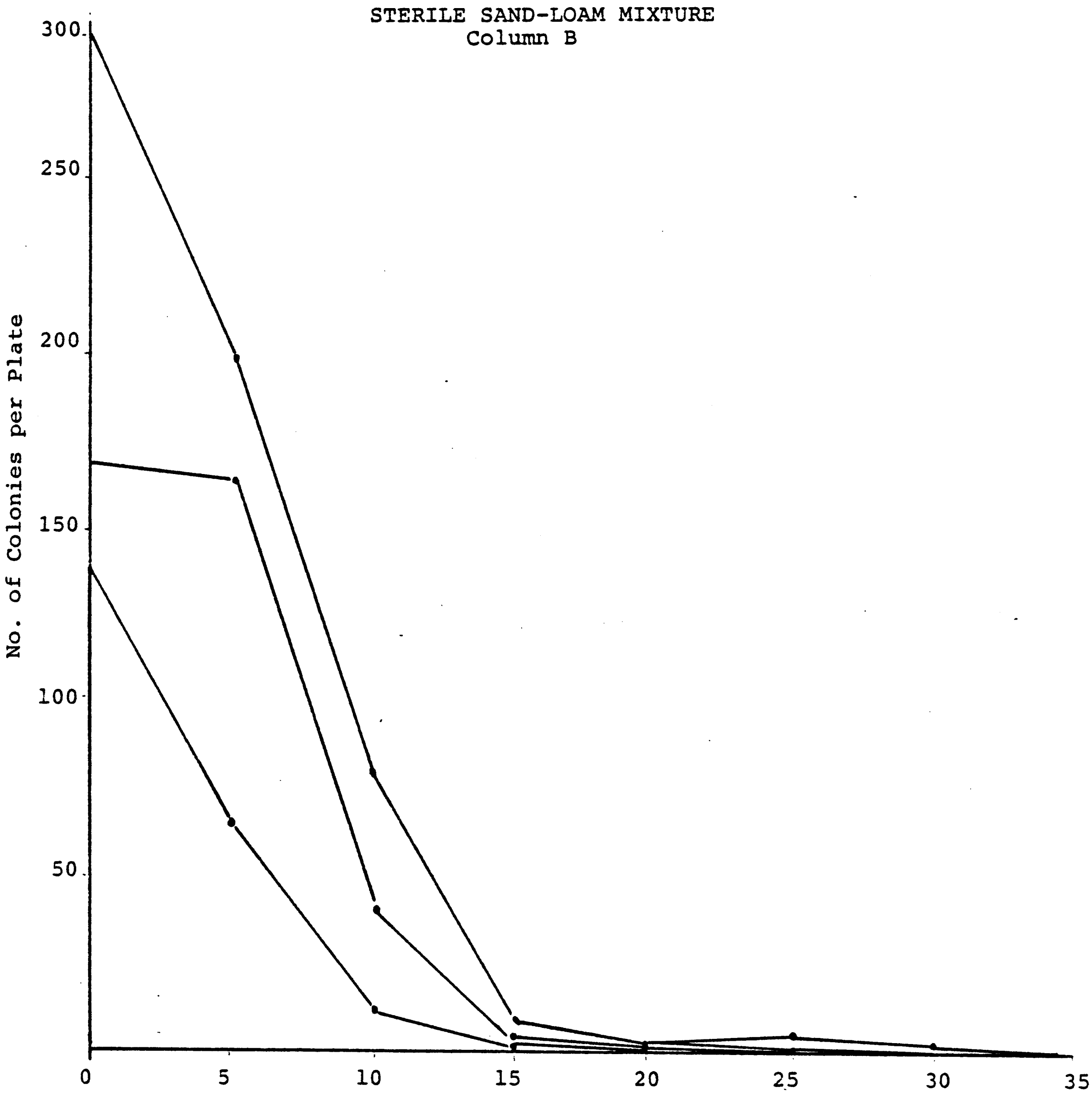

Fig. 15. Distribution of spores of Metarhizium anisopliae versus depth in Column B of sterile sand-loam mixture after topical application of 2ml of spore suspension and 150ml of sterile distilled water.

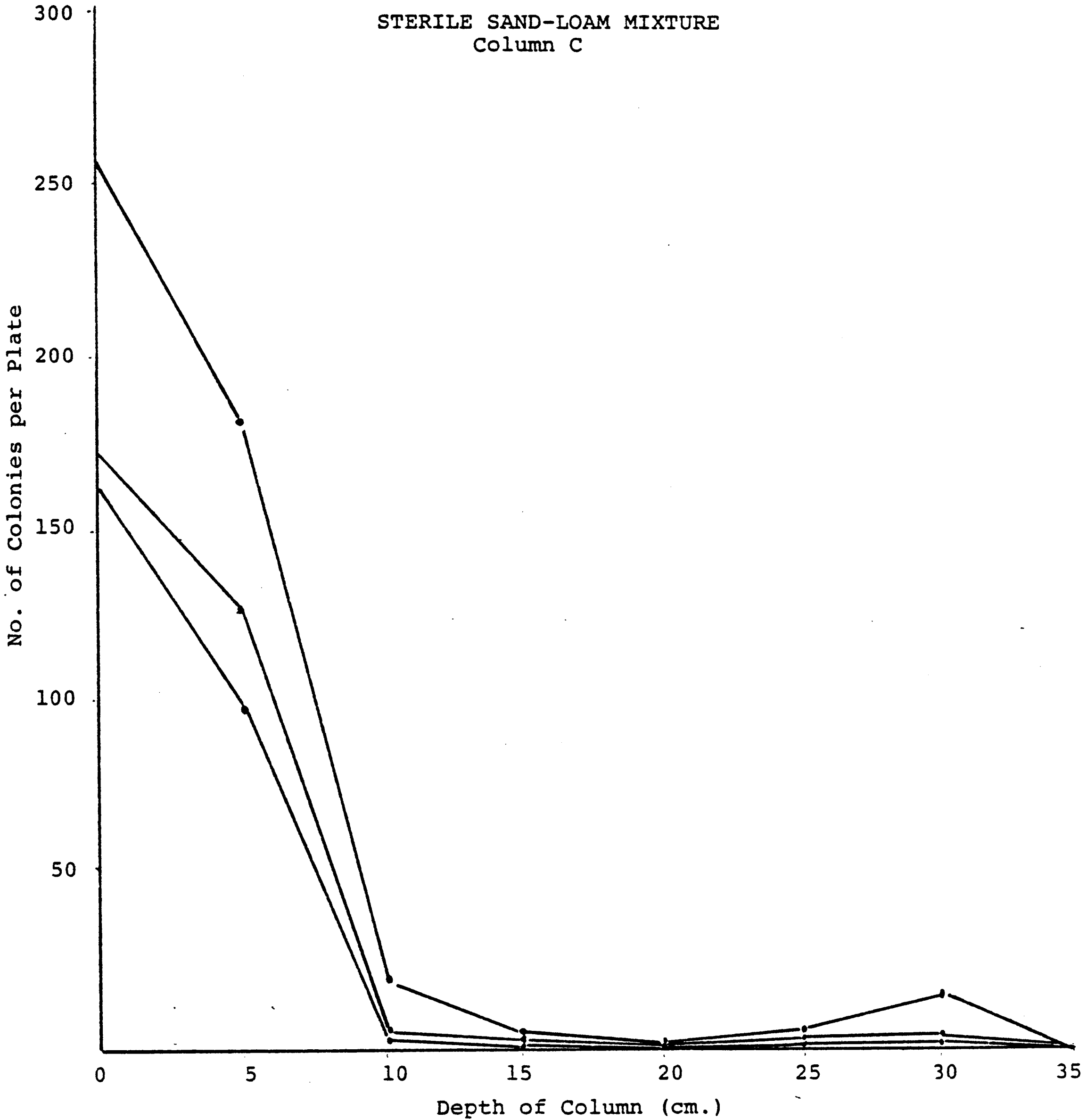

Fig. 16. Distribution of spores of Metarhizium anisopliae versus depth in Column C of sterile sand-loam mixture after topical application of 2ml of spore suspension and 150ml of sterile distilled water.

between the columns while Fig. 14, 15, and 16 show the variabilities observed within the columns. These curves indicate that the spores of M. anisopliae migrated to a depth of 5cm. At increased depths the number of colonies decreased sharply approaching zero between 10 and 15cm. The pattern of scatter between the three columns were relatively similiar showing the repeatability of the migration of spores through columns containing a sterile sand-loam mixture under laboratory conditions.

Sterile Plainfield soil

Fig. 17 shows the variability of migration of spores versus depth for the three columns containing the sterile Plainfield soil. Fig. 18, 19, and 20 represent the variability within the columns of soil. These graphs have a much wider range of variation than those representing the sterile sand and sand-loam mixture.

Column A (Fig. 18) shows a gradual decrease in the number of spores to the 10cm depth followed by a slight increase in concentration of spores between 15 and 20cm. This was followed by a decrease in spore concentration which approached zero by 35cm.

Column B (Fig. 19) shows a decrease in the number of spore concentration at 10cm similiar to the increase noted in Columns A and C. By 30cm, all replicates had few if any colonies plating out.

Column C (Fig. 20) shows a general decrease in con-

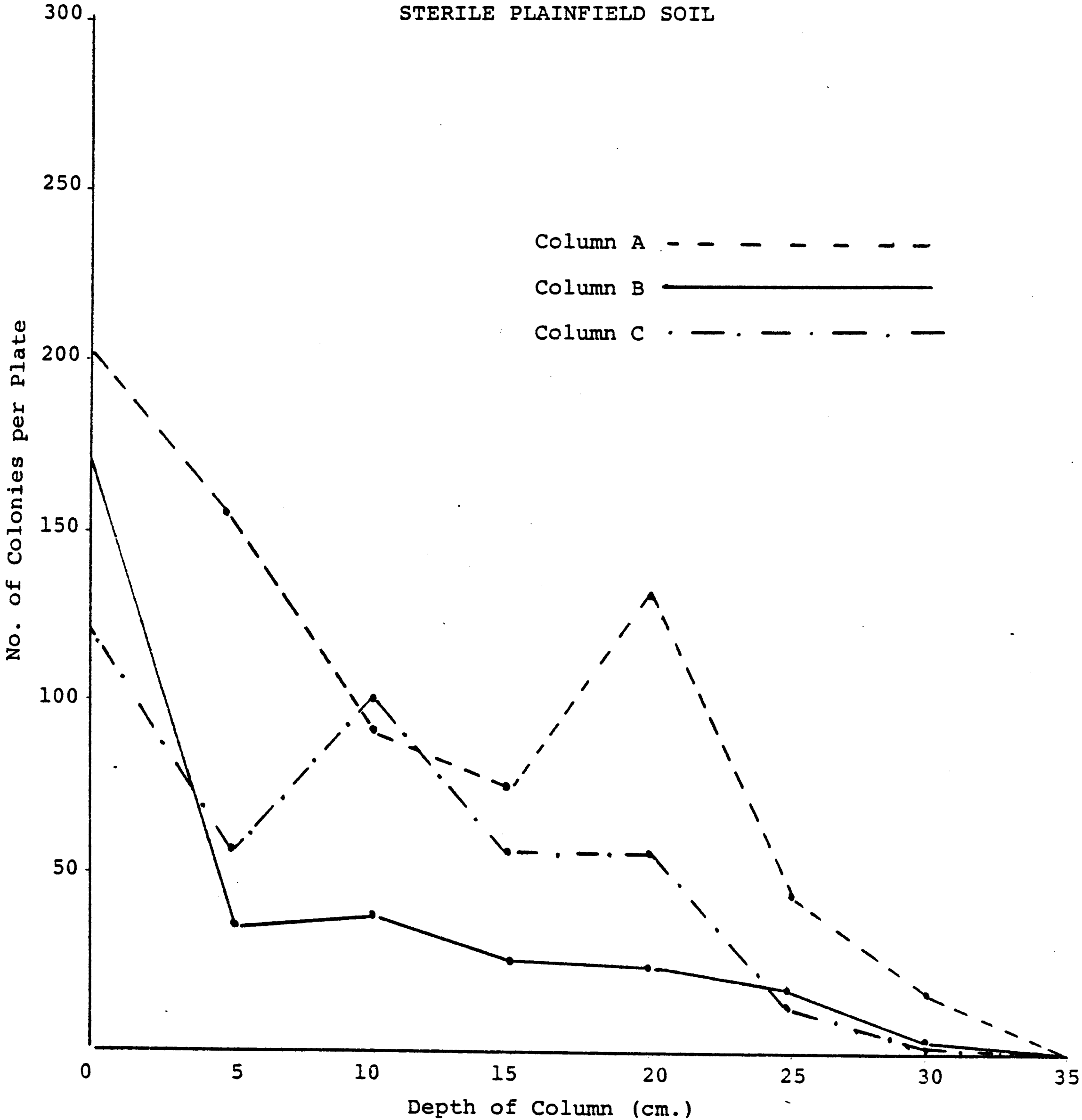

Fig. 17. Distribution of spores of Metarhizium anisopliae versus depth in three columns of sterile Plainfield soil after topical application of 2ml of spore suspension and 150ml of sterile distilled water. Each plotted value represents an average of three replicates obtained from each column.

Fig. 18. Distribution of spores of Metarhizium anisopliae versus depth in Column A of sterile Plainfield soil after topical application of 2ml of spore suspension and 150ml of sterile distilled water.

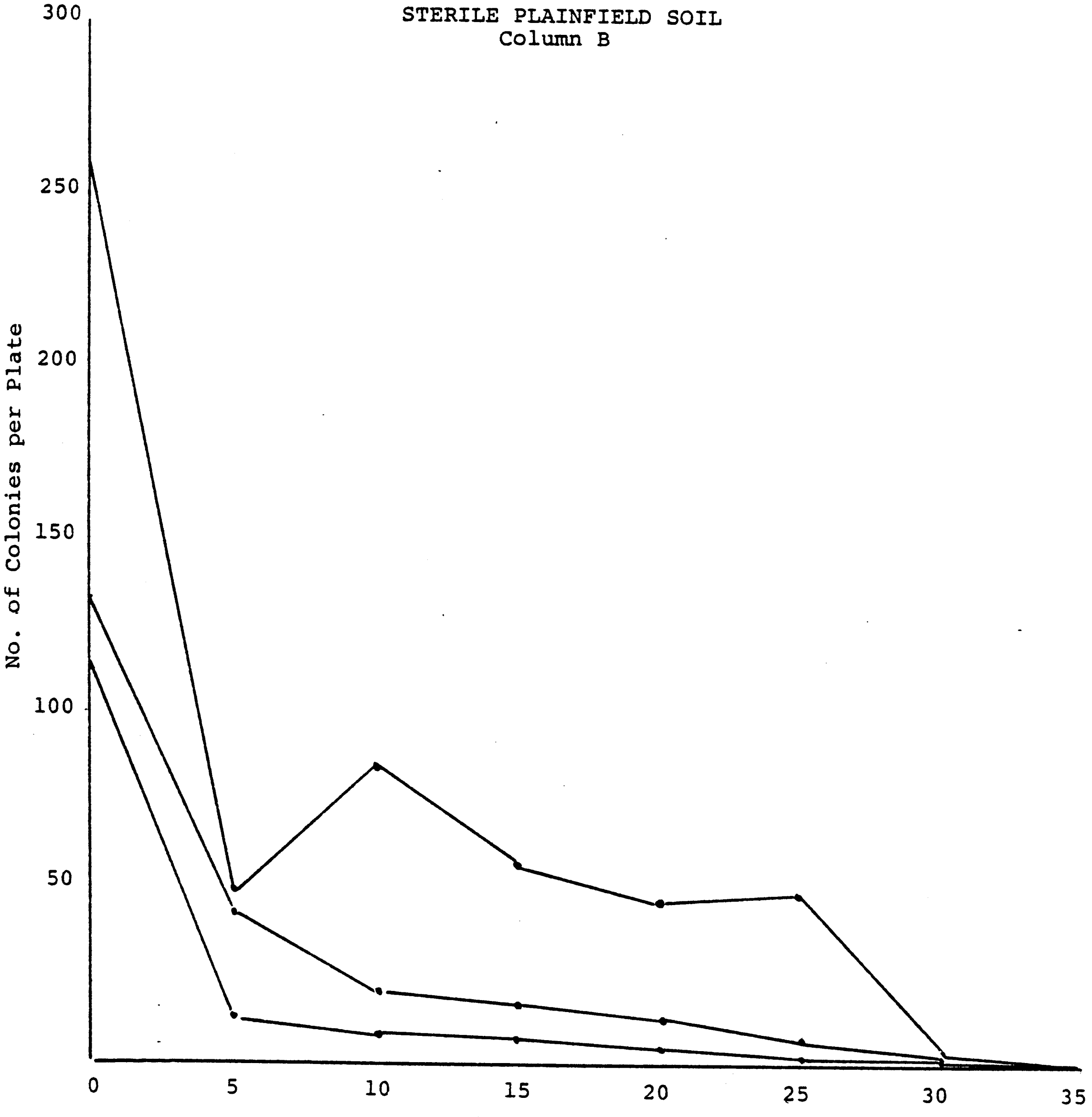

Fig. 19. Distribution of spores of Metarhizium anisopliae versus depth in Column B of sterile Plainfield soil after topical application of 2ml of spore suspension and 150ml of sterile distilled water.

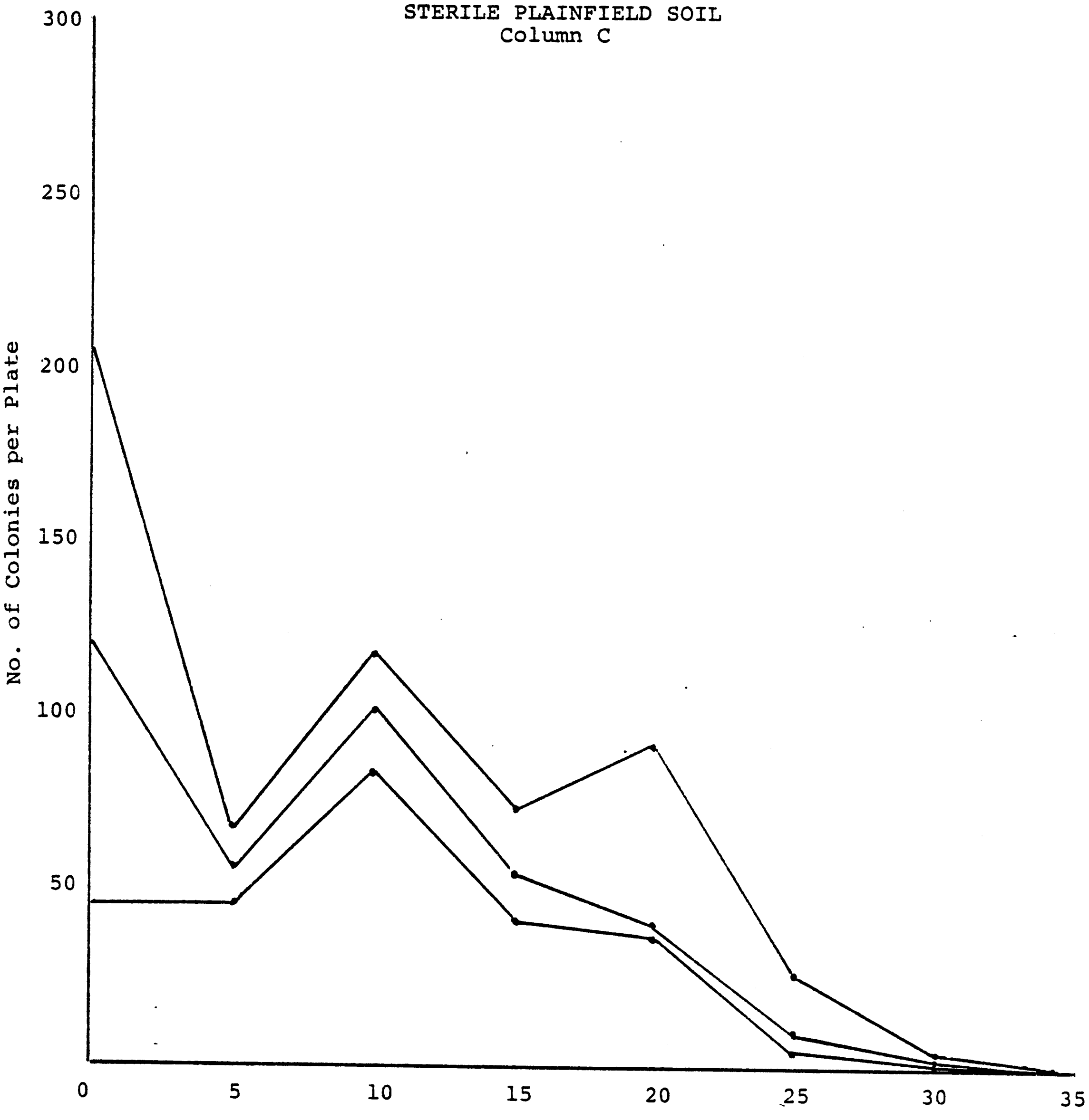

Fig. 20. Distribution of spores of <u>Metarhizium</u> <u>anisopliae</u> versus depth in Column C of sterile Plainfield soil after topical application of 2ml of spore suspension and 150ml of sterile distilled water.

centration of spores to the 5cm depth followed again by an increase in spore count at 10cm. After 10cm, spore concentration gradually diminished with depth to virtually zero by 35cm.

Unsterile Plainfield soil

The trial initiated with the columns of unsterile soil taken from the field test area showed a general downward migration of spores similiar to those columns containing the sterile soil. Table 1 represents the depths at which colonies of _M. anisopliae_ were present on the culture plates. The number of colonies of _M. anisopliae_ from each sample could not be counted as there were other contaminants growing on the plates even though a selective medium for the isolation of _M. anisopliae_ was utilized. It was only determined if _M. anisopliae_ was present or absent at the depths sampled. The cultures indicated that spores were present in relatively high numbers to the 15cm depth showing a general downward migration trend. By 20cm, the number of colonies on the culture plates had decreased and by 30cm had virtually approached zero. Cultures of the drainage water indicated no evidence of any colonies of _M. anisopliae_ migrating completely through any of the columns containing the unsterile soil.

Field Trial

Soil samples were taken from eight test plots which had had spores of _M. anisopliae_ sprayed on the surface.

	Column A	Column B	Column C
Surface	+++	+++	+++
5cm	+++	+++	+++
10cm	++	++	+++
15cm	+	+++	+
20cm	0	+	+
25cm	0	0	+
30cm	0	0	0

Table 1. Vertical distribution of spores of *Metarhizium anisopliae* in three columns of unsterile Plainfield soil after topical application of a spore suspension and 150ml of sterile distilled water. +++ = 70-100% coverage on the culture plates; ++ = 30-70% coverage; + = 1-30% coverage; 0 = no colonies observed on the culture plates. Initial observation taken two weeks after inoculation.

Two months after the initial application of spores, it was observed that the spores had migrated downward to 18cm (Table 2). Fungal colonies were present from the surface to 18cm. By 20cm, no colonies were observed for any of the eight plots. The soil samples were placed on the selective medium to reduce some of the contaminants. Accurate counts of the number of colonies found at each depth could not be taken due to other contaminants, however, the cultures did indicate that colonies of *M. anisopliae* could be grown from samples of soil taken from the test plots down to a depth of 18cm. Viable inoculum were found in 68% of all samples taken from the plots which were scalped to mineral soil and 75% of the plots which were left undisturbed after two months.

Two samples were taken at 5cm intervals from the field plots and placed on the selective medium four months after the initial application of spores (Table3). The percent of plots with viable inoculum was 75% in samples taken from the plots which had been scalped to mineral soil, and 50% on the undisturbed plots. Seventy five percent of the plots showed evidence that the inculum had migrated to 20cm while 38% indicated migration to 25 and 30cm. Table 3 shows the results of the positive cultures of *M. anisopliae* at the various depths in samples obtained from the field plots four months after initial application of spores.

Plot #	Surface	2cm	4cm	6cm	8cm	10cm	12cm	14cm	16cm	18cm	20cm	Ave. %
1	X	X	X	X	0	X	X	X	X	X	0	
2	X	X	X	X	X	X	0	0	0	X	0	
3	X	X	X	0	0	0	X	X	0	X	0	
4	X	X	X	X	X	0	X	X	X	0	0	
% Present	100	100	100	75	50	50	75	75	50	75	0	68
5	X	X	X	X	X	X	X	X	X	X	0	
6	X	X	X	X	0	X	X	0	X	X	0	
7	X	X	X	X	X	X	X	X	X	X	0	
8	X	X	X	X	0	0	0	X	X	0	0	
% Present	100	100	100	100	50	75	75	75	100	50	0	75

Table 2. Soil samples obtained from field plots two months after initial application of a spore suspension containing $6x10^7$ spores per ml of <u>Metarhizium</u> <u>anisopliae</u>. X indicates presence, 0 indicates absence of the fungus. Plots 1-4 were scalped to mineral soil, plots 5-8 were left undisturbed. The soil is classified in the Plainfield series.

Plot #	Sur-face	5cm	10cm	15cm	20cm	25cm	30cm	Ave. %
1	X	0	X	X	X	X	X	
2	0	X	X	X	0	0	0	
3	X	X	X	X	X	X	X	
4	X	X	X	X	X	0	0	
% Present	75	75	100	100	75	50	50	75
5	X	0	0	X	X	0	0	
6	0	X	X	X	X	X	X	
7	X	0	0	0	0	0	0	
8	X	0	X	X	X	0	0	
% Present	75	25	50	75	75	25	25	50

Table 3. Soil samples obtained from field plots four months after initial application of a spore suspension containing 6x10^7 spores/ml of *Metarhizium anisopliae* X indicates presence, 0 indicates absence of the fungus. Plots 1-4 were scalped to mineral soil, plots 5-8 were left undisturbed. The soil is classified in the Plainfield series.

Control Trials

None of the control samples indicated that *M. anisopliae* was naturally present in the soil. A few colonies that appeared suspiciously like *M. anisopliae* were transferred to the DPY agar and allowed to sporulate. However, these colonies turned out to be *Penicillium*. *Metarhizium* was not found to be present in any of the control samples.

Bioassay

The larvae of the greater wax moth which were inoculated with the spores of *M. anisopliae* were examined every 24 hours. Thirteen percent of the larvae were dead after 24 hours. Forty eight hours after inoculation, 78% of the larvae were dead and after 72 hours, there was 100% mortality. All larvae showed flaccidity and shrinkage. Within two weeks, the larvae were covered with the characteristic fungal growth diagnostic of *M. anisopliae* (Fig. 21 and 22).

The control group of larvae showed no sign of any fungal infection after 14 days.

Fig. 21. Larvae of the greater wax moth (Galleria mellonella) 10 days after inoculation with spores of Metarhizium anisopliae originating from cultures obtained from spores which had migrated through 15cm of sterile sand. The larvae show signs of external fungal growth characteristic of M. anisopliae

Fig. 22. Larva of the greater wax moth (Galleria mellonella) two weeks after inoculation with spores of Metarhizium anisopliae originating from cultures obtained from spores which had migrated through 20cm of sterile sand-loam mixture. The insect is covered with the fungal growth diagnostic of M. anisopliae.

DISCUSSION

The objective of this research was to determine whether M. anisopliae would migrate vertically through soils following topical application of spores. This factor would be essential if the fungus is to be considered for field application as a microbial insecticide against soil-inhabiting insects. This research revolved around the possibility of M. anisopliae reaching white grubs, Phyllophaga spp. which attack the roots of various nursery and seedling stock including red pine. Red pine grows best on well-drained sandy soils and has been extensively planted in Central Wisconsin as a source of pulpwood for the area's paper mills. Since light sandy soil is also a favorite habitat of white grubs, red pine seedlings are often planted in areas of high grub infestation.

The three types of soil tested in this experiment are commonly found in Central Wisconsin, the area of this research. Thirty percent of the soils in Central Wisconsin are classified in the Plainfield series (Hole 1976). This research was designed to determine the migration of spores of M. anisopliae through coarse sand and sand-loam mixture of which the Plainfield soils consist. If spores traveled through these soils, it was assumed they would also travel through the soil most commonly associated with red pine and white grubs. Because of the reduction of chemical spraying for the control of white grubs due to enforcement by environmental groups, a biological agent such as M. anisopliae which is capable of existing in soils and is able to migrate through soils would be of importance.

The laboratory tests indicate that spores of M. anisopliae are capable of dispersing in soil through the direct action of water. Water may affect dispersal through splash, run-off, and percolation under natural conditions. Dispersal by water is also dependent on interstitial pore space, spore shape, and consistency of spore coat. Spore dispersal by water is considered effective in a vertical mode rather than a lateral one.

Fungi which produce a mucilaginous spore mass are more capable of dispersing in the soil through the action of water than fungi which produce dry and powdery spores (Burges 1950, Hepple 1960). Spores of M. anisopliae were suspended in a wetting agent (Tween 20) to help alleviate the antagonistic action between the spores and water by artificially changing the behavior of the spores to lessen their resistance to wetting. The concentration of Tween 20 was .4%, which is known not to interfere with the viability or pathogenicity of the spores.

The trials undertaken in the laboratory were concerned only with the dispersal of spores by the influence of water combined with Tween 20. The SDW poured on the columns and the distilled water sprayed on the field plots after the addition of the spore suspension, were equivalent to approximately one and one-quarter inches of rain per acre. This amount was derived as an amount of rain that can be expected in the spring when red pine seedlings are planted.

If tree planting could coincide with a forecast of heavy rain, the spores would have a good chance of being washed into the upper layers of soil thus protecting them from direct exposure to the elements.

The results from the trials conducted in the laboratory were fairly constant due to the fact that the variables were kept to a minimum. The columns filled with the sterile sand and sand-loam mixture were consistent in particle size and compaction to each other and the methods of experimentation were the same. The results indicated this by the repeatability of the trials. Some variations could have occurred due to human inconsistency as to speed in which the SDW was added and the length of time elapsed between the final addition of SDW and the taking of the samples.

The spores were moved rapidly downward to the 10cm level in the columns filled with sterile sand. The reason for this retention of spores at that level is not clear, but it is possible that it may be due to the strong adhesion of the spores to the sand grains. An insignificant number of spores did migrate all the way down the column although not completely through the column. This research was concerned only with the possibility of spores migrating to a certain depth and not with the quantity of spores that reached that depth. Although spores did migrate to the 35cm depth, the amount of spores probably would not be significant in the incidence of infection in insects.

The columns containing the sterile sand-loam mixture also showed a general downward migration of spores but the spores migrated only to a depth of 20cm with the majority of spores retained at the 5cm depth. This higher retention of spores at the upper levels of the columns might be attributed to the finer consistency of the soil. Small bodies such as spores also may carry electrical charges and it is possible that this ionization between the spores and the soil might be responsible for the retention of spores after traveling only a short distance. Spomer (1980) has shown that soils in containers develop a perched water table with the bottom 8-10cm of the soil having a 100% pore saturation. This water distribution exhibits a sharp gradient in sand and silty clay loam soils and may block access of the spores to lower column levels.

Results from samples of soil taken from the field and then sterilized showed the most variation. This was due partly to the method of obtaining the sample. Each sample was taken separately and on different days as only one stainless steel column was used in this part of the experiment. Only one column was constructed because of the difficulty and expense in making the column. In comparison, the sterile sand and sand-loam mixtures were placed in three columns and the trials for all three replicates were accomplished at one time. Since each soil sample was obtained on different days, the soil sample would have been in a different state of moisture content. One sample could have been more tightly packed in the column itself than another. Each sample was sterilized intact in the column and the trial then proceeded in the same manner as those conducted with the sand and sand-loam mixtures. The results indicated that the spores moved through the column of soil without any of the sharp drops or peaks associated with the other types of soils. The majority of spores reached the 20cm depth before dropping off to insignificant levels. This further penetration of spores could have been the result of the roots of the grasses providing channels through which the spores could more easily pass. The smaller number of spores at the surface of the columns of soil could have been a result of a looser consistency of the soil due again to the vegetative growth. Different horizons could act as a filter bed for the spores washed down from the soil surface, or the nature of the soil horizon itself could result in the migration or retention of the spores.

The trial consisting of the three replicates of unsterile soil was procured and conducted in the same fashion as the trial in which the soil was sterilized. One column was again utilized and each trial was obtained and conducted on different days. The same variables would thus enter into the results. The effect of unsterile soil on the spores of the fungus has to be considered. Microorganisms which are naturally found in the upper layers of soil and especially associated with the roots of grasses could have had an antibiotic or fungistatic effect which might account for the fewer number of spores observed on the surface and upper layers of the columns of unsterile soil.

A selective medium for the isolation of M. anisopliae was poured over the soil samples. An accurate count of the colonies of M. anisopliae could not be taken due to other fungal and bacterial contaminants. Fungistasis or antibiosis could have influenced the results. There did appear to be fewer colonies of M. anisopliae present on the plates than those samples taken from the soils which had been sterilized. The reduced number of colonies could also have been due to samples being placed in the selective medium which includes various antibiotic substances acting as bacterial and fungal inhibitors. Although these antibiotics are not supposed to inhibit the growth of M. anisopliae, they might reduce the germinating power of the spores. Fungistasis is an occurrence that must be taken into consideration when attempting to employ a fungus as a microbial insecticide.

There is apparently no clear evidence of the origin or nature of soil fungistasis. Jackson (1965) reviews some of the possible sources of soil fungistasis with the conclusion that the inhibiting conditions in the soil could be ascribed to a complex of different inhibitory factors including antibiotic reaction, a form of staling between like and unlike organisms, and/or toxic metabolites. Roberts and Campbell (1977) report that other microorganisms found in the soil could also produce fungistatic compounds. These interrelating factors probably act together in a synergistic fashion to produce conditions which are unsuitable for spore germination. Fungistasis has been described from tropical to subartic soils and in a wide range of soil types. Lockwood (1964) reviews the theory, origins, and work conducted on soil fungistasis. Fungistasis would appear to be a factor in the germination of the spores of _M. anisopliae_ under natural conditions as Walstad _et al_.(1970) state that the spores do not germinate in unsterile soil.

No attempt was made to determine whether other factors such as soil structure, soil microorganisms, wind, erosion, etc. would have an effect on the migration of spores of _M. anisopliae_. In establishing _M. anisopliae_ as a microbial control agent, these dispersal factors must be taken into consideration. Once the inoculum is placed in the field, it is subject to the vagaries of the environment. The importance of the dispersion of spores has been emphasized by Tanada (1963) in his statement that an insect pathogen lacking a high dispersal capacity may have a low potential of developing an epizootic even though it may possess a high virulence for the host coupled with efficient survival capacities.

Dispersal in nature occurs in various ways which include both passive and active movement. Passive dispersal employs such agents as wind, water, animals, and other vectors. Active dispersal depends on either the mobility of the organism itself or on its growth. This growth can exhibit a definite search pattern for the host. Since the spores of M. anisopliae are not motile and have not been found to germinate and grown in soil (Walstad et al. 1970), the fungus must depend on passive mechanisms for its spores to be dispersed throughout the soil.

Vectors such as earthworms, nematodes, mites, and various microorganisms are important biotic agents contributing to the dispersal of fungi. Insects are other important agents, especially the primary hosts since they have the closest association with the particular pathogen. These insects may contract the disease and transmit infective material either externally or through the digestive system in the excretion of spores. Non-susceptible insect species may carry spores adventitiously through the soil. Mites have also been associated with the distribution of entomopathogenic soil fungi in a horizontal and vertical mode (Samšiňáková and Samšiňák 1970). Schabel (in press) reports on the possible role of several species of phoretic mites as carriers of the inoculum of M. anisopliae against soil-inhabiting insects. Small animals, birds, and man also contribute to the dispersal of fungal spores.

The dispersal of spores of *M. anisopliae* under natural conditions would depend on too many external and uncontrollable factors for dependable and repeated success in the field. Spore dispersal therefore should rely primarily on manipulated dispersion. This would involve direct introduction of the inoculum in an area which is in close approximation to the susceptible host. *M. anisopliae* could be used as a microbial insecticide where thorough coverage through repeated applications may place infective material in contact with the pest species.

The soil which was used for this research was designated as a Plainfield sand having a 2-4% slope. The hazard to water erosion is slight and that of blowing soil severe. Permeability is rapid and the available water is low. Plainfield sand is suitable for forestation with species such as red pine, Eastern white pine (*Pinus strobus*) and Jack pine (*P. banksiana*) with red pine being the preferred species. Red pine has a high potential productivity with a yearly growth per acre of 210 board feet (USDA Soil Cons. Serv. 1977). While seedling mortality is low on Plainfield soils, white grubs are a serious pest of red pine seedlings especially when the pine transplants are planted in soils that have been idle for a year or more and have a heavy grass or weed cover (Rose and Lindquist 1973). Damage is most severe on light soils such as

Plainfield sand. The white grub has been recognized as a problem for more than 50 years. In 1953, white grubs caused the principal injury to young plantations on 8000 acres in South Carolina (Speers and Schmiege 1971) while in Central Wisconsin a loss of 10-15% of nursery stock is not unusual especially in the age class below 2-2 (Shenefelt and Simkover 1950). The white grub was thus targeted as the insect used for this research. The insect is susceptible to green muscardine disease and _M. anisopliae_ has been an important factor in grub control on several continents (Ritcher 1958). There are more than 100 species in the genus _Phyllophaga_ and most cause some type of damage to crops, grass pastures, and nursery plantings. The larvae of all species inhabit the soil and have a one to three year life cycle. Those species having a three year life cycle are considered the most injurious and happen to be commonly found in Wisconsin. The larvae cause damage by severing or girdling the lateral and tap roots of young seedlings causing injury or death. Populations of white grubs can build up on open land and populations of two or more per two square feet can cause high mortality (Speers and Schmiege 1971).

The adults lay eggs in the soil at a depth of 5-15cm. These hatch in two to three weeks and the larvae feed on soil organic matter. The larvae hibernate in the soil at various depths depending on frost levels. The second summer they feed on roots and are most injurious at this stage. The grubs again hibernate in the winter and return to the surface the following spring where they feed on roots until June. At this time, they make earthen cells at depths ranging from 8-30cm and change to the inactive pupal stage (Ritcher 1958). They remain in this stage until the following spring when they emerge as adults.

The larvae are very sensitive to moisture conditions and move up and down in the soil as moisture conditions change (Ritcher 1958). Therefore, it could be assumed that *M. anisopliae* would not be effective during dry years as the grubs would be at a depth to which the spores would be unlikely to migrate.

The effect of *M. anisopliae* on the insect family Scarabaeidae (to which the genus *Phyllophaga* belongs) has been studied by other researchers in its possible use as a biological control agent against these insects. Latch (1965) reported on the possible use of *M. anisopliae* for controlling pasture-inhabiting grubs. Urs and Govindu (1971) experimented with *M. anisopliae* and infected several species of Scarabaeidae to observe disease incidence and found a number of species were susceptible to the fungus. Latch (1976) tested the pathogenicity of *M. anisopliae* to the coconut rhinoceros beetle and attempts to control this pest with the fungus have been made by spraying a spore suspension on the beetle's breeding sites. These studies have found *M. anisopliae* to be effective against the insect family Scarabaeidae in the field.

Several white grubs obtained from the soils of Central Wisconsin were inoculated with spores of *M. anisopliae* to determine the effectiveness of green muscardine disease on this particular insect. All the larvae subsequently died of mycosis and were covered with the characteristic fungal tufts of growth diagnostic of *M. anisopliae* within three weeks. The identity of the fungus was confirmed by transferring mycelial growth on the larvae to a nutrient agar medium and also by microscopic examination of the spores. It was assumed that the grubs which are native to the soils of Central Wisconsin are susceptible to *M. anisopliae*.

The spores which were applied to the soil were exposed to changes in temperature and moisture conditions and subjected to direct radiation. The weather following the application of spores in mid-June was warm, sunny, and dry. No water was applied to the plots despite the dry conditions except the three liters of distilled water initially sprayed on the surface of the plots. The first sampling of the plots was taken after two months had elapsed from the initial application of spores. In this time, 7.24 inches of rain had fallen. Most of that precipitation came in the month of August with June recording only .63 inches of precipitation. The average temperature for the two month period was 70.2°F. with the sunshine averaging 66% (App. 1).

This first sampling produced colonies of *M. anisopliae* on the selective medium to a depth of 18cm. This was verified by transferring suspected colonies of *M. anisopliae* to the DPY agar, allowing these cultures to sporulate, and observing the spores under a microscope. A few other contaminants including *Fusarium*, *Penicillium*, *Aspergillus*, and *Streptomyces* were also found growing on the medium.

The rains began in earnest shortly after the first sampling of the plots had been taken in mid-August and continued through September. Between mid-August and mid-October when a second sampling was taken, an average of 10.09 inches of precipitation had fallen, the average temperature was 59.9°F. and the possible sunshine was 57% (App. 1). This second sampling indicated that the spores of *M. anisopliae* had migrated to a depth of 30cm. The environmental conditions in this portion of the research could not be controlled. It is not known whether the spores would have migrated further if the application of spores had been followed by wet conditions, either through natural means or through artificial irrigation.

The first sampling indicated that the plots which were left undisturbed had a higher percentage of viable spores than those plots which were scalped to the mineral soil. This could have been a result of the protection the sod provided. The grasses could have created a more favorable microenvironment by producing slightly lower soil temperatures and a higher available moisture content. Spores were readily cultured from samples taken at the surface and upper layers of soil. Four months after the initial application of spores, the samples indicated a different percentage between the two types of field plots. A higher percentage of viable spores was cultured from those plots which had been scalped and the percent of viable spores from the undisturbed plots had decreased by 25%. Roots are associated with their own microorganisms and these could have caused a fungistatic or antibiotic effect on the spores creating unfavorable conditions for their survival. There were fewer colonies of spores observed from the surface and upper layers of soil.

A bioassay was devised to determine whether *M. anisopliae* remains virulent as it migrates through soils. Greater wax moth larvae were used for this bioassay. This insect was well suited for the bioassay because of its ready availability and its sensitivity to small amounts of the toxins produced by *M. anisopliae*. The larvae had been treated with insect growth regulators to prevent them from entering the pupal stage. Spores were brushed on the head and integument of the larvae. No attempt was made to determine the number of spores applied. A few of the larvae did spin a cocoon but not enough to affect the results. Roberts (1965) used the greater wax moth in his studies on the production of toxins produced by *M. aniso-*

pliae.

Is *M. anisopliae* then a suitable organism for microbial control of white grubs and other noxious insects? The outlook for practical application of *M. anisopliae* as a microbial insecticide in reducing pest populations is considered favorable for a number of reasons. The inoculum is easily prepared in bulk on natural or synthetic media from conidia. The spores can be disseminated over large areas either in an aqueous solution mixed with a wetting agent or in combination with dry fillers such as sand, silt, or talc. The conidia are able to withstand cold and temperature fluctuations and can adjust to either a saprophytic or parasitic mode of existence. Virulence can be maintained through a number of generations on artificial substrates. It has been shown that *M. anisopliae* can survive under field conditions for a period of time (Bell and Hamalle 1970, Walstad *et al*.1970, Bell 1975, Müller-Kögler 1976).

M. anisopliae has a wide host range and cross infection capabilities and has long been studied as a control agent against major insect pests. Adamek (1965), Schaerffenberg (1964), Latch (1965, 1976), Bell and Hamalle (1970), and Schabel (1976, 1978), have indicated that *M. anisopliae* indeed has potential and successfully infects a number of insect pests under laboratory conditions and in a few instances with small field trials. However, results of large scale field tests (Latch 1965, 1976; Fox and Jaques

1958), have ended with only minor successes and often with negative results. These results support the theory that control is dependent on proper conditions of temperature, humidity, and light which affect fungal spore viability and competitive ability. Fox and Jaques (1958) state that the quantity of spores applied is of secondary importance to environmental conditions which become the limiting factor. Even though M. anisopliae was found to migrate through the soil profile, environmental conditions would appear to prevail in control measures. This does not imply that M. anisopliae could not be successfully employed in large scale pest control. Much of this research is not recent and the unsuccessful attempts could be due to a lack of knowledge on the background of the fungus (dosage requirements, biochemical relationship between the fungus and insect, microenvironmental requirements, dispersal capabilities).

The factors that do prevail are the environmental conditions. Environmental conditions can be altered to favor the fungus. Changing the soil by modifying cultural practices or including a selective fungicide with the fungus to suppress agents in the soil that might inhibit it could be implemented. Repeated applications of the fungus in the role of a biological insecticide may also counteract the effect of the microenvironmental conditions.

M. anisopliae by its natural existence in the soil, has been involved in naturally occurring biological control. Natural control can be defined as "the maintenance of a more or less fluctuating population density of an organism within certain definable upper and lower limits over a period of time" (DeBach 1964). Classical biological control on the other hand, is commonly understood as the regulation of a pest population by manipulating resident natural enemies to increase their regulating capabilities (Caltagirone 1981). These pests usually reach a high population density and present economic problems to man. Biological control is dependent upon a foundation of ecological principles and is implemented by manipulating biological materials.

A successful control program for the use of *M. anisopliae* against insect pests probably lies in an integrated program. Basically integrated control is a comprehensive systems approach to pest control that is ecologically sound and which utilizes a variety of control technologies compatible in a pest management system with the ultimate objective to produce otimum return (crop, comfort, recreation) at minimum cost (Falcon 1973). It would appear that none of the traditional methods of control; chemical, biological, genetic, or cultural, alone can provide the final answer to pest control. However, a combination of two or more practices can often produce favorable results. The prime requisite for integrated control is basic ecological knowledge, a thorough understanding of the target pest, and information about the pathogen in its use, safety, selectivity, persistence, and dissemination.

An example of a successful program utilizing the integrated approach in a combination of practices including the application of M. anisopliae was established in Northeast Brazil in the sugarcane fields. This program involved 1) chemical insecticide which was combined with 2) cultural control with the burning of the sugarcane straws at the end of the season, 3) biological control using insect parasites, and 4) microbial control with the mass dissemination of spores of M. anisopliae. In this combination of integrated control, it was found that M. anisopliae was the most important mortality factor in the regulation of the pest species in the sugarcane fields. M. anisopliae used alone in this case, would probably have met with little success (Falcon 1974).

An integrated program for the control of white grubs in potential plantation or nursery sites is envisioned to include a three point attack, involving 1) cultural, 2)chemical, and 3) microbial practices. Preventive measures should be taken before seedlings are planted such as discing or plowing up the sod the spring preceding planting. This would expose the insects to the environment and predators such as various mammals and birds. The field should be kept free of grasses and weeds so that the adult insect

CONCLUSION

Mankind is in constant competition with many pest species that interfere with his ability to produce food and fiber. There will be a continual need to provide means for effective control and management of these pests. *Metarhizium anisopliae* appears that it could be an effective candidate as a microbial agent of certain soil-inhabiting insects. It can be easily mass·produced on artificial media, it is fairly stable under field conditions, and it remains virulent and effective against a number of soil-inhabiting insects. Spores can migrate downward through soils with the aid of a wetting agent (Tween 20) and water and thus may be dispersed to areas inhabited by pest populations. Therefore, *M. anisopliae* should be effective in pest control management, especially in an integrated aspect and in habitats where optimum environmental conditions exist.

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APPENDIX 1.

Local Climatological Data - June 1980 through October 1980.

JUNE 1980
MADISON, WISCONSIN
NATIONAL WEATHER SERVICE OFC
TRUAX FIELD

Local Climatological Data

MONTHLY SUMMARY

JUNE 1980 MADISON, WISCONSIN

LATITUDE 43 °08 'N LONGITUDE 89 °20 'W ELEVATION (GROUND): 858 FT. STANDARD TIME USED: CENTRAL WBAN #14837

	TEMPERATURE °F					DEGREE DAYS BASE 65°		WEATHER TYPES ON DATES OF OCCURRENCE 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW, ICE PELLETS OR ICE ON GROUND AT 06AM IN.	PRECIPITATION		AVG. STATION PRESSURE IN. ELEV. 866 FEET M.S.L.	WIND					SUNSHINE		SKY COVER TENTHS		
DATE	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	HEATING (SEASON BEGINS WITH JULY)	COOLING (SEASON BEGINS WITH JAN.)			WATER EQUIVALENT IN.	SNOW, ICE PELLETS IN.		RESULTANT DIR.	RESULTANT SPEED M.P.H.	AVERAGE SPEED M.P.H.	FASTEST MILE SPEED M.P.H.	FASTEST MILE DIRECTION	MINUTES	PERCENT OF POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT	DATE
1	2	3	4	5	6	7A	7B	8	*9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	65	55	60	-2	53	5	0	1 8	0	.06	0	28.84	11	7.6	9.1	19	SE	35	9	10	10	1
2	77	52	65	3	55	0	0	1 3 8	0	.49	0	28.81	09	1.8	6.2	19	N	526	58	6	7	2
3	73	52	63	1	52	2	0	2 8	0	0	0	29.09	06	.9	3.7	10	SE	711	78	5	5	3
4	74	52	63	0	50	2	0		0	.01	0	29.26	16	7.0	8.2	22	S	653	72	8	8	4
5	79	56	68	5	56	0	3	1 3 8	0	.88	0	28.97	15	7.9	9.9	24	NW	248	27	9	9	5
6	79	61	70	7	60	0	5	3 8	0	.24	0	28.87	21	2.4	8.5	19	S	322	35	7	9	6
7	82	53	68	4	59	0	3	3 5 8	0	1.01	0	28.85	31	3.7	12.1	44	NW	568	62	6	7	7
8	69	45	57	-7	42	8	0		0	0	0	29.20	30	12.4	12.7	24	NW	777	85	3	3	8
9	71	42	57	-7	47	8	0	3	0	.11	0	28.95	30	11.1	11.4	22	NW	463	50	8	5	9
10	68	37	53*	-12	37	12	0		0	0	0	29.07	33	4.5	5.8	15	NW	876	95	5	4	10
11	77	40	59	-6	43	6	0		0	0	0	29.28	25	2.2	3.7	10	SW	920	100	0	0	11
12	81	51	66	1	48	0	1		0	0	0	29.23	18	9.8	10.2	19	S	709	77	9	7	12
13	81	59	70	5	55	0	5	1 8	0	T	0	29.04	18	9.3	9.1	18	SW	505	55	9	9	13
14	87	60	74	8	60	0	9	8	0	T	0	28.92	20	4.6	6.5	24	SW	832	90	3	5	14
15	63	44	54	-12	48	11	0	1 8	0	.05	0	29.03	05	11.9	12.2	19	NE	110	12	10	9	15
16	71	37*	54	-12	39	11	0		0	0	0	29.26	01	3.5	4.6	12	S	922	100	0	0	16
17	75	45	60	-6	48	5	0		0	0	0	29.18	21	8.4	9.5	16	SW	912	99	3	2	17
18	74	51	63	-4	52	2	0		0	.06	0	29.06	03	1.3	7.2	16	NE	326	35	9	9	18
19	68	48	58	-9	46	7	0	3	0	T	0	29.06	36	7.7	9.6	20	N	603	65	6	6	19
20	79	43	61	-6	46	4	0		0	0	0	29.21	25	3.4	4.2	10	SW	849	92	4	4	20
21	82	56	69	2	49	0	4		0	0	0	29.12	22	7.0	7.3	16	SW	800	87	5	6	21
22	88	60	74	6	56	0	9		0	0	0	29.05	20	5.9	6.5	14	SW	512	55	9	9	22
23	91	58	75	7	60	0	10	8	0	0	0	29.04	16	3.7	4.0	14	S	467	51	10	9	23
24	90	58	74	6	62	0	9	1 8	0	0	0	29.05	10	3.2	4.6	16	SE	746	81	5	5	24
25	93	62	78	10	65	0	13	2 8	0	0	0	29.06	22	4.7	4.9	14	SW	815	88	3	3	25
26	96*	64	80*	12	68	0	15	1 8	0	0	0	29.03	25	5.0	8.2	16	W	608	66	9	8	26
27	79	58	69	1	55	0	4	3	0	.49	0	29.03	08	11.4	11.7	18	SW	299	32	9	9	27
28	88	62	75	6	61	0	10	1 3	0	.03	0	28.91	28	3.5	7.6	33	E	830	90	2	3	28
29	72	55	64	-5	52	1	0		0	0	0	28.89	28	10.1	11.8	22	NW	489	53	5	4	29
30	78	51	65	-4	54	0	0	1 8	0	0	0	29.06	25	3.4	5.9	10	SW	830	90	5	5	30

SUM	SUM				TOTAL	TOTAL			TOTAL	TOTAL	FOR THE MONTH:						TOTAL	%	SUM	SUM
2350	1567				34	100	NUMBER OF DAYS		3.43	0	29.05	22	1.2	7.9	44	NW	18313	FOR	182	179
AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.						DATE: 07		POSSIBLE MONTH		AVG.	AVG.
78.3	52.2	65.3	-0.5	53	12	4	> .01 INCH	11	-0.90								27580	66	6.1	6.0
					SEASON TO DATE		SNOW, ICE PELLETS													
NUMBER OF DAYS					TOTAL	TOTAL	> 1.0 INCH	0	GREATEST IN 24 HOURS AND DATES					GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE						
MAXIMUM TEMP.		MINIMUM TEMP.			7726	147	THUNDERSTORMS	3	PRECIPITATION		SNOW, ICE PELLETS									
> 90	< 32	< 32	< 0		DEP.	DEP.	HEAVY FOG	2	1.12	5- 6	0			0						
4	0	0	0		-4	33	CLEAR 7	PARTLY CLOUDY 11	CLOUDY 12											

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT
+ ALSO ON AN EARLIER DATE, OR DATES.
HEAVY FOG: - VISIBILITY 1/4 MILE OR LESS.
FIGURES FOR WIND DIRECTIONS ARE TENS OF DEGREES CLOCKWISE FROM TRUE NORTH. 00 = CALM.
DATA IN COLS. 6 AND 12-15 ARE BASED ON 7 OR MORE OBSERVATIONS PER DAY AT 3-HOUR INTERVALS.
FASTEST MILE WIND SPEEDS ARE FASTEST OBSERVED ONE-MINUTE VALUES WHEN DIRECTIONS ARE IN TENS OF DEGREES. THE / WITH THE DIRECTION INDICATES PEAK GUST SPEED.
ANY ERRORS DETECTED WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL SUMMARY

SUMMARY BY HOURS

HOUR LOCAL TIME	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE IN.	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	RELATIVE HUMIDITY %	WIND SPEED M.P.H.	DIRECTION	SPEED M.P.H.
00	5	29.06	58	54	51	77	7.3	19	.3
03	6	29.03	56	53	50	81	5.9	18	1.8
06	6	29.06	58	54	51	80	5.8	06	.6
09	6	29.08	67	59	53	61	9.2	25	2.7
12	6	29.06	73	62	54	52	10.2	23	2.5
15	7	29.03	76	63	54	47	9.7	24	2.8
18	6	29.02	73	62	54	54	8.9	21	1.4
21	6	29.04	63	58	53	70	6.2	13	.4

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A. M. HOUR ENDING AT												P. M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
1			T	T	.35	.01	T	T	T																1
2																		.01	.35	.12	.01				2
3																									3
4																								.01	4
5				T	.01	T	T	.06	.01	.29	T												.07	.44	5
6	.10	.14	T																						6
7							1.01																		7
8																									8
9																	T	.11	T						9
10																									10
11																									11
12																									12
13																T	T							T	13
14	T	T	T																						14
15			T	T	.01	.01	T	.01	T	T	T	.02	T												15
16																									16
17																									17
18																	T	T				.04	.01	.01	18
19	T					T	T																		19
20																									20
21																									21
22																									22
23																									23
24																									24
25																									25
26																									26
27																					T	.13	.36		27
28	.03																								28
29																									29
30																									30

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Daniel B. Mitchell
DIRECTOR, NATIONAL CLIMATIC CENTER

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
					DAY 01											DAY 02											DAY 03						
00	10	100	10			64	63	62	93	00	0	10	90	10			64	62	60	87	00	0	2	UNL	10			61	60	60	97	00	0
03	3	UNL	10			58	57	57	96	06	3	10	50	10		T	68	62	59	73	09	8	0	UNL	10			61	60	60	97	00	0
06	2	UNL	10			59	58	58	97	00	0	10	80	10		TRW	63	61	60	90	36	5	0	UNL	10			59	58	58	97	00	0
09	2	UNL	10			79	67	60	52	23	6	10	65	9			63	62	61	93	06	8	0	UNL	9			73	67	63	71	34	3
12	0	UNL	10			89	70	59	36	30	7	10	150	10			75	66	61	62	07	9	7	320	9			77	66	59	54	18	4
15	2	UNL	10			92	71	61	36	27	5	10	80	10			74	66	62	66	05	5	3	UNL	10			85	66	55	36	29	5
18	4	UNL	10			87	70	61	42	31	6	8	UNL	10			76	68	63	64	32	6	0	UNL	10			80	65	56	44	20	5
21	4	UNL	10			65	61	59	81	00	0	1	UNL	10			64	62	61	90	00	0	0	UNL	10			66	62	59	78	00	0
					DAY 04											DAY 05											DAY 06						
00	6	250	10			66	64	63	90	17	5	10	9	10			68	67	66	93	17	6	0	UNL	10			61	60	59	93	02	3
03	5	UNL	10			64	62	61	90	13	6	2	UNL	6		F	65	65	65	100	19	4	10	210	9			61	60	60	97	00	0
06	10	200	10			65	62	61	87	18	9	10	UNL	6		F	65	64	63	93	19	5	10	140	7			67	66	65	93	00	0
09	10	140	8			74	66	62	66	18	11	2	UNL	7			73	67	63	71	22	6	10	75	7		RW	73	70	68	84	17	5
12	10	140	8			81	72	68	65	18	13	1	UNL	10			82	68	61	49	22	7	3	UNL	10			85	73	68	57	19	5
15	10	140	6		H	84	75	71	65	19	7	0	UNL	10			85	69	61	45	21	11	7	60	10			96	75	70	59	18	2
18	10	65	6		H	81	75	72	74	24	5	0	UNL	10			83	66	55	38	29	6	0	UNL	10			96	75	70	59	18	7
21	10	80	4		RWF	69	68	67	93	19	18	1	UNL	10			68	64	61	78	19	6	0	UNL	10			75	72	70	85	18	5
					DAY 07											DAY 08											DAY 09						
00	3	UNL	10			73	72	71	93	18	5	4	UNL	10			67	66	66	97	18	5	6	25	5		F	64	64	64	100	00	0
03	10	80	6		TRW	64	64	64	100	16	13	10	60	8			67	66	66	97	05	4	0	UNL	7			62	62	62	100	00	0
06	10	38	10			64	64	64	100	01	16	10	55	7		TRW	64	63	63	97	01	7	10	250	7			62	62	62	100	00	0
09	10	40	7			65	64	64	97	09	5	7	250	7			69	67	66	90	18	13	10	80	7			69	68	67	93	02	4
12	7	250	7			79	73	70	74	18	13	7	250	10			81	74	71	72	25	9	10	250	7			77	70	67	71	11	5
15	9	50	8		TRW	73	72	72	97	14	10	10	250	10		RW	77	71	68	74	28	7	10	80	10			78	71	68	71	06	6
18	10	30	6		TRW	69	68	67	93	20	7	10	250	10			74	71	70	87	27	5	10	47	10			73	69	67	82	07	6
21	10	70	6		TRW	68	67	67	97	31	7	5	UNL	10			68	67	67	97	00	0	10	40	10			68	64	61	78	06	5
					DAY 10											DAY 11											DAY 12						
00	10	21	7			64	63	63	97	04	7	2	UNL	10			62	62	62	100	00	0	0	UNL	10			60	60	60	100	31	4
03	10	14	7		RW	63	62	61	93	08	4	10	80	4		F	64	64	64	100	00	0	0	UNL	10			58	58	58	100	00	0
06	10	27	7		RW	63	62	62	97	10	4	10	5	2	8	F	66	66	66	100	18	9	0	UNL	5		F	55	55	55	100	34	4
09	10	100	4		RWF	68	67	66	93	00	0	10	11	1	8	RWF	68	67	67	97	00	0	0	UNL	10			68	62	58	71	36	3
12	9	9	5		RWF	72	69	68	87	29	6	10	55	7			67	65	64	90	30	8	1	UNL	10			76	65	58	54	30	5
15	8	45	10			74	70	68	92	05	6	6	25	10			75	69	66	74	30	7	7	UNL	10			79	66	58	49	31	3
18	7	UNL	10			76	69	65	69	36	4	2	UNL	10			75	69	66	74	30	6	1	UNL	10			76	65	59	56	07	4
21	5	UNL	10			65	64	64	97	00	0	0	UNL	10			65	63	62	90	30	3	2	UNL	10			63	61	59	87	16	5
					DAY 13											DAY 14											DAY 15						
00	5	UNL	10			63	61	60	90	18	6	8	60	6		F	62	62	62	100	00	0	8	100	10			62	61	61	97	00	0
03	10	250	10			62	60	59	90	19	4	5	UNL	0	3	F	59	59	59	100	00	0	10	3	3		F	61	61	61	100	05	10
06	10	75	7		RW	62	60	59	90	19	6	5	UNL	0	8	F	59	59	59	100	00	0	10	10	7			61	60	60	97	06	6
09	10	75	5		RWF	61	60	60	97	18	10	7	250	7			75	68	65	71	32	5	9	250	10			68	61	57	68	06	9
12	10	100	10			67	64	62	84	17	10	10	250	10			78	68	63	60	31	5	10	UNL	10			72	62	56	57	06	8
15	5	UNL	10			73	68	65	76	19	6	10	250	10			77	67	61	58	31	5	9	UNL	10			73	62	54	51	06	7
18	1	UNL	10			74	69	56	76	24	4	10	250	10			75	66	61	62	31	4	8	250	10			68	61	56	66	06	8
21	2	UNL	10			65	64	64	97	00	0	4	UNL	10			63	62	61	93	00	0	8	UNL	10			55	53	52	90	07	5
					DAY 16											DAY 17											DAY 18						
00	8	UNL	10			53	52	52	96	06	6	10	28	8			55	54	54	96	12	10	10	8	4		F	65	65	65	100	24	6
03	10	140	10			55	54	53	93	06	8	10	10	7		L	57	56	56	96	09	8	0	UNL	7			58	58	58	100	30	3
06	10	250	10			52	51	51	96	06	5	10	5	2	8	F	58	58	58	100	16	7	2	UNL	4		F	53	53	53	100	00	0
09	10	160	10			60	56	53	78	07	10	10	4	4		F	59	59	59	100	15	8	0	UNL	8			70	64	61	73	19	5
12	10	100	8		R	58	56	55	90	09	8	10	7	4		F	64	63	62	93	18	7	0	UNL	10			77	68	63	62	19	4
15	10	160	8		R	59	58	57	93	09	12	10	12	4		H	70	66	64	81	18	7	0	UNL	10			94	71	65	53	18	7
18	10	16	4		RF	58	56	55	90	11	9	10	34	5		H	69	66	65	87	19	5	0	UNL	10			79	70	66	65	18	5
21	10	45	7		R	56	55	54	93	12	15	6	UNL	4		F	64	64	64	100	18	5	0	UNL	10			70	68	67	90	18	5
					DAY 19											DAY 20											DAY 21						
00	1	UNL	10			70	69	69	97	18	6	2	UNL	10			77	75	74	91	23	4	10	14	7		TRW	69	68	67	93	20	9
03	10	36	4		TRWF	70	70	70	100	19	[illegible]	0	UNL	10			74	73	73	97	18	5	10	8	10			69	68	68	97	19	7
06	10	100	7		RW	64	63	63	97	06	18	3	UNL	7			71	70	70	97	18	4	2	UNL	5		F	70	69	69	97	24	8
09	3	UNL	10			72	68	66	82	17	12	8	55	7			83	77	75	77	11	8	0	UNL	10			76	68	64	66	26	8
12	0	UNL	10			83	76	73	72	18	10	8	UNL	7			90	80	76	64	16	8	1	UNL	10			78	68	63	60	29	11
15	4	UNL	10			91	80	76	62	20	12	8	UNL	10			92	79	74	56	18	10	1	UNL	10			81	68	61	51	30	12
18	3	UNL	10			87	78	75	68	20	3	7	250	10			86	77	74	68	18	8	0	UNL	10			77	66	59	54	31	6
21	2	UNL	10			78	76	75	91	18	4	10	20	6		TRW	69	68	68	97	31	8	0	UNL	10			66	62	59	78	28	5
					DAY 22											DAY 23											DAY 24						
00	0	UNL	10			60	58	57	90	34	3	0	UNL	10			57	56	56	96	00	0	0	UNL	10			63	60	58	84	18	5
03	0	UNL	10			55	55	55	100	00	0	0	UNL	5		F	54	54	54	100	00	0	0	UNL	10			62	60	59	90	18	5
06	0	UNL	10			55	55	55	100	32	3	0	UNL	6		GF	54	53	53	96	00	0	5	UNL	4		F	61	60	59	93	18	5
09	0	UNL	10			73	64	59	62	31	5	0	UNL	10			74	66	61	64	18	7	7	UNL	7			74	67	63	69	18	9
12	0	UNL	10			79	64	55	44	36	6	1	UNL	10			80	66	57	45	18	7	8	UNL	7			82	70	64	55	19	9
15	0	UNL	10			82	66	56	41	31	5	5	UNL	10			82	66	57	43	19	5	10	250	7			80	69	64	58	19	7
18	0	UNL	10			79	66	58	49	31	3	8	250	10			76	65	58	54	17	13	10	120	10			75	69	66	74	18	4
21	0	UNL	10			61	60	59	93	36	3	2	UNL	10			64	62	60	87	10	3	7	UNL	10			69	67	66	90	14	5
					DAY 25											DAY 26											DAY 27						
00	5	UNL	10			68	65	64	87	16	5	4	UNL	7			70	67	65	84	19	5	4	UNL	4		F	71	70	69	93	18	5
03	8	100	10			66	64	63	90	18	7	10	UNL	6		F	68	65	64	87	20	5	10	90	0	8	F	65	65	65	100	36	4
06	10	100	6		H	67	64	62	84	18	5	8	UNL	5		F	65	64	63	93	18	3	10	90	0	4	F	65	65	65	100	05	5
09	10	90	5		H	69	66	64	84	08	7	10	UNL	2	8	H	74	69	66	76	18	6	10	3	1	4	F	63	63	63	100	05	5
12	8	70	6		H	74	70	68	82	11	8	8	UNL	2	8	H	84	74	70	63	16	7	10	6	2		F	70	67	66	87	04	4
15	5	UNL	7			82	72	67	61	18	11	4	UNL	3		H	90	75	68	48	09	6	10	6	2	8	RWF	64	63	62	93	36	8
19	0	UNL	7			78	71	67	69	18	10	1	UNL	5		H	83	75	72	70	18	6	10	8	2	8	F	64	63	62	93	04	5
21	0	UNL	6		H	72	68	66	82	18	6	3	UNL	6		F	73	72	71	93	18	4	10	20	3		TRWF	61	61	61	100	06	12
					DAY 28											DAY 29											DAY 30						
00	10	8	10			60	60	60	100	06	4	0	UNL	0	8	F	64	64	64	100	35	4	3	UNL	3		F	68	67	66	93	18	7
03	10	6	6		F	60	60	60	100	06	3	10	1	0	2	F	69	69	69	100	00	0	5	UNL	3		F	67	66	66	97	18	4
06	9	3	1	8	F	61	61	61	100	08	5	10	2	0	4	F	68	68	68	100	06	4	6	UNL	1	8	F	64	64	64	100	08	4
09	10	3	1	12	F	65	65	65	100	12	4	10	6	4		TRWF	65	64	64	97	05	9	10	42	7		T	63	62	61	93	00	0
12	10	11	2		H	75	70	67	76	26	5	10	150	7			70	67	65	84	08	3	10	60	10			65	63	62	90	16	6
15	10	UNL	2		H	80	73	70	72	33	5	10	UNL	8			90	72	69	69	17	9	10	250	10			73	67	63	71	18	6
18	2	UNL	2	8	H	76	72	70	82	32	4	6	UNL	3		H	79	75	73	82	16	4	7	250	10			72	67	65	79	19	5
21	10	250	2	8	F	67	67	67	100	00	0	10	250	3		H	72	69	67	84	18	6	8	70	7			66	65	65	97	00	0
					DAY 31																												
00	10	UNL	7			63	63	63	100	00	0																						
03	10	60	7		R	64	64	64	100	18	3																						
06	10	13	3		F	64	64	64	100	06	4																						
09	10	5	3		F	68	67	67	97	13	5																						
12	10	16	10			70	67	65	84	17	8																						
15	9	13	10			72	69	67	84	17	5																						
18	7	30	10			74	69	67	79	18	3																						
21	3	UNL	8			66	65	65	97	00	0																						

NOTES

CEILING

UNL INDICATES UNLIMITED

WEATHER

*	TORNADO
T	THUNDERSTORM
Q	SQUALL
R	RAIN
RW	RAIN SHOWERS
ZR	FREEZING RAIN
L	DRIZZLE
ZL	FREEZING DRIZZLE
S	SNOW
SP	SNOW PELLETS
IC	ICE CRYSTALS
SW	SNOW SHOWERS
SG	SNOW GRAINS
IP	ICE PELLETS
A	HAIL
F	FOG
IF	ICE FOG
GF	GROUND FOG
BD	BLOWING DUST
BN	BLOWING SAND
BS	BLOWING SNOW
BY	BLOWING SPRAY
K	SMOKE
H	HAZE
D	DUST

WIND

DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. ENTRY OF 00 IN THE DIRECTION COLUMN INDICATES CALM.

SPEED IS EXPRESSED IN KNOTS; MULTIPLY BY 1.15 TO CONVERT TO MILES PER HOUR.

STATION

MADISON WISC

YEAR & MONTH

80 08

U.S. DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N.C. 28801

JULY 1980
MADISON, WISCONSIN
NATIONAL WEATHER SERVICE OFC
TRUAX FIELD

Local Climatological Data

MONTHLY SUMMARY

JULY 1980 MADISON, WISCONSIN

LATITUDE 43°08'N LONGITUDE 89°20'W ELEVATION (GROUND) 858 FT. STANDARD TIME USED: CENTRAL WBAN #14837

DATE 1	TEMPERATURE °F MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	DEGREE DAYS BASE 65° HEATING (SEASON BEGINS WITH JULY) 7A	COOLING (SEASON BEGINS WITH JAN.) 7B	WEATHER TYPES ON DATES OF OCCURRENCE 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW 8	SNOW, ICE PELLETS OR ICE ON GROUND AT 06AM IN. 9	PRECIPITATION WATER EQUIVALENT IN 10	SNOW, ICE PELLETS IN. 11	AVG. STATION PRESSURE IN. ELEV. 866 FEET M.S.L. 12	WIND RESULTANT DIR. 13	RESULTANT SPEED M.P.H. 14	AVERAGE SPEED M.P.H. 15	FASTEST MILE SPEED M.P.H. 16	DIRECTION 17	SUNSHINE MINUTES 18	PERCENT OF POSSIBLE 19	SKY COVER TENTHS SUNRISE TO SUNSET 20	MIDNIGHT TO MIDNIGHT 21	DATE 22
1	89	59	74	5	61	0	9	8	0	T	0	28.97	24	3.4	8.5	14	S	525	57	7	7	1
2	80	56	68	-1	53	0	3		0	0	0	29.18	07	4.5	5.8	12	SE	781	85	6	4	2
3	86	48	67	-2	53	0	2		0	T	0	29.13	22	1.4	2.2	9	SW	656	71	5	5	3
4	87	64	76	7	61	0	11		0	T	0	29.03	19	3.6	5.0	12	SE	737	80	3	5	4
5	85	61	73	4	65	0	8	3	0	.81	0	29.00	32	6.4	9.4	22	N	772	84	3	5	5
6	79	51	65	-4	57	0	0		0	0	0	29.19	12	5.2	6.8	14	SE	685	75	5	4	6
7	99*	65	82	12	69	0	17	8	0	0	0	28.95	21	8.5	9.8	17	SW	806	88	5	5	7
8	87	65	76	6	63	0	11		0	0	0	29.04	04	2.8	7.1	14	N	845	92	7	7	8
9	85	57	71	1	62	0	6	3 8	0	.38	0	29.02	13	1.3	4.9	22	N	444	49	8	7	9
10	93	62	78	8	67	0	13	1 8	0	0	0	29.00	27	3.2	3.6	12	SW	849	93	1	1	10
11	96	64	80	10	71	0	15	1 3	0	0	0	28.97	21	4.8	5.6	13	SW	656	72	7	7	11
12	89	67	78	8	73	0	13	1 3 8	0	T	0	28.92	35	1.8	6.0	17	S	373	41	8	8	12
13	91	59	75	5	65	0	10	2 8	0	0	0	29.09	17	4.1	4.9	11	S	784	86	5	4	13
14	93	70	82	12	72	0	17	1 3 8	0	.01	0	28.95	18	9.1	9.2	18	S	497	55	8	5	14
15	95	71	83*	13	67	0	18	1 3	0	.08	0	28.93	25	3.6	6.2	22	N	480	53	8	7	15
16	89	62	76	6	63	0	11	1 3	0	.79	0	28.93	29	3.2	10.5	22	N	777	86	4	4	16
17	90	62	76	6	61	0	11		0	0	0	29.02	30	3.8	5.6	18	SE	856	95	3	2	17
18	88	64	76	6	65	0	11		0	T	0	29.02	18	8.0	9.5	19	S	322	36	8	8	18
19	87	65	76	6	67	0	11	1 8	0	T	0	29.07	09	3.4	4.5	13	SE	480	53	7	7	19
20	95	66	81	11	69	0	16	3	0	.12	0	28.97	21	2.1	8.5	20	NW	493	55	7	8	20
21	85	61	73	3	65	0	8	1	0	0	0	29.10	30	2.7	3.9	10	NW	409	46	9	7	21
22	81	55	68	-2	59	0	3	1	0	0	0	29.11	34	6.7	7.3	14	NW	489	55	6	4	22
23	84	49	67	-4	55	0	2		0	0	0	29.16	01	1.7	3.3	9	NE	816	92	3	2	23
24	87	54	71	0	59	0	6		0	0	0	29.11	19	6.6	6.8	17	SW	855	96	2	2	24
25	87	65	76	5	63	0	11	1	0	.06	0	29.06	19	4.2	6.2	14	S	140	16	10	10	25
26	67	58	63*	-8	62	2	0	2	0	.36	0	29.07	02	5.6	6.3	13	N	0	0	10	10	26
27	80	53	67	-4	58	0	2	1	0	0	0	29.04	03	4.1	5.0	11	NE	629	71	5	4	27
28	86	47*	67	-4	58	0	2	1 8	0	0	0	28.99	23	3.4	4.6	13	SW	771	88	3	4	28
29	87	58	73	2	60	0	8	1 8	0	0	0	29.00	34	2.6	4.5	13	NW	835	95	1	1	29
30	74	58	66	-5	62	0	1	1 3 8	0	.06	0	28.97	15	5.9	7.8	25	SE	73	8	10	9	30
31	92	61	77	6	64	0	12	1 8	0	0	0	28.94	31	5.7	5.6	14	NW	661	76	3	5	31

SUM	SUM				TOTAL	TOTAL		TOTAL	TOTAL	FOR THE MONTH:						TOTAL	%	SUM	SUM
2693	1957				2	268	NUMBER OF DAYS	2.67	0	29.03	22	1.1	6.3	25	SE	19496	FOR	177	168
AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION	DEP.						DATE: 30		POSSIBLE	MONTH	AVG.	AVG.
86.9	59.3	73.1	3.3	63	-12	36	≥ .01 INCH 9	-1.14								27920	66	5.7	5.4

				SEASON TO DATE		SNOW, ICE PELLETS	
NUMBER OF DAYS				TOTAL	TOTAL	≥ 1.0 INCH	0
MAXIMUM TEMP.		MINIMUM TEMP.		2	415	THUNDERSTORMS	9
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	2
9	0	0	0	-12	+29	CLEAR 9 PARTLY CLOUDY 13 CLOUDY 9	

GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
PRECIPITATION		SNOW, ICE PELLETS			
.37	15-16	0		0	

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT
+ ALSO ON AN EARLIER DATE, OR DATES.
HEAVY FOG: - VISIBILITY 1/4 MILE OR LESS.
FIGURES FOR WIND DIRECTIONS ARE TENS OF DEGREES CLOCKWISE FROM TRUE NORTH. 00 = CALM.
DATA IN COLS. 6 AND 12-15 ARE BASED ON 7 OR MORE OBSERVATIONS PER DAY AT 3-HOUR INTERVALS.
FASTEST MILE WIND SPEEDS ARE FASTEST OBSERVED ONE-MINUTE VALUES WHEN DIRECTIONS ARE IN TENS OF DEGREES. THE / WITH THE DIRECTION INDICATES PEAK GUST SPEED.
ANY ERRORS DETECTED WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL SUMMARY

SUMMARY BY HOURS

HOUR LOCAL TIME	AVERAGES SKY COVER TENTHS	STATION PRESSURE IN.	TEMPERATURE AIR °F	WET BULB °F	DEW PT. °F	RELATIVE HUMIDITY %	WIND SPEED M.P.H.	RESULTANT WIND DIRECTION	SPEED M.P.H.
00	5	29.03	67	64	62	86	4.7	14	.3
03	5	29.02	64	61	60	90	4.9	17	.5
06	7	29.04	65	63	61	89	5.3	18	1.4
09	6	29.05	74	68	64	71	7.8	24	1.8
12	6	29.04	81	70	64	58	8.1	25	1.7
15	6	29.02	84	71	64	51	7.5	27	1.9
18	5	29.01	81	70	64	58	6.9	23	1.6
21	5	29.03	71	66	64	79	5.0	17	1.4

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A. M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	P. M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	DATE
1									T																1
2																									2
3																								T	3
4	T																								4
5		.60	.17		.04																				5
6																									6
7																									7
8																									8
9				.32	.06			T																	9
10																									10
11																									11
12		T	T																						12
13																									13
14												T	T	T	.01										14
15							.06	T	.02	T															15
16	.07	.61	.06	.05	T																				16
17																									17
18			T				T	T	T	T	T														18
19														T											19
20			.01			.08	T										T	.03							20
21																									21
22																									22
23																									23
24																									24
25										T	T				T	T	T	.04	T	T	.01	.01	T		25
26					T	.01	.11	.04	.09	.06	.03	.01		.01	T	T				T					26
27																									27
28																									28
29																									29
30				T	T	.03	.01	.02	T					T	T					T					30
31																									31

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noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA AND INFORMATION SERVICE

Daniel B. Mitchell
DIRECTOR, NATIONAL CLIMATIC CENTER

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR	SKY COVER TENTHS	CEILING HNDS.OF FT.	VISI-BILITY		WEATHER	TEMPERATURE			REL. HUM. %	WIND		SKY COVER TENTHS	CEILING HNDS.OF FT.	VISI-BILITY		WEATHER	TEMPERATURE			REL. HUM. %	WIND		SKY COVER TENTHS	CEILING HNDS.OF FT.	VISI-BILITY		WEATHER	TEMPERATURE			REL. HUM. %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW PT. °F		DIR	SPEED KNOTS			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW PT. °F		DIR	SPEED KNOTS			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW PT. °F		DIR	SPEED KNOTS
					DAY 01											DAY 02											DAY 03						
00	8	200	10			64	60	57	78	17	6	6	100	10			64	59	56	75	31	4	0	UNL	10			56	51	46	69	00	0
03	1	UNL	10			63	59	56	78	17	6	0	UNL	10			60	58	56	87	06	7	0	UNL	10			50	48	46	86	00	0
06	10	UNL	6		H	65	61	58	78	18	8	3	UNL	10			59	55	52	78	06	4	0	UNL	10			57	53	50	78	00	0
09	10	140	8			70	64	61	73	19	10	7	250	10			67	58	51	57	06	8	0	UNL	10			71	60	52	51	20	6
12	7	UNL	8			76	68	64	66	26	5	7	UNL	10			75	62	54	48	06	7	8	UNL	10			78	66	58	50	30	5
15	0	UNL	8			88	74	67	50	31	8	8	UNL	10			76	62	53	45	12	3	9	UNL	10			85	67	56	37	00	0
18	8	UNL	10			84	70	63	49	31	10	7	UNL	10			74	62	53	48	09	3	10	100	10			78	65	57	49	18	4
21	8	250	10			69	62	58	68	35	6	2	UNL	10			61	55	51	70	12	4	10	90	10			71	63	58	64	00	0
					DAY 04											DAY 05											DAY 06						
00	10	75	10		RW	66	63	62	87	00	0	10	250	7			73	70	69	87	20	5	10	25	10			61	58	56	84	07	8
03	10	75	7			65	62	60	84	35	5	10	250	7			65	64	64	97	33	6	3	UNL	10			55	53	52	90	07	3
06	7	100	7			68	64	61	78	00	0	8	UNL	10			68	66	65	90	27	7	7	30	10			54	53	52	93	00	0
09	0	UNL	8			74	62	54	50	17	5	0	UNL	10			79	73	70	74	30	10	5	UNL	10			67	60	55	66	17	7
12	4	UNL	10			82	65	55	40	18	6	2	UNL	10			83	72	67	59	32	12	10	UNL	10			75	65	59	58	07	6
15	3	UNL	10			87	70	61	42	19	8	3	UNL	10			82	69	62	51	32	11	5	UNL	10			79	69	63	58	12	7
18	3	UNL	7			84	71	65	53	20	6	2	UNL	10			80	68	62	54	01	7	0	UNL	10			75	67	62	64	16	7
21	7	UNL	7			73	69	67	82	19	5	5	UNL	10			68	63	60	76	05	7	0	UNL	10			69	63	59	71	14	9
					DAY 07											DAY 08											DAY 09						
00	6	60	10			65	61	58	78	15	7	0	UNL	10			81	76	74	79	27	6	7	250	10			65	59	54	68	07	4
03	10	70	10			68	63	60	76	17	6	7	UNL	7			74	73	73	97	35	10	10	47	9		T	64	58	53	68	09	6
06	10	UNL	7			71	68	66	94	19	12	6	UNL	10			69	63	60	73	35	7	10	80	7			57	56	55	93	14	8
09	10	100	6		H	78	73	71	79	22	7	6	UNL	10			76	65	58	54	06	6	10	9	6		H	64	62	60	87	18	6
12	4	UNL	7			92	79	74	56	19	9	2	UNL	10			81	68	60	49	08	7	9	UNL	8			77	70	67	71	31	6
15	1	UNL	10			97	80	74	48	24	9	10	250	10			82	68	60	47	11	5	4	UNL	10			83	73	69	63	00	0
18	4	UNL	10			95	80	74	51	23	10	10	250	10			79	67	61	54	12	4	10	30	10			80	72	68	67	28	4
21	2	UNL	10			86	77	73	65	24	8	10	250	10			71	64	59	66	15	4	0	UNL	10			71	70	69	93	00	0
					DAY 10											DAY 11											DAY 12						
00	2	UNL	10			67	66	66	97	00	0	0	UNL	10			71	69	68	90	00	0	10	80	7			76	75	74	94	13	4
03	4	UNL	1	8	F	63	63	63	100	00	0	1	UNL	8			67	66	65	93	18	4	10	100	5		F	76	74	73	90	18	10
06	0	UNL	1	8	F	65	65	65	100	00	0	7	UNL	6		F	70	69	69	97	18	4	10	16	2		F	74	73	72	94	04	3
09	1	UNL	6		H	82	74	71	69	29	4	10	UNL	8			86	77	74	68	27	6	7	20	2		H	87	79	76	70	30	4
12	1	UNL	7			89	73	65	45	30	4	8	80	8			91	79	75	60	23	8	10	14	2		H	83	75	72	70	34	8
15	1	UNL	10			92	75	67	44	30	6	8	UNL	10			95	78	72	47	18	3	8	19	4		H	86	77	73	65	36	8
18	0	UNL	10			88	75	69	53	25	6	8	100	10			90	78	74	59	21	8	4	UNL	5		H	84	76	72	67	34	5
21	0	UNL	10			78	72	69	74	23	5	4	UNL	7			80	76	74	82	18	6	10	35	7			72	71	70	93	00	0
					DAY 13											DAY 14											DAY 15						
00	0	UNL	4		F	67	66	66	97	07	4	0	UNL	10			73	69	67	82	18	7	0	UNL	10			79	74	72	79	18	5
03	6	UNL	1	8	F	60	60	60	100	00	0	0	UNL	7			71	67	65	81	18	8	0	UNL	10			78	72	70	77	21	6
06	6	UNL	0	1	F	62	62	62	100	00	0	8	UNL	4		H	73	71	70	90	18	8	10	250	7			79	73	70	74	26	9
09	2	UNL	3		H	77	71	68	74	18	4	10	UNL	4		H	85	76	73	67	20	10	10	120	9		RW	72	71	70	93	32	12
12	8	UNL	7			87	72	65	48	18	5	10	80	4		RWH	86	77	74	68	18	8	8	UNL	10			77	69	65	67	19	7
15	4	UNL	10			90	72	63	41	18	3	10	90	3		TH	85	78	76	75	18	8	6	UNL	10			94	71	59	31	30	4
18	3	UNL	10			86	73	67	53	17	9	8	100	6		H	90	79	75	61	18	9	8	UNL	10			89	71	62	41	00	0
21	0	UNL	10			77	72	69	76	17	8	0	UNL	10			82	77	75	79	18	6	8	100	10			72	67	65	79	00	0
					DAY 16											DAY 17											DAY 18						
00	10	90	10			75	68	65	71	36	15	0	UNL	10			67	61	57	70	30	5	6	UNL	10			65	63	62	90	12	11
03	10	30	7		TRW	63	62	62	97	11	9	0	UNL	10			64	60	57	78	29	5	10	100	10			66	63	61	84	17	6
06	9	250	10			65	64	63	93	16	9	0	UNL	10			66	61	58	76	29	6	10	250	10			67	64	62	84	17	7
09	9	40	10			74	69	67	79	20	8	0	UNL	10			80	69	63	56	30	4	10	80	8			71	66	64	79	18	6
12	2	UNL	10			84	74	69	61	30	12	2	UNL	10			86	71	63	46	33	5	8	UNL	10			81	72	67	63	19	13
15	0	UNL	10			88	70	60	39	30	9	9	UNL	10			88	72	64	45	23	4	8	140	10			87	75	69	55	23	10
18	0	UNL	10			85	69	61	45	28	6	5	UNL	10			85	70	62	46	30	4	4	UNL	10			95	73	68	57	21	8
21	0	UNL	10			70	63	59	68	29	5	2	UNL	10			71	68	67	87	06	6	10	UNL	10			77	72	70	79	19	5
					DAY 19											DAY 20											DAY 21						
00	3	UNL	9			72	70	69	90	00	0	10	80	9			73	69	67	92	17	6	10	180	9			68	67	67	97	00	0
03	8	28	2		F	68	67	67	97	00	0	10	80	10		T	69	66	65	87	07	6	10	9	10			68	67	67	97	31	3
06	3	UNL	4		F	69	68	67	93	00	0	10	20	6		TRW	68	66	65	90	13	10	10	140	5		F	68	67	67	97	00	0
09	7	80	10			80	71	66	62	05	4	6	80	8			82	74	70	67	18	8	10	250	7			72	69	67	84	31	5
12	7	UNL	10			87	72	64	46	06	6	7	80	8			95	80	75	53	22	8	10	30	7			77	69	65	67	24	4
15	7	100	10			85	72	66	53	16	7	8	80	8			93	78	72	51	30	9	10	45	7			81	71	66	60	32	5
18	10	100	8			92	74	70	67	11	7	10	80	10			74	71	70	87	31	5	8	UNL	10			81	69	63	54	31	7
21	10	23	10			75	69	66	74	07	7	7	UNL	10			71	70	70	97	31	7	0	UNL	10			65	61	59	81	12	3
					DAY 22											DAY 23											DAY 24						
00	0	UNL	10			61	60	59	93	00	0	0	UNL	10			56	55	54	93	00	0	0	UNL	10			62	60	58	87	18	5
03	2	UNL	10			59	58	58	97	31	5	0	UNL	10			53	52	52	96	00	0	0	UNL	10			55	54	53	93	00	0
06	10	7	7			62	61	61	97	34	9	3	UNL	10			58	57	56	93	36	3	2	UNL	10			61	59	57	87	00	0
09	8	16	10			71	65	62	73	02	10	0	UNL	10			74	65	59	60	31	5	1	UNL	8			74	65	59	60	21	6
12	7	28	10			72	65	61	68	35	8	5	UNL	10			80	65	55	42	30	4	3	UNL	8			83	68	60	46	18	7
15	4	UNL	10			77	65	58	52	31	9	4	UNL	10			79	63	53	41	05	5	3	UNL	8			84	69	60	44	20	12
18	4	UNL	10			77	64	56	48	34	7	3	UNL	10			78	64	55	45	06	3	0	UNL	10			81	68	61	51	18	10
21	0	UNL	10			62	58	55	78	31	3	0	UNL	10			62	58	56	81	11	3	2	UNL	10			71	65	61	71	18	7
					DAY 25											DAY 26											DAY 27						
00	4	UNL	10			66	63	61	84	18	4	10	45	2		F	67	67	67	100	00	0	2	UNL	6		F	59	59	59	100	32	4
03	10	100	10			67	63	60	78	23	4	10	14	1		F	65	65	65	100	33	4	10	19	6		F	55	55	55	100	33	4
06	10	UNL	10			68	63	60	76	19	7	10	2	0	4	RWF	64	64	64	100	05	10	8	19	10			58	57	56	93	02	4
09	10	70	10			74	66	61	64	22	8	10	4	1	8	RWF	61	61	61	100	05	6	4	UNL	10			67	62	59	76	05	8
12	10	80	7			82	70	63	53	18	10	10	4	3		F	59	59	59	100	35	7	6	25	10			73	65	60	64	05	5
15	10	80	7			79	70	65	62	03	6	10	3	2		LF	60	59	59	97	01	7	6	25	10			80	67	59	49	06	5
18	10	60	2	8	RWF	70	69	68	93	17	4	10	5	5		F	60	59	59	97	02	6	2	UNL	10			74	64	57	55	04	5
21	10	40	6		F	68	67	67	97	00	0	10	10	6		F	60	59	59	97	04	4	1	UNL	10			59	58	57	93	00	0
					DAY 28											DAY 29											DAY 30						
00	0	UNL	10			54	54	54	100	32	3	10	70	10			71	66	64	79	19	6	4	UNL	10			59	58	57	93	36	3
03	0	UNL	10			49	49	49	100	00	0	2	UNL	7			66	64	63	90	00	0	2	UNL	10			60	58	57	90	20	6
06	6	UNL	5		F	53	53	53	100	00	0	0	UNL	3		F	64	63	63	97	00	0	10	70	6		RW	63	62	61	93	18	6
09	0	UNL	10			75	66	61	62	30	5	0	UNL	10			77	69	65	67	31	7	10	250	5		FH	64	63	62	93	13	8
12	0	UNL	10			80	67	59	49	19	4	3	UNL	10			84	69	60	44	36	6	10	80	7			71	66	64	79	18	9
15	7	250	10			83	69	61	48	22	7	1	UNL	10			86	67	55	35	36	7	10	80	7			73	67	63	71	16	11
18	2	UNL	10			80	68	61	52	20	7	0	UNL	10			83	66	55	38	36	5	10	100	7			72	67	65	79	10	6
21	7	80	10			72	67	64	76	21	6	0	UNL	10			64	60	58	81	00	0	10	90	10			69	65	63	81	13	5
					DAY 31																												
00	10	250	10			65	64	63	93	04	4																						
03	10	90	4		F	63	62	62	97	31	3																						
06	3	UNL	1		F	62	62	62	100	33	3																						
09	0	UNL	6		H	75	70	67	76	30	6																						
12	5	UNL	7			84	72	66	55	32	6																						
15	3	UNL	7			89	73	66	47	30	7																						
18	4	UNL	10			85	72	65	51	30	5																						
21	7	250	10			71	66	63	76	30	5																						

NOTES

CEILING

UNL INDICATES UNLIMITED

WEATHER

*	TORNADO
T	THUNDERSTORM
Q	SQUALL
R	RAIN
RW	RAIN SHOWERS
ZR	FREEZING RAIN
L	DRIZZLE
ZL	FREEZING DRIZZLE
S	SNOW
SP	SNOW PELLETS
IC	ICE CRYSTALS
SW	SNOW SHOWERS
SG	SNOW GRAINS
IP	ICE PELLETS
A	HAIL
F	FOG
IF	ICE FOG
GF	GROUND FOG
BD	BLOWING DUST
BN	BLOWING SAND
BS	BLOWING SNOW
BY	BLOWING SPRAY
K	SMOKE
H	HAZE
D	DUST

WIND

DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH; I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. ENTRY OF 00 IN THE DIRECTION COLUMN INDICATES CALM.

SPEED IS EXPRESSED IN KNOTS; MULTIPLY BY 1.15 TO CONVERT TO MILES PER HOUR.

STATION

MADISON WISC

YEAR & MONTH

80 07

U.S. DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N.C. 28801

AUGUST 1980
MADISON, WISCONSIN
NATIONAL WEATHER SERVICE OFC
TRUAX FIELD

Local Climatological Data

MONTHLY SUMMARY

AUGUST 1980 MADISON, WISCONSIN

LATITUDE 43 °08 'N LONGITUDE 89 °20 'W ELEVATION (GROUND) 858 FT. STANDARD TIME USED: CENTRAL WBAN #14837

DATE	TEMPERATURE °F MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS BASE 65° HEATING (SEASON BEGINS WITH JULY)	COOLING (SEASON BEGINS WITH JAN.)	WEATHER TYPES ON DATES OF OCCURRENCE 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW, ICE PELLETS OR ICE ON GROUND AT 06AM IN.	PRECIPITATION WATER EQUIVALENT IN	SNOW, ICE PELLETS IN.	AVG. STATION PRESSURE IN. ELEV. 864 FEET M.S.L.	WIND RESULTANT DIR.	RESULTANT SPEED M.P.H.	AVERAGE SPEED M.P.H.	FASTEST MILE SPEED M.P.H.	DIRECTION	SUNSHINE MINUTES	PERCENT OF POSSIBLE	SKY COVER TENTHS SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT	DATE
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	93	55	74	3	60	0	9		0	0	0	28.98	29	2.6	3.9	12	SW	838	96	3	4	1
2	78	60	69	-2	61	0	4	1 3	0	.59	0	28.80	05	4.4	5.9	17	N	463	53	9	8	2
3	86	56	71	0	59	0	6		0	0	0	28.85	24	1.3	2.5	10	SE	868	100	2	2	3
4	86	63	75	4	66	0	10	1 3 8	0	.17	0	28.81	18	9.9	10.6	24	SW	201	23	10	9	4
5	86	61	74	3	62	0	9	1	0	.01	0	28.93	21	6.3	7.3	17	SW	815	95	2	3	5
6	89	58	74	4	66	0	9		0	T	0	29.11	18	3.0	3.9	18	S	534	62	6	5	6
7	83	63	73	3	67	0	8	1 3	0	2.37	0	29.12	16	3.8	10.9	35	N	183	21	9	9	7
8	85	64	75	5	67	0	10	1 3	0	.66	0	29.02	24	2.8	7.2	26	N	304	36	9	8	8
9	80	58	69	-1	65	0	4	1 3	0	.14	0	29.05	07	3.3	3.7	17	E	141	17	9	8	9
10	79	62	71	1	65	0	6	1	0	.02	0	28.98	04	2.7	4.5	13	SE	243	29	9	8	10
11	78	60	69	-1	65	0	4	1	0	1.02	0	28.98	28	3.0	4.6	17	NW	253	30	7	6	11
12	80	54	67	-3	58	0	2	1	0	0	0	29.12	33	1.7	4.0	10	SE	835	99	2	2	12
13	74	60	67	-3	62	0	2	1	0	.20	0	29.02	19	6.3	6.6	16	S	277	33	7	8	13
14	79	58	69	-1	61	0	4	2 8	0	0	0	29.00	31	2.7	2.7	10	NW	298	35	8	7	14
15	76	52	64	-5	57	1	0	1	0	0	0	29.14	06	7.6	7.6	14	NE	506	60	9	9	15
16	60	51	56*	-13	54	9	0	1	0	.46	0	29.18	09	9.5	10.4	18	SE	10	1	10	10	16
17	73	55	64	-5	60	1	0	1 8	0	T	0	29.04	15	6.9	8.2	17	SE	0	0	10	9	17
18	85	50*	68	-1	62	0	3	2	0	0	0	29.04	20	4.2	5.0	10	S	805	97	0	1	18
19	92	64	78	9	71	0	13	1 3	0	.93	0	28.97	17	7.0	10.9	28	NW	565	68	5	5	19
20	94*	68	81*	13	73	0	16	3	0	.50	0	28.88	18	5.0	7.9	29	NW	493	60	7	7	20
21	81	60	71	3	64	0	6	1 3	0	.08	0	28.92	26	7.2	9.5	21	NW	772	94	1	3	21
22	82	52	67	-1	57	0	2		0	0	0	29.22	33	3.7	4.0	9	N	819	100	0	0	22
23	83	51	67	0	57	0	2	1	0	0	0	29.31	17	4.7	5.0	18	SE	717	88	3	2	23
24	84:	61	73	6	62	0	8	1 8	0	0	0	29.23	18	6.7	6.9	17	S	560	69	8	6	24
25	84	65	75	8	65	0	10	1 8	0	T	0	29.16	16	6.9	8.5	17	SE	199	25	7	6	25
26	90	64	77	10	67	0	12	1 8	0	0	0	29.13	17	5.1	6.0	11	S	597	74	7	7	26
27	71	60	66	0	64	0	1	23	0	.65	0	29.16	04	5.1	6.9	17	E	0	0	10	10	27
28	82	60	71	5	65	0	6	1 3 8	0	T	0	29.19	03	1.4	4.3	8	E	135	17	9	8	28
29	82	63	73	7	67	0	8	23 8	0	.84	0	29.16	11	2.4	5.6	27	NW	243	30	10	9	29
30	77	62	70	5.	64	0	5	1 3	0	.35	0	29.05	17	3.9	4.6	17	NW	162	20	9	8	30
31	75	62	69	4	65	0	4	1	0	.50	0	28.98	15	3.2	4.0	16	SE	118	15	9	9	31

SUM	SUM				TOTAL	TOTAL		TOTAL	TOTAL	FOR THE MONTH:						TOTAL	%	SUM	SUM
2529	1832				11	183	NUMBER OF DAYS	9.49	0	29.05	16	2.3	6.3	35	N	12954	FOR	206	194
AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION	DEP.						DATE: 07		POSSIBLE	MONTH	AVG.	AVG.
81.5	59.1	70.3	1.6	63	-29	24	≥ .01 INCH 17	5.44								25372	50	6.6	6.3
					SEASON TO DATE		SNOW, ICE PELLETS												
NUMBER OF DAYS					TOTAL	TOTAL	≥ 1.0 INCH 0	GREATEST IN 24 HOURS AND DATES						GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE					
MAXIMUM TEMP		MINIMUM TEMP			13	539	THUNDERSTORMS 12	PRECIPITATION		SNOW, ICE PELLETS									
≥ 90°	≤ 32°	≤ 32°	≤ 0°		DEP.	DEP.	HEAVY FOG 4	2.37	7	0				0					
4	3	0	0		-40	158	CLEAR 3 PARTLY CLOUDY 7 CLOUDY 16												

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT
+ ALSO ON AN EARLIER DATE, OR DATES.
HEAVY FOG: - VISIBILITY 1/4 MILE OR LESS.
FIGURES FOR WIND DIRECTIONS ARE TENS OF DEGREES CLOCKWISE FROM TRUE NORTH. 00 = CALM.
DATA IN COLS. 6 AND 12-15 ARE BASED ON 7 OR MORE OBSERVATIONS PER DAY AT 3-HOUR INTERVALS.
FASTEST MILE WIND SPEEDS ARE FASTEST OBSERVED ONE-MINUTE VALUES WHEN DIRECTIONS ARE IN TENS OF DEGREES. THE / WITH THE DIRECTION INDICATES PEAK GUST SPEED.
ANY ERRORS DETECTED WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL SUMMARY

TOTAL PCPN IS NEW RECORD FOR AUG.

SUMMARY BY HOURS

HOUR LOCAL TIME	AVERAGES SKY COVER (TENTHS)	STATION PRESSURE IN.	TEMPERATURE AIR °F	WET BULB °F	DEW PT. °F	RELATIVE HUMIDITY %	WIND SPEED M.P.H.	RESULTANT WIND DIRECTION	SPEED M.P.H.
00	5	29.05	64	63	63	94	4.5	17	2.1
03	6	29.04	63	62	62	96	4.9	13	2.3
06	7	29.06	62	61	61	96	5.6	09	1.6
09	7	29.07	69	65	63	82	7.2	14	2.9
12	7	29.06	76	68	64	68	8.3	18	3.2
15	7	29.04	79	69	65	64	8.1	19	2.4
18	5	29.02	76	69	65	69	6.7	20	2.2
21	5	29.05	66	65	63	90	5.0	16	2.0

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A. M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	P. M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	DATE
1																									1
2			T	.18	.01	T	T	.27	.13	T				T	T										2
3																									3
4					T														.04	.08	.05	T		T	4
5	T	.01			T																				5
6								T	T	T															6
7		.47	.04	T		T	.38	.25	.12	.01	.12			.13	.14		.02	.13	.04		.20	.32			7
8				.04	.11	.16	.22	.05	.08						T	T									8
9																						T	.07	.07	9
10		T	T	T	T	.01	T	T	T	.01	T	T	T												10
11				T	T			T	.09	.71	.08	T					.14								11
12																									12
13					T	T	.08	.05	.05	.01	.01														13
14																									14
15																									15
16											T	.05	T	.02	.01	.02	.17	.16	.02	.01	T	T	T	T	16
17			T	T	T	T	T	T	T																17
18																									18
19			T	T	.34	.55	T																		19
20																					.35	.06	.08	.01	20
21	.08	T																							21
22																									22
23																									23
24																									24
25												T													25
26																									26
27															T	T					.65	T			27
28					T			T	T																28
29				T	T			T	.71	.06	.07	T													29
30								.08	T	.18	.05	.04	T	T											30
31			T	T		T	.50	T																	31

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noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA AND INFORMATION SERVICE

Daniel B. Mitchell
DIRECTOR, NATIONAL CLIMATIC CENTER

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY		WEATHER	TEMPERATURE			REL. HUM. %	WIND		SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY		WEATHER	TEMPERATURE			REL. HUM. %	WIND		SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY		WEATHER	TEMPERATURE			REL. HUM. %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW PT. °F		DIR	SPEED KNOTS			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW PT. °F		DIR	SPEED KNOTS			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW PT. °F		DIR	SPEED KNOTS
					DAY 01											DAY 02											DAY 03						
00	10	UNL	10			55	51	47	75	08	8	10	1	0	12	FH	60	58	57	90	19	7	9	6	4		F	55	53	52	90	32	5
03	10	80	10			56	51	47	72	10	10	7	UNL	6		F	56	55	54	93	28	5	8	90	1		F	54	52	51	90	00	0
06	10	47	8		R	55	53	51	86	10	12	3	UNL	6		F	57	55	54	90	34	3	4	UNL	5		F	55	53	52	90	02	4
09	10	14	7			59	56	53	81	07	10	10	11	7			61	56	53	75	01	5	10	22	8			66	58	53	63	08	3
12	10	12	6		H	65	59	55	70	11	8	3	UNL	7			68	61	56	66	11	5	4	UNL	10			70	61	54	57	08	3
15	10	10	5		H	64	59	55	73	13	5	4	UNL	7			76	63	55	48	17	4	6	UNL	10			71	60	52	51	04	3
18	10	9	4		H	64	60	57	78	18	6	10	47	6		TRW	68	62	58	71	06	5	0	UNL	10			71	60	53	53	21	3
21	4	UNL	4		FH	60	58	56	87	17	4	10	250	10			59	57	55	87	08	9	0	UNL	10			62	56	52	70	17	5
					DAY 04											DAY 05											DAY 06						
00	0	UNL	10			60	56	53	78	18	6	10	100	10			58	53	49	72	18	11	10	20	3		TRW	63	59	57	81	32	15
03	8	UNL	10			53	51	49	96	00	0	10	100	10			57	51	46	67	11	8	10	100	10			63	59	56	78	17	14
06	10	250	10			54	51	49	83	06	4	10	38	7			57	53	50	78	11	8	8	31	10			63	59	57	81	30	7
09	10	250	10			64	55	47	54	18	8	10	16	6		TRWH	61	57	55	81	18	11	10	23	10			66	61	58	76	18	3
12	10	160	10			69	59	51	53	16	7	10	140	6		H	67	63	60	78	18	13	10	22	10			72	65	60	66	19	4
15	8	UNL	10			73	61	52	48	18	11	10	12	4		H	76	68	64	66	18	6	10	14	10			77	68	63	62	18	5
18	1	UNL	10			70	60	53	55	13	14	8	45	5		H	75	68	65	71	09	8	10	17	10			77	69	64	64	17	6
21	10	250	10			61	53	47	60	15	7	10	38	5		H	67	63	61	81	11	4	10	UNL	10			69	65	63	81	06	5
					DAY 07											DAY 08											DAY 09						
00	10	250	7			67	64	62	84	08	6	2	UNL	10			53	47	42	66	32	15	0	UNL	10			57	50	44	62	28	10
03	10	20	6		TH	66	62	59	78	13	5	3	UNL	10			46	44	41	83	32	8	1	UNL	10			56	50	44	64	28	9
06	10	8	4		TH	65	62	60	84	10	10	0	UNL	10			50	45	40	69	31	10	6	UNL	10			56	50	45	67	29	8
09	10	200	10			69	65	62	79	19	8	1	UNL	10			58	49	39	49	30	11	9	120	10			63	54	46	54	30	11
12	5	UNL	10			79	68	62	56	23	8	1	UNL	10			65	53	43	45	30	12	10	55	10			67	56	48	51	30	14
15	3	UNL	10			80	67	59	49	31	11	10	55	10			66	53	42	42	30	13	7	250	10			67	57	50	55	31	12
18	8	33	10			70	62	56	61	31	16	2	UNL	10			66	55	45	47	29	13	10	36	10		RW	59	55	51	75	31	10
21	10	60	10			63	57	52	68	33	20	0	UNL	10			58	51	45	62	28	6	0	UNL	10			56	53	51	93	30	5
					DAY 10											DAY 11											DAY 12						
00	2	UNL	10			42	39	36	79	06	4	0	UNL	10			47	43	39	74	34	3	2	UNL	10			52	48	45	77	09	3
03	4	UNL	10			39	38	36	89	00	0	0	UNL	10			42	40	38	86	00	0	4	UNL	10			51	47	44	77	18	4
06	3	UNL	10			38	37	35	89	00	0	0	UNL	10			48	45	43	83	00	0	5	UNL	10			56	52	48	75	18	6
09	2	UNL	10			53	44	33	47	26	4	0	UNL	10			66	54	43	43	29	7	10	UNL	10			70	59	50	49	18	13
12	7	UNL	10			63	50	38	40	35	10	0	UNL	10			~~73~~	~~57~~	~~44~~	37	21	6	10	UNL	10			78	61	48	35	18	12
15	3	UNL	10			67	53	39	36	31	10	0	UNL	10			76	58	44	32	28	4	10	UNL	10			81	62	48	32	18	16
18	9	UNL	10			66	52	38	36	31	8	0	UNL	10			72	58	46	40	18	6	10	UNL	10			72	60	52	50	18	6
21	1	UNL	10			54	47	40	59	35	4	0	UNL	10			60	53	47	62	00	0	6	UNL	10			68	57	48	49	18	11
					DAY 13											DAY 14											DAY 15						
00	4	UNL	10			59	53	48	67	18	7	10	55	6		RWH	69	62	58	68	19	10	10	7	5		H	62	59	57	84	06	13
03	8	120	10			60	54	49	67	18	8	10	80	10			68	60	55	63	18	4	10	4	2		LFH	58	56	55	90	06	13
06	10	100	10			62	56	51	67	18	6	7	250	10			64	60	57	78	17	4	10	28	7		RW	53	50	48	83	05	10
09	7	70	10			70	61	54	57	18	10	0	UNL	10			76	65	59	56	19	7	10	70	7			53	50	47	80	05	8
12	9	45	10			72	63	58	62	18	10	1	UNL	10			83	69	62	49	21	8	10	60	7		RW	54	51	49	83	05	11
15	10	28	7			74	65	59	60	18	10	2	UNL	10			87	70	61	42	29	4	10	90	10			59	52	46	62	02	14
18	8	UNL	6		H	71	65	61	71	17	7	10	UNL	10			84	71	64	51	25	5	10	80	10			59	50	42	54	06	12
21	10	300	6		H	65	61	59	81	18	5	6	UNL	8			71	65	62	73	01	3	8	UNL	10			53	47	41	64	06	4
					DAY 16											DAY 17											DAY 18						
00	0	UNL	10			45	43	41	86	07	4	0	UNL	10			52	47	41	66	18	9	3	UNL	10			60	55	51	72	22	8
03	0	UNL	10			40	39	38	93	31	4	0	UNL	10			47	44	40	77	18	5	10	70	10			59	55	51	75	26	3
06	0	UNL	10			45	43	40	83	34	4	1	UNL	10			53	49	45	74	18	5	9	80	10			59	56	53	81	00	0
09	0	UNL	10			59	49	39	48	02	7	8	250	10			63	56	50	63	26	12	8	80	10			69	60	54	59	27	5
12	0	UNL	10			66	51	35	32	34	7	1	UNL	10			72	60	52	50	23	9	9	80	10			71	61	55	57	31	8
15	0	UNL	10			69	53	37	31	00	0	3	UNL	10			74	61	52	46	22	10	8	80	10			72	63	58	62	05	6
18	0	UNL	10			68	52	37	32	04	3	0	UNL	10			70	60	52	53	22	9	9	UNL	10			67	58	52	59	07	11
21	0	UNL	10			52	47	41	66	08	3	0	UNL	10			63	57	52	68	20	7	10	60	10			58	49	41	53	08	9
					DAY 19											DAY 20											DAY 21						
00	10	47	10		RW	51	49	47	86	06	5	0	UNL	10			50	47	44	80	00	0	8	100	10			58	53	49	72	00	0
03	10	80	10			52	50	48	86	17	3	0	UNL	10			45	43	40	83	18	3	10	80	10			61	54	48	63	22	7
06	10	9	10			51	50	49	93	03	10	1	UNL	10			52	48	45	77	00	0	5	UNL	10			59	54	50	72	18	3
09	10	10	10			52	49	47	83	36	13	1	UNL	10			70	59	51	51	23	6	6	250	10			74	60	50	43	22	8
12	8	20	10			59	52	45	60	36	15	3	UNL	10			76	58	44	32	29	5	3	UNL	10			81	63	50	34	22	11
15	4	UNL	10			67	55	45	45	32	14	9	UNL	10			78	59	45	31	24	6	2	UNL	10			81	62	48	32	23	9
18	0	UNL	10			67	55	44	44	01	7	6	UNL	10			75	59	47	37	23	5	6	UNL	10			75	59	47	37	22	7
21	0	UNL	10			55	50	45	69	00	0	8	UNL	10			65	57	50	59	30	4	8	UNL	10			62	55	49	63	18	6
					DAY 22											DAY 23											DAY 24						
00	6	UNL	10			61	55	50	67	19	5	10	250	10			61	57	55	81	00	0	0	UNL	6		H	65	61	58	78	06	3
03	8	UNL	10			65	59	54	68	19	10	10	UNL	10			59	57	55	87	00	0	1	UNL	2		F	61	59	58	90	00	0
06	9	140	10			64	59	56	75	18	6	9	45	7			65	61	58	78	00	0	1	UNL	1	8	F	66	63	61	84	00	0
09	9	UNL	9			75	64	57	54	25	8	10	UNL	8			79	66	59	50	17	5	1	UNL	4		H	76	68	63	64	06	3
12	8	UNL	10			86	68	57	37	21	10	10	UNL	9			88	71	62	42	12	8	9	UNL	7			86	71	64	48	08	9
15	10	UNL	10			87	67	56	35	18	6	10	35	8			85	70	63	48	17	9	8	UNL	10			89	73	65	45	09	10
18	10	250	10			80	67	60	51	00	0	10	UNL	6		H	81	70	65	58	18	6	6	34	6		H	84	71	64	51	19	8
21	10	250	10			68	61	57	68	00	0	10	UNL	5		H	68	64	62	81	00	0	10	UNL	5		H	70	66	64	81	00	0
					DAY 25											DAY 26											DAY 27						
00	10	120	5		F	67	64	63	87	00	0	1	UNL	6		H	74	69	67	79	22	7	4	UNL	7			64	59	56	75	07	7
03	4	UNL	2		F	66	64	63	90	00	0	7	UNL	6		F	67	65	64	90	10	4	10	250	10			60	57	54	81	06	7
06	9	16	0		F	65	64	64	97	00	0	10	UNL	2		F	72	69	67	84	23	3	10	UNL	10			59	55	51	75	06	7
09	1	UNL	4		H	81	71	66	60	19	5	10	UNL	3		H	85	74	69	59	27	12	10	250	10			67	59	54	63	07	11
12	2	UNL	8			88	72	65	47	21	8	10	UNL	5		H	90	77	71	54	22	8	10	26	8			74	63	56	54	07	11
15	4	UNL	10			90	74	67	47	24	8	10	250	6		H	94	78	72	49	22	10	6	UNL	8			77	65	57	50	09	13
18	0	UNL	7			88	73	66	48	21	8	3	UNL	6		H	92	78	73	54	29	6	10	250	7			73	64	58	59	09	15
21	1	UNL	5		H	74	69	66	76	23	5	10	UNL	6		H	81	69	62	53	36	7	10	100	7			65	60	57	75	08	10
					DAY 28											DAY 29											DAY 30						
00	10	14	3		TRW	63	62	61	93	04	10	0	UNL	10			65	59	55	70	25	5	0	UNL	[illegible]			55	52	50	93	29	5
03	10	120	10			66	63	62	87	30	6	0	UNL	10			64	60	57	78	19	8	0	UNL	10			54	52	50	86	30	5
06	4	UNL	7			66	64	63	90	07	4	1	UNL	10			66	57	50	57	27	14	0	UNL	6		H	58	55	52	81	30	3
09	1	UNL	7			75	69	66	74	23	6	1	UNL	10			68	57	49	51	30	15	1	UNL	10			69	61	55	61	29	4
12	3	UNL	10			80	69	63	56	29	8	8	36	10			69	58	50	51	30	12	5	UNL	10			74	62	54	50	19	8
15	2	UNL	10			87	67	56	35	25	7	9	45	10			68	58	51	55	30	10	10	UNL	10			76	64	56	50	30	6
18	0	UNL	10			84	66	54	36	27	7	9	47	10			66	58	52	61	30	10	10	250	10			73	63	56	55	18	5
21	0	UNL	10			70	63	59	68	22	5	2	UNL	10			61	55	51	70	30	8	8	UNL	10			66	61	57	73	18	5

NOTES

CEILING

UNL INDICATES UNLIMITED

WEATHER

*	TORNADO
T	THUNDERSTORM
Q	SQUALL
R	RAIN
RW	RAIN SHOWERS
ZR	FREEZING RAIN
L	DRIZZLE
ZL	FREEZING DRIZZLE
S	SNOW
SP	SNOW PELLETS
IC	ICE CRYSTALS
SW	SNOW SHOWERS
SG	SNOW GRAINS
IP	ICE PELLETS
A	HAIL
F	FOG
IF	ICE FOG
GF	GROUND FOG
BD	BLOWING DUST
BN	BLOWING SAND
BS	BLOWING SNOW
BY	BLOWING SPRAY
K	SMOKE
H	HAZE
D	DUST

WIND

DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. ENTRY OF 00 IN THE DIRECTION COLUMN INDICATES CALM.

SPEED IS EXPRESSED IN KNOTS; MULTIPLY BY 1.15 TO CONVERT TO MILES PER HOUR.

STATION	YEAR & MONTH
MADISON WISC	80 06

U.S. DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N.C. 28801

AN EQUAL OPPORTUNITY EMPLOYER

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-210

FIRST CLASS

76.

SEPTEMBER 1980
MADISON, WISCONSIN
NATIONAL WEATHER SERVICE OFC
TRUAX FIELD

Local Climatological Data

MONTHLY SUMMARY

SEPTEMBER 1980 MADISON, WISCONSIN

LATITUDE 43 ° 08 ' N LONGITUDE 89 ° 20 ' W ELEVATION (GROUND) 858 FT. STANDARD TIME USED: CENTRAL WBAN #14837

DATE	TEMPERATURE °F MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS BASE 65° HEATING (SEASON BEGINS WITH JULY)	COOLING (SEASON BEGINS WITH JAN.)	WEATHER TYPES ON DATES OF OCCURRENCE 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW, ICE PELLETS OR ICE ON GROUND AT 06AM IN.	PRECIPITATION WATER EQUIVALENT IN	SNOW, ICE PELLETS IN.	AVG. STATION PRESSURE IN. ELEV. 866 FEET M.S.L.	WIND RESULTANT DIR.	RESULTANT SPEED M.P.H.	AVERAGE SPEED M.P.H.	FASTEST MILE SPEED M.P.H.	DIRECTION	SUNSHINE MINUTES	PERCENT OF POSSIBLE	SKY COVER TENTHS SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT	DATE
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	77	63	70	5	65	0	5	1 3	0	.09	0	28.95	20	6.3	7.2	17	SW	105	13	10	9	1
2	76	55	66	2	60	0	1		0	0	0	29.11	30	4.8	5.5	15	NW	757	96	2	3	2
3	83	54	69	5	60	0	4		0	0	0	29.16	17	8.2	8.3	18	S	772	98	4	4	3
4	78	49	64	1	59	1	0	3	0	.16	0	29.13	26	5.0	6.6	17	W	326	42	7	5	4
5	80	46	63	0	55	2	0	2	0	0	0	29.22	21	4.2	4.5	12	SW	732	94	4	3	5
6	78	52	65	2	57	0	0	1 3	0	.02	0	29.23	04	1.0	6.0	15	SE	512	66	6	6	6
7	74	58	66	4	62	0	1	1 3	0	1.80	0	29.13	17	6.0	7.1	17	SE	138	18	9	9	7
8	87*	58	73*	11	66	0	8	1 8	0	0	0	29.12	17	3.6	3.6	11	S	587	76	4	5	8
9	75	50	63	1	58	2	0	1 3	0	.80	0	29.18	31	6.3	8.3	20	N	538	70	8	7	9
10	71	43	57	-4	48	8	0		0	0	0	29.30	29	3.5	3.6	10	W	766	100	0	0	10
11	66	46	56	-5	52	9	0		0	T	0	29.11	08	1.9	4.3	10	NE	50	7	10	8	11
12	71	58	65	4	61	0	0	1 3 8	0	1.53	0	28.96	13	6.2	8.3	16	SE	57	8	10	10	12
13	79	60	70	10	64	0	5	1 3	0	.23	0	28.99	24	4.3	5.9	17	SW	473	62	5	6	13
14	61	53	57	-3	56	8	0	1	0	.02	0	29.16	34	5.2	6.8	13	NE	0	0	10	10	14
15	59	52	56	-4	53	9	0		0	0	0	29.11	14	3.2	6.3	14	SE	17	2	10	9	15
16	60	48	54	-5	52	11	0	1 3 5	0	.61	0	28.84	28	3.2	6.8	15	NW	27	4	10	9	16
17	62	36	49	-10	38	16	0		0	0	0	29.01	33	2.5	6.2	13	NW	553	74	4	5	17
18	71	45	58	-1	48	7	0		0	T	0	29.11	22	5.4	9.5	15	SW	478	64	5	4	18
19	76	43	60	2	52	5	0	3	0	T	0	29.11	16	7.1	8.8	20	S	501	68	8	7	19
20	77	62	70	12	64	0	5	1 3 8	0	1.00	0	28.91	21	1.6	8.6	26	S	191	26	8	8	20
21	74	59	67	9	60	0	2	3	0	.48	0	28.82	25	5.0	8.6	24	S	306	42	6	6	21
22	68	47	58	0	56	7	0	1 3	0	.85	0	28.91	31	4.9	9.2	20	NW	276	38	8	6	22
23	61	38	50	-7	40	15	0		0	0	0	29.21	01	2.9	5.3	9	N	689	95	2	1	23
24	62	42	52	-5	44	13	0		0	0	0	29.13	19	3.6	3.9	14	S	304	42	8	7	24
25	60	43	52	-5	45	13	0	1	0	.09	0	29.08	30	6.4	6.8	21	NW	171	24	9	8	25
26	57	31*	44*	-13	36	21	0		0	0	0	29.40	28	3.8	6.5	11	N	708	98	2	4	26
27	69	45	57	1	44	8	0		0	0	0	29.25	21	6.5	7.1	17	SW	671	94	4	3	27
28	60	44	52	-4	51	13	0	1 8	0	.16	0	29.22	10	3.6	5.0	11	SE	0	0	10	8	28
29	72	44	58	2	50	7	0	1 8	0	0	0	29.09	18	6.4	6.6	14	S	677	95	3	3	29
30	75	48	62	7	56	3	0	1 8	0	0	0	28.98	25	1.8	4.5	10	SW	257	36	8	6	30
	SUM	SUM				TOTAL	TOTAL			TOTAL	TOTAL	FOR THE MONTH:						TOTAL	%	SUM	SUM	
	2119	1472				173	31	NUMBER OF DAYS		7.34	0	29.10	22	2.3	6.5	26	S	11639	FOR	194	179	
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.							DATE: 20	POSSIBLE	MONTH	AVG.	AVG.	
	70.6	49.1	59.3	3.2	54	5	17	≥ .01 INCH 14		4.48								22499	52	6.5	6.3	

NUMBER OF DAYS				SEASON TO DATE		SNOW, ICE PELLETS	GREATEST IN 24 HOURS AND DATES			GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
MAXIMUM TEMP.		MINIMUM TEMP.		TOTAL	TOTAL	≥ 1.0 INCH 0	PRECIPITATION		SNOW, ICE PELLETS	
≥ 90°	≤ 32°	≤ 32°	≤ 0°	191	529	THUNDERSTORMS 12	1.32	6- 7	0	0
0	0	1	0	DEP.	DEP.	HEAVY FOG 1				
				-35	175	CLEAR 5 PARTLY CLOUDY 10 CLOUDY 15				

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT
+ ALSO ON AN EARLIER DATE, OR DATES.
HEAVY FOG: - VISIBILITY 1/4 MILE OR LESS.
FIGURES FOR WIND DIRECTIONS ARE TENS OF DEGREES CLOCKWISE FROM TRUE NORTH. 00 = CALM. DATA IN COLS. 6 AND 12-15 ARE BASED ON 7 OR MORE OBSERVATIONS PER DAY AT 3-HOUR INTERVALS. FASTEST MILE WIND SPEEDS ARE FASTEST OBSERVED ONE-MINUTE VALUES WHEN DIRECTIONS ARE IN TENS OF DEGREES. THE / WITH THE DIRECTION INDICATES PEAK GUST SPEED.
ANY ERRORS DETECTED WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL SUMMARY

SUMMARY BY HOURS

HOUR LOCAL TIME	AVERAGES SKY COVER (TENTHS)	STATION PRESSURE IN.	TEMPERATURE AIR °F	WET BULB °F	DEW PT. °F	RELATIVE HUMIDITY %	WIND SPEED M.P.H.	RESULTANT WIND DIRECTION	SPEED M.P.H.
00	6	29.09	56	54	53	90	5.9	20	2.1
03	5	29.09	53	52	52	94	5.5	20	1.5
06	7	29.10	53	52	52	96	4.9	23	1.0
09	7	29.12	61	58	55	81	7.6	23	2.9
12	7	29.12	66	59	54	68	8.4	24	4.4
15	6	29.09	68	61	55	64	7.9	25	3.6
18	5	29.08	63	59	55	76	6.8	22	1.1
21	5	29.09	57	55	54	90	5.2	14	1.3

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	P.M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	DATE
1			T	.02	T													.05	.02						1
2																									2
3																									3
4		.07	.03	.05	.01																				4
5																									5
6																					T	.01	.01		6
7	T	.04	.17	.28	.12	.17	.25	.19	.35	.20	.03		T	T											7
8																									8
9		.48	.32	T																					9
10																									10
11																		T	T						11
12				.05	.23	.24	.37	.49	.12	T												T	T	.03	12
13	.20	.01	.01			T													T	.01					13
14							T	T	T	T	T	T	.02	T											14
15																									15
16							T	T		T			.25	.22	.06	.07	.01	T							16
17																									17
18								T																	18
19																								T	19
20	.40	.14	.19	.13	.11	.02	.01	T		T		T										T	T		20
21																						.01	.06	.41	21
22	T	.12	.60	.12	T				T	.01	T	T													22
23																									23
24																									24
25					T	.06	.02					T	.01							T			T	T	25
26																									26
27																									27
28							.11	T	T					T	.02	.03	T								28
29																									29
30																									30

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noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA AND INFORMATION SERVICE

Daniel B. Mitchell
DIRECTOR, NATIONAL CLIMATIC CENTER

USCOMM—NOAA—ASHEVILLE 10/31/80 500

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
					DAY 01						
00	0	UNL	7			53	53	53	100	18	4
03	0	UNL	7			59	58	58	97	18	7
06	10	250	7			58	56	55	90	18	6
09	10	250	7			61	58	56	84	28	8
12	10	120	10			63	56	51	65	32	12
15	10	80	10			58	53	48	70	31	7
18	3	UNL	7			53	49	45	74	26	5
21	5	UNL	7			52	48	45	77	28	7
					DAY 02						
00	0	UNL	7			46	44	43	89	30	6
03	0	UNL	7			45	43	40	83	27	6
06	0	UNL	7			41	40	38	89	14	4
09	7	100	10			55	49	44	67	27	12
12	8	UNL	10			58	51	44	60	30	10
15	9	42	10			55	48	41	59	30	17
18	10	13	7		RW	45	44	43	93	31	11
21	10	12	7		RW	39	38	37	93	01	7
					DAY 03						
00	10	27	10			38	37	35	89	33	10
03	6	45	10			34	33	31	89	33	8
06	5	UNL	10			31	31	30	96	34	5
09	10	40	10			41	38	34	76	32	7
12	10	27	10			42	37	31	65	33	8
15	10	45	10			44	38	29	56	32	8
18	10	50	10			40	37	32	73	00	0
21	10	55	10			36	35	33	89	06	3
					DAY 04						
00	10	55	10			34	34	33	96	00	0
03	10	55	10			35	35	34	96	00	0
06	10	50	10			36	35	34	92	33	3
09	2	UNL	7			43	38	31	63	05	9
12	9	42	7			47	39	29	50	04	7
15	6	55	7			46	38	28	50	35	8
18	0	UNL	10			37	33	27	67	05	5
21	0	UNL	10			30	29	27	89	00	0
					DAY 05						
00	0	UNL	10			27	27	26	96	00	0
03	0	UNL	10			25	25	24	96	00	0
06	0	UNL	6		F	23	23	23	100	00	0
09	0	UNL	7			44	38	31	60	00	0
12	0	UNL	7			50	41	30	46	20	6
15	0	UNL	7			54	43	30	40	30	4
18	0	UNL	10			43	38	31	63	18	5
21	0	UNL	10			38	36	32	79	18	6
					DAY 06						
00	0	UNL	10			40	37	32	73	19	7
03	3	UNL	10			39	36	32	76	19	6
06	5	UNL	10			44	39	33	65	19	10
09	6	250	10			52	44	36	55	22	12
12	0	UNL	10			62	52	42	48	24	10
15	8	UNL	10			65	54	44	47	30	9
18	10	UNL	10			56	49	43	62	29	4
21	10	250	10			53	48	43	69	29	6
					DAY 07						
00	7	200	10			46	44	42	86	00	0
03	0	UNL	10			41	40	39	93	00	0
06	3	UNL	7			37	37	36	96	00	0
09	0	UNL	7			58	52	46	65	18	6
12	0	UNL	10			70	58	49	47	23	9
15	0	UNL	10			73	59	49	43	21	11
18	2	UNL	10			65	56	49	56	19	12
21	1	UNL	10			60	53	48	65	19	7
					DAY 08						
00	0	UNL	7			58	52	47	67	20	9
03	0	UNL	7			55	50	46	72	20	5
06	0	UNL	7			48	46	45	89	19	3
09	0	UNL	8			65	56	49	56	32	10
12	0	UNL	10			74	61	51	45	33	7
15	0	UNL	10			76	60	49	39	30	10
18	0	UNL	10			62	54	47	58	33	4
21	0	UNL	10			49	46	44	83	07	7
					DAY 09						
00	0	UNL	7			46	44	43	89	06	6
03	0	UNL	7			42	41	39	89	35	4
06	0	UNL	7			35	35	35	100	35	4
09	0	UNL	10			51	47	43	74	06	7
12	0	UNL	10			60	50	41	50	07	8
15	0	UNL	10			64	53	43	47	11	7
18	0	UNL	10			51	46	40	66	09	6
21	0	UNL	10			46	42	37	71	16	6
					DAY 10						
00	1	UNL	10			43	41	38	83	18	6
03	4	UNL	10			47	44	40	77	19	7
06	5	UNL	10			48	45	41	77	22	10
09	9	120	8			53	48	44	72	25	7
12	0	UNL	10			65	51	36	34	29	10
15	0	UNL	10			65	49	31	28	28	12
18	1	UNL	10			57	45	31	37	24	8
21	10	70	10			56	46	34	44	30	13
					DAY 11						
00	10	42	10			49	42	34	56	30	13
03	10	34	10			45	39	32	60	30	12
06	10	28	10			42	37	31	65	30	12
09	10	25	10			43	38	32	65	31	15
12	10	26	10			45	39	32	60	30	13
15	10	31	10			45	39	31	58	30	14
18	10	36	10			43	37	28	56	30	11
21	10	40	10			42	37	30	63	31	12
					DAY 12						
00	2	UNL	10			35	31	25	67	33	10
03	0	UNL	10			30	28	25	82	31	5
06	1	UNL	10			32	20	26	79	31	8
09	8	27	10			41	36	28	60	35	13
12	0	UNL	10			47	39	29	50	30	8
15	0	UNL	10			50	40	26	39	30	7
18	0	UNL	10			40	36	29	65	00	0
21	0	UNL	10			33	31	28	82	00	0
					DAY 13						
00	0	UNL	10			27	27	25	92	00	0
03	0	UNL	8			25	25	24	96	05	4
06	1	UNL	8			24	24	23	96	32	3
09	1	UNL	10			42	37	31	65	06	7
12	3	UNL	10			49	41	30	48	07	6
15	10	250	10			50	41	30	46	12	7
18	10	80	10		RW	47	41	33	58	07	8
21	10	75	10			42	39	35	76	10	10
					DAY 14						
00	10	75	10			41	38	35	79	08	9
03	10	80	10			43	40	36	76	08	14
06	10	42	10		RW	42	41	39	89	09	14
09	10	10	5		F	44	43	42	93	06	14
12	10	16	5		F	48	46	44	86	06	11
15	10	25	6		H	50	47	44	80	06	9
18	10	27	6		FH	46	44	43	89	06	10
21	10	4	3		F	44	43	43	96	05	11
					DAY 15						
00	10	4	1	8	F	43	42	42	96	05	8
03	10	4	3		F	43	42	42	96	05	7
06	10	4	2		F	42	42	42	100	04	6
09	10	7	2		F	43	42	41	93	04	9
12	10	10	3		F	46	44	42	86	06	8
15	10	11	3		F	46	44	42	86	06	7
18	10	10	3		F	45	44	42	89	07	5
21	10	6	3		F	44	43	43	96	06	5
					DAY 16						
00	10	6	3		F	44	44	44	100	07	3
03	10	4	3		F	45	45	45	100	06	4
06	10	2	1	9	F	47	47	47	100	06	4
09	10	3	1		F	50	50	50	100	09	8
12	10	28	1	8	F	58	56	55	90	10	10
15	10	10	1		RWF	58	58	58	100	18	10
18	10	40	1	8	RWF	61	60	60	97	17	11
21	10	28	5		RWF	62	60	59	90	18	10
					DAY 17						
00	10	14	7			63	61	60	90	18	14
03	9	14	7			63	61	60	90	18	8
06	4	UNL	7			61	60	59	93	18	12
09	5	UNL	7			63	59	56	78	19	20
12	3	UNL	10			67	54	43	42	20	20
15	2	UNL	7			58	48	38	48	24	18
18	2	UNL	10			48	42	34	59	25	18
21	10	19	10			48	42	35	61	25	15
					DAY 18						
00	10	25	10			46	40	33	61	24	13
03	10	25	10			46	41	34	63	27	11
06	9	25	10			46	41	34	63	23	10
09	10	25	10			44	39	33	65	29	15
12	10	36	10			48	41	33	56	29	13
15	10	28	10			46	41	34	63	28	13
18	10	16	10			43	39	34	71	27	13
21	10	25	9		L	40	37	32	73	30	10
					DAY 19						
00	10	17	10			39	36	33	79	29	10
03	10	26	10			39	37	34	82	30	8
06	8	40	10			37	36	34	89	28	8
09	0	UNL	10			43	39	33	68	29	7
12	7	80	10			51	41	27	39	23	14
15	10	70	10			50	41	29	44	25	8
18	10	50	10			47	41	33	58	29	5
21	10	70	10			44	41	37	76	30	3
					DAY 20						
00	2	UNL	10			35	35	34	96	00	0
03	10	42	10			42	40	37	83	27	5
06	2	UNL	10			36	35	34	92	36	3
09	1	UNL	6		H	45	42	39	80	27	8
12	8	33	10			54	46	37	53	29	10
15	6	40	10			55	47	38	53	29	13
18	0	UNL	9			48	44	39	71	24	7
21	0	UNL	10			49	46	42	77	20	12
					DAY 21						
00	10	70	10			54	48	41	62	28	9
03	0	UNL	10			45	41	36	71	30	8
06	0	UNL	10			37	34	29	73	31	9
09	0	UNL	10			45	39	32	60	30	10
12	2	UNL	10			54	44	32	43	30	11
15	9	250	10			53	43	30	41	30	9
18	8	UNL	10			43	38	30	60	34	3
21	8	70	10			37	35	31	79	00	0
					DAY 22						
00	0	UNL	10			31	30	29	92	00	0
03	0	UNL	10			27	27	25	92	32	3
06	0	UNL	10			25	25	25	100	00	0
09	7	UNL	8			44	39	33	65	09	4
12	10	250	10			49	41	32	52	13	7
15	10	200	10			50	42	31	48	13	9
18	10	50	9			45	41	37	74	09	11
21	10	UNL	9			42	39	34	73	09	11
					DAY 23						
00	10	250	10			40	38	36	86	12	7
03	6	100	10			42	40	37	83	12	8
06	7	90	10			42	39	36	79	12	8
09	10	UNL	10			48	42	36	63	14	12
12	10	250	7			54	48	42	64	15	14
15	10	UNL	7			60	52	44	56	13	15
18	8	100	10			51	47	42	71	12	12
21	10	100	10			53	47	42	66	16	15
					DAY 24						
00	7	65	10			55	47	39	55	16	13
03	7	70	10			52	45	37	57	18	9
06	10	45	10			46	42	37	71	13	6
09	10	20	2		RWF	45	44	44	96	29	3
12	10	13	7		R	44	43	43	96	31	10
15	10	7	5		LF	41	41	40	96	30	11
18	10	15	5		RF	38	37	35	89	30	10
21	10	5	5		RF	34	34	33	96	30	10
					DAY 25						
00	10	18	7			35	34	32	89	30	7
03	10	31	10			34	31	27	76	30	8
06	10	38	10			32	30	27	82	30	14
09	10	36	8		S	33	31	27	79	30	11
12	10	26	9		SW	35	31	25	67	30	14
15	10	25	7		RSSG	34	31	26	73	30	15
18	10	33	10			34	30	24	67	30	17
21	10	38	10			33	29	23	67	30	16
					DAY 26						
00	10	33	10			33	29	22	64	30	14
03	10	31	10			32	28	21	64	30	10
06	10	30	10			31	27	20	64	30	15
09	10	28	10			32	28	20	61	30	13
12	10	29	10			35	30	21	57	31	12
15	9	33	10			35	30	21	57	30	10
18	7	UNL	10			29	27	21	72	28	5
21	5	UNL	10			22	22	21	96	00	0
					DAY 27						
00	6	250	10			22	22	21	96	00	0
03	10	250	8			21	21	21	100	00	0
06	10	250	10			22	22	21	96	00	0
09	10	200	6		F	30	29	26	95	00	0
12	10	200	6		H	34	30	23	64	17	5
15	10	70	8			34	30	23	64	00	0
18	10	90	10			32	30	26	79	36	6
21	10	100	10			31	29	25	78	00	0
					DAY 28						
00	2	UNL	10			25	25	23	92	33	9
03	1	UNL	10			21	21	20	96	32	8
06	0	UNL	10			20	20	19	96	34	8
09	0	UNL	10			32	29	24	72	33	9
12	0	UNL	10			38	31	18	44	31	12
15	0	UNL	10			43	33	16	34	30	9
18	0	UNL	10			31	26	17	56	30	7
21	0	UNL	10			29	25	16	58	30	9
					DAY 29						
00	0	UNL	10			24	23	18	78	31	4
03	0	UNL	10			20	19	16	84	31	3
06	0	UNL	10			17	17	15	92	00	0
09	6	UNL	7			31	28	22	69	29	4
12	6	UNL	7			43	34	17	35	24	7
15	3	UNL	7			45	34	13	27	30	6
18	0	UNL	10			32	27	18	56	00	0
21	0	UNL	10			26	24	20	78	00	0
					DAY 30						
00	0	UNL	10			30	27	21	69	22	5
03	0	UNL	8			29	28	25	85	20	9
06	0	UNL	7			29	28	25	85	20	10
09	6	200	6		H	38	33	26	62	20	15
12	8	120	7			47	40	30	52	21	16
15	4	UNL	7			53	44	33	47	25	17
18	0	UNL	7			47	42	35	63	22	10
21	0	UNL	10			42	39	35	76	26	3
					DAY 31						
00	0	UNL	10			39	36	31	73	27	9
03	1	UNL	10			39	35	29	67	26	8
06	3	UNL	10			37	33	27	67	30	4
09	4	UNL	10			44	37	27	51	28	11
12	4	UNL	10			55	42	25	31	28	15
15	7	UNL	10			56	42	23	28	29	13
18	8	UNL	10			49	39	24	38	29	8
21	0	UNL	10			39	33	24	55	30	6

NOTES

CEILING

UNL INDICATES UNLIMITED

WEATHER

*	TORNADO
T	THUNDERSTORM
Q	SQUALL
R	RAIN
RW	RAIN SHOWERS
ZR	FREEZING RAIN
L	DRIZZLE
ZL	FREEZING DRIZZLE
S	SNOW
SP	SNOW PELLETS
IC	ICE CRYSTALS
SW	SNOW SHOWERS
SG	SNOW GRAINS
IP	ICE PELLETS
A	HAIL
F	FOG
IF	ICE FOG
GF	GROUND FOG
BD	BLOWING DUST
BN	BLOWING SAND
BS	BLOWING SNOW
BY	BLOWING SPRAY
K	SMOKE
H	HAZE
D	DUST

WIND

DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. ENTRY OF 00 IN THE DIRECTION COLUMN INDICATES CALM.

SPEED IS EXPRESSED IN KNOTS: MULTIPLY BY 1.15 TO CONVERT TO MILES PER HOUR.

STATION

MADISON WISC

YEAR & MONTH

80 10

U.S. DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N.C. 28801

AN EQUAL OPPORTUNITY EMPLOYER

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-210

U.S.MAIL

FIRST CLASS

OCTOBER 1980
MADISON, WISCONSIN
NATIONAL WEATHER SERVICE OFC
TRUAX FIELD

Local Climatological Data

MONTHLY SUMMARY

OCTOBER 1980 MADISON, WISCONSIN

LATITUDE 43 ° 08 ' N LONGITUDE 89 ° 20 ' W ELEVATION (GROUND) 858 FT. STANDARD TIME USED: CENTRAL WBAN #14837

DATE	TEMPERATURE °F MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS BASE 65° HEATING (SEASON BEGINS WITH JUL 1)	COOLING (SEASON BEGINS WITH JAN 1)	WEATHER TYPES ON DATES OF OCCURRENCE 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW, ICE PELLETS OR ICE ON GROUND AT 06AM IN.	PRECIPITATION WATER EQUIVALENT IN	SNOW, ICE PELLETS IN.	AVG. STATION PRESSURE IN. ELEV. 866 FEET M.S.L.	WIND RESULTANT DIR.	RESULTANT SPEED M.P.H.	AVERAGE SPEED M.P.H.	FASTEST MILE SPEED M.P.H.	DIRECTION	SUNSHINE MINUTES	PERCENT OF POSSIBLE	SKY COVER TENTHS SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT	DATE
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	66	46	56	1	51	9	0		0	T	0	28.82	27	4.7	8.1	16	NW	152	22	9	6	1
2	60	38	49	-6	41	16	0		0	.08	0	28.91	30	8.4	10.5	20	NW	353	50	6	6	2
3	45	31	38	-17	32	27	0		0	0	0	29.04	33	6.6	7.1	14	N	54	8	10	8	3
4	48	27	38	-17	30	27	0		0	0	0	29.10	03	4.0	4.6	13	N	385	55	7	6	4
5	56	23	40	-14	28	25	0	1	0	0	0	29.35	20	2.2	3.0	10	S	693	100	0	0	5
6	65	37	51	-3	38	14	0		0	0	0	29.21	23	6.8	9.2	18	SW	577	84	6	6	6
7	75	37	56	2	45	9	0	1	0	0	0	29.06	20	6.2	6.5	16	SW	630	92	0	1	7
8	77*	46	62*	9	47	3	0		0	0	0	28.86	29	3.0	7.9	12	N	685	100	0	0	8
9	65	35	50	-3	40	15	0		0	0	0	29.09	07	4.8	6.9	15	E	682	100	0	0	9
10	67	43	55	2	37	10	0		0	T	0	28.89	25	8.0	10.5	28	W	474	70	3	5	10
11	47	35	41	-11	31	24	0		0	0	0	28.95	30	14.6	14.7	24	NW	3	0	10	9	11
12	50	27	39	-13	27	26	0		0	0	0	29.23	32	6.9	7.3	14	N	523	78	3	1	12
13	54	23	39	-12	29	26	0		0	.03	0	29.27	08	5.3	6.5	14	SE	421	63	5	5	13
14	51	41	46	-5	41	19	0	1 8	0	.04	0	29.08	07	12.9	13.2	19	NE	0	0	10	10	14
15	46	41	44	-7	42	21	0	1	0	T	0	29.15	05	7.8	7.9	13	NE	0	0	10	10	15
16	63	44	54	4	52	11	0	1 3	0	.50	0	28.98	13	5.8	8.6	18	S	0	0	10	10	16
17	67	46	57	7	48	8	0	1	0	0	0	28.66	21	15.6	18.0	28	SW	422	64	4	6	17
18	50	39	45	-4	33	20	0		0	T	0	28.86	27	13.1	14.1	22	W	80	12	9	10	18
19	52	35	44	-5	33	21	0	1	0	0	0	28.97	27	8.1	9.1	17	SW	293	45	7	6	19
20	56	34	45	-4	38	20	0	1 8	0	0	0	28.96	27	6.5	8.3	17	NW	303	47	6	5	20
21	55	31	43	-5	33	22	0		0	0	0	29.07	30	8.3	8.5	19	NW	520	90	4	3	21
22	53	23	38	-10	31	27	0		0	0	0	29.28	10	5.3	6.5	15	SE	261	40	8	6	22
23	61	40	51	4	39	14	0	3	0	.02	0	29.26	14	12.6	13.1	21	SE	319	50	10	9	23
24	55	34	45	-2	39	20	0	1	0	.46	0	28.96	27	4.1	10.4	16	NW	0	0	10	10	24
25	35	31	33	-13	26	32	0		0	T	T	28.96	30	14.7	14.7	23	NW	0	0	10	10	25
26	37	20	29	-17	21	36	0		0	0	0	29.15	30	11.3	11.4	23	NW	130	21	10	9	26
27	35	20	28*	-17	23	37	0	1 8	0	0	0	29.16	04	.2	1.6	10	NE	0	0	10	9	27
28	43	18	31	-14	19	34	0	1	0	0	0	29.23	32	9.9	10.2	15	NW	628	100	0	0	28
29	45	16*	31.	-13	17	34	0	1	0	0	0	29.37	28	3.0	3.5	9	W	626	100	5	2	29
30	53	29	41	-3	29	24	0	1 8	0	0	0	29.20	22	11.5	12.2	20	SW	465	75	5	2	30
31	59	31	45	2	26	20	0		0	0	0	29.11	28	10.4	10.6	19	W	529	85	5	3	31

SUM	SUM				TOTAL	TOTAL			TOTAL	TOTAL	FOR THE MONTH:						TOTAL	%	SUM	SUM
1691	1021				651	0	NUMBER OF DAYS		1.13	T	29.07	28	3.2	9.2	28	SW	10209	FOR	192	175
AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.						DATE: 17+		POSSIBLE MONTH		AVG.	AVG.
54.5	32.9	43.7	-6.2	34	177	-6	≥ .01 INCH	6	-1.03								20523	50	6.2	5.6
					SEASON TO DATE		SNOW, ICE PELLETS													
NUMBER OF DAYS					TOTAL	TOTAL	≥ 1.0 INCH	0	GREATEST IN 24 HOURS AND DATES								GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE			
MAXIMUM TEMP.		MINIMUM TEMP.			942	629	THUNDERSTORMS	2	PRECIPITATION			SNOW, ICE PELLETS								
≥ 90°	≤ 32°	≤ 32°	≤ 0°		DEP.	DEP.	HEAVY FOG	0	.50	16		T	25				T	25		
0	0	14	0		142	169	CLEAR 7	PARTLY CLOUDY 11	CLOUDY 13											

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT
\+ ALSO ON AN EARLIER DATE, OR DATES.
HEAVY FOG: - VISIBILITY 1/4 MILE OR LESS.
FIGURES FOR WIND DIRECTIONS ARE TENS OF DEGREES CLOCKWISE FROM TRUE NORTH. 00 = CALM.
DATA IN COLS. 6 AND 12-16 ARE BASED ON 7 OR MORE OBSERVATIONS PER DAY AT 3-HOUR INTERVALS.
FASTEST MILE WIND SPEEDS ARE FASTEST OBSERVED ONE-MINUTE VALUES WHEN DIRECTIONS ARE IN TENS OF DEGREES. THE / WITH THE DIRECTION INDICATES PEAK GUST SPEED.
ANY ERRORS DETECTED WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL SUMMARY

SUMMARY BY HOURS

HOUR LOCAL TIME	AVERAGES SKY COVER (TENTHS)	STATION PRESSURE IN.	TEMPERATURE AIR °F	WET BULB °F	DEW PT. °F	RELATIVE HUMIDITY %	WIND SPEED M.P.H.	RESULTANT WIND DIRECTION	SPEED M.P.H.
00	5	29.07	40	38	35	82	7.6	27	2.4
03	5	29.06	39	37	34	83	7.2	27	2.3
06	5	29.07	37	35	33	86	7.4	27	2.0
09	6	29.09	45	41	36	71	10.6	29	3.7
12	6	29.08	51	44	35	56	12.0	28	4.8
15	7	29.05	52	44	34	54	11.6	28	6.3
18	6	29.06	45	41	35	67	8.8	27	2.7
21	6	29.08	42	39	34	76	9.2	27	1.9

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A. M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	P. M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	DATE
1													T		T	T									1
2										T	T			.02		.02	T	.01	.03	T	T	T	T		2
3																									3
4																									4
5																									5
6																									6
7																									7
8																									8
9																									9
10								T	T																10
11																									11
12																									12
13																		T	.03	T					13
14					.02	.02	T	T																	14
15																						T	T	T	15
16				.02	.02								T	.29	.17	T	T	T	T	T	T	T	T	T	16
17																									17
18																				T	T	T			18
19																									19
20																									20
21																									21
22																									22
23											.01	.01													23
24							T	T	.12	.11	.09	T	.01	T	.01	T	.01	.03	.04	.01	.02	.01	T		24
25							T	T	T	T	T	T	T	T	T										25
26																									26
27																									27
28																									28
29																									29
30																									30
31																									31

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noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA AND INFORMATION SERVICE

Daniel B. Mitchell
DIRECTOR, NATIONAL CLIMATIC CENTER

OBSERVATIONS AT 3-HOUR INTERVALS

DAY 01

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	300	4		F	63	63	63	100	09	3
03	10	20	2		TRWF	68	67	66	93	18	6
06	10	170	10			65	65	65	100	18	4
09	10	250	10			67	63	64	90	23	6
12	10	250	10			72	67	65	79	22	7
15	10	UNL	10			76	70	67	74	21	7
18	8	28	8		RW	72	68	66	82	19	10
21	3	UNL	8			68	67	66	93	19	7

DAY 02

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	6	UNL	10			66	65	65	97	23	4
03	10	250	10			63	63	63	100	28	3
06	1	UNL	7			59	58	58	97	30	8
09	0	UNL	10			67	63	60	78	30	6
12	4	UNL	10			73	64	58	59	29	3
15	6	UNL	10			74	64	57	55	30	5
18	1	UNL	10			72	64	59	64	36	4
21	4	UNL	10			58	57	57	96	00	0

DAY 03

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	2	UNL	7			59	58	57	93	15	3
03	6	80	10			59	58	57	93	14	3
06	6	UNL	10			57	56	55	93	17	6
09	3	UNL	10			72	65	61	68	18	8
12	4	UNL	10			80	68	61	52	18	8
15	0	UNL	10			83	69	62	49	18	13
18	0	UNL	10			77	67	62	60	18	9
21	0	UNL	10			69	64	61	76	17	8

DAY 04

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	250	10			66	62	59	78	18	9
03	10	90	10		RW	63	61	60	90	00	0
06	10	120	10			62	61	61	97	00	0
09	9	120	10			69	65	63	81	23	8
12	9	16	10			69	66	64	84	29	10
15	4	UNL	10			77	67	62	60	29	9
18	0	UNL	10			70	60	52	53	24	6
21	0	UNL	10			58	55	53	84	29	5

DAY 05

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	10			49	49	49	100	00	0
03	0	UNL	10			49	48	48	96	18	6
06	3	UNL	10			49	49	49	100	00	0
09	9	UNL	10			67	60	56	68	23	5
12	2	UNL	10			75	62	53	46	19	9
15	2	UNL	10			79	67	61	54	23	6
18	1	UNL	10			75	68	65	71	22	5
21	0	UNL	10			62	61	61	97	00	0

DAY 06

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	2	UNL	2		F	57	57	57	100	32	6
03	1	UNL	1		F	53	53	53	100	31	5
06	0	UNL	3		F	53	53	53	100	32	5
09	0	UNL	10			69	61	55	61	06	4
12	8	UNL	10			76	64	57	52	18	5
15	10	250	10			77	64	56	48	19	3
18	10	270	10			69	64	61	75	07	8
21	10	90	10		TRW	66	63	61	84	12	6

DAY 07

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	80	10		T	63	60	58	84	18	9
03	10	50	6		TRWF	60	59	58	93	19	6
06	10	70	4		TRWF	60	59	59	97	18	9
09	10	40	5		TRWF	61	60	60	97	20	8
12	10	55	10		T	65	63	62	90	18	4
15	3	UNL	10			72	69	67	84	18	4
18	10	47	10			67	66	66	97	11	5
21	10	30	10			65	64	64	97	09	4

DAY 08

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	7	250	10			62	62	62	100	00	0
03	2	UNL	10			58	58	58	100	00	0
06	6	250	3		F	58	58	58	100	00	0
09	0	UNL	5		H	71	65	62	73	17	5
12	1	UNL	5		H	80	72	68	67	18	5
15	4	UNL	6		H	87	78	75	68	16	5
18	7	UNL	7			80	76	74	82	18	5
21	10	250	7			74	73	73	97	18	5

DAY 09

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	250	7			75	72	71	87	19	5
03	10	40	7		TRW	67	67	67	100	13	3
06	7	100	10			65	64	64	97	32	8
09	9	250	10			63	60	58	84	31	11
12	9	250	10			66	60	55	68	31	9
15	9	UNL	10			67	57	50	55	32	13
18	4	UNL	10			62	56	51	67	31	6
21	1	UNL	10			52	50	49	90	35	3

DAY 10

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	10			51	49	48	90	00	0
03	0	UNL	10			45	45	45	100	31	4
06	8	UNL	10			44	44	44	100	00	0
09	0	UNL	10			61	54	49	65	30	6
12	0	UNL	10			66	54	44	45	29	4
15	0	UNL	10			71	59	50	48	29	7
18	0	UNL	10			65	57	50	59	27	4
21	0	UNL	10			54	52	50	86	00	0

DAY 11

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	10			49	48	48	96	00	0
03	3	UNL	10			50	48	47	89	04	3
06	8	UNL	10			47	47	47	100	00	0
09	10	100	10			62	57	53	73	18	5
12	9	90	10			65	53	52	63	23	5
15	10	90	10			65	60	57	75	06	4
18	10	75	7		RW	62	60	58	87	04	7
21	10	80	10			58	56	55	90	07	6

DAY 12

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	70	10			60	57	55	84	11	7
03	10	50	10			60	58	57	90	10	7
06	10	11	1		TRWF	59	59	59	100	11	6
09	10	4	2	8	RWF	59	59	59	100	08	9
12	9	13	5		H	66	63	61	84	18	13
15	8	14	5		H	69	65	63	81	18	8
18	10	250	4		FH	67	66	65	93	09	4
21	10	250	5		FH	67	66	65	93	19	4

DAY 13

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	30	4		TRWF	66	65	64	93	19	8
03	10	80	7			64	63	62	93	22	7
06	10	120	7		RW	60	60	60	100	00	0
09	4	UNL	10			70	66	63	79	20	9
12	4	UNL	10			75	69	66	74	28	10
15	2	UNL	10			77	69	64	64	29	5
18	4	UNL	10			72	68	66	82	31	3
21	5	UNL	10			63	63	63	100	00	0

DAY 14

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	2	UNL	10			61	60	60	97	30	5
03	9	14	10			59	58	58	97	30	5
06	10	19	10			59	58	57	93	31	6
09	10	8	10			58	57	57	96	31	7
12	10	5	2		LF	58	58	58	100	32	5
15	10	12	10			57	55	54	90	02	8
18	10	20	7			55	53	52	90	03	6
21	10	23	10			54	52	51	90	04	5

DAY 15

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	30	10			53	52	51	93	03	5
03	10	8	10			52	51	51	96	05	4
06	10	8	10			52	51	51	96	05	4
09	10	34	8			56	54	53	90	11	5
12	10	26	10			59	55	52	78	17	5
15	10	17	8			59	56	54	84	19	5
18	9	26	10			59	56	54	84	18	7
21	6	250	10			57	55	54	90	18	9

DAY 16

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	6	UNL	10			56	55	55	96	18	7
03	0	UNL	7			56	55	55	96	18	5
06	10	7	3		F	58	57	57	96	19	5
09	10	6	2		F	60	60	60	100	29	5
12	10	30	7			56	52	48	75	31	6
15	10	42	5		TRW	50	49	48	93	30	5
18	10	75	10			51	49	47	86	33	8
21	10	75	10			49	47	46	89	32	6

DAY 17

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	90	10			48	46	44	86	33	10
03	0	UNL	10			40	40	39	96	32	6
06	0	UNL	10			37	37	37	100	00	0
09	1	UNL	10			54	48	41	62	35	6
12	3	UNL	10			59	46	32	36	34	5
15	10	120	10			58	46	31	36	28	4
18	5	UNL	10			52	45	37	57	15	7
21	7	100	10			49	44	39	69	14	5

DAY 18

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	9	90	10			48	44	40	74	18	10
03	7	100	10			48	45	43	83	18	8
06	10	70	10			49	47	45	96	19	8
09	7	90	7			58	53	48	70	21	10
12	7	90	7			65	57	51	61	24	10
15	4	UNL	7			70	61	54	57	30	9
18	0	UNL	10			60	56	53	78	32	8
21	0	UNL	10			49	48	47	93	05	3

DAY 19

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	10			46	45	45	96	00	0
03	0	UNL	10			44	43	43	96	03	3
06	3	UNL	7			45	44	44	96	07	4
09	8	UNL	7			60	57	55	84	14	10
12	5	UNL	7			72	65	60	66	17	11
15	10	250	7			75	65	59	58	18	10
18	10	200	7			72	61	54	53	18	12
21	10	200	10			69	61	55	61	18	11

DAY 20

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	36	10		TRW	68	61	57	68	31	10
03	10	36	5		TRW	63	62	62	97	20	9
06	10	7	1	8	RWF	62	62	62	100	18	10
09	10	17	4		F	67	66	65	93	30	3
12	8	90	5		H	71	67	65	81	00	0
15	10	21	6		H	73	70	68	84	07	6
18	0	UNL	5		H	69	68	67	93	29	10
21	8	100	4		FH	64	63	63	97	11	12

DAY 21

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	6	250	7			73	68	66	79	18	13
03	0	UNL	10			72	66	63	73	23	12
06	10	17	10			62	60	59	90	28	10
09	10	14	10			61	[illegible]	[illegible]	90	30	7
12	9	24	10			65	[illegible]	58	78	29	9
15	2	UNL	10			72	[illegible]	57	59	25	4
18	2	UNL	10			65	[illegible]	[illegible]	78	00	0
21	8	80	10			59	58	58	97	06	5

DAY 22

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	47	7		TRW	60	60	60	100	15	10
03	10	40	7		TRW	60	60	60	100	08	6
06	8	5	3		F	58	58	58	100	33	5
09	10	12	4		F	64	63	63	97	32	5
12	10	16	7			64	62	60	87	30	11
15	9	100	10			62	56	51	67	31	14
18	0	UNL	10			56	52	48	75	30	8
21	0	UNL	10			49	47	46	89	29	5

DAY 23

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	10			47	45	42	83	31	7
03	0	UNL	10			41	40	39	93	33	5
06	0	UNL	10			38	38	37	96	02	4
09	0	UNL	10			50	46	42	74	34	6
12	4	UNL	10			55	48	40	57	05	4
15	3	UNL	10			60	50	39	46	00	0
18	0	UNL	10			52	47	41	66	07	4
21	2	UNL	10			45	44	42	89	11	7

DAY 24

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	1	UNL	10			44	43	42	93	00	0
03	10	120	10			45	44	43	93	00	0
06	7	120	10			45	44	43	93	00	0
09	8	UNL	10			55	51	47	75	18	9
12	10	100	10			58	51	45	62	18	7
15	10	250	10			61	53	45	56	23	6
18	6	250	10			55	50	45	69	18	5
21	2	UNL	10			47	46	45	93	00	0

DAY 25

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	2	UNL	10			43	43	43	100	00	0
03	7	120	10			44	43	43	96	00	0
06	10	40	4		RWF	49	48	47	93	30	6
09	9	40	10			55	52	50	83	22	3
12	8	34	10			57	54	51	80	30	9
15	8	47	10			58	50	43	58	30	13
18	6	47	10			50	46	42	74	30	9
21	2	UNL	10			45	44	43	93	31	7

DAY 26

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	4	UNL	10			43	41	38	83	32	10
03	0	UNL	10			34	34	33	96	32	5
06	0	UNL	10			32	32	32	100	31	4
09	0	UNL	10			48	42	35	61	29	6
12	4	UNL	10			53	45	35	51	29	6
15	3	UNL	10			56	46	35	45	18	4
18	6	80	10			50	44	37	61	20	6
21	10	75	10			50	45	39	66	18	4

DAY 27

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	70	10			50	45	39	66	18	7
03	4	UNL	10			47	43	39	74	18	10
06	9	30	10			50	45	40	69	19	5
09	3	UNL	10			58	51	44	60	23	11
12	4	UNL	10			65	55	47	52	23	8
15	2	UNL	10			67	57	49	53	22	8
18	3	UNL	10			57	54	51	80	00	0
21	0	UNL	10			47	46	46	96	00	0

DAY 28

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	1	UNL	10			46	45	45	96	00	0
03	7	250	10			46	46	46	100	04	4
06	10	47	7			49	48	48	96	06	4
09	10	6	3		F	53	52	52	96	10	5
12	10	9	4		F	56	55	54	93	13	7
15	10	80	5		RW	58	56	55	90	18	6
18	8	90	7			55	55	55	100	11	4
21	7	250	7			52	52	52	100	06	5

DAY 29

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	4	UNL	7			50	50	50	100	18	3
03	0	UNL	7			46	46	46	100	17	4
06	0	UNL	3		F	45	44	44	96	14	4
09	0	UNL	4		H	58	55	52	81	18	7
12	2	UNL	7			69	59	52	55	19	11
15	8	UNL	7			71	60	52	51	19	13
18	5	UNL	7			61	56	53	75	19	4
21	6	UNL	7			50	50	50	100	00	0

DAY 30

HOUR	SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	4	UNL	7			52	51	51	96	23	4
03	3	UNL	7			48	47	47	96	35	4
06	9	42	4		F	54	53	53	96	17	3
09	10	26	5		F	61	59	57	87	29	3
12	3	UNL	7			70	64	60	71	26	7
15	8	UNL	10			73	65	60	64	23	3
18	7	250	7			65	62	60	84	06	4
21	3	UNL	7			57	56	56	96	18	3

NOTES

CEILING

UNL INDICATES UNLIMITED

WEATHER

*	TORNADO
T	THUNDERSTORM
Q	SQUALL
R	RAIN
RW	RAIN SHOWERS
ZR	FREEZING RAIN
L	DRIZZLE
ZL	FREEZING DRIZZLE
S	SNOW
SP	SNOW PELLETS
IC	ICE CRYSTALS
SW	SNOW SHOWERS
SG	SNOW GRAINS
IP	ICE PELLETS
A	HAIL
F	FOG
IF	ICE FOG
GF	GROUND FOG
BD	BLOWING DUST
BN	BLOWING SAND
BS	BLOWING SNOW
BY	BLOWING SPRAY
K	SMOKE
H	HAZE
D	DUST

WIND

DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH; I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. ENTRY OF 00 IN THE DIRECTION COLUMN INDICATES CALM.

SPEED IS EXPRESSED IN KNOTS; MULTIPLY BY 1.15 TO CONVERT TO MILES PER HOUR.

STATION

MADISON WISC

YEAR & MONTH

80 09

U.S. DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N.C. 28801

APPENDIX 2.

Formulation of Media

Dextrose-Peptone-Yeast Agar (DPY) as formulated by Schaerffenberg (1964).

30g	dextrose
10g	meat peptone
5g	yeast extract
20g	agar
1000ml	distilled water

Selective medium for the isolation of *Metarhizium anisopliae* as formulated by Veen and Ferron (1966).

10g	dextrose
10g	meat peptone
15g	oxgall
.068g	rose bengale
30g	agar
1000ml	distilled water
0.5g	Chloramphenicol R
0.01g/ml	Actidione R with 25ml of distilled water placed in the medium after sterilization.