

The effect of temperature, relative humidity and rainfall on airborne ragweed pollen concentrations

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Abstract

Major weather parameters have long been known to alter airborne pollen and spore concentrations. The following study was conducted to study the effect of three of these parameters on airborne ragweed pollen concentrations. During the ragweed (RW) season for the years 1997 and 1998, 10 minute pollen collections were taken at least every 4 hours using an Allergenco MK-3 spore trap. Slides were fixed, and counted microscopically at 400X. During this same period, weather parameters were monitored by an Automated Weather Systems recording station located within a few meters of the collector. The ragweed season for this region begins in mid August and ends by mid October. Temperature patterns for the period demonstrated usual daily fluctuations with highs 13 to 35 °C and lows 8 to 24 °C. Relative humidity readings for the period varied between 25 and 100%. Highest RW values were seen after seasonal cooling in September. Daily rainfall for the period varied between 0 and 100 mm. Airborne RW always declined sharply after strong rainfall events (> 10 mm/day). Peak airborne RW concentrations were often associated with the passing of frontal boundaries and the change in wind direction and velocity that accompanies that passing. Factors influencing airborne RW concentrations are multiple and complex, but atmospheric forces have great influence. The passing of major weather fronts and the associated temperature drops, wind disturbances and rainfall are the major factors.

Introduction

Ragweed pollen levels in the atmosphere are a function of three processes: production, release and dispersal. Production is dependent on the suitability of the growing season and the availability of land for ragweed growth. Pollen release occurs when pollen grains or clumps of them are expelled from anthers on inflorescent vegetation. This release is likely governed by the time of day, daily low temperatures and relative humidity. The released pollen must dry out from its exposure to morning dew and be transferred from surrounding surfaces into the atmosphere for dispersal. This process is supposed to be related to temperature, humidity, wind speed and relative turbulence.

Weather related factors as precipitation, wind speed, temperature and relative humidity have often

been noted to influence airborne pollen concentrations (Emberlin and Norris-Hill, 1996). These parameters, therefore, have influence on release and dispersal of ragweed pollen grains. In the ideal situation the relationship between production and release of ragweed pollen, and measured atmospheric concentrations would be predictable (Comtois and Boucher, 1996). However, differing climatic conditions impact different factors in the equation that predicts measurable airborne ragweed pollen levels and the associated discomfort of persons sensitive to the proteins contained in these grains (Comtois and Sherknies, 1992; Raynor and Hayes, 1970). Several authors have addressed the relationship of ragweed pollen and meteorological parameters. For example, peak pollen production has been described to occur shortly after sunrise (Bianchi et al., 1959; Ogden et al., 1969)

and may be related to photocycle or cooler morning temperatures and lower humidity. Additionally, in northern latitudes total pollen production in a given year has been related to the cumulative heating degree-days (Comtois and Boucher, 1996). Also, atmospheric conditions as inversion layers and rainfall events are expected to strongly influence ambient ragweed pollen concentrations (Ogden et al., 1969). Using data collected in Kansas City, Missouri during the ragweed seasons of 1997 and 1998 we tested three hypotheses. First, the occurrence of heavy rainfall reduces airborne ragweed pollen concentrations. Second, the presence of exceptionally high temperatures tends to result in lowered airborne ragweed concentrations. Third, the coincidence of periods of high relative humidity result in increased airborne ragweed concentrations.

Materials and methods

Air for visual identification and enumeration of pollen grains and fungal spores was collected on top of a 5-story building in the center of the Kansas City Metropolitan area using a Hirst type pollen and spore trap (MK-3, Allergenco/Blewstone Press, San Antonio TX, USA). The device was calibrated to collect 15 liters of air per minute using a Vitilograph Spyrometer (Vitilograph, Lenexa, KS, USA). Materials for collection including microscope slides, cover slips and storage boxes were obtained from Curtin Matheson, Scientific (Houston TX, USA). Chemicals and ingredients for mounting media and stains were obtained from Sigma Chemical Company (St. Louis, MO, USA).

The Allergenco device was not wind oriented and was protected from direct rainfall by a 1-meter square roof suspended 2 feet over the device. For this study the Allergenco sampler was programmed to collect for 10 minutes at the beginning of every 2-hour period in 1997 and every 4-hour period in 1998. The unit produced at least 6 individual discrete collections during a 24-hour period at 0:00, 4:00, 8:00, 12:00, 16:00 and 20:00 hours. The data described represent the months of August, September and October and encompass the entire ragweed pollination season for Kansas City, Missouri, USA.

All samples from the collector were examined microscopically using methods described previously (Cage et al., 1996). Briefly, slides were stained with glycerin jelly containing 1.0% Calberla's solution, fitted with a coverslip, and examined at 400×

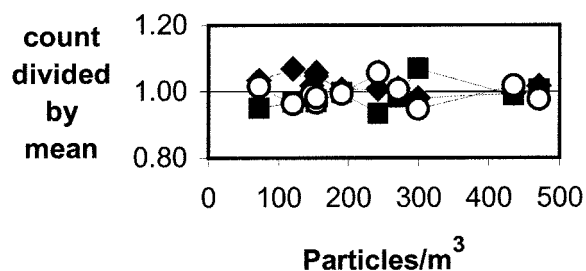


Figure 1. The variation between the three individual counters is derived by having each count the same set of slides multiple times. The value for an individual counter is divided by the mean value obtained by all three counters for each of 12-time periods counted and displayed on the y axis against the average particles for all counters displayed on the x axis. This figure indicates the variability between counters is not significant and does not change as particle counts increase.

for pollen using a Zeis Axioscope microscope. No factors reflecting a presumed collection efficiency of the sampler units were applied. All of the pollen grains in the 10-minute collection were counted and divided by 0.15 cubic meters of air to arrive at particles per cubic meters of air. In order to test the potential variation introduced by different persons counting the slides, each counter evaluated a set of identical slides. The numbers of pollen grains counted was averaged to produce a mean for all counters. The counts of individuals were compared to that mean.

Meteorological data was monitored within 20 meters of the collection site using a station obtained from Automated Weather Source (Gaithersburg, MD, USA). The station provided data on temperature, humidity, rainfall, wind velocity and direction. The weather station includes a datalogger, which collects up to 4 months of data and provides for downloading and archiving data on a personal computer.

Results

We initially conducted an examination of possible variations in the counts that might be introduced by different individuals. Quality control evaluations of variations in results generated by an individual counter and variations in counts generated by all counters are shown in Figure 1. Variations in counts generated by a single counter and those generated by all counters were within 10% of the mean. The normalized counts for all counters center on 1.0 (Figure 1) and there is no increase in variation as particle numbers decrease.

The object of this work is to examine the ragweed pollen counts during the 1997 and 1998 pollen season

in the Kansas City Metropolitan area as they vary with temperature, relative humidity, wind speed and precipitation. The data generated for the 1997 and 1998 seasons is illustrated in Figures 2 and 3 respectively. The 1997 season (Figure 2) encompassed 10 weeks (8/14/97 to 10/13/97). Highest counts were in the first and second weeks of September. RW pollen counts peaked in the 5th week (9/03/97 at 10:00 AM) and declined thereafter. 1997 was an unusually cool year in Kansas City. Temperatures stayed below 35 °C. Elevated RW counts began during the second week of the season when a cool front moved through the area (Figure 2A). At this time the wind speed picked up and there was a constant and prolonged shift in wind direction from 0° (North) through 360° that took the entire week (Figure 2C & D). This initial peak fell after the heavy rainfall on the 5th day of the week (Figure 2C). This pattern is repeated as temperatures fell the 5th week of the season and again there was a gradual wind shift over the week representing a front passing. This peak however did not end in a rainfall. The RW peak the 6th week of the season was also associated with a wind shift, but a fall in temp was not present. The season ended with the rainfall event in the 10th week (Figure 2C).

The data for 1998 is displayed in Figure 3. 1998 was overall a warmer year than 1997 with temperatures over 35 °C for at least 10 days (Figure 3A). The 1998 ragweed season encompassed 9 weeks (8/10/98 to 10/4/98) with the highest counts generated the first and second weeks in September. The season ended with the rainfall in the middle of October (Figure 3E). RW pollen counts peaked in the sixth week (9/11/98) with counts nearly as high in the seventh week. The first strong RW release occurred after a temperature drop in the 4th week of the season (Figure 3A) when there was a wind shift from 360 to 0° over 2 days (Figure 3D). The rainfall event on day 2 and 3 of week 4 brought the levels back to 0 (Figure 3E). RW rebounded after the cool snap and wind shift at the end of week 4 and the start of week 5, but was back down after the rainfall in week 5. RW rose again during the cool period in week 6 (Figure 3A). This coincided with a lot of shifting wind but no constant directional change. The heavy rain at the end of week 6 lowered counts intermittently (Figure 3E), but counts were back up by week 7. The season ended with a prolonged rainfall during week 9.

RW count for both years normalized and displayed as a percentage of the whole day is seen in Figures 4 and 5. This revealed that highest daily counts are

at noon and the lowest daily counts are in the early morning. This pattern was the same for both 1997 and 1998. Other daily parameters are as expected. High temperature for the day was in the late afternoon and low temperatures in the early morning. Relative humidity exhibits the reverse pattern. Atmospheric pressure peaks about noon and wind speed is up in the late afternoon and around midnight. Rainfall for 1997 is highest at 4:00 AM but for 1998 most rain occurred during the night. Since the normal diurnal fluctuations in RW counts and in temperature follow the same pattern a direct plot of these two parameters (not shown) reveals a significant correlation, however the diurnal pattern makes this correlation trivial. For 1997 and 1998 combined a comparison of maximum daily temperature and airborne RW (Figures 2A and 3A) has a negative correlation of 0.3. However, peak RW levels always occur after seasonal cooling begins so this seasonal pattern is reflected in the correlation.

Discussion

The results of our quality control efforts were mostly as anticipated. Variations in the counts that could have been introduced by different individuals who produced the counts were minimal (Figure 1). Ragweed pollen grains are of a very characteristic appearance and quite easily distinguished from other airborne pollens found in this area at this time of year. The collections for the MK-3 device were precise 10-minute periods spaced by discrete time intervals (110 minutes in 1997 and 230 minutes in 1998). The lack of wind orientation of the collecting device did not have a significant impact on the pollen collections. The absence of a bias in favor of the wind-oriented collector was not unexpected and has been addressed in a separate publication (Portnoy et al., 1999). Ogden and Raynor (Ogden and Raynor, 1960) in 1960 indicated that variations in collection efficiency are not expected when wind speeds are near the inlet velocity of the collector.

Overall, these data relate specific airborne ragweed pollen particulate counts in Kansas City for the 1997 and 1998 ragweed pollen season. The overall RW season for both years is similar. The season started slightly earlier in 1997 and ended slightly earlier in 1998 producing a one-week disparity in the length of the season. This may be related to temperature differences but heavy rainfall in 1998 probably had more influence. Comtois and Boucher (1996) have reported a relation between overall temperature and

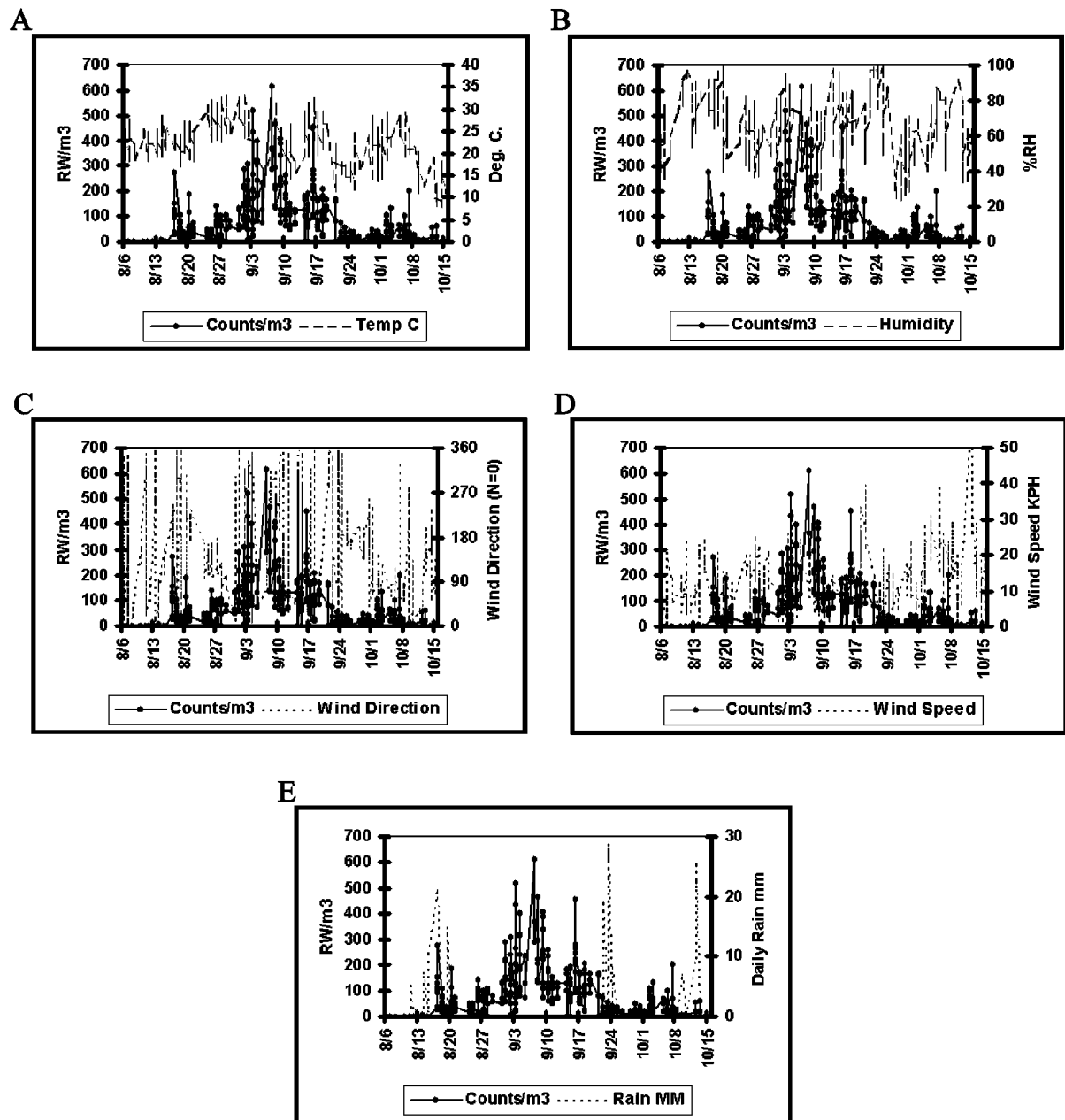


Figure 2. The 1997 RW counting and weather data is represented. The RW count is the solid line in each figure. Differing weather parameter for those periods is represented by the broken lines. Figure 2A presents RW counts and temperature. Figure 2B presents RW counts and relative humidity. Figure 2C presents RW counts and wind direction. Figure 2D presents RW counts and wind speed. Figure 2E presents RW counts and precipitation.

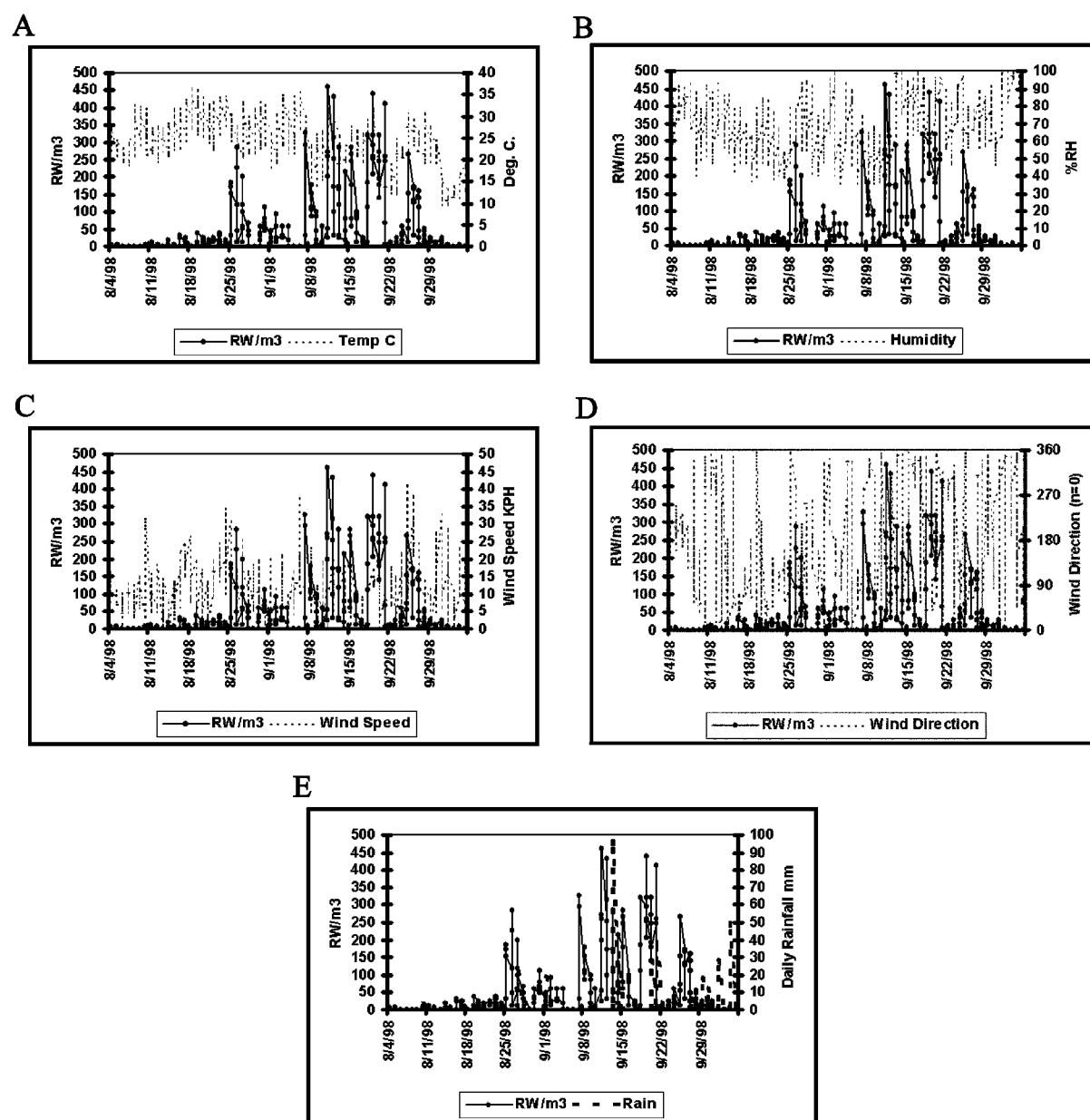


Figure 3. The 1998 RW counting and weather data is represented. The RW count is the solid line in each figure. Differing weather parameter for those periods is represented by the broken lines. Figure 3A presents RW counts and temperature. Figure 3B presents RW counts and relative humidity. Figure 3C presents RW counts and wind speed. Figure 3D presents RW counts and wind direction. Figure 3E presents RW counts and precipitation.

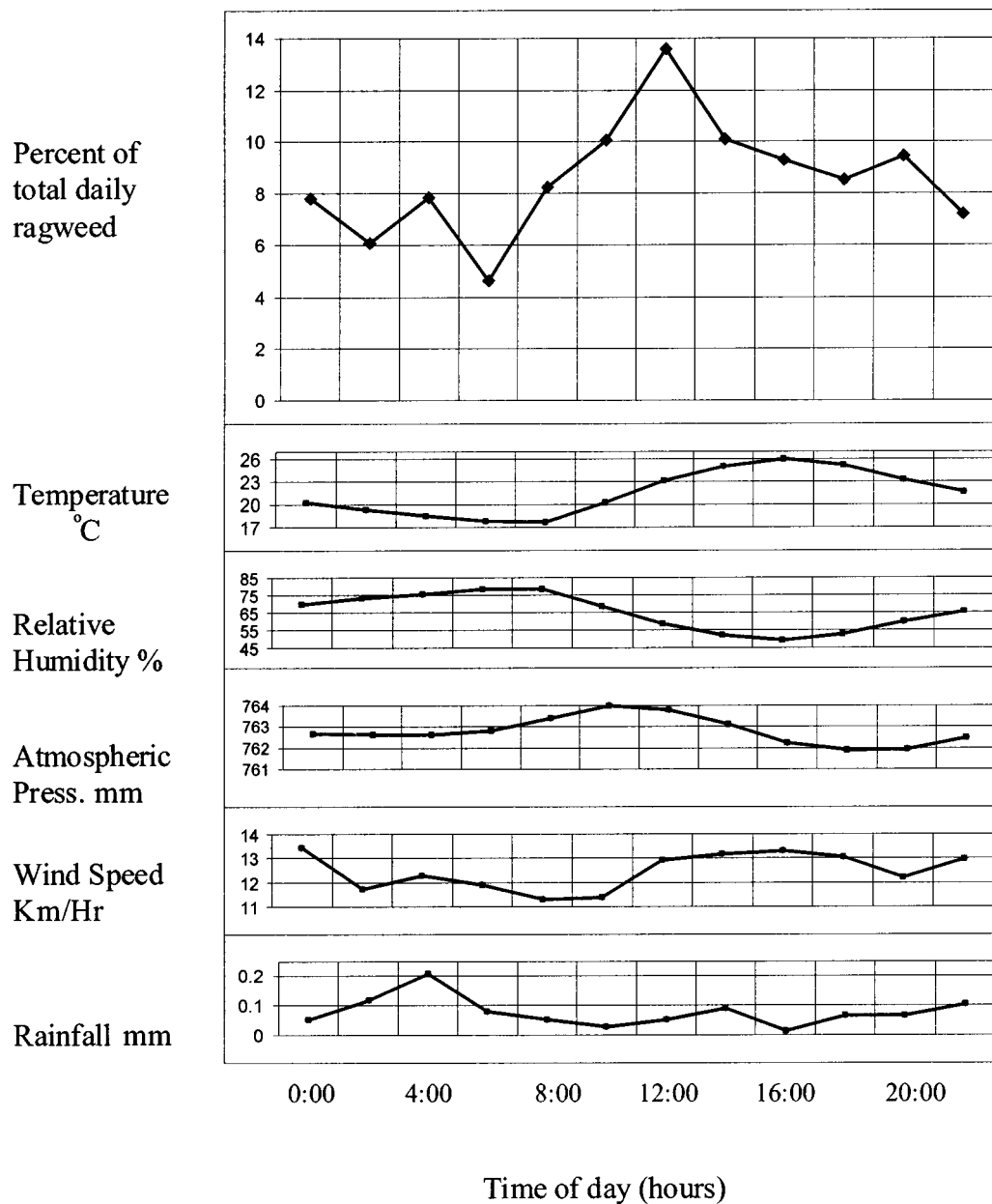


Figure 4. The normalized RW day for 1997 is represented. The total RW count for each day was determined and the percentage of the total daily RW occurring at every 2-hour interval is calculated. The percentages are then average to give an approximation of how much RW should be found in the air at any time on a typical day during RW season. Weather parameters of temperature, humidity, atmospheric pressure, wind speed and rainfall are also averaged and represented in this fashion.

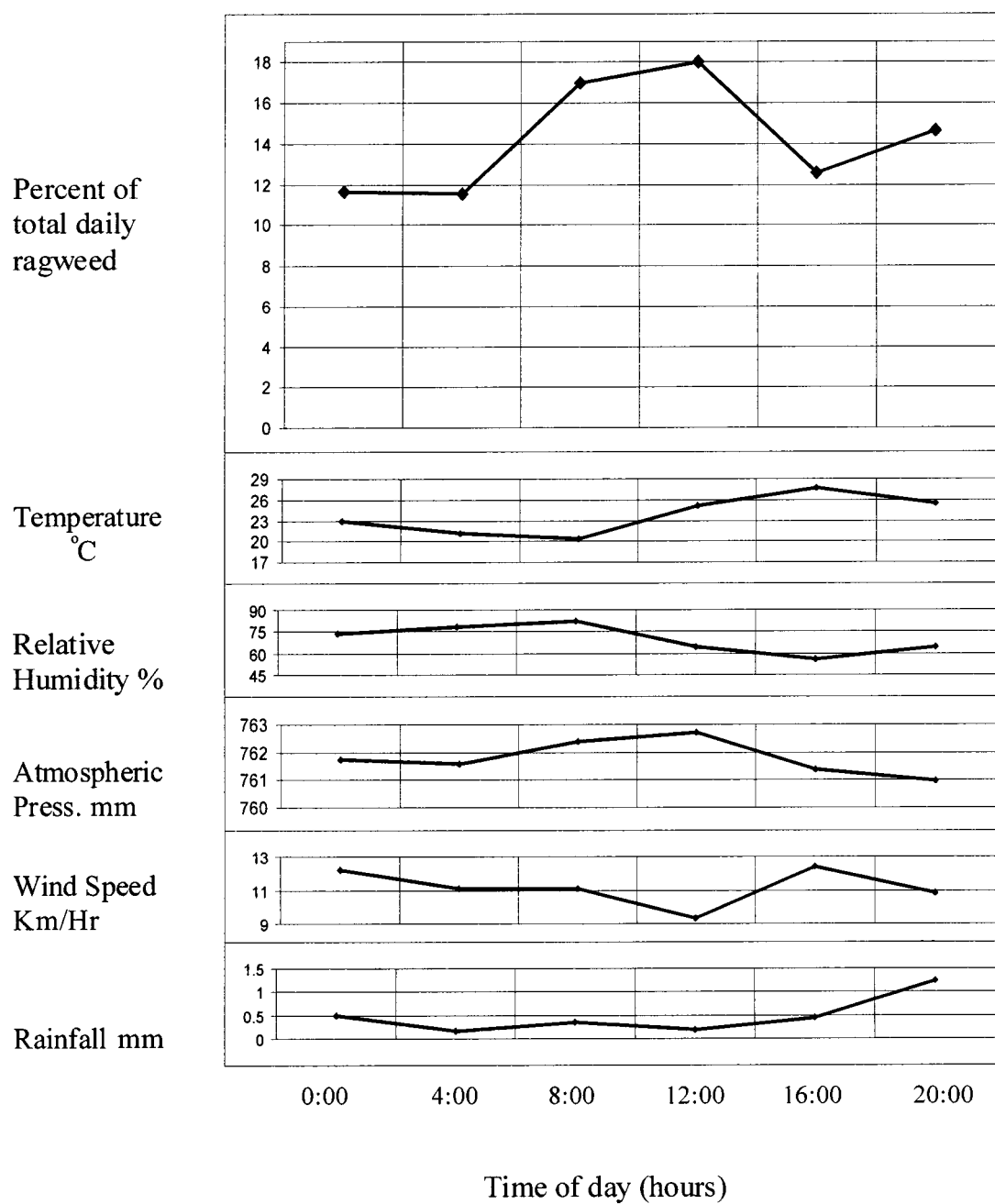


Figure 5. The normalized RW day for 1998 is represented. The total RW count for each day was determined and the percentage of the total daily RW occurring at every 4-hour interval is calculated. The percentages are then average to give an approximation of how much RW should be found in the air at any time on a typical day during RW season. Weather parameters of temperature, humidity, atmospheric pressure, wind speed and rainfall are also averaged and represented in this fashion.

the initiation of RW season yet their hypothesis is that the season would start later in the event of cooler temperatures. This data should not be used to test that hypothesis. These collections are conducted in a generally hotter climate and any minimum total of temperature days necessary for pollination was easily reached by the first of August in both years. There is a distinct disparity in the magnitude of the counts between the two years. Pollen levels are higher in the cooler year. This could be related to increased midseason rainfall in 1997.

The normalized daily collection results (Figures 4 and 5) agreed with numerous other investigators who observed that ragweed pollen is expelled from the flower about sunrise (around 6:00 AM) and becomes airborne as the pollen dries out and the ambient wind distributes the grains. This distribution process results in highest counts around midday. Numerous other authors have documented this phenomenon (Solomon and Mathews, 1990; Bianchi et al., 1959; Ogden et al., 1969). The observation of highest counts at noon and lowest counts at 6:00 is very consistent with both expected results and previous observations.

The influences of the weather on the ragweed pollen counts were variable. On several occasions (4 in 98 and 3 in 97) RW peak releases followed temperature drops. These drops are usually accompanied by strong weather changes including increased wind speeds, constant wind-shift and rainfall. This is in good agreement with the observations of Ogden et al. (1969) who recorded peak pollen emissions associated with the establishment of unstable weather conditions including increasing winds. The one constant observation in these studies is that rain usually lowered pollen counts and heavy rainfall always lowered counts.

Conclusions

We conclude that airborne ragweed pollen counts are generally lowest at 6:00 AM right around sunrise and highest around noon after pollen grains have had the opportunity to dry and become airborne. This

is consistent with previous measurements and with observations of the pollination process itself. Our data supports the hypothesis that heavy rainfall reduces airborne counts. We conclude that under normal weather conditions, temperature and relative humidity have minimal effects on the day to day ragweed pollen counts; however, unstable atmospheric conditions such as the passing of a cold front has the greatest impact of all the weather-related events on airborne ragweed pollen counts.

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