

A METEOROLOGIC APPROACH TO THE HAY FEVER PROBLEM

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I. THE SIGNIFICANCE OF THE HAY FEVER PROBLEM

THE seriousness of the disease called "hay fever" is readily demonstrated by an estimation of its magnitude: hay fever and asthma stood fourth in prevalence in a 1935-36 survey list of chronic diseases.¹ About 2 to 4 per cent of the entire population of the United States suffers from hay fever,² and the prevalence has increased steadily each year.³ Furthermore, approximately 40 per cent of those who suffer from hay fever eventually develop the more serious malady of asthma, according to early surveys.^{4, 5} Entirely aside from the probability of extended or permanent disability, the economic importance of a few days' to several weeks' annual discomfort and partial disability due, for example, to ragweed pollen sensitivity in three million people is considerable.

II. HISTORY OF THE PROBLEM

The literature on this subject dates back to Blackley⁶ and to the complaints of Daniel Webster, quoted by Barker,⁷ but the complexity of the problem has not been sufficiently appreciated until quite recently. Scheppegrell,⁸ who first introduced a physical approach to pollen research, has been attacked by a number of writers⁹⁻¹¹ for the mistakes he made in applying Stokes's law, but his critics failed to achieve a real solution because they made important mistakes of their own. The most usual error is oversimplification. The general assumption that the fall rates of pollen grains in still air are directly representative of their behavior in moving air is an example. What is not clear to the nonmeteorologist is that the air near the ground is often very turbulent during summer days, and that this turbulence frequently is more important than gravity in determining the motions of small particles.

Wodehouse¹² has expressed the view that the study of hay fever is the province of "the clinical and the botanical" specialists. His viewpoint appears to be exceptional, but probably none of the biologic group expresses the need for meteorologic participation as appropriately as Stakman¹³ does. The meteorologists, on the other hand, have tended to find other interests more pressing, but not without exception. Bergeron,¹⁴ in commenting upon a misinterpretation of meteorologic possibilities in the transport of *Aloina* spores, presents an analysis of the problem of transport of particles in the atmosphere. Hewson¹⁵ has included a concise review of the pollinosis problem

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in his discussion of atmospheric pollution, and Dingle¹⁶ has presented suggestions for the more adequate understanding of pollen counts in relation to simultaneous symptoms.

III. THE ROLE OF THE WEATHER

Almost invariably, the writers in this field have sought to relate the observed phenomena to the weather. That there exist some relationships is obvious; what the relationships are is more obscure. Scheppegrell⁸ observed, "It is well known that hay-fever patients improve during a rain of several days' duration, and that their symptoms become aggravated during the prevalence of high winds. . . . It has been frequently reported that hay-fever is aggravated by hot weather, but the records for the past year indicate that high temperatures have no special effect. On the contrary, the records . . . show that most of the severe stages of hay-fever developed . . . when the temperature was unusually low for the season. . . . The lower temperature, however, was due to the high wind which blew from the northeast. . . ." He then incorporated maximum and mean wind speeds, wind direction, mean temperature, and amount of rainfall with his pollenometric counts. Durham¹⁷ was also frustrated by the complex interactions of weather phenomena, pollen development and release, and clinical symptoms. Correlations between air temperatures and pollen counts were, for his data, sometimes strikingly high and at other times very disappointing in support of the conclusion of Scheppegrell. His discussion of antecedent weather influences upon the development of the pollen source plants and of rain, wind, and humidity upon the release and transport of the pollen grains gives a good picture of the complexity of the total problem. In a later paper,¹¹ he has reported on the effect of extremes of humidity upon pollen densities. Hawes and his associates¹⁸ devised a volumetric counting device and attempted to measure diurnal changes of volumetric pollen counts in Los Angeles, but they found no consistent diurnal pattern. More recently, Smith and Rooks¹⁹ found that, on the average, airborne ragweed pollen grains were about ten times as plentiful during the day (6 A.M. to 6 P.M.) as during the night at Iowa City in the ragweed season, Aug. 7 to Sept. 20, 1952. These writers, together with many who have preceded them, have overlooked the fact that their averages characterize in a very limited way only the period and place that they studied. The important feature of the weather that seems uniformly to be omitted from consideration is its extreme variability. That is to say, for example, never before was there a season exactly like the 1952 season at Iowa City, nor will there ever be again. The point that requires emphasis is that relationships of the pollen counts to specific weather events and atmospheric conditions are required. These events and conditions are approximately repeated and, by prediction and interpretation of their relationships to atmospheric pollen incidence, effective guidance for the allergist and his hay fever patients is possible. To choose an extreme example, it is entirely possible that a season characterized by frequent nocturnal cold front passages and cool, calm days at Iowa City

could seriously alter, if not completely reverse, the figures presented by Smith and Rooks. It is true that the atmosphere tends, on the average, to be more unstable (that is to say, more prone to convection and turbulence) during the day than during the night, but frontal systems, circulation patterns, and the larger-scale atmospheric disturbances progress on a time scale independent of the period of the earth's rotation. Since these phenomena are especially effective in lifting the pollen grains into the air in great numbers and in carrying them to great heights and extreme distances, one should not expect pollen counts or symptoms to be completely controlled by diurnal influences.

The Production of Ragweed Pollen.—Long before the hay fever season begins, the weather exerts its impact upon the plants. Durham¹⁷ states that “. . . rainfall is by far the most important” factor influencing the annual pollen crop, and that “Its greatest effect is preseasonal.” He reports some preliminary estimates: “Statistics seem to indicate that the amount of rainfall in July has more influence on the pollen crop than the rainfall of any other similar period. . . .” Brown²⁰ writes that the amount of rainfall in June, July, and August determines the size of the ragweed crop, just as the quantity of rainfall influences food crops. He also gives the rule: “the larger the plants the more pollen they produce.” Wilmer and Cobe²¹ emphasize the effects that the drought of 1930 produced in delaying the onset of the pollen season and the date of maximum atmospheric pollen counts. Durham²² points out that this delay was quite general over the eastern part of the United States. The literature contains a number of such references, indicating a general agreement that the cumulative effects of antecedent weather must affect the pollen crop, but no quantitative criteria or estimates are to be found. Such criteria have been developed for purposes of predicting yields of a few farm crops,²³⁻²⁵ suggesting by the analogy Brown²⁰ used that a quantitative solution for ragweed pollen predictions is also possible.

The Quality of the Pollen Crop.—In addition to the quantity of pollen released during the hay fever season, the factor of quality or chemical composition of the pollen is considered by many to be important in determining the severity of symptoms experienced. Wilmer and Cobe²¹ found strong indication that the antigenicity of pollen varied from place to place and from season to season, and they suggested that the soil, the weather, and microbiologic influences needed to be considered in this regard. Specifically, the pollen season of 1930 “. . . produced a different type of pollen which exhibited more potency as a stimulant . . .” than that of earlier seasons. Cobe,²⁶ in response to Durham's²² question, cited the following hypothetical case, based on experience: “. . . pollen collected . . . in a field . . . within the first two or three days of pollination . . . made up into extract may give us a three-plus skin test, and two or three days afterward there will be a severe rainfall and something has changed the pollen collected from the same . . . area, whose nitrogen content has not been altered very much. It may give only a one-plus or plus-minus reaction. Apparently something has happened to the potency of the pollen in that area . . .” which exhibits sufficient acuity of observation to be

significant. Furthermore, this observation is reasonably consistent with the analogous observations on crops. Salmon²⁷ writes, of cereal grains, that “. . . A marked deficiency of moisture during the latter part of the growth period . . . leads to higher protein content of grain . . . because of reduced photosynthesis and a lower yield.” Here, then, is a plausible process whereby the protein content of pollen grains also may be modified. Hopkins²⁴ suggests another, again an observation on the response of wheat: “. . . temperature conditions during the period of formation and ripening of the wheat grain may affect . . . protein content. . . . This is presumably the result of an actual reduction in carbohydrates due to accelerated respiration . . . the rate of respiration (in wheat) is approximately doubled by each 10° C. rise in temperature.” Peirce²⁸ reports a large variation, dependent upon weather conditions, of the vitamin content of forage crops. Kramer and his co-workers²⁹ have prepared a monograph on the influence of meteorologic factors on the yield and quality of barley. All these findings are significant, by analogy, as indicators of the probable role that weather plays in determining the severity or moderation of any particular hay fever pollen situation.

IV. POLLEN PREDICTIONS

That weather factors influence pollen productivity and antigenicity and that hay fever pollen in general depends upon the atmosphere for its transport and dispersion imply that an adequate evaluation of the influences of weather should make pollen predictions possible. Two distinct types of prediction are to be anticipated: a long-term, preseason prediction and a short-term, day-to-day prediction of relative pollen counts during the hay fever season. As is the case with all weather predictions, those for hay fever pollen must be made for specific areas or regions, that is to say, they cannot be generalized to cover the entire United States, or even one-half the nation, and still retain any real meaning. In a measure, this may be true, even of a single city, as regards day-to-day forecasts, particularly in the first few days of the pollen season.

Seasonal Forecasts.—Apparently the best cues with regard to long-term prediction of the hay fever season are to be found in the work which has been done on various agricultural crops. The solution of the pollen prediction problem should follow in similar lines. Dates for the most advantageous harvesting of canning peas have been determined for some years on the basis of the governing weather factors. Curry³⁰ presents data for staggering harvests of peas along the Atlantic Seaboard. Thornthwaite and Mather³¹ present a comprehensive discussion of the research in progress at the Johns Hopkins University Laboratory of Climatology. Based upon seedbed and early growth conditions in May, and using climatic data and/or long-range forecasts for June and July conditions, the date of beginning of the ragweed season and the antigenicity and amount of pollen to be expected may be “foreshadowed.”⁷⁷ As the season evolves, phenologic observations on the plants and cumulative weather effects may be applied to correct the initial estimates and thereby to

adjust and improve the prediction. This method should provide a high accuracy of prediction at least two weeks before pollen release begins. Such forecasts as these might apply to fairly extensive regions, such as New England, etc. Direct benefits to hay fever victims would evolve, but one immediate gain would be the use of such information for planning a pollen season vacation away from areas of anticipated high pollen counts in relatively mild seasons and entirely out of the ragweed areas for the bad seasons.

Day-to-Day Forecasts During the Season.—When the anthers have developed to the bursting point, the need for more specific information on the degree of pollen pollution and the pollen antigenicity becomes apparent. Furthermore, the general seasonal type forecast becomes nearly useless except as a rather flexible guide. At this point, the release of the pollen grains and their transport become a complex of specific phenomena in response to specific weather events.

It is well known that vigorous cold fronts, squall lines, and thunderstorms are capable of carrying large amounts of pollen to great heights and over long distances and that these events usually produce extremely high local pollen concentrations for a limited time. Such an occurrence cannot be averaged over a day or any other period of time, nor does the patient average the high pollen count out in his symptoms. The storm and the pollen storm are incidents, and should be thought of, predicted, and perhaps treated for as incidents.

More subtle than these storms is the weather development characteristic of the slow-moving, strong polar anticyclones that frequently traverse the northern half of the hay fever region. The initial event is the passage of a cold front with its associated squall and thunderstorm activity and extremely high pollen counts. Following this, the wind gradually dies and the fresh polar air, as yet quite free of pollen grains, rests coolly and quietly on the land, providing relief for the hay fever patient. A gradual cumulative warming of the air follows, usually over a period of two or three days, and as it does so, the ragweed unrelentingly produces its pollens. Toward the end of this period, the slightest disturbance of a ragweed plant will produce a visible shower of pollen. Undoubtedly, the pollen crop accumulates both in ripe anthers and in loose deposits on leaves and on the dry ground surface. Then the breeze, most often from the south or southwest, begins, slightly gusty at first and increasingly so as time passes. The pollen grains are borne aloft in ever greater numbers and to increased heights as the breeze develops, and the patient experiences progressively increasing discomfort. Continued intensification of the southerly wind, gustiness, and warming are precursors of a fresh cold front passage which frequently, but not always, will begin an approximate repetition of the sequence.

The continuous development of weather sequences such as that just cited is the key to their day-to-day predictability. It is not sufficient, as Scheppegrell,⁸ Durham,¹⁷ and many others have found, to take one weather element,

such as temperature, as the determining factor. The atmospheric concentration of pollen depends upon the whole complex of atmospheric conditions and events which we call "weather," and it can be consistently predicted within reasonable limits only by virtue of the continuity and predictability of the whole weather picture.

Thus, day-to-day prediction of atmospheric pollen concentrations is a specialized problem of forecasting, but one well within the grasp of the meteorologist whose understanding of the pollen problem is adequate and who has sufficient botanical guidance as regards the state and distribution of the source plants. Advantages of predicted pollen counts over the standard gravity slide counts would be at least threefold:

1. They would be available thirty-six to forty-eight hours before the gravity slides could be counted. This would make possible the anticipation of the degree of exposure which a patient should expect to encounter on the day following the forecast. Such information should be of greater value clinically than the day-old pollen counts available under the present system.

2. They usually would be more representative of the atmosphere overlying a whole city, for example, than the pollen count at any particular place would be. That is to say that, because of the ever-present local and micro-influences upon spot observations, which can and do fluctuate widely, the prediction based upon the anticipated state of the atmosphere and of the pollen sources would be a better estimate of the general level of pollen concentration in the air than any spot observation is likely to be.

3. They would include estimates of the time variation of pollen concentrations throughout the forecast period. Anticipation of reasonably specific periods of minimum and maximum pollen concentrations, with estimates of relative pollen counts, based upon predicted weather events and conditions, would provide for planning of the hay fever patient's activities during the forecast period.

V. SUMMARY

Meteorology is of primary importance in the problem of hay fever, as the atmosphere carries the allergens to the hay fever patients. This transportation function is accomplished in different ways, depending upon the states of the atmosphere and of the source plants: (a) certain weather *events* are known to produce very high pollen counts for short periods of time, and (b) certain weather *sequences* tend to produce an extended cumulative effect. Generally speaking, such processes as these are not properly evaluated by the use of time or space averages, or by the assumption of uniformity in time and/or space. The meteorologist with suitable botanical guidance is thus

placed in a position from which he can render substantial aid to the hay fever clinician. Potential contributions of the meteorologist to the problem include the following:

1. He can help to procure meaningful measurements of atmospheric pollen concentrations and to interpret them.
2. He can help to anticipate the degree of severity of the developing hay fever season by means of long-term predictions, progressively modified.
3. During the season, he can help to chart the day-to-day course of activity and treatment for the patient by means of specialized daily predictions based upon phenologic and meteorologic information.

The problem is of sufficient importance and complexity to justify a coordinated attack by meteorologic, botanical, clinical, and immunochemical specialists.

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