conditions there is so much spatial variation in light intensity, this variation itself varying in time, that it is necessary to use large numbers of detectors, which must therefore be inexpensive. The question of what range of wave-lengths to include in the light measurements is also important and must depend on a knowledge of the plant processes under investigation. However, within that range the same principle applies, that it is essential to measure light on a scale with a definite physical meaning and then compare the response of the plant with the amount of light, rather than beg the question by adjusting the light scale to some assumed plant response. Thus the measuring instrument should give as nearly as possible a constant response, preferably per quantum rather than per unit of energy, at all wave-lengths within the range included, rather than be made to follow, for example, an action spectrum for photosynthesis measured under a certain set of controlled conditions. (The confusion that this last arrangement would cause becomes obvious when it is remembered that the action spectrum changes with light intensity above the range where light is severely limiting.) Changes of light quality within the periods for which plant response is to be related to the time integral of the measured light, like changes of intensity, are likely to decrease the accuracy of the estimated relationship. Changes of quality between such periods, if they can be detected by other means and correlated with changes in the plant response to amount of light, may provide clues to be followed up by experimentation under controlled conditions.

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[1] McCree, K. J., *Nature*, **206**, 527 (1965).

PROF. HEATH raises the fundamental question of the purpose of making light measurements, and I am happy to give my point of view. I think that it will eventually be possible to predict the growth rates of plants from measurements on their environments, given sufficient understanding of the principles behind the interactions between plant and environment. The models will have to be complex, because plants are complex, but this presents no difficulty to an electronic computer. The limitation is not in our ability to speculate, but in our ability to describe the principles of plant behaviour in numbers rather than in words.

As more sophisticated models of plant behaviour are developed, they must be tested at every stage against facts obtained by growing plants in the field. In experiments designed for this purpose, the climate measurements will be confined to those which the theory says are relevant. I hope there will be more of this type of field experiment in the future. Even in experiments designed to determine the growth rate of a particular plant in a particular place, where climatological data are collected only as a guide to the factors which might be influencing the growth rate, there is room for a great deal more selection of climate measurements than is common at present.

For example, it is simply not true that the departure from linearity of the relationship between growth rate and the various totals of a linear light integrator is a measure of the light response of the plant. The departure could just as well be due to water stress or abnormally high temperatures, accompanying high levels of radiation. But if one makes a quantitative allowance for the non-linearity of the plant, based on laboratory measurements of the curve for carbon dioxide uptake, then the light effects can legitimately be separated from the effects of other factors.

This quantitative allowance for the response of the plant needs to be applied before the light is integrated with respect to time. The totals of the usual linear light integrator are not sufficient; one needs information about how each total was made up. In my previous communication I indicated how this information might be collected, and we are now developing an instrument for this purpose. At the same time we are conducting experiments to find out how well the readings of such an instrument can be related in practice to the growth rates of plants.

In his discussion of 'physical' and 'empirical' scales, Prof. Heath appears to be investing physical measurements with an almost mystical significance. But even in physics, a measurement has meaning only after it has been interpreted. This is the real test of the superiority of one scale over another—take, for example, the various scales which can be used for measuring spectral colours. The physicist uses a frequency scale when he is studying photoelectric effects, because he interprets in terms of quanta; in interferometry, he uses a wave-length scale, because he interprets with the wave theory; in photometry, he uses a scale which biases the strengths of the various colours in the same way as an 'average' human eye. In the same way, when measuring light for plant growth studies, it is logical to use a scale which takes account of the photosynthetic efficiency of different colours. On any other scale, the measurements would be more difficult to interpret.

Of course, in each case it is essential that everyone should agree to use the same scale. In science, an 'interpretation' is not complete unless it can be repeated. But this is not an argument against using a scale which fits the purpose of the experiment.

I have discussed elsewhere[1] the problems of choosing and agreeing on a scale for photosynthetically active radiation. The difficulties raised by Prof. Heath are just those which were raised in the 'twenties when a photometric scale was being discussed. Yet the scale which was internationally agreed in 1931 has worked very well in practice, despite its known deficiencies—in fact, a whole branch of engineering is based on it. Since I do not believe that the human eye is inherently any less complex than the photosynthetic system of a plant, I hope it will not be too long before 'green plant engineers' will agree to adopt their own scale of light measurement. I am sure it will then be easier to interpret the measurements.

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[1] McCree, K. J., *Agric. Meteorol.* (in the press).

Clarity in recording Germination Data

TIMSON[1] suggests that, compared with straight germination percentages, the following procedure would provide a more meaningful evaluation of germination data: the total percentage of seeds which have germinated to date is recorded every day for a stated number of days from sowing, and these daily values are summed. Timson terms the result thus obtained from observations up to, for example, day 10, the '$\Sigma 10$'. This scheme is possibly as successful an attempt as any at producing a unified expression of two values, germination percentage and time to germination. But any such expression is apt to obscure, rather than clarify, the situation, except when germination is both rapid and high or both slow and low. For example, with two hypothetical seed samples the percentages germinating on successive days may be 40, 20, 0, 0, 0 of sample A, and 10, 30, 30, 30, 0 of sample B. Timson's $\Sigma 4$ would therefore be $40 + 60 + 60 + 60 = 220$ for A, and $10 + 40 + 70 + 100 = 220$ for B, although the two samples are dissimilar in both germination percentage and time to ultimate germination. More-