LETTERS TO THE EDITOR.

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Meteorology and Wheat Shortage.

IN looking through some old papers I came across one entitled "The Law of Sequence in the Yield of Wheat for Eastern England for 1885–1904," contributed by Sir Napier Shaw to the *Hann Band der meteorologischen Zeitschrift*, 1906, pp. 208–16 (Brunswick: Fried. Vieweg und Sohn, 1906). From a study of the rainfall and its connection with the amount of the harvest, Sir Napier Shaw applied the method of harmonic analysis to the quantity in question, and obtained a formula according to which its fluctuations are periodic, the period being eleven years. In Fig. 42 (p. 212) curves are shown in which the agreement between the calculated and observed results is very close. It now becomes interesting in the light of recent events to extend Sir Napier Shaw's predictions for a further period of eleven years, with the following results, the numbers representing average yield in bushels per acre :—The highest maximum of about 35·5 should have occurred in 1909–10, followed by a minimum of about 29·5 in 1911–12. The predicted yield next rises to about 32·5 in 1912–13, and then decreases, the lowest minimum being about 27·0 bushels per acre and occurring at the beginning of the war, in 1914–15. From now on the predicted yield should increase, but would not reach its former maximum of 35·5 until 1920–21. For the period 1915–17 the predicted yield is not much more than 29 bushels per acre. It will be seen, therefore, that, according to theory, it was to be expected, both here and abroad, that England's wheat supply, so far as it depends on the eastern counties, would be at its lowest at and about the present time.   G. H. BRYAN.

PROF. BRYAN's reminder of my work of twelve years ago upon the yield of wheat in the eastern counties of England comes at an opportune moment. It may be of interest to recall how the "theory," to which he refers, arose. In considering the figures for the yield of wheat for England in the twenty-one years 1884 to 1904, I had noted that they were so closely related to the rainfall of the "principal wheat-producing districts" (approximately the part of Britain east of a line from Portland to Inverness) for the previous autumn that one might almost rely upon losing a bushel and a quarter per acre from the crop for every inch of rain recorded for the region in the previous autumn. There were some exceptional years, and in the hope of getting something still more amenable to rule I restricted the area to the counties of the meteorological district "England East," and took out the figures for wheat from the returns of the Board of Agriculture and for rainfall from the Weekly Weather Report. From these it appeared that every inch of rain in the autumn meant a loss of 2·2 bushels of wheat per acre for the eastern counties, but the occasional exceptions were not less pronounced than for the wider area, but more so.

Trying to circumvent these vexatious exceptions to an obviously useful general rule, I was working with a graph of the twenty yields 1885 to 1904, and discovered accidentally that it was reversible with reference to the epoch 1895–96. The individual values varied from 25·2 to 36·3, but the means for the pairs of years 1895–96, 1894–97, 1893–98, and so on, were nearly iden-

tical; the means of any other set of pairs not so. The only explanation of a reversibility of that kind that I could imagine was the combination (possibly fortuitous or occasional) of a series of periodic variations of any periods whatever which happened to be concurrent in a node in 1895–96. By a crude process of trial and error I was led to the conclusion that the best representation of the actual figures on that basis was to be got by combining a sine-curve of eleven years period with five of its harmonics of selected amplitude, each with a node at 1895–96; five of the nodes were ascending, one descending. This is a different matter from taking any graph between zero values eleven years apart and finding the harmonic components that will give the best fit, because the graph that I was working with crosses the zero line twelve times in twenty years. There is little or nothing suggestive of an interval of eleven years, but it followed from my analysis that the figures must repeat themselves after eleven years, a conclusion which I had not previously conjectured, but which turned out to be verified in an astonishing number of cases, and led to a most accurate prediction of the yield for 1905, which was then unknown.

There were thus two "theories" in the field, one that the yield of wheat depended (negatively) upon the rainfall of the previous autumn, the other that the figures repeated themselves after eleven years in consequence of the periodic changes with a fundamental interval of which "eleven years" was the nearest whole number. A curious point was that the years which were exceptional as regards the rainfall-rule did not appear as exceptions to the rule of reversal with regard to 1895–96. Thus the year 1903 is 6·2 bushels in defect of the rainfall-rule, but it compensates the yield for 1888 quite properly; on the other hand, 1904 gives a yield 4 bushels too small to compensate the yield of 1887, but it agrees quite well with the rainfall, while 1887 itself does not. In fact, if 1887 had agreed with the rainfall the repetition in 1898 and compensation in 1904 would have been quite good.

Thus there is a good deal of tantalising attraction about either "theory," and the relation of the one to the other. Mr. R. H. Hooker took the matter up, and discussed the yields of the various crops in relation to the weather conditions of different parts of the year in a well-known paper published by the Royal Statistical Society. He gave his opinion in favour of autumn rainfall as against "eleven years," in spite of the triumphant success of the latter's first prediction, that for 1905, which gave 32·8 bushels per acre to compare with an actual 32·0, whereas autumn rainfall would have given 37·6.

I have not looked into the matter critically since 1906, although the question is obviously one of immense practical importance, particularly at the present time, when the extension of the wheat area is being urged. To some of my friends the period of eleven years, which in this case could not be evaded or concealed, is anathema, and to others all such imagined periods and apparent relations are more likely to turn out will-o'-the-wisps than beacon-lights. So I thought it best to let the question rest until another eleven years had expired. That time has now arrived, and the question certainly deserves further investigation.

But there are certain pitfalls in the way of the continuance of the investigation. "Autumn rainfall" is a conventional expression, so is "eastern counties" in regard to the yield of wheat. One is apt to get off the line of continuity if one tries to deal with the matter amid the press of other things. And even with the additional figures properly computed we shall not necessarily secure the continuity which the investigation requires. The years that have elapsed have been memorable for the progress that has been made in the successful breeding of wheat, and success in breeding