THE PRACTICAL APPLICATION OF METEOROLOGY TO AGRICULTURE.*

The subjoined account of the way in which meteorology is applied to agriculture in Europe is of especial interest to New Guinea.

Climatology.

(*a*) General Application of Climatology in the Improvement of Crops.

Weather forecasting is not, as generally thought, the only branch of meteorology which can be useful to agriculturists. There is a second—climatology—of which many agriculturists are unaware, which can, however, render them considerable service. A precise knowledge of climate, that is to say, of the meteorological elements not solely of the air in which we live, but of the air at the surface of the soil and in the soil, can play a capital part in agriculture for the following reasons:—

(1) It will help to increase yields by facilitating the choice of varieties of crops best adapted to the climate; varieties resistant to cold in the east, or drought in the south; early varieties in regions where the heat of July causes "burning" to be feared; varieties of which the critical periods (earing of cereals for example) coincide to the maximum of probability with favorable meteorological phenomena.

(2) It affords a powerful aid in the application of preventive treatment against fungus diseases. Two kinds of conditions are needed for the development of these diseases—those favorable for the fungus and those predisposing the plant to disease. High temperatures, drought, and a high exposure to sunlight are factors propitious to fungi attacking the plant, which is already weakened by a partial withering of its tissues; they form, on the contrary, a powerful obstacle to the development of the propagative organs of the fungus, whose existence they menace. On the other hand, a soft and humid weather favorable to the fungus produces the maximum of turgescence in the tissues of the plant, which is thus better able to resist fungus attack. In order to produce an epidemic it is necessary that these two opposite kinds of conditions must immediately succeed each other, leading, in the first place, to predisposition of the plant to attack, and then to the development of the fungus before the plant can react. Thus at the beginning of the warm weather the plants wither in the day time; now if, in the course of the night, temperature is lower and a mist is produced (an element propitious for the propagation of fungus spores) the fungus attacks the plants, which will not have had time sufficiently to regain their turgescence and the epidemic will break out. On the basis of these data, and from the observation that potato blight always travels from west to east, one can, in

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certain conditions of temperature and humidity, and with observation posts judiciously placed, announce the probable advance of this disease in a given region and advocate the necessary preventive treatment.

(3) It will sometimes allow measures to be employed to counteract certain atmospheric phenomena which are particularly dangerous at certain times of the year—use of artificial clouds against spring frosts, formation of societies intended to prevent or insure against hail.

(4) It will assist the rational use of manures. It is known, for example, that lack of water in arable soil impedes nitrification. In very dry regions the extensive use of easily soluble manures may remedy this to a certain extent. In districts with abundant rainfall, where fungus diseases and storms are particularly to be feared, dressings of potassic and phosphatic manures will be increased. These same manures will induce vegetative activity in regions where winter cold and spring frosts lead to the risk of damage to advanced crops. The climatology of the country will be also utilized to fix the dates of spreading manures; for example, the application of potassic manures will be the earlier the drier the climate, that of nitrogenous manures on grass will be carried out as far as possible on dry days at the end of February when rain is imminent. Liming and marling will be done in the dry periods of autumn.

(5) It is indispensable when new crops are tried. Thus, in France, an increase in the area under sugar beet is very desirable. Before this crop is grown in certain departments, their climatology must be known; in particular, whether the distribution of average quantities of rain over the summer months will permit of the advantageous acclimatization of this crop. Sugar is produced as much through the water in the soil as from the carbonic acid in the air. Evaporation from the leaves of beet is considerable, and may reach 350,000 to 500,000 gallons of water per acre, corresponding to a rainfall of about 20 inches, which must be spread over half a year (May to October). It must be ascertained, therefore, that the rainfall can satisfy the need of this crop for water.

(6) Finally, certain meteorological data can be instanced which are of service to agriculturists, e.g., the monthly and annual distribution of rainfall and the amount of maximum falls in the case of the construction of cisterns; the system of winds in the case of the installation of a mill or an airwheel; and extremes of temperature, duration of frosts and their intensity, in the case of heating in glass houses.

(b) Study of a Particular Climatological Factor, e.g., Influence of Rain in Agriculture.

Among the climatological phenomena having an important effect on agricultural production, rainfall seems to take first place, and it seems useful by way of example to study, in some detail, the role of rainfall in agriculture.

The amount of rainfall is expressed in inches, a precipitation of 1 inch corresponding to 4.7 gallons of water (i.e., 47 lb.) per square yard, i.e., 22,500 gallons per acre. In France, the average quantity of rain received annually varies according to district, the minimum in the neighbourhood of Paris and the maximum in the neighbourhood of the mountains.

Fertilizing Effects of Rainfall.—The physical and chemical effects of rainfall are well known. Minerals in the soil are rendered soluble, without which they cannot be utilized for the formation of plant tissues. It is, also, through rainfall that fermentation indispensable to plant life takes place in the soil. There is one point to which particular attention must be called, namely, the fertilizing effect of rainfall due to the ammoniacal or nitric nitrogen which it contains in quantities far from negligible. Determinations carried out in France and Belgium have shown that rain contains, on the average, .0002 per cent. of ammoniacal nitrogen and .00007 per cent. of nitric nitrogen. Winter rainfall is, in general, richer in nitrogen than summer rainfall. It is seen that rain brings in an average year some 13 lb. of nitrogen per acre in the region of Paris, and more than 26 lb. in the wetter districts of the country. In Germany and in Italy, the average quantity of nitrogen brought per acre by rainfall has been found to be about 10 lb., and in England about 7 lb., of which three-quarters are ammoniacal nitrogen and one-quarter nitric nitrogen, while, in the United States, it is as large as 20 lb., of which 13 lb. are ammoniacal nitrogen and 7 lb. nitric nitrogen. Rainfall is about ten times richer in nitrates in tropical regions than in temperate climates. The proportion of ammonia is also much higher, which explains the luxuriant vegetation on certain African soils which, from their composition, would be considered as poor. These quantities of nitrogen furnished by rain are much superior to those given in manures, especially in France.

Thus, in some degree, rainfall supplies manure, but the reverse is sometimes the case, and manure can, at least in part, replace water. In order, for example, in the case of wheat, for the plant to manufacture 1 gram of dry matter it has been established that 0.53 pints of water are necessary in unmanured soil and only 0.35 pints in the same soil with average manurial dressings. The transpiration of cereals is, in fact, diminished by the use of manures, and, varying with the dressing of the latter and the nature of the soil, the quantity of water required to produce 33 bushels of wheat per acre, weighing 71 lb. per bushel, has been reduced from 24 inches to 8 inches.

Disadvantages of Excessive Rainfall.—(1) Potash salts are retained by the absorptive power of the soil and suffer only insignificant losses from rainfall. No loss is to be feared so far as concerns soluble phosphatic manures. It is different, however, with nitrates, which are in danger of being lost in drainage water through abundant rainfall in autumn and winter. This point must, however, not be exaggerated. The loss of nitrates in the sub-soil is much less rapid than is often imagined; thus after a rainfall of half an inch, it was found that nitrate only descended a few tenths of an inch in the soil, while the humidity produced by this rain falling on a dry soil had penetrated in one day to 2½ inches. Further in warm weather nitrate may be brought back quite quickly by capillarity from a considerable depth to the surface. Nitrate 10 inches deep in the soil was thus returned to the surface in a fortnight. During this season, capillarity causes the water in the soil to rise to replace that lost in evaporation. This water brings with it dissolved products deep in the soil, products which thus come to be concentrated in the neighbourhood of the roots of plants. Too deep a burying of nitrates following rain need not be feared when the manures are applied in spring, even if they are ploughed or harrowed in. As, however, nitrates are subject to denitrification in very humid soils, it is advisable, where too heavy rains or a high humidity are to be feared, to replace nitrates by ammoniacal manures. Sulphur, and, above all, lime, are lost through rainfall in larger quantities than any other manurial element. Losses of lime, naturally more important in rainy climate than in a dry district, attain on the average in France 3 to 4 cwt. per acre per annum; in very rainy years they have even reached 4¾ cwt. The practice of liming is, therefore, absolutely necessary, as lime is an indispensable element in the nutrition of plants equally with nitrogen, phosphoric acid, and potash.

(2) Soils which are too wet, i.e., which contain more than 40 per cent. of their weight of water, are, in general, impermeable to air, and thus any gaseous exchange between the soil and the atmosphere is rendered impossible. There results a stoppage of respiration of plant roots, leading to asphyxiation of the plants and a lowering of the temperature of the soil harmful to their growth. The water (which is a bad conductor of heat) remaining in the top layers of the soil is not replaced by air, and, in consequence, these layers, although superficially warm in spring, cannot transmit this warmth to the lower layers, which remain cold. There results, among other things, from this lack of warmth, the impossibility of production of carbonic acid gas in the soil, an indispensable element in the development of the plant, as a complement of carbonic acid gas in the atmosphere. Soils which are too wet lack air and are cold, but it is possible by drainage to aerate and warm them. Experiments have shown that the average temperature of a drained soil can be 6 degrees Centigrade higher than that of an undrained soil.

(3) The substances necessary for the nutrition of plants, concentrated in the neighbourhood of the root hairs, penetrate these latter with the soil water by capillarity and endosmosis and ascend through the plant cells under the impulse of these forces. Their ascension and their absorption are considerably increased by transpiration, which leads to the consumption of an enormous quantity of water compared with that strictly necessary for the tissues. Thus fertilizing elements from the soil reach right to the leaves. If the soil is too dry, transpiration is greater than absorption and plants wither, but, if the soil is saturated, the plants are "gorged" with water and their vegetative apparatus is developed to the detriment of their reproductive apparatus. In this latter case, in effect, the substances in the soil are diluted to too large a degree with liquid, and, since the roots can only absorb a certain volume of water, the plants are deprived of a certain amount of their nutrients, notably phosphates, without which it is impossible for them to live normally. On the other hand they have other nutrients at their disposal in greater quantity, particularly nitrogen brought down in the rainfall. There results an exaggerated growth of the vegetative organs, a diminution of precocity, and a marked tendency to the invasion of fungus parasites. This can be remedied by increasing the potassic and phosphatic dressings.

(4) The year 1927 showed once more that, while abundant summer rain has not always a bad effect on the quantity, it has on the quality of the crop. For wheat, in particular, it has been established that rain at harvest does not lead to the germination of the grain in the sheaf unless accompanied by a sharp fall

in temperature such as is produced at the time of a storm. Such fall of temperature is not an obstacle to germination as one would be tempted to think, but, on the contrary, the determining cause. The damage to the crop is the greater the longer the temperature remains below the normal after rainfall; and inversely the damage is the smaller the more rapidly the thermometer regains the average for the season. In regions where rainfall is abundant during the months of July and August, it is to the interest of farmers to select varieties of wheat which are resistant to this special effect of summer rains.

Correlation Between Rainfall and the Yield of Wheat.

The preceding considerations show the important part played in agriculture by rainfall. It has long been known (it is found for instance in the Bible) that harvests are intimately dependent on rainfall. For the central region of France, in particular, the following rules have been drawn up on the relation between rainfall in the quarter April, May, June, and the yield of the wheat crop:—

(1) If the rainfall during these three months is below average, the yield will be above average so long as the temperature is not more than 1 deg. C. above the average. If the temperature is more than 1 deg. C. above average, the crop is damaged by burning.

(2) If the rainfall during these three months is above average, the yield of wheat is below average.

Analogous conditions have been found in the north of Italy and in Ohio, where a diminution of rain in the spring is accompanied by an increase in the yield of wheat. On the contrary, in the south of France and the southern part of the Italian Peninsula, the effect of rainfall is quite the opposite.

PHASES OF THE MOON, 1938.

RABAUL.

January—		
2-New moon	.. ..	4.58 a.m.
10-First quarter	.. ..	12.13 a.m.
16-Full moon	.. ..	3.53 p.m.
23-Last quarter	.. ..	6.9 p.m.
31-New moon	.. ..	11.35 p.m.
15-Perigee	.. ..	12.0 noon
27-Apogee	.. ..	4.0 p.m.
February—		
8-First quarter	.. ..	10.33 a.m.
15-Full moon	.. ..	3.14 a.m.
22-Last quarter	.. ..	2.24 p.m.
12-Perigee	.. ..	4.0 p.m.
24-Apogee	.. ..	11.0 a.m.
March—		
2-New moon	.. ..	3.40 p.m.
9-First quarter	.. ..	6.35 p.m.
16-Full moon	.. ..	3.15 p.m.
24-Last quarter	.. ..	11.6 a.m.
11-Perigee	.. ..	6.0 p.m.
24-Apogee	.. ..	7.0 p.m.
April—		
1-New moon	.. ..	4.52 a.m.
8-First quarter	.. ..	12.10 a.m.
15-Full moon	.. ..	4.21 a.m.
23-Last quarter	.. ..	6.14 a.m.
30-New moon	.. ..	3.28 p.m.
5-Perigee	.. ..	2.0 p.m.
21-Apogee	.. ..	3.0 a.m.
May—		
7-First quarter	.. ..	7.24 a.m.
14-Full moon	.. ..	6.39 p.m.
22-Last quarter	.. ..	10.36 p.m.
29-New moon	.. ..	Midnight.
2-Perigee	.. ..	11.0 p.m.
18-Apogee	.. ..	7.0 p.m.
31-Perigee	.. ..	3.0 a.m.
June—		
5-First quarter	.. ..	2.32 p.m.
13-Full moon	.. ..	9.47 a.m.
21-Last quarter	.. ..	10.52 a.m.
28-New moon	.. ..	7.10 a.m.
15-Apogee	.. ..	4.0 a.m.
28-Perigee	.. ..	11.0 a.m.
July—		
4-First quarter	.. ..	11.47 p.m.
13-Full moon	.. ..	1.5 a.m.
20-Last quarter	.. ..	10.19 p.m.
27-New moon	.. ..	1.54 p.m.
12-Apogee	.. ..	7.0 a.m.
26-Perigee	.. ..	9.0 a.m.
August—		
3-First quarter	.. ..	12.0 noon
11-Full moon	.. ..	3.57 p.m.
19-Last quarter	.. ..	6.30 a.m.
25-New moon	.. ..	9.17 p.m.
8-Apogee	.. ..	1.0 p.m.
24-Perigee	.. ..	3.0 a.m.
September—		
2-First quarter	.. ..	3.28 a.m.
10-Full moon	.. ..	6.8 a.m.
17-Last quarter	.. ..	1.12 p.m.
24-New moon	.. ..	6.34 a.m.
5-Apogee	.. ..	3.0 a.m.
20-Perigee	.. ..	10.0 p.m.
October—		
1-First quarter	.. ..	9.45 p.m.
9-Full moon	.. ..	7.37 p.m.
16-Last quarter	.. ..	7.24 p.m.
23-New moon	.. ..	6.42 p.m.
31-First quarter	.. ..	5.45 p.m.
2-Apogee	.. ..	9.0 p.m.
16-Perigee	.. ..	6.0 p.m.
30-Apogee	.. ..	5.0 p.m.
November—		
8-Full moon	.. ..	8.23 a.m.
15-Last quarter	.. ..	2.20 a.m.
22-New moon	.. ..	10.5 a.m.
30-First quarter	.. ..	1.59 p.m.
11-Perigee	.. ..	2.0 p.m.
27-Apogee	.. ..	1.0 p.m.
December—		
7-Full moon	.. ..	8.22 p.m.
14-Last quarter	.. ..	11.17 a.m.
22-New moon	.. ..	4.7 a.m.
30-First quarter	.. ..	8.53 a.m.
9-Perigee	.. ..	11.0 a.m.
28-Apogee	.. ..	5.0 a.m.

(Apogee.—The point in the moon's orbit farthest from the earth.)
(Perigee.—The point in the moon's orbit nearest the earth.)

CALENDAR FOR 1938.

JANUARY.

Sunday	..	2	9	16	23	30
Monday	..	3	10	17	24	31
Tuesday	..	4	11	18	25	..
Wednesday	..	5	12	19	26	..
Thursday	..	6	13	20	27	..
Friday	..	7	14	21	28	..
Saturday	1	8	15	22	29	..

FEBRUARY.

Sunday	..	6	13	20	27	..
Monday	..	7	14	21	28	..
Tuesday	1	8	15	22	..	..
Wednesday	2	9	16	23	..	..
Thursday	3	10	17	24	..	..
Friday	4	11	18	25	..	..
Saturday	5	12	19	26	..	..

MARCH.

Sunday	..	6	13	20	27	..
Monday	..	7	14	21	28	..
Tuesday	1	8	15	22	29	..
Wednesday	2	9	16	23	30	..
Thursday	3	10	17	24	31	..
Friday	4	11	18	25	..	..
Saturday	5	12	19	26	..	..

APRIL.

Sunday	..	3	10	17	24
Monday	..	4	11	18	25
Tuesday	..	5	12	19	26
Wednesday	..	6	13	20	27
Thursday	..	7	14	21	28
Friday	1	8	15	22	29
Saturday	2	9	16	23	30

MAY.

Sunday	1	8	15	22	29	..
Monday	2	9	16	23	30	..
Tuesday	3	10	17	24	31	..
Wednesday	4	11	18	25	..	..
Thursday	5	12	19	26	..	..
Friday	6	13	20	27	..	..
Saturday	7	14	21	28	..	..

JUNE.

Sunday	..	5	12	19	26	..
Monday	..	6	13	20	27	..
Tuesday	..	7	14	21	28	..
Wednesday	1	8	15	22	29	..
Thursday	2	9	16	23	30	..
Friday	3	10	17	24	..	..
Saturday	4	11	18	25	..	..

JULY.

Sunday	..	3	10	17	24	31
Monday	..	4	11	18	25	..
Tuesday	..	5	12	19	26	..
Wednesday	..	6	13	20	27	..
Thursday	..	7	14	21	28	..
Friday	1	8	15	22	29	..
Saturday	2	9	16	23	30	..

AUGUST.

Sunday	..	7	14	21	28
Monday	1	8	15	22	29
Tuesday	2	9	16	23	30
Wednesday	3	10	17	24	31
Thursday	4	11	18	25	..
Friday	5	12	19	26	..
Saturday	6	13	20	27	..

SEPTEMBER.

Sunday	..	4	11	18	25	..
Monday	..	5	12	19	26	..
Tuesday	..	6	13	20	27	..
Wednesday	..	7	14	21	28	..
Thursday	1	8	15	22	29	..
Friday	2	9	16	23	30	..
Saturday	3	10	17	24	..	..

OCTOBER.

Sunday	..	2	9	16	23	30
Monday	..	3	10	17	24	31
Tuesday	..	4	11	18	25	..
Wednesday	..	5	12	19	26	..
Thursday	..	6	13	20	27	..
Friday	..	7	14	21	28	..
Saturday	1	8	15	22	29	..

NOVEMBER.

Sunday	..	6	13	20	27	..
Monday	..	7	14	21	28	..
Tuesday	1	8	15	22	29	..
Wednesday	2	9	16	23	30	..
Thursday	3	10	17	24	..	..
Friday	4	11	18	25	..	..
Saturday	5	12	19	26	..	..

DECEMBER.

Sunday	..	4	11	18	25
Monday	..	5	12	19	26
Tuesday	..	6	13	20	27
Wednesday	..	7	14	21	28
Thursday	1	8	15	22	29
Friday	2	9	16	23	30
Saturday	3	10	17	24	31