A FEW SCIENTIFIC NOTES TAKEN DURING THE PRESENT DROUGHT.

By THOMAS P. LUCAS, M.R.C.S., Eng.; L.S.A., Lond.; L.R.C.P., Ed.

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COMMUNITIES may learn wisdom even from adversity. The study of nature is a search for knowledge. Knowledge of the cosmos must be of special service in framing the constitutions and helming the interests of a nation. The disasters of flood and drought, in the natural necessities of our existence, call for brain work and scientific research, and in practical experiences herald us to discoveries of the laws and activities of nature. To know the laws of nature is to be able to use nature as the servitor of power for men's physical and social needs.

In the present continued drought, water-holes and other supplies of water are being dried up. To weep and wail is folly. To set ourselves to compass the situation and mitigate the uncomfortable conditions resultant therefrom is justifiable and healthy, intellectually and morally. I have a twenty-acre piece of orchard, about eight miles south from Brisbane, gradually sloping to a chain of water-holes, and by these separated from another twenty acres of timberland, gradually sloped upwards on the opposite side. In flood time the intervening valley channel was that of a narrow stream of rushing water; in ordinary seasons and weather, simply a chain of water-holes twenty to fifty yards apart. I have held possession of the land for ten years, and until this year never knew the water to fail. But about four months ago all the water-holes were dry, excepting one. This evidently communicated with a spring of slightly brackish water, as it was always full, and in spite of cattle drinking and evaporation, etc., it always looked clear and fresh in the centre. The depth was from four to six feet. In erratic heavy showers during the last six months, three of the higher holes were again filled with surface water and still hold their supply, but the holes below the brackish water-hole have continued dry.

Being desirous of finding water for irrigation, we sunk through three feet of marly clay at the botton of the first dried-up water-hole. We then came upon a deposit of leaves and general vegetable matter some six feet thick, gradually thinning to the contour much beyond present dimensions. There is a slight mixture of sand, but not sufficient to prevent the mass being a black carbonized substance of vegetable nidus. I need not say that the deposit works up well for vegetable manure, which we are appyling to the fruit trees. It is not a true peat, lacking of course the sphagnum mosses, and not being formed in bogs but in a water-hole, evidently the accumulation of years, until a sudden high flow washed down a quantity of sand and clay to form a thick bed over it.

After clearing this carbonized deposit away we came upon a basis of marly sandy rocks, soft and friable and alternating with inferior and coloured pipeclays, also mixed with sand. Sinking eight feet through these beds we got an abundance of fresh water. The water is soft and tastes slightly of soda, and is evidently from an entirely different drainage to that of the water in the water-hole higher up, and which as I said was slightly but decidedly brackish.

On the side of the hole now dug out twelve feet deep (not reckoning the eight feet bore for water), was a large dead tree-stump its roots spreading into the soil, being thus exposed. In seeking to undermine this stump with a pick a nest of eels was disturbed. They were coiled in interlacing companionship into a solid ball evidently to mutual moisture and sustained vitality. There were four specimens about eighteen inches each in length, and they had instinctively thus located themselves under a lacing of roots, at once expedient for protection against the hardening humus, and probably supplying a degree of air and moisture as well as a rude domicile.

I must now ask you to visit Hemmant. The Doughboy Creek, an estuarine salt creek, runs by the side of Mr. Carlisle's vineyard; but there, as elsewhere, fresh water is lacking. In his difficulty the owner commenced to dig a hole, or rather to enlarge a formerly dug-out water-hole, but now dry. After passing through some feet of surface humus and washed (flood) matter he came upon a soft, plastic, black, marly, clayey deposit. In the twelve or fourteen feet of this deposit that were passed through, four bands of shell conglomerates were found. The three higher beds are eighteen to twenty inches apart, but the lowest one is quite four feet from the one above it. The shells are mostly an estuarine recent species of bivalve with an occasional piece of worn coral, now and then a stray oyster-shell and very rarely a solitary shell of another species. I am informed that in driving the piles for the railway bridge over the creek near by similar shelly beds were met with and, if I am correct, at a depth of twenty-eight feet fresh water.

Do not geologists tell us that in former times the Brisbane River was a very much larger and probably differently distributed water channel? It appears to me that both instances which I have recorded go to support this view. To-day the estuarine portion of the river appears to be much further out than formerly. In the floods of the nineties, oyster beds a distance beyond the present mouth of the river were destroyed by the sudden freshes of the Brisbane River. It takes four years for oyster spawn to form new beds, and the supply of such spawn is under other conditions. The shell beds at Hemmant do not certainly suggest local oyster habitats, but they do prove the occurrence of such at the time, at no great distance. But these beds appear most conclusively to prove that that the shell colonies were established near to the mouth of the river and in the flux of the salt water tides; for when in floods the fresh water poured in hyperabundantly the estuarine salt water shell-fish were killed, and did not appear again until deposits to 16 or 18 inches had been laid down. And in the section laid open this evidences as having occurred four times. Doubtless by deeper sinking more such and on a larger scale would be proved.

Another point is worthy of notice. If these shells had been buried as they died and immediately covered over with the flood water muds, they ought largely to be found bedded in pairs (bivalves). Instead of this they are mostly found singly or forced into irregular conglomerates in all ways and fashions, as they would be if long exposed after death to the tides and on a mud bottom.

If then my deductions are correct, the present Doughboy Creek must in pre-historic human age (post-pleistocene) have been a wide estuarine mouth of the Brisbane River, instead of as at present a moderately wide sub-tidal creek. And considering the number of sub-tidal creeks—Norman Creek, Breakfast Creek, etc.—may it not be that in earlier times these formed portions of many channels and interbranching water courses at the mouth of a large estuarine river. If so I can understand how the chain of water holes in my orchard, and which show superficial deposits of twelve feet deep, were at that time the bed of a fairly sized stream tributary.

Another consideration is worthy of notice—the question of time. In my orchard the superficial deposits, that is of the human period (the underlying rocks being mesozoic) are only twelve or so feet thick. And at Hemmant, judging by the inflow of fresh water, the depth of such superficial deposits is only twenty-eight feet. Twelve feet and twenty-eight feet deposits may represent the work of a score of years, or they may represent that of centuries of the human period. It would be necessary to know the history of possible previous denudations, and in the geology of the whole country the higher and lower levels of the land drained. It is not for me to go into these questions in this paper excepting to add the above evidences to the valuable information already tabulated by our Geological Survey. And I would, in the prestige of the Royal Society, suggest the consideration by the Agricultural and Geological Departments of the State Service of a general supervision of drought-stricken farms and districts, to the exploration for water, surface or sub-surface drainage or natural springs. In a scientific and practical guidance the cost should be but a fraction of the benefits gained.

ON THE POSSIBILITY OF PREVENTING DAMAGES BY FROST.

By P. OLSSON-SEFFER, Ph. D.

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In his first report on the sugar industry of Queensland, Dr. W. Maxwell says :—" The occurrence of killing frosts in any district appears to be so rare as to cause special remark when it occurs, which indicates conditions very far removed from those obtaining in such a sugar-growing country as Louisiana, where frost is an annual occurrence, and where precautions are regularly taken to protect some part of the crop against its action."

Only a few days previous to my reading this passage I had been an eye-witness to the damages done by frost to sugar-cane and to some other crops in the Maroochy district. Shortly afterwards I experienced three nights of severe frost in the Wide Bay district, close to the coast, and I was assured by cane-growers and farmers there that frost with damaging results was by no means so infrequent in South Queensland.

Nothing is more discouraging for the farmer, who perhaps has toiled for a whole year, than to see his promising crop killed by one night's frost. A killing frost is not a yearly occurrence. If it were so the farmer would most likely be prepared for it, but as several years slip by without an attack from the enemy, he is lulled into security, and only when the damage is done does he wake to the fact that he might have averted the misfortune.

Can this be done ? Is there any prevention against the result of frost? Certainly there are means of preventing damages by frost, but it is necessary to have a certain amount of experience when taking these protective measures, so as not to cause a still greater damage by the preventives than by the frost itself.

Fertilizers, applied to the soil without judgment, medicines given to a patient with no discrimination, may cause serious injuries. The using of frost preventives must also be based on knowledge and experience.

As, however, not only the climate generally in a country, but also local conditions influence the phenomena connected with the frost, it is impossible to lay down a general rule as to the methods for avoiding frost. My own experience of frost in Queensland is far too limited to allow me to speak of it with regard to this country; but my experience gathered in other countries will enable me to offer some suggestions as to the frost phenomena in general and the causes of its appearance. I will also give a short summary of the results of the frost investigations made in Sweden and Finland, the two coldest countries in the world where agriculture is carried on, the countries where Jack Frost is the worst foe of the agriculturist.

My short notes are chiefly founded on the excellent works of Professor Selim Lemström, of Helsingfors, Finland, whose researches on the Polar light and night frosts, have made his name familiar to the scientific world. Through the courtesy of the present chairman of the Finnish Society of Science, Dr. Th. Homén, Professor of Applied Physics at the University of Helsingfors, I recently received some of his latest works on the frost question, and they will enable me to discuss some of the latest results of experiments made.

THE CAUSES OF NIGHT-FROSTS.

Since the investigations of Wells in Surrey, England, in the beginning of last century, it has been known that the principal cause of night-frosts is the radiation of heat from the surface of the earth and from the substances that are upon it. Every body, the temperature of which is higher than that of its surroundings, suffers a constant loss of heat until temperature is the same everywhere.

On a summer day the surface of the earth is heated by the sun, *i.e.*, the earth obtains a surplusage of heat, which in various kinds of surfaces is different, and which penetrates more or less deeply into the ground, depending on its heat conducting power. When the sun's effect has ceased, the earth and the objects on it begin to give out heat through radiation into space. The temperature of the earth sinks at first very rapidly, being higher in comparison with that of space, but later more slowly, depending on its surroundings. The radiated heat has to go through the atmosphere, which contains besides the principal ingredients of air, aqueous vapour, carbonic acid, small quantities of ozone, nitric oxides, ammonia and water in solid and liquid form, and particles of dust of various kinds.

The gaseous matter round the earth hinders the radiation of heat, as it returns theheat to the earth more or less, and thus compensates for the loss.

The degree of the fall of temperature caused by radiation depends on the following circumstances :—

I.—The Aqueous Vapour of the Air.

The heat which radiates into space ccmes in most cases from plants on the surface of the earth. The plants receive heat from below by radiation from the bare earth, and by conduction through the plants themselves, and the heat escapes first to the atmosphere, on the state of which depends the degree of the fall of temperature, and secondly into space.

From the latest researches on the powers of emission and absorption of gases we learn that while the pure and clear air is nearly diathermous for heat, even the small quantities of carbonic acid which are present in the atmosphere exercise a perceptible absorption, which yet is not determined with sufficient exactitude.

It is probable that other gaseous matters in the air have very little influence, which also seems to be the case with the nitric oxides and the ammonia though they are the most absorbent gases.

Aqueous Vapour and Water.

Thinly scattered as the molecules of aqueous vapour are in the atmosphere, we might be inclined to disregard them as carriers to the waves of heat, and imagine that these undulations must be intercepted by the gases which form the great bulk of the atmosphere, and not by the aqueous vapour which is sparingly diffused among them.

According to Tyndall, the action of a single atom of aqueous vapour is 10,000 times than that of a single atom of oxygen or nitrogen. According to others, the absorbing power of vapour of water on the dark rays of heat is hardly greater than that of air. Concerning the power of liquid water, that is to say in this case condensed vapour, all agree that it is great and attains nearly 90 per cent. of the radiated heat.

Although dust or the solid particles of different kinds in the air exists only to a small extent, its influence is still very great. Acknowledging the fact that clear air and transparent vapour do not radiate or absorb in a marked degree, the principal radiation from the atmosphere itself falls in the very beginning on these solid particles, and their action becomes that of leading into *condensation of vapour*, being first cooled down under the temperature of their surroundings and then attaining the dew point. When condensation has once begun radiation hastens towards the earth as well as into space, because the radiant power of the atmosphere is increased by the condensed vapour, and it is soon formed into a cloudy veil.

This veil partly hinders the continued radiation from the earth, and lessens the loss of heat and thereby the fall of temperature, which stops at a point or continues to fall, though very slowly.

The degree of humidity thus determines the fall of temperature ; the clearer and drier the air, the more intense the radiation and cooling. It is on account of the absence of this qualifying agent that the thermometric range is so enormous in Australia. A clear day and a dry day, however, are very different things. The atmosphere may possess great visual clearness while it is charged with aqueous vapour, or even water in condensed form, and on such occasions great chilling cannot occur by terrestrial radiation.

During the first half-hour after sunset the fall of temperature is rapid, but afterwards it becomes slower, for by degrees a cloudy veil, more or less transparent, arises through condensation, and gives back the greater part of the heat. This veil is such a serious hindrance to the radiation that, when appearing distinctly, the temperature on the surface of the earth will not sink under zero even in places sensitive to the frost. The warmer the summer day the more intense is the evaporation, the greater the amount of vapour in the air, and the thicker the veil of clouds. Considering that vapour in its turning from a gaseous into a liquid state gives out a great quantity of heat, the cause of this great effect will be easily understood. By preventing nocturnal radiation into space the clouds of vapour preserve many a tender plant from being nipped by the frosts.

II.—The dust particles and the condensed vapour radiate heat, but the air itself only does so very slightly, and thus the *cooling of the air results principally from its touching the ground and the plants on it.* Hence the remarkable fact, that the air is coolest near the surface of the earth, and that its temperature increases with the height. From this circumstance follows a particular series of movements in the air. The cooled air, by reason of its increased density, flows from the plants towards the ground, and slides down it towards the lower parts of the field, and from the mountains to the valley, where it accumulates, and if there is no issue it stays there. As this movement lasts the whole night the chilled stratum of air on the lowest places increases in depth, and the cooling is there much greater than on the places situated a little higher. This movement, which is a result of nocturnal radiation, ought not to be mistaken for such movements as are caused by a breeze however gentle. The direction of the particles of air in a wind always forms a little angle with the surface of the ground, and hence results a warming effect caused by the mixing of the cold and warm layers of air, and then by the heat which the air conveys to the ground, because, owing to the oblique direction new particles always touch its surface. A horizontal movement will certainly be without effect, unless it sweeps away a thick layer of air. A breeze so gentle that it will scarcely move the leaves of a tree will produce a considerable increase of temperature.

III.—The Radiating of Heat from the Ground to the Plants growing on it.

In order to answer the question as to the effect of radiating heat from the earth itself during the night, we have only to consider a piece of ground with plants. Let us look at the phenomena arising here and exercising a perceptible influence on the temperature.

From the fact that plants radiate more heat into space than they receive from the ground, the latter becomes warmer than the plants, and thus constitutes a source of heat the influence of which ought to be explained.

The heat which the ground has received from the sun penetrates into it, and is conducted during the night towards the surface, radiating thence to the plants. Different kinds of soil are in this respect very dissimilar, depending on the circumstance that the evaporation from the surface layer of the earth is relatively great.

It is only in later times that attention has been directed to this phenomenon by the researches of R. Russell, E. Wallny, and S. Lemström. The latter has shown by actinometric experiments that heat which radiates from the surface of the earth after sunset is scarcely perceptible on a frosty night.

The influence of this radiated heat is diminished by the circumstance that it meets the short grass which generally covers the ground in places where preventives against the damage of frost might be used. This source of heat is without any influence and may therefore be neglected.

IV.—Evaporation.

Every hour of the day water evaporates from the ground and the vegetation with more or less intensity, and thereby heat is consumed in considerable quantities. The degree of evaporation determines the degree of humidity in the atmosphere.

The aqueous vapour thus formed is mixed mechanically with the surrounding atmosphere, exercising a pressure which may be measured by the weight of a column of mercury of a certain height in the same way as the pressure of the atmosphere is measured. The evaporation only continues until the surrounding air is saturated with vapour.

Experiments show that the pressure of the aqueous vapour in case of saturation depends solely on temperature.

The degree of evaporation again, and hence the quantity of vapour formed, depends on the followiug circumstances :—

(*a*) It is proportional to the evaporating surface.

(*b*) It is proportional to the difference between the highest pressure and the pressure ruling at the moment.

(*c*) It is also inversely proportional to the pressure of air.

(*d*) The quantity of moisture depends finally on the pureness and temperature of the evaporating fluid, as well as upon the temperature of the surrounding atmosphere and its pureness.

The vapour can sometimes remain in this form even if the temperature has fallen beneath the dew point, just as a fluid is heated above the boiling point without turning into steam. These phenomena have their origin in the play of the forces of molecules, which play remains without influence if the air contains particles of dust, as is usually the case.

If we follow the changes in the moisture of the atmosphere during a clear day we find the amount of vapour rising and falling with the temperature. The changes vary greatly in different regions of the earth. We must make a distinction between a place on the sea coast and a place in a country without lakes.

The smallest quantity of moisture is found in the atmosphere about sunrise, increasing until 9 a.m., then falling till about 2 p.m.; rising again till 8 p.m. and falling by slow degrees until morning.

The degree of humidity determines the dew-point. When the temperature has fallen so low that the air is saturated, it cannot remain in form of vapour if the temperature is still falling, but turns into water.

The evaporation ceases as soon as the dew-point is reached, as it probably does long before the temperature attains 32 deg., F., and instead of an absorption of heat by producing vapour, heat is now created by condensation.

When summing up all the acting and counteracting causes of lowering of temperature on a clear night, we get among the former in the first place, *radiation of heat*; in the second place, *movements in the air*, caused by the cooling of air through its touching the plants and its running down into the lowest places. As counteracting causes we have in the first place *condensation of aqueous vapour in the atmosphere* in general, by which the radiation is lessened; in the second place *condensation of aqueous vapour near the surface of the earth* by which first dew and then hoar-frost is produced; and in the third place *movements in the air in the form of slight breezes or faint draughts* which mix the different strata of the air.

All the other causes of the fall of temperature during a clear night may be regarded as of so small influence that they scarcely need to be taken into consideration.

All these causes prevent the loss of heat from vegetation by radiation, making the fall of temperature produced by it slower and slower. At last it reaches a limit which cannot be exceeded, *i.e.*, the heat emitted by the plants is then restored to very nearly the same amount.

The causes of night-frosts have been the subject of special study not only by Lemström and Homén in Finland, but also by Hamberg and Juhlin in Sweden.

We have now to consider the question—*To what temperature can plants be exposed without damage?* In this matter the experience is still very limited, especially as the general climatic conditions of a country influence the vegetation, and consequently the question has to be made a separate study for each country. Some important conclusions might still be derived from what is known at the present time.

Numerous but by no means final researches have shown that temperatures between the freezing point of water on the one hand and about 112° F. on the other indicate those intensities of heat motion at which plant-life generally is still possible. It happens, however, occasionally, that certain phenomena of vegetation may still occur even below the freezing point of water, because from various causes the water contained in the cells only begins to crystallize at a few degrees below zero. However these are isolated cases; in the great majority the vital movements in general only begin at a few degrees above the freezing point.

When the temperature of any portion of a plant sinks below the minimum necessary for the production and continuance of the chemical processes of metabolism—that is to say, for the calling into action of the vital forces—a period of rest ensues which continues until the necessary thermal conditions are again restored in the tissues. Should the temperature sink considerably below 32° F., the plant is frosted. In other words, a portion of the water of imbibition in the cell-walls, and a portion of the water of the cell-sap separate in the form of ice-crystals, while a more concentrated solution with a lower freezing point remains behind in the liquid form.

When the tissues of the leaves and in fact when any parenchymatous tissues are frosted, pure water is withdrawn into the adjoining intercellular spaces, but the cells themselves do not generally freeze. The result is that the cells lose their turgidity and at the same time begin to droop. This explains the familiar phenomenon of lilies, hyacinths, &c., which have been caught by frost, being prostrated on the ground until the ice melts and the cells reabsorb the water into their interior and again become turgid, when the plants resume an erect position.

As a rule when living plant tissues that contain much water are frosted—and this applies especially to young leaves and shoots that are affected by frost—large masses of ice are formed in certain regions, and notably underneath the epidermis of leaves and shoots and in the medulla. The tissues, however, remain entirely free of ice, merely shrinking in proportion to the quantity of water that is lost. These masses of ice consist of parallel prismatic crystals, which are arranged at right angles to the tissues from which the water has been abstracted.

The cortical parenchyma of the shoot usually contains numerous intercellular spaces, especially along the line that marks the limits of the collenchymatous tissues of the outer cortex. Owing to the formation of a sheet of ice in this region, a separation of the cortical tissues may take place which, however, may occasion but little damage to the plant.

It is of importance to notice the resulting circumstances at the forming of ice. They are principally *the releasing of the melting heat* (according to Lemström 80 Cal. for every kilogram water) and *the increase of volume.* The heat released by the freezing is partly utilized by the plant, and the ice formed by the dew is a good coverlet which hinders further loss of heat. Thereby the freezing of the cellwater is for a short time prevented. If the loss of heat still continues the cellwater freezes and causes the death of the plant.

When a thaw occurs in the frosted parts of a plant the tissues usually regain the conditions which characterized them before the frost appeared. As the water is set free by the melting of the ice it is slowly absorbed by the cell walls and the cell contents, so that when the cells have attained the temperature at which chemical processes are possible the normal conditions of imbibition have also been again restored, and the metabolic processes which were temporarily suspended are resumed under the influence of the higher temperature. The case is different, however, when the frosted parts of plants are rapidly thawed, as occurs for instance when they are suddenly warmed by the sun. The rapid accession of heat induces the ice in the intercellular spaces to thaw rapidly, and the ice water being but slowly absorbed by the cellwalls and protoplasm flows into the intercellular spaces and drives out the air, with the result that leaves which are suddenly thawed become translucent. The normal conditions of imbibition have not been restored when the chemical processes start afresh under the influence of the rise in temperature. Instead of these processes assuming the normal features of metabolism, they lead to chemical decomposition in the comparatively dry and withered tissues. In other words the plant is dying. It is therefore emphatically to be recommended that plants affected by night-frost should be protected against a too rapid thaw.

Views have been divided as to the manner in which death of the plants is caused by frost. It was at one time admitted that destruction took place by the bursting of the walls of the vessels caused by the augmentation of volume which took place at the freezing. Hoffman attributes a part of the mechanical injury from freezing to the separation from the cell-sap of the air previously contained therein. Later researches have shown that the destruction is caused by the diminution of water which the protoplasm undergoes at freezing, as mentioned above.

There has also been a controversy with regard to the time when frost proves fatal. While Göppert concludes that death occurs during the continuance of the frost, Sachs is of the opinion that the tissues die only after they have thawed, and that a fatal issue depends very much on the manner and rate of thawing. The two views may to a certain extent be reconciled, for it is possible that during winter death occurs during the continuance of the frost, whereas in the case of a summer night-frost it appears at the moment of thawing.

All plants are not equally effected by a low temperature. Among our common European vegetables the potato is one of the most sensitive. Far less susceptible are the cereals, as oats, barley, rye, wheat; more sensitive pea, &c., at least during the first stages of growth.

Certain plants are seriously injured by low temperatures which are considerably above the freezing point of water, but these are exceptional cases. In some of our familiar spring plants of Europe the leaves may be frozen and thawed without apparent mischief, but in general the thawing must take place slowly; if it proceeds rapidly the plant may be irreparably injured. There are however also well known cases in which plants may be thawed quickly without serious injury. Sachs has shown that the leaves of the cabbage, turnip, and certain beans, frozen at a temperature of from —5° C. to —7° C. and placed in water at 0° C. are immediately covered with a crust of ice, upon the slow disappearance of which they resume their former turgidity. If such frozen leaves are placed in water of + 75° C. they at once become flaccid.

The behaviour of certain plants during exposure to low temperatures affords some of the best illustrations of the adaptability of vegetation to its surroundings; and the question as to increasing the tolerance of a given species or variety to the adverse influence of cold by careful selection of seeds for a series of years has been successfully answered by cultivators in some northern countries of Europe.

Apart from specific peculiarities we also find individual differences, and it is this fact which makes it possible for us to acclimatize plants. As the ability to resist frost varies amongst individuals of the same species just like any other physiological or morphological peculiarity, it becomes possible to acclimatize a tender plant by propagating hardy varieties.

We have already mentioned the lowest temperature at which perceptible growth takes place, but this minimum does not necessarily suffice for the developement of chlorophyll, or for assimilation, or for the irritability of motile organs and so forth; and when this is determined for one species of plant, the lower zero points of these functions in another species are by no means necessarily the same. The diversity of the lower zero-points of the various functions may however bring it about that at certain lower temperatures the various functions no longer work harmoniously together, so that pathological conditions are induced. It is observed in northern countries that the young leaves of cereal plants grow in the early spring, but in spite of bright illumination they remain yellow, because the lower limit of temperature for growth is not so high as that for the development of chlorophyll.

Not only the low temperature but also the length of its duration will be decisive for the destiny of the plant. We have no exact observations as to the length of time during which the vitality of a frozen plant persists. It is stated that after the recession of a glacier in Chamouni several plants which had been covered by ice for at least four years resumed their growth.

If the rays of the sun immediately after its rising reach the frozen plant, the ice will not only melt but also evaporate, consuming a great quantity of heat. The greatest part of this heat naturally comes from the sun, but one part is still derived from the little store of the plant, and it is probable that the last determining cause of the damage done by a night frost often depends on this circumstance. It would be wrong to believe that whenever rime round the plants is produced, the sunrise being clear, damage by frost will instantly occur. Lemström has shown that plants possess a certain power of resistance against frost, and that they are not in general destroyed if they are covered with ice at a temperature of —2° C. near the ground by clear sunrise, the time of the duration of the low temperature not exceeding 1½ hours. Kihlman and others have come to the same conclusion.

On the basis of what we have pointed out above with regard to the causes of night frosts and their effect on the vegetable world, we get a

Theory of Frost Prevention

that ravages by night-frosts can be avoided if we can restore to the field the amount of heat lost by radiation, or if we can reduce this radiation, or prevent a too rapid thawing of the frozen plants.

We can effect a communication of heat to the plants in the following way:—

(*a*) By a reduction of the radiation by means of artificial clouds;

(*b*) By movements in the air which mix the different strata;

(*c*) By condensed moisture that affords heat.

Nature herself offers certain opportunities which are of the greatest importance:—

(*a*) The condensation of vapour continually going on during the night;

(*b*) The universal calm which is reigning during a frosty night.

Now we will consider how this theory can be put into practical use, and give a resumé of

The Methods of Frost Prevention.

From time immemorial it has been known that frost will not occur when the sky is cloudy, and in many lands trials have been made to produce artificial clouds by burning different kinds of more or less cheap combustibles. The ancient Romans used this method as we learn from their literature, and in Peru the old inhabitants used smoke as a preventive against frost long before the country was taken possession of by Europeans.

No completely successful method has however yet been devised, and smoke as a preventive has therefore got into dis-repute. In France, for instance, the people say it succeeds but always for the advantage of our neighbours, thus indicating that smoke and vapour pass to their neighbours' fields. I have heard the same remarks in Queensland. But neither the French nor the Queenslanders have formed any association, as is the case in many parts of Germany, where attempts have been made to protect vineyards and orchards against both spring and autumn frosts by the burning of coal tar.

Avoiding frost by means of smoke is since olden times well known to the peasantry in Sweden and Finland, and during the winter on many a frosty night well-applied smoke-producing fires have saved valuable crops.

The formation of artificial clouds consisting of smoke and vapour must however be effected by fuel possessing the following qualities :—

It must be handy and cheap ;
It must be easily transportable ;
It must be easily kindled ;
It must burn slowly ;
It must produce much smoke, vapour and heat ;
It must not be so inflammable that danger of spreading the fire arises.

It is of course very difficult to combine all these qualities in one combustible. Professor Lemström has constructed a kind of *frost-torch* for which he claims the said properties.

These frost-torches consist of tubes of well-dried mud, and of kindling cylinders which can be inserted into the tubes. The torches may be placed in the field which is to be protected and remain there all the time frost may be expected or until they are used, for the rain affects only their surface and they dry very soon. Frost-torches of this kind can be manufactured at a price of less than ½d. apiece.

For a description of these frost-torches and their use we can refer to a leaflet by the inventor "On the method of providing against summer night frosts by the use of torches."

The writer has had experience of these frost-torches and found them to answer the purpose of producing a thick smoke. They do not however burn long, and it is necessary to determine the exact time when they are to be kindled, so as to be sure that they are still producing smoke at sunrise, when the danger is greatest.

The inventor claims also for his frost-torches the property of producing heat to such an extent as to affect a movement in the air strata, thus bringing warmer air down for the benefit of the vegetation. This effect is however still an open question, and Homén among others is of a different opinion.

Whatever kind of smoke producing fuel is used, it is however necessary to be careful when placing the fires so as to get the use of all the natural conditions that will benefit, and to counteract those which are of an injurious character. Care must thus be taken that strong currents of cooled air are kept out from the lower parts of the field, etc. Local circumstances have to guide all the measures taken, and a careful study and thorough knowledge of the phenomenon is necessary for the successful use of this remedy.

We have already hinted at the fact that a misapplied remedy often may be more injurious than the frost itself. We have witnessed several instances when big fires kindled after the freezing of the plants had taken place caused a too rapid thawing and subsequently death. The same fires kindled half-an-hour earlier would have saved the crop.

We have full faith in the effectiveness of smoke as a frost-preventive, but the methods have to be developed, and for that purpose a co-operation of science and practice is wanted.

On the principle of movements in the air as preventing injurious effects of frost, several methods have been tried. The Finns used to pass to and fro dragging a rope over the field, thereby causing a wave-like movement of the straw which results in a success, but this method is of course only possible on a small patch.

We have not been able to ascertain from the records whether the Stiger Vortex gun has been used in connection with frost experiments, but it seems to me that shooting over a field during a night-frost would be successful through causing the air strata to be mixed, and thereby effecting a restoration to the field of heat lost by nocturnal radiation.

ON FORECASTING OF NIGHT-FROSTS.

For the practical agriculturist who wishes to avert from his crop the evil effects of frost, it is of the greatest importance to be able to interpret correctly the warning signs given by Nature herself before a frosty night, so that the protective measures be not needlessly precipitated. A night-frost never comes unawares, and its forewarnings are fortunately sure and easily interpreted.

Every meteorological handbook contains information on this head, so we need not go into that question. As we said before the occurrence of frost and the phenomena connected therewith are however dependent on not only the climatic conditions in general, but also on local circumstances. A careful investigation of the frost question is necessary in every country where frost occurs, and the scientists, both the meteorologist and the biologist, as well as the agriculturists have to work hand in hand with their colleagues in other parts of the world.

We need scarcely say that, by reason of its geographical position, Australia is especially a good place for meteorological researches. The well established system of meteorological stations distributed all over the country and the high-level mountain observatories already in work—an undertaking showing great foresight on the part of its initiator—make it possible to forecast the weather conditions with an accuracy which cannot be surpassed in any other country. The rapid development of communication, railways, telegraphs, telephones, etc., will make it possible to spread intelligence of a threatening frost into nearly every cottage, so that the farmer need not even in this instance rely upon his own judgment, but can throw his responsibility on more experienced shoulders.

THE FROST INVESTIGATIONS IN SWEDEN AND FINLAND.

The first scientific inquiry *re* the frost phenomenon in those countries was made by a Professor Hällström, in Finland, 1804. He published a prize essay, for a long time considered and used as a standard-work on this question. In Sweden Hamberg took up the question in the seventies, and Lemström started at the same time his investigations in Finland. The interesting results obtained by these scientific inquiries caused a general interest in the question. Homën made some valuable experiments during 1880 and has since devoted himself to the study of the frost phenomenon.

In 1892 the Geographical Society of Finland commenced investigations about night frosts and their distribution in the country. Circulars containing questions relative to the night frost and its effects on the vegetation were distributed to all parts of the country, and detailed reports were voluntarily sent to the Society. The information thus collected has been compiled and published from year to year in the Society's bulletins by a prominent biologist, Professor Kihlman, and many a doubtful question has thus been settled.

Meanwhile the Government has interested itself in the matter. Besides giving the above mentioned Society all assistance in form of free postage, etc., a frost commission consisting of scientists and practical farmers was appointed for establishing an official scientific inquiry.

Recognizing the importance of drainage as diminishing the danger of frost, the Government has set apart funds from which cheap loans are given for the special purpose of giving the farmers an opportunity of getting their fields properly drained.

In Sweden the Government has taken similar steps. Last year for instance a sum of £23,000 was voted by the Riksdag for the current year for loans to be used for draining purposes, and for diminishing the frost danger, and every year a sum of £56,000 is placed to a fund from which small farmers get loans at 3 per cent. interest, and to the amount of 70 per cent. of the value of the proposed improvements.

For nearly a century the Finnish Society of Science has through interested persons in every part of the country been making phenological observations which are of great importance in connection with the frost question, as showing the season of growth and the effects of the climate not only on the indigenous vegetation but also on the cultivated plants. In Sweden too similar phenological data have for a long time been available.

A co-operative company was established a few years ago in Stockholm insuring against damages by frost, and this has proved to be a thorough success.

SUGGESTIONS.

As far as is known to the writer very little has been done in Australia in connection with the study of frost phenomena or with regard to practical attempts to prevent damages by night-frosts. Last year the late manager of the Biggenden State Farm, Mr. H. A. Tardent, strongly advocated in the papers the use of smoke as a frost preventive, and experiments were subsequently made on the sugar fields of the Isis district. However lack of confidence in the method and insufficient co-operation between the neighbours seemed to have caused, if not a failure, at least not a satisfactory result.

Co-operation is the great word in all matters connected with modern agriculture. If all the farmers in a neighbourhood combine, and after getting sufficient information from a meteorologist make up their minds to fight their common enemy, the frost, there is no doubt they could with a very small outlay save a considerable sum. But without co-operation, no success.

In the future we shall have legislation to the effect that nobody must neglect his duty if he thereby injures his neighbour, and this will apply to all branches of social life; but we are not advanced so far yet. We cannot therefore advocate legislative proceedings with regard to frost prevention, but we must try to persuade the farmer not to leave all to an uncertain hope, but to watch his own interest and that of his neighbour also.

With all the advantages of the already named system of meteorological stations, and the Weather Bureau in Brisbane which makes forecasting of frost so available, and by reason of the geographical position of Queensland on the very edge of the tropics, there is hardly any country in the world where the frost phenomenon could be studied with such a success as here. Also the presence in Queensland of such a distinguished meteorologist as Mr. C. L. Wragge is a reason for going into the study of this question.

I do not know which Society in Queensland is the proper one for taking up the practical part of this question of preventing damages by frost; but I think in addressing this body of scientific workers that I have placed the question in the hands of the men who are the most suitable for giving the matter a scientific attention, the result of which would be beneficial not only to this country but to the whole humanity.

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