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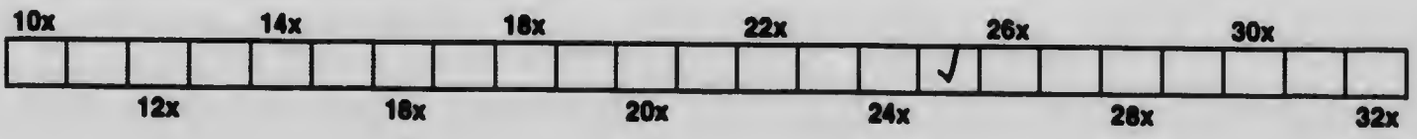

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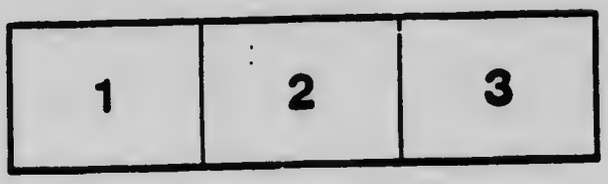

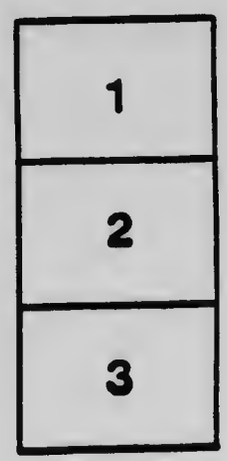

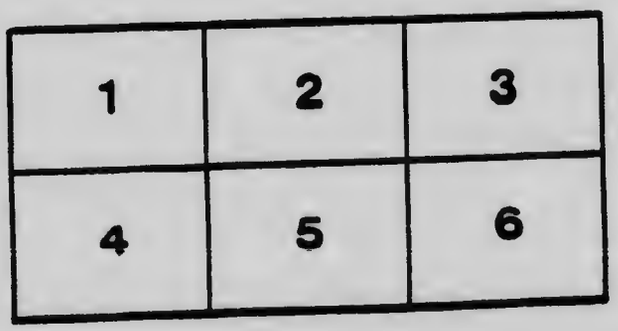

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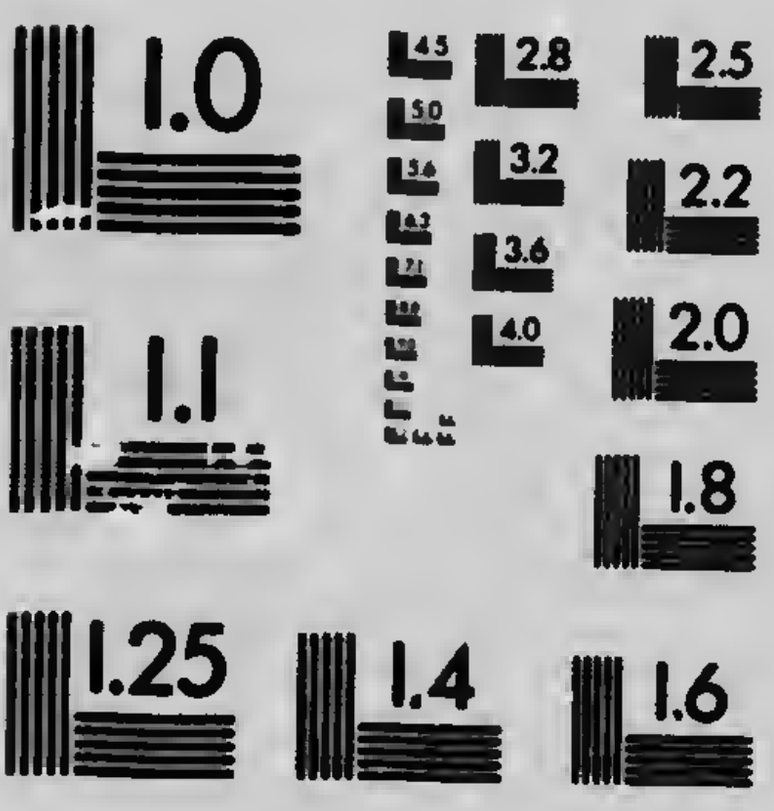

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ALKALI SOILS

THEIR NATURE AND RECLAMATION

BY

FRANK T. SHUTT, M.A.

Chemist of the Dominion Experimental Farms

BULLETIN No. 4

Second Series

Bulletins of the Second Series treat of such subjects as are of interest to a limited class of readers, and will be mailed only to those to whom the information is likely to be useful. Copies may, however, be obtained by anyone desiring them, as long as the edition lasts, by application to the Director of the Experimental Farms.

Published by direction of the Hon. SYDNEY A. FISHER, Minister of Agriculture, Ottawa, Ont.

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Published by direction of the Hon. SYDNEY A. FISHER, Minister of Agriculture, Ottawa, Ont.

To the Honourable
The Minister of Agriculture.

SIR,—I have the honour to submit for your approval Bulletin No. 4 of Series 2 on 'Alkali Soils their Nature and Reclamation,' which has been prepared by the chemist of the Dominion Experimental Farms, Mr. Frank T. Shutt.

In this bulletin the origin of the different sorts of 'alkali' soils is discussed, also their composition and characteristics, and methods of treatment are suggested whereby the alkali in such soils may be lessened or removed. It is believed that the information contained in this bulletin will be very useful to farmers living in those parts of the great Northwest plains and British Columbia where alkali is occasionally found.

As the alkali here referred to is rarely, if at all, found in Eastern Canada the distribution of this bulletin will be limited to those portions of the Dominion where alkali in the soil is found. Provision however is made whereby copies may be had by farmers in any other part of the Dominion on application to the Director, Central Experimental Farm, Ottawa.

I have the honour to be,
Your obedient servant,

WM. SAUNDERS,
Director of Experimental Farms.

ALKALI SOILS

THEIR NATURE AND RECLAMATION

BY

FRANK T. SHUTT, M.A., F.I.C.

Chemist, Dominion Experimental Farms.

The past five years have witnessed the preparation for tillage and settlement of many areas in the semi-arid districts of Canada—situated more particularly in parts of British Columbia and Southwestern Alberta. From the attention that is to-day being called to the natural advantages of such districts, more especially for fruit and vegetable growing in British Columbia, and alfalfa and general farming crops in Alberta, the probability is that during the next five years there will be a still larger influx of settlers into these parts and many as yet new and untried areas will be taken up. It is with the object of assisting those who are already occupying ranches, as well as those who propose taking up land, in these semi-arid districts—and in which 'alkali' occurs in places—that the information contained in this bulletin is furnished.

While as yet it may not be definitely settled as to the boundaries of these semi-arid districts, there can be no doubt on two points in regard to many of these areas now under cultivation or at present being exploited, viz.: the necessity of irrigation for ensuring success, and the occurrence in many places of alkali spots or tracts, either naturally present or developed subsequent to occupation through injudicious irrigation. Irrigation has been and is being provided on a comprehensive scale in certain localities but where such large systems are not in existence or are not possible, many individuals have made the effort, each farmer for himself, to establish a local water supply, chiefly from mountain streams. Instances of the former, for example, are to be found working satisfactorily in the Okanagan district; while with regard to the latter, we find the settlers in the valleys of the Columbia, Kootenay and Nicola for the most part dependent on possibly a limited and more or less strictly local source. Successful agriculture under irrigation calls for a special knowledge in the management of water. The primary use of water by irrigation is, of course, to supply the crops' needs, but it may also be employed as an important agent in the reclamation of lands more or less sterile through the presence of certain mineral salts, known commonly as alkali. On the other hand, the injudicious use of irrigation water may injure most severely land capable of producing excellent crops, through causing a 'rise of alkali.' Further, the excessive use of water is to be avoided, even on well drained land, from the fact that such retards the natural maturation or ripening of the crop.

From a consideration of what has been said it will be obvious that the agricultural problems of the semi-arid districts differ widely from those the farmer in other places in Canada has to encounter. Two of these are here more particularly discussed: the reclamation of alkali lands where such naturally occur and the precautions to be taken against the appearance of alkali on lands at present fertile.

'Alkali' does not exist in Canada to the same extent as in many of the Northwestern States; indeed, it is not a serious menace to the settlement and successful cultivation of the greater part of the semi-arid belt. But few extensive areas or tracts of alkali land naturally occur in the Dominion; the chief difficulty in this matter arises from the so-called occasional presence of alkali spots or patches. These vary greatly in size, from a few square feet to, perhaps, several acres, and in the majority of instances are caused by impregnation of the soil by 'white' alkali. The more injurious 'black' alkali is of a much less frequent occurrence.*

THE NATURE AND FORMATION OF SOILS IN GENERAL.

Arable soils are made up of two great classes of constituents: (1) mineral, as derived from the disintegration and partial decomposition of rock material; and (2) vegetable matter (humus), the semi-decomposed remains of past generations of plant life. It is from the former that the stores of lime, phosphoric acid, potash, etc., present in the soil are furnished, while the latter supplies the nitrogen required for crop growth and at the same time acts as an important factor in regulating the temperature, the moisture-content and the aeration of the soil.**

Though our virgin soils are the product of many centuries, soil formation is not merely a matter of the past; it is now going on. Under natural conditions, as in the forest, our soils are being constantly enriched in humus from decaying roots, fallen leaves—from the death and decay of vegetation generally, and, further, by chemical re-actions favoured by warmth, moisture, carbonic acid, &c., the rock elements of the soil are being continually, though no doubt slowly, decomposed, giving rise to soluble mineral compounds, some of which may be useful and others injurious to plant life.

THE ORIGIN OF ALKALI SOILS.

In humid districts, *i.e.*, those enjoying a more or less generous rainfall, the mineral salts formed by these processes, known popularly as 'weathering,' are disposed of as produced. In part they are utilized by vegetation, and any remaining injurious salts leach downward and drain away; there can be no accumulation of them in the surface soil.

But such is not always the case in arid and semi-arid districts. Here we find the scanty rainfall, while sufficient to promote the formation of these soluble mineral salts, quite inadequate to their removal by drainage. If they descend a few inches, or even a few feet, there is not enough flow of water through the soil to carry them right away and subsequent evaporation of the water that holds them in solution and the action of capillarity brings them to the surface, where they accumulate, forming the so-called alkali, rendering the soil more or less unsuitable for agricultural purposes. The alkali may simply impregnate the surface soil, or if evaporation greatly exceeds the rainfall, it may appear as an incrustation or efflorescence.

This explanation makes it clear that alkali does not betoken any original property of the soil inimical to vegetation—indeed, the greater number of alkali soils when

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* Further information respecting the conditions under which farming and horticulture is carried on in many parts of the semi-arid areas of Northwestern Canada will be found in the report of the Chemical Division of the Experimental Farms for 1904 and 1906, which contain an account by the writer of two extended visits to British Columbia and Southwestern Alberta.

** Humus is Nature's storehouse for nitrogen. As the humus in a soil is increased or decreased so is the nitrogen increased or decreased. Humus performs the useful purpose of so favourably affecting the physical condition of both clays and sands as to render them suitable for the support of crops. It furnishes the material upon which the micro-organisms of the soil feed, thus fostering a valuable agency in the preparation of plant food. And, again, it serves in the maintenance of soil productiveness by constantly liberating in its decomposition certain small amounts of mineral matter in forms peculiarly available for absorption by the roots of plants.

Reclamation of "Black Alkali" soil:—
A—Treated with Land-plaster or Gypsum, showing flocculation and precipitation of humus.
B—Untreated. Humus in solution. Very little sedimentation after several days.

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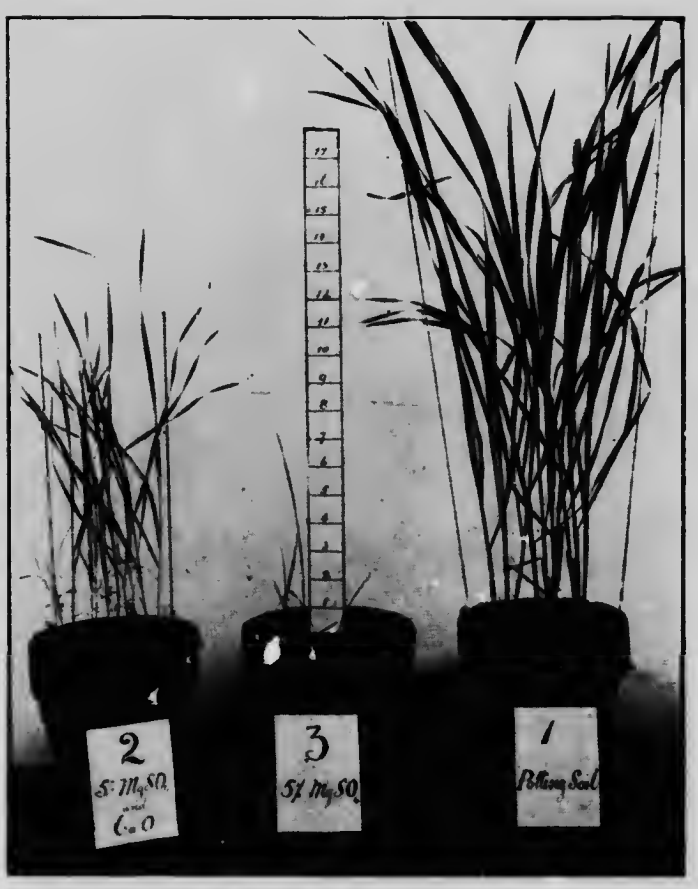

Illustrating beneficial effect of Lime on Magnesian "Alkali":
1. Grain in potting soil. 2. Grain in soil containing Epsom Salts and lime.
3. Grain in soil containing Epsom Salts.

freed from the excess of alkali are exceedingly fertile*—but that its presence is simply owing to certain climatic conditions, briefly, to an insufficient rainfall. Alkali soils, therefore, are characteristic of arid or semi-arid districts only, and these in Canada may be said to be restricted to certain areas in British Columbia, South-western Alberta and in a limited degree, Saskatchewan and Manitoba.

THE COMPOSITION AND DISTRIBUTION OF THE SALTS IN ALKALI SOILS.

The compounds known collectively as alkali comprise chiefly sodium sulphate (Glauber's salts), sodium carbonate (washing soda), sodium chloride (common salt), magnesium sulphate (Epsom salts), and occasionally the chlorides of calcium and magnesium. The total amount of these salts present is extremely variable, percentages from 0·1 to 3·0 being recorded for a depth of the first four inches, from which fact it naturally follows that great differences exist amongst alkali soils as regards their degree of injuriousness to plant life. Again, the 'alkali' may be practically confined, in a concentrated form, to the immediate surface or perhaps upper six inches of soil, or it may be distributed throughout three or four feet, forming an almost negligible percentage of the total soil, depending on the nature of the soil and the amount of rainfall. Towards the end of the dry season, however, there will always be more or less of accumulation of the alkali towards the surface.**

'WHITE' AND 'BLACK' ALKALI.

While the amount of alkali present is undoubtedly a factor gravely affecting the productiveness of a soil and the possibility of its profitable reclamation, the nature of the alkali is a matter of still greater importance. Two classes of alkali are generally recognized 'white' and 'black,' (so-called from the appearance of the respective incrustations) differing as regards the intensity of their toxic action on vegetable life, and also in their amenableness to simple remedial measures.

White alkali consists chiefly of the sulphate and chloride of sodium (Glauber's salt and common salt), but may also contain notable quantities of chloride and sulphate of magnesium (bittern and Epsom salts). Instances have been met by the writer in which the greater part of the alkali was made up almost entirely of these salts of magnesium, but such are not very common. White alkali is, therefore, a generic term, and is used to designate any or all of the aforementioned salts; as already remarked, it is commonly a mixture of several of them.

Black alkali is characterized by the presence of sodium carbonate (sal soda, washing soda), though this compound is almost always associated with one or more of the chlorides and sulphates mentioned in the preceding paragraph. Sodium carbonate is, as is well known, white, but from the fact that it acts upon and dissolves the decayed vegetable matter (humus) of the soil the incrustation is tinged dark brown or black—hence the name. Water standing in pools on soils impregnated with the carbonate is invariably of a darker colour and much resembles a strong solution of coffee.

INJURY TO PLANTS BY ALKALI.

It follows from what has been said regarding the soluble nature of the 'alkali' salts that the soil-water on such impregnated land is a more or less concentrated solution of these compounds. It is the soil moisture which assists in the germination of

* Chemical analysis has shown that as a class the soils of arid or semi-arid regions are considerably richer in plant food than those of humid districts, and this is particularly true as respects lime and potash.

** Associated with the salts named and which must all be considered injurious to crops, are notable quantities of many compounds useful as plant food, *e.g.*, compounds of potash and phosphoric acid, and these give to the soil, freed from alkali, the high degree of fertility for which such soils are remarkable.

the seed and which is the means of conveying food to the plant rootlets; for the performance of these important functions, it is obvious that it should possess no injurious properties. Experiment has demonstrated that the effect of a solution such as we find in alkali soils on the cells in the tissues of the roots is to extract or withdraw from them by a process known as osmosis their natural water. As a result the cells lose their turgidity, their protoplasmic contents shrink from the cell wall, the plant wilts and death may ensue. The higher the percentage of alkali—in other words, the more concentrated the solution—the more severe the effect in this direction.

Again, there can be little doubt that many of these alkali salts, after absorption by the plant, act as true poisons on the life of the vegetable cell.

As already remarked, 'black' alkali is more violent in its action than 'white' alkali, and consequently is much more to be feared. The sodium carbonate it contains is directly corrosive, cutting into and eating away the tissues, especially at the immediate surface of the soil. Very small quantities in a soil are sufficient to prevent seed germination or to destroy the tender rootlets of the seedling, if the young plant appears. It is also more injurious than white alkali to fruit trees, corroding the tissues of their bark at the surface of the soil, i.e., at the crown of the root. Signs of this girdling are to be observed in the leaves turning yellow and dropping prematurely—such indications are usually the precursor to an esrly death.*

While speaking of the effect of black alkali on the plant, a word may be added respecting its action on the physical condition of the soil. All kinds of alkali have a tendency to injure a soil's tilth but this is particularly marked in the case of black alkali. The soil readily puddles, flocculation, or the property of forming flakes, is destroyed and the land becomes in a large degree impervious to water. On drying, hard refractory masses are formed and the soil is extremely difficult to work. Very frequently a hard, practically impenetrable hard-pan forms under such soils, making it almost impossible to put in a system of tile sub-drainage.

RECLAMATION OF ALKALI SOILS.

By leaching and under-draining.—Since, as has been shown, the formation or occurrence of alkali is due to an insufficient rainfall, it naturally follows that thoroughly washing the soil should prove an effective means of getting rid of the injurious soluble salts. It forms, indeed, of all remedial measures the one that gives the most satisfactory and permanent results. Alkali lands for the most part occur in regions where provision is made for supplying the crops' needs with water by irrigation. This water can be used to wash out and carry away the alkali. However, if the natural drainsge of the soil is not good, flooding by irrigation should be preceded by the construction of an adequate system of under-drainage. Irrigation of lands at all heavily charged with alkali and underlaid by a hard-pan, without under-drainage, makes matters worse. Flooding may furnish temporary relief by washing the alkali below the zone occupied by the roots of the crop at the beginning of the season, but as the water evaporates (it cannot escape by drainsge) alkali is again brought to tho surface by capillarity. If the water has penetrated layers of soil containing much alkali then the surface soil will, as the result of this evaporation, be worse than before the flooding, for it will now be impregnated with salts that were previously distributed through probably 3 to 5 feet of soil. This is known as 'rise of alkali,' a direct result

*The symptoms of suffering from black alkali are very similar to those produced by too high a water table. The writer examined several orchards on low lying areas in British Columbia in which the trees were dying, supposedly from black alkali, but which were found to be planted on a soil practically free from alkali but in which the water stood within a few inches of the surface for weeks together at certain seasons of the year. It is well, therefore, if the trees show injury, to examine into the matter, bearing this in view. Drainage is essential, and if not naturally good, it must be provided, whether alkali is present or not. Further, if carbonate of soda is suspected, even in traces, land plaster should be sprinkled around the base of the trees and quite close to the trunk, to prevent carrosion of the tissues. It will be found an excellent preventive against injury from black alkali.

of the injudicious irrigation or flooding. It is the 'rise of alkali' caused in this way (irrigation without drainage) that has ruined in the United States large areas of once cultivable fertile lands.

Closely related to this matter is the irrigation of slopes and hill sides. Some provision should be made to carry off the seepage or drainage which otherwise will flood the lower levels and bottom lands, causing much injury either through rise of the water level, so that the crops' roots are 'drowned,' or by the accumulation of alkali. Several areas have been examined by the writer that have been seriously injured by such seepage, in one or other of these ways—frequently through both—and which were but a few years ago yielding excellent crops. It seems strange to those who have not given the matter thought that alkali should appear on these bottom lands when before irrigation there would be no indication of it either in the soil of the hill side or bottom land, but it must be remembered that in a semi-arid country there will always be in the soil more or less mineral matter (salts) that can be washed out. This, after a few seasons, accumulates and by concentration may assume dangerous proportions; indeed, it may utterly ruin the land on flats and lower areas unless efficient drainage is provided. Surface drains are of some value, but tile drainage is much more effective.

The treatment of black alkali.—Some years ago it was pointed out by Prof. Hilgard, Director of the California Experiment station, that the application of land plaster (ground gypsum) to soil impregnated with black alkali would convert the corrosive carbonate of sodium into the sulphate of sodium, the chief constituent of white alkali, which, as we have seen, is a milder form as regards vegetable life. This suggestion has proved most valuable, enabling large tracts of useless soil in the United States to be effectively and cheaply reclaimed. If the carbonate is only present in small amounts, the land may be rendered cultivable simply by a dressing of land plaster, but in the majority of instances it will be necessary to subsequently wash, as already described, the resulting sulphate before the soil is fit for bearing crops. The amount of land plaster to be used for complete conversion of the carbonate into sulphate can only be calculated after an analysis has been made determining the amount of carbonate present in the soil—it may vary from several hundredweights per acre to as many tons. However, as Hilgard has pointed out, 'it is not usually necessary to add the entire quantity at once ,provided that sufficient be used to neutralize (convert into sulphate) the sodic carbonate near the surface, and enough time be allowed for the action to take place.'

A word must be added regarding the beneficial effect of the land plaster on the texture of black alkali soil. An improvement is almost immediately seen. Hilgard says: 'The blackish puddles and spots disappear, because the gypsum renders the dissolved humus insoluble and thus restores it to the soil. The latter soon loses its hard, puddled condition and crumbles and bulges into a loose mass, into which water now soaks freely, bringing up the depressed spots to the general level of the land. On the surface thus changed, seeds now germinate and grow without hindrance; and as the injury from alkali occurs at or near the surface, it is usually best to simply harrow in the plaster, leaving the water to carry it down and the solution of soluble phosphates present are decomposed so as to retain finely divided, but less soluble, earth phosphates in the soil.' Drainage, which usually is exceedingly difficult on black alkali soils is by the use of gypsum made practicable. Excess of gypsum can do no harm; indeed, it may be considered a fertilizer of some value, but naturally it can be of no service to soils impregnated with white alkali.

Removal of alkali from the surface of the soil.—When the alkali occurs, as it frequently does, in spots or patches of limited areas, and flooding and drainage are impracticable or impossible, the alkali may be removed, wholly or in part, by the use of a horse scraper or similar implement. Three to six inches of the surface soil are usually sufficient to take off and, as pointed out by Hilgard, 'this loss is of little moment on the deep soils of the arid regions.'

The prevention of surface evaporation.—All methods of culture that tend to check evaporation are useful and should be employed on alkali soils, for it should be always borne in mind that it is this evaporation that causes the accumulation of alkali at or near the surface.

Frequent cultivation breaks up capillarity and thus arrests evaporation. In many cases of white alkali where the proportion of salts is light, this may in itself prove sufficient, and on such spots a root or other hoed crop may be planted that will allow the surface to be kept continually in the condition of a loose, dry mulch.

Various mulching materials, e.g., straw, manure, etc., have been employed to check evaporation, but have not been found so successful as cultivation, though possibly they have a value for orchards and small fruit plantations.

Crops which furnish abundant shade, *e.g.*, fruit trees, alfalfa, &c., are often effective in preventing a rise of the alkali by evaporation, but naturally they are more effective in preventing the occurrence of alkali where it exists in very small amounts —probably not discernable—than on soils where alkali already occurs in considerable quantities.

Cultivation should be associated with deep—extra deep—ploughing. The bulk of the alkali is already at the surface and the turning under of the surface soil and its consequent mixing with the relatively free lower soil may often suffice in itself to produce a soil in which ordinary crops will grow. This deep tillage must, of course, be followed by frequent and fairly deep cultivation in order to prevent the subsequent rising of the alkali. Hilgard says on this point: 'Whatever else is done towards reclamation, *deep preparation and thorough cultivation* must be regarded as prime factors for the maintenance of production on alkali lands.'

Application of manure.—Heavy and repeated applications of manure—more especially horse manure—have been found of great value for alkali spots. This treatment is frequently entirely successful in reclaiming the soil in the course of two or three seasons and may be confidently recommended for trial in cases where the alkali content is not high.

Possibly the beneficial action of manure is in three directions: First, as furnishing immediately available food for the young plant. Thus, while the rootlets are in the most tender and susceptible stage they readily find nourishment and the crop is forced along until it has gained sufficient robustness and vigour to withstand a certain amount of alkali. Secondly, the mixing of the manure with the soil must vastly improve the mechanical condition or texture of the latter, rendering it more mellow and permeable to water and allowing its more ready aeration—in fact, in many ways making the soil a more comfortable foraging ground for roots. And, lastly, while destroying capillarity in the surface soil it also acts partly as a surface mulch and thus serves very materially in preventing the accumulation of alkali.

Lime for magnesian alkali.—Occasionally alkali is found that consists largely, almost entirely of magnesium sulphate (Epsom salts), though sodium salts will not be altogether absent. Such 'alkali' may be corrected by an application of lime, or marl, followed by drainage and irrigation. Experiments carried on by the writer some years ago showed very clearly the beneficial effect on vegetation following the mixing of lime or marl with the soil—the chemical reaction being the conversion of the injurious magnesium sulphate into an insoluble, inert magnesium compound—sulphate of lime (gypsum) being at the same time formed.

It is important before making any application of lime to ascertain the nature of the alkali present—or the results may be disastrous. If lime were added to soils containing more than traces of sulphate or carbonate of sodium ('white' and 'black' alkali) appreciable quantities of caustic soda would be formed, and this is a most corrosive compound and one exceedingly injurious to vegetation. In bringing to a conclusion this discussion on remedial measures, I am led to say a word regarding the popular impression prevailing among farmers in districts affected with alkali, that there is or ought to be some chemical which if applied to the commonly occurring

white alkali (chiefly sulphate and chloride of sodium) will 'kill' or neutralize the injurious compounds. Such is not the case. As already stated, washing out and carrying away by drainage furnish the only means of getting rid of the alkali.

CROPS FOR ALKALI SOILS.

Plants differ in their alkali-resistant powers: some will thrive and come to maturity on soils so highly impregnated that for the majority of crops there can be no possible hope of success. Such plants are, of course, of great value in alkali districts. Again, certain plants will absorb considerable quantities of white alkali without much retardation of their growth, and these may be used as an agent in the reclamation of impregnated areas.

Sugar beets are remarkably tolerant of alkali; their growth removes large quantities of the mineral salts, so that in a few seasons, where the alkali is not severe, this crop may so far improve the soil as to make it agreeable to grain, grasses, etc. At first the beets may be too bitter for stock, but their remedial action is such, we think, as to well compensate for the loss of the crop.

Closely following sugar beets are mangels. While not possessing alkali-resistant power quite equal to beets, they have proven very fairly satisfactory in removing deleterious salts. As these are both hoed crops, the necessary cultivation assists in checking evaporation and, therefore, in retarding the rise and accumulation of alkali.

As for cereals, opinions differ as to the relative resistant powers of oats and barley. Generally, barley is considered the more successful crop for affected land, though Jensen has shown oats to be more resistant where the greater part of the alkali is sodium sulphate. Wheat is more susceptible than either barley or oats; of varieties commonly sown, the macaroni or durum wheats are stated to be the most resistant.

Among the good grasses that can be grown on alkali lands are Timothy, Awnless Brome Grass, Red Top and Perennial Rye Grass. Evidence has accumulated in Canada to show that Brome Grass is particularly valuable for this purpose; apparently it can withstand a fair amount of white alkali.

The legumes, with perhaps the exception of Alfalfa and Sweet Clover, appear to be particularly sensitive to alkali. Alfalfa is grown on tracts which show alkali spots, and, once fairly established, yields large returns. To obtain a catch it is necessary that the upper few inches of soil in which the seed must germinate should be practically free of alkali. When fully grown, no doubt the feeding part of the root system of the Alfalfa is far below the layers of soils containing alkali. The shade produced by the crop is instrumental in preventing accumulation of alkali at the surface.

In writing of crops for alkali infected land, Mr. W. H. Fairfield, Superintendent Experimental Farm, Lethbridge, Alta., who has had considerable experience in the reclamation of alkali soils, says: 'Among the legumes, Sweet Clover (*melilotus alba*) will grow on land where few other plants will. However, it is of little or no value for feed, and is often a bad weed. It has been found of value to grow on alkali ground preparatory to the sowing of crops with less alkali-resistant power.'

Very few vegetables can be successfully grown on alkali soil. The tolerance of beets has already been referred to; asparagus is also another exception. The latter can resist and thrive in soil containing considerable amounts of white alkali. Potatoes are also an alkali-resistant crop, but the tubers are usually poor in quality and do not keep well. Artichokes are stated to be fairly tolerant of alkali.

As regards fruit trees, both large and small, very little can be said as to relative resisting power. One author gives orchard trees in the order of tolerance as follows: Pear, quince, olive, fig, apples, almond, peach, plum, orange and lemon. As previously remarked, instances have come under the writer's notice in which trees were suffering rather from standing water (a high water-table) than from alkali. Attention to drainage is therefore of the first importance in alkali districts when an orchard is to be planted.