Reclamation of Sodic Soils by Biological Methods

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Commonly in the Argentine Republic we give the name of "suelos salitrosos" to those soils affected by several processes of alkalization. These soils occupy huge areas in the dry and semi-arid regions of the country, existing also in areas stretching over several millions of hectares even in west regions, as for example the lowlands of Buenos Aires Province, the south of Entre Rios, the middle of Santa Fé, the west of Chaco and Formosa and so on.

These soils, totally or partially unproductive, spread out more and more due mostly to the over-grazing which is currently practiced in nearly all the country.

This work is restricted to the recovery of sodic soils in the semi-arid region, especially to the west of Buenos Aires. The common chemical methods (such as gypsum, sulphur, sulphuric acid and so on), used on irrigation lands are inapplicable because of their high costs in relation to the land value and also because of the lack of irrigation water and suitable drainage.

Their low permeability in natural conditions, place these soils among those classified by BLACK [1] "as unrecoverable under the present economic conditions".

This adds new interest to the finding of simpler and cheaper methods to bring about their recovery. Among these, we believe that the biological processes described in this work deserve to be tested.

Materials and methods

The soils studied were of soils of varying textures, generally with little or no structure and having in all cases an impermeable layer in some horizon. This gives them the general characteristics of lands which easily flood, especially during periods of heavy rain. In wet regions we can find these soils in the low poorly-drained areas.

The presence of salts such as chlorides or sulphates is generally low and very often these salts are found only as traces. However the pH is very high. In the superficial layers of soils during the period of drought we can found pH values of 11.6. Between 20—50 cm. there is generally a hard layer very rich in calcium carbonate.

We have worked particularly with the alkali lowlands in the C. R. E. A. group of Pirovano-Bolivar, but this method is being tested in irrigation

zones of the Rio Negro Province and in many other Argentina provinces such as Santa Fé, Chaco, and Dórdoba.

The process of recovery begins with the sowing of a very rustic species, such as the "broom corn" *(Sorghum technicum)* a producer of a large quantity of cellulosic materials.

Generally the sowing results are unequal; as a matter of fact in places with very high pH-values the plants fail or remain very poor. In regions of better soils they often reach heights of more than 6 feet. Afterwards the "broom corn" is subjected to an intensive grazing period with 8—10 cows per hectare for a time sufficient to permit the cattle to consume 60—70% of the pasture. The remainder of 30—40% is incorporated into the soil by means of a "one way" plow or a heavy disk harrow (Goble disk Massey Harris). This method leaves a thick stubble over the ground.

Besides reducing the cost of the process of recovery, intensive grazing enables the equalization of the soil, eliminating the "spots" of barren soil. Actually the cattle act as equipment to move fertility from the good parts of the soil to the poor ones. This is facilitated by the preference of the cattle to sleep in places without vegetation, the alkali spots. Under these conditions large amounts of the dung and urine are left in these areas. Another important factor is that in the excrement of the cattle there is a microflora with a great quantity of anaerobic bacteria, which attack cellulose and other polysaccharides. Tests made in the laboratory seem to prove the lack of anaerobic cellulose bacteria in the alkali spots; that is why the addition of dung acts as a "starter", which accelerates the decomposition of cellulose.

The importance of the anaerobic decomposition of cellulose and of other polysaccharides in the production of substances that could be used by the *Azotobacter* in order to fix the nitrogen of the air (MOLINA and QUANT, [3]) is of special interest to this aspect of the problem.

In the second stage of reclamation we proceed to the sowing of the permanent pasture. It is done at the end of the autumn or at the beginning of the winter using a mixture of plants, especially adapted to these soils, such as "tall wheat grass" *(Agropyron elongatum)*, "white sweet clover" *(Melilotus alba)*, "yellow sweet clover" *(Melilotus officinalis var. Madrid)*, "high fescue" *(Festuca elatior var. alta)* and discarded alfalfa seeds from the sweeping of barns, cleaning of seeds, an so on. The sowing is done over the thick stubble mulch left by the "broom corn". This mulch protects the soil, lessening the evaporation and enabling the germination of seeds in such difficult conditions.

The pastures planted by the method described gave excellent results as forage and as seed producers. The "tall wheat grass" dominates in the more alkali soils while "sweet clover" and "fescue" prosper in soils of better quality. The most striking result is that, although the soils are easily flooded, the few kilos of alfalfa which were sown produced a considerable quantity of plants, and also a good yield of seeds.

Apparently the effect of the constant drainage by the roots of the tall wheat grass enable the survival of alfalfa under conditions which are generally considered limiting for its development.

As quantitative data of production, we can report that in the first 440 hectares reclaimed, the following results were obtained with regard to livestock and crops;

Before

1. A badly fed cow per 4 hectares.
2. Meat production per ha was very low.
3. There were no crops.

After

1. Two cows per hectare under excellent conditions throughout the year.
2. Meat production is nearly 200 kg/hectare/year, similar to that of the best land of the zone.
3. A crop of tall wheat grass *(Agropyron elongatum)* seed is obtained. In 1964, 25 tons of this seed were harvested from the 440 hectares, its value being around US $ 0.80 per kg.

These results have stimulated the application of this method in other zones of the Argentine Republic and actually some 42,000 hectares of these non saline-alkali lowlands have been reclaimed.

The production obtained from these lands that before were considered useless has raised their sale value.

During the rigorous droughts which have occurred in these zones during the last three years, these fields have constituted one of the best areas of forage production.

Discussion of the results

After these spectacular results it was necessary to find a suitable theoretical explanation. The literature contained several works which have many things in common with our method, but which always differ in that they were done in irrigated areas and with the help of water and drainage. We can mention the works of SINGH [7], OVERSTREET ET AL. [5, 6] and so on.

On the basis of the results obtained it is our opinion that even without irrigation water or drainage it is possible to try reclamation of alkali soils without resorting to the utilization of chemicals. The principal factor that regulates pH in alkali soils according to WHITNEY and GARDNER [9] is the carbon dioxide concentration. If we succeed in increasing the carbon dioxide in the soil atmosphere we can lower the pH very easily. In our investigations (MOLINA and QUANT, [4] we can lower the pH from 11.6 to 6.5 by increasing the carbon dioxide concentration in the soil.

As the salt content of these soils is generally low, once the problem of pH is solved, it is relatively easy to install a permanent pasture. The respiration of the roots of the plants of the pasture will maintain the carbon dioxide concentration at a high level in the soil.

In theory the improvement of the soil could be permanent meanwhile the pasture is not overgrazed, especially in summer. Overgrazing according to HEADDEN [2] sharply reduces the respiration of the roots of plants and in this way the carbon dioxide production is decreased.

We attribute the progressive alkalination and desertation of regions which have formerly had excellent natural pastures, as for example the west of the Chaco and Formosa, to the continuous overgrazing of these regions.

Summary

We are testing on a large scale employing over 42,000 hectares a biological method for the reclamation of sodic soils in a semiarid region, without using irrigation water or drainage. This biological method has given so far very good results.

The method, based on the influence of carbon dioxide on the pH of alkali soils because of the low cost will enable the improvement of the huge areas now affected by this problem in the Argentine Republic.

References

[1] Black, C. A.: Soil-plant relationships. John Wiley and Sons, New-York. 1957.
[2] Headden, W. P.: Colo. Agr. Exp. Sta. Chemistry Sect. Bull 319. 1927.
[3] Molina, J. S. & Quant, J.: Carbon sources used by Azotobacter in moulded soil plates: Volatile substances produced in anaerobic fermentation into the soil. (Spanish.) Ciencia e Investigation **16.** 474—476. 1960.
[4] Molina, J. S. & Quant, J.: Different methods of pH determination in relation with biological processes in alkali soils. (Spanish.) Boletin Reuniones de Intercambio Asociacion Amigos del Suelo. (2) (Buenos Aires — Argentina) 1962.
[5] Overstreet, R., Martin, J. C. & King, H. M.: Gypsum, sulfur and sulfuric acid for reclaming an alkali soil of Fresno series. Hilgardia **21.** 113—127. 1951.
[6] Overstreet, T., Martin, J. C., Schultz, H. K. & McCutcheon, C. D.: Reclamation of an alkali soil of the Hacienda series. Hilgardia **24.** 53—68. 1954.
[7] Singh, R. N.: Reclamation of "usar" lands in India through blue-green algae. Nature **165.** 325—326. 1950.
[8] Sauberán, C. & Molina, J. S.: Reclamation of alkali soils. (Spanish) Ciencia e Investigation **16.** 337—338. 1960.
[9] Whitney, R. S. & Gardner, R.: The effect of carbon dioxide on soil reaction. Soil Sci. **55.** 127—141. 1943.

Мелиорация засоленных почв биологическими методами

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Резюме

За последние семь лет проведена мелиорация 440 гектаров неплодородных засоленных почв равнины югозападной части области Буэнос-Айрес (Аргентина).

Теоретические основы проведенных работ весьма простые и общеизвестные. Теория основана на действии углекислоты, выделяемой в процессе дыхания солеустойчивыми растениями и на микробиологическом разложении растительных остатков в почве.

Результаты мелиорации указанных выше 440 гектаров в отношении развития растений и поголовья скота следующие:

до мелиорации:

1. Одна голова крупного рогатого скота плохой упитанности на каждые 4 гектара.
2. Производство мяса на один гектар практически равно нулю.
3. Растениеводство на этой площади равно нулю.

по окончании работ по мелиорации:

1. По две головы крупного рогатого скота хорошей упитанности на гектар.
2. Производство мяса на один гектар в год около 200 кг, как и в лучших районах округа.
3. Производство семян пырея (*Agropyron elongatum*). В 1964 году на 440 гектарах выращено 25 тонн семян этого растения. Стоимость семян около 0,90 США долларов за килограмм.

Эти результаты стимулировали применение этого метода и в других областях Аргентинской республики, в итоге чего проведена мелиорация 45 000 га этих равнинных засоленных земель.

Урожаи, получаемые с этих считавшихся ранее бесплодными площадей повысили и их ценность.