First IUSS Conference on Sodic Soil Reclamation

July 30. 2021，Changchun，China

Book of Abstracts

Edited by Zhichun Wang and Tibor Tóth

Northeast Institute of Geography and Agroecology,

Chinese Academy of Sciences

Changchun, 2021

ORGANIZING COMMITTEE

Tibor Tóth, International Union of Soil Sciences, Chairman of Commission 3.6. "Salt-affected soils", Institute for Soil Sciences, Centre for Agricultural Research, Hungary
Haitao Wu, Northeast Institute of Geography and Agroecology, CAS
Zhichun Wang, Northeast Institute of Geography and Agroecology, CAS
Xiaojing Liu, Institute of Genetics and Developmental Biology, CAS
Fenghua An, Northeast Institute of Geography and Agroecology, CAS

SCIENTIFIC COMMITTEE

Tibor Tóth, International Union of Soil Sciences, Chairman of Commission 3.6. "Salt-affected soils", Institute for Soil Sciences, Centre for Agricultural Research, Hungary
James Oster, University of California, Riverside, USA
Pichu Rengasamy, University of Adelaide, Australia
Jinsong Yang, Soil Research Institute, CAS
Xiaojing Liu, Institute of Genetics and Developmental Biology, CAS
Changyan Tian, Xinjiang Institute of Ecology and Geography, CAS
Gu Feng, China Agricultural University
Zhichun Wang, Northeast Institute of Geography and Agroecology, CAS
Laosheng Wu, University of California, Riverside, USA
Manzoor Qadir United Nations University, Canada.
Stephen Grattan, University of California, Davis, USA
Thomas DeSutter, Department of Soil Science, North Dakota State University, USA
Huangcheng Pang, Chinese Academy of Agricultural Sciences
Xing Xu, Ningxia University, China
Rongjiang Yao, Soil Research Institute, CAS
Fan Yang, Northeast Institute of Geography and Agroecology, CAS
Hongyuan Ma, Northeast Institute of Geography and Agroecology, CAS
Zhenyong Zhao, Xinjiang Institute of Ecology and Geography, CAS
Hongyong Sun, Institute of Genetics and Developmental Biology, CAS
Hongbin Wang, Jilin Agricultural University
Zhongyi Qu, Inner Mongolia Agricultural University
Shujuan Wang, Qinghua University
Jianqiu Zhang, Jilin Forestry Academy of Science
Huaxin Zhang, China Forestry Academy of Science

ORGANIZED BY

- The International Union of Soil Sciences
- The Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences (CAS)
- The Salt-affected Commission of the Soil Science Society of China
- The People's Government of Jilin Province, China

Table of Contents

Introduction

Best suited areas for irrigated agriculture are used as such for centuries. Parallel to the continuous spreading of irrigated agriculture, less than optimal soils, drainage conditions, waters are utilized. Stepping out of the optimum into risky areas may cause undesired consequences, soil salinization and sodification are the worst of them. New knowledge is needed for sustaining irrigation in such areas, and with increasing population pressure such knowledge is more and more appreciated and needs forum for discussion, such as this conference. China has large areas of natural salt-affected soils, but also secondary salt-affected soils, and extensive areas are affected not only by salinity but also by sodicity. In Northeastern China, inside the Songnen Plain, there are areas with extreme levels of sodicity and alkalinity, but on the other hand in some areas irrigation is spreading, therefore a varied picture of salt-affected lands is present there, and that motivated the organizers to have the meeting in the Northeast Institute of Geography and Agroecology, where long experience has been accumulated on the Songnen Plain. Such specialized meetings are not frequent, but inspired by the success of the 2018 domestic meeting, which was organized by the Salt-affected Commission of the Soil Science Society of China in Changchun, organizers intended to attract international participation on this very much relevant topic.

There were many conferences organized on salt-affected soils by the Subcommission, Working Group and Commission on Salt-affected Soils of the International Union of Soil Sciences (IUSS) earlier. Being the first focusing on reclamation, this event was named First IUSS Conference on Sodic Soil Reclamation. Originally scheduled to take place between Sept. 17 and 19 in 2020, but due to the world lockdown following COVID19 pandemic outbreak, it was postponed to May10-12, 2021. Due to still ongoing strict restrictions it was at last re-postponed to July 30-Aug. 1, 2021, the fixed date of the conference. Pandemic is not yet over, international and domestic travel is still complicated with COVID19 tests and quarantines, therefore the conference is organized in a hybrid manner, some participants are physically present, others online abroad or sitting in quarantine. To facilitate online international participation the registration is completely free. Conference registration was available at http://ssr.csp.escience.cn.

The conference focuses on the key scientific issues of sodic soil reclamation, the theoretical innovation of soil sodification and improvement of sodic soil management. It intends to build a communication platform for scholars, enterprises and decision-makers, exchange the latest scientific frontiers through a variety of ways such as academic reports, posters and seminars. It provides useful references for the improvement and utilization of sodic land in different regions of the world.

The conference is jointly organized by the International Union of Soil Sciences (IUSS), the Chinese Academy of Sciences (CAS) and the People's Government of Jilin Province, China. It is hosted by the Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences and the Salt-affected Commission of the Soil Science Society of China. It is held in Changchun, Jilin Province, China.

We wish fruitful participation in the meeting and encourage the readers to contact the authors of presentations for further information directly if limited contact during the conference did not permit that.

Editors

Assessment of NDVI for forecasting wheat productivity under soil salinity stress

A.A. ABD EL-KADER, R.R. ALI, A.A. HUSSEIN, E.F. ESSA

Soils and Water Use Dept., National Research Centre, Egypt

Normalized Difference Vegetation Index (NDVI) is considered as a potential screening tool for estimating wheat grain and straw yield. Field experiment was conducted with wheat cultivar Sakha 93 to scrutinize NDVI response range to grain and straw yield. The investigated area is located in Dawar-Gabla village, Sinnuris district, El-Fayoum governorate, Egypt. This area was subjected to the effects of various soil amendments i.e. gypsum, compost and organic manure which have significant impact on soil salinity and hence productivity. The experiment adopted a split plot design arranged in randomized blocks with three replications and Landsat8 NDVI values were recorded during a two-year period between 2015 and 2016. Main plots were raised bed plots (row). Subplots consisted of four amended plots as follows: without amendments, gypsum, compost, and mixture of them complemented by the recommended fertilization rate as follows: unfertilized, 75% and 50% of the recommended dose for wheat growing season 2015. Concerning season 2016 the experimental design was a split plot with four replications. The salinity level treatment occupied the main plots and "Nile Fertile" natural bio-mineral treatments were allocated randomly in subplots. The irrigation water salinity levels were 0, 3, 6 and 9 dS m^{-1} while "Nile Fertile" application rates were 0, 400, 800 and 1200 kg/ha applied before wheat cultivation. The interaction of different concentrations of compounds was also assessed in addition to untreated plots (control). The results showed high correlation between NDVI and straw where R^2 range between 0.86 and 0.90 while the correlation between NDVI and grain yield was significant with R^2 in the range between 0.76 and 0.77. The high correlation between NDVI and grain and straw yields revealed the possibility of relying on NDVI as indicator for wheat yield forecasting. Anthesis growth stage as a good depictive and reliable stage is suggested for wheat yield forecasting with NDVI under adverse agro-climatic conditions.

Keyword: NDVI, wheat productivity, soil salinity, El-Fayoum depression

Physiological and biochemical responses of maize (*Zea mays* L.) to foliar applied antitranspirants under water stress

Sohail ASLAM

University of Agriculture, Faisalabad, Pakistan
Email: sohailaslam.agri@gmail.com

Drought is a serious threat to agricultural production. A decrease in transpiration rate can increase drought tolerance and improve growth when plants are facing temporal or physiological drought. The present project was carried out to evaluate physiological and biochemical responses of maize to foliar applied antitranspirants under water stress. There were two independent experiments. In first experiment eight maize cultivars were screened for their growth under osmotic stress (Control, - 0.2 MPa, - 0.4 MPa, and - 0.6 MPa) using PEG - 6000 solutions to evaluate their water deficiency stress tolerance at germination stage. Cultivars with contrasting differences in growth were selected for pot experiment to study their physiological and biochemical response under water stress. The selected cultivars were sown in pots. Two antitranspirants (kaolin and $MgCO_3$) were evaluated with two levels of water applications (100 and 50 % of field capacity) and three replications. Treatments were arranged according to factorial complete random design. After five weeks of growth, photosynthetic rate, transpiration rate and sub stomatal CO_2 concentration were recorded and plants were harvested. Fresh and dry weight of leaves were recorded. The stored leaf samples were analyzed for osmotic potential, water potential, chlorophyll content and K^+ concentration. Standard statistical procedure was followed to compute the significance of the treatments. Results showed that compared to $MgCO_3$, kaolin gave good response; and compared to EV 1089, the variety Agati gave good results.

Keywords: antitranspirants, PEG-6000

Aggregate stability of Hungarian salt-affected soils

Gyöngyi BARNA[1], András MAKÓ[1,2], Hilda HERNÁDI[2], Viktória LABANCZ[3], Zsófia BAKACSI[1] , Márton TÓTH[1] , Mihály KOCSIS[2], Zsuzsanna LADÁNYI[4], Tibor TÓTH[1]

[1] Institute for Soil Sciences, Centre for Agricultural Research, Eötvös Loránd Research Network, Budapest, Hungary;

[2] Georgikon Campus, Hungarian University of Agriculture and Life Sciences, Keszthely, Hungary;

[3] Szent István Campus, Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary;

[4] Department of Physical Geography and Geoinformatics, University of Szeged, Szeged, Hungary

Corresponding author: Gyöngyi Barna: gyongyi.barna@rissac.hu

In a recent study characteristic Hungarian soils were sampled for soil physical evaluation, out of which seven were classified as salt-affected: three profiles in grassland and four in cropland. Since most of cropland topsoils are non saline and non sodic, the constraint for agronomy in the typical dryland cultivation is the unfavourable soil structure. Especially heavy salt-affected soils have very narrow range of available soil water, therefore timing of spring tillage is difficult after smearing wet and before dry hard conditions. As the best indicator of soil tillability, aggregate stability was investigated, measured by wet sieving method (Eijkelkamp device). There were great differences between topsoil and subsoil horizons, since soil organic matter was the determinant factor of aggregate stability. Other factors affecting aggregate stability were alkalinity, sodicity, salinity. Grassland topsoil horizon showed larger aggregate stability than croplands.

Acknowledgements

This study was financially supported by National Research, Development and Innovation Office—NKFIH grant number OTKA 119475; and by the ÚNKP 20-3 New National Excellence Program of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund.

Is the adverse effect of sodicity on crop growth mediated by salinity in semi-arid rainfed environments?

Ed BARRETT-LENNARD

Transient salinity is the salinity associated with dispersive soils. In Australia, up to 20% of the cropped landscape could be affected by this stress. In rainfed semi-arid environments there are two causes of soil dispersion, sodicity and alkalinity. The main source of salt is likely to be from rainfall, with the salt accumulating in soils over hundreds to thousands of years, but concentrating in the root-zone of crops in response to the interplay between seasonal rainfall (leading to salt leaching) and evaporation (leading to salt accumulation through capillary rise). We have studied the effects of the interplay between these factors, soil salinity and the yield of barley (*Hordeum vulgare* L.) in a rainfed environment near Merredin (average annual rainfall 280 mm) in the south-west of Australia.

We hypothesized that two approaches could help overcome this stress: (a) improved micro-water harvesting at the soil surface, which would help maintain soil hydration, decreasing the salinity of the soil solution, and (b) soil amelioration using small amounts of gypsum, elemental sulfur or gypsum plus elemental sulfur, which would ensure greater salt leaching. In our experiments, improved micro-water harvesting was achieved using a tillage technique consisting of exaggerated mounds between furrows and the covering of these mounds with plastic sheeting. The combination of the mounds and the application of a very low rate of gypsum in the furrow (50 kg ha^{-1}) increased yields of barley grain by 70% in 2019 and by 57% in 2020, relative to a control treatment with conventional tillage, no plastic sheeting and no amendment. These increases in yield were related to changes in salt concentrations in the soil. Our data are consistent with the view that the main cause of decreased crop growth in this sodic alkaline soil was the salt stored in the soil profile which decreased the availability of water for grain filling. Treatments that decreased this salinity, increased crop yields.

The transcriptome of saline-alkaline resistant industrial hemp (Cannabis sativa L) exposed to NaHCO3 stress

*Kun CAO, Xiaonan WANG**

Daqing Branch of Heilongjiang Academy of Sciences, Daqing, Heilongjiang 163319, China

E-mail：caokun3383@sina.com

*E-mail：wxn_fern@163.com

The paper reports the gene expression profiling of industrial hemp exposed to $NaHCO_3$ stress. RNA-sequencing was used for gene expression profiling of industrial hemp roots exposed to 100 mM $NaHCO_3$ (for a period of 0, 1, 6, and 12 h). The results revealed that some pathways (plant hormone signal transduction and synthesis, phenylpropanoid biosynthesis, and metabolic pathways of starch, sucrose, nitrogen, and amino acids) may be related to the response under $NaHCO_3$ stress. Furthermore, sixteen modules were identified by weighted gene co-expression network analysis, of which six were significantly associated with $NaHCO_3$ stress. These six modules were enriched in pathways associated with endocytosis, starch and sucrose metabolism, nitrogen metabolism, and phenylpropanoid biosynthesis. The hub genes of key pathways were associated with GTP-binding protein, glutamate synthase, trehalose-phosphate, glycosyltransferase, and lignin synthesis. The results elucidate the molecular mechanism of the response of industrial hemp to $NaHCO_3$ stress.

Keywords: *Cannabis sativa* L, saline-alkaline resistant, root, transcriptome

Spatial distribution characteristics of soil salinity in coastal saline-alkali area in Chongming based on electromagnetic induction method

Yan CAO, Yujie BAI, Jinwen LI, Xiaohua CHEN, Genxiang SHEN

Shanghai Academy of Environmental Sciences, Shanghai 200233, China

Soil salinization is the major obstacle to high quality and high yield of crops. The management and utilization of saline-alkali land is of great significance for food security and ecological protection. The conventional identification and classification of saline soil is based on the spot sampling and monitoring. Due to the heavy workload, poor representativeness and high analysis cost, it is not suitable for accurate, fast and large-scale evaluation. In this study, an electromagnetic instrument was used to assess and obtain the spatial distribution of soil salinity in a typical farm in Chongming coastal area, Shanghai, in order to provide guidance to agricultural production as well as scientific and accurate improvement according to the classification and division. The results showed that there was a significant positive linear correlation between the apparent electric conductivity (ECa) and soil salt content in 0-40 cm soil ($R > 0.8$), which indicated that ECa could be used to characterize the variation of the soil salt content. The soil salinity and soil texture, organic matter content and major ions (Na^+, Cl^-) content were analyzed by spatial interpolation, and the mechanism of salinization was explored. The distribution and spatial variation of soil salinity in the study area were described by Kriging interpolation, and according to the classification and spatial distribution of soil salinity, the area was divided into very saline, moderately saline and slightly saline zones. Such approach can overcome the shortage of traditional manual sampling monitoring method, and ensure rapid, scientific and dynamic monitoring of soil salinization, which will facilitate efficient and sustainable utilization of saline-alkali lands.

Keywords: saline-alkali land, electromagnetic induction, soil salinity coastal, area electric conductivity

Characteristics of surface soil salt accumulation under mulched drip irrigation

Wenjuan CHEN[1], Mingsi LI[2], Qinglin LI[2], Dongwei LI[2]*

[1]College of Sciences, Shihezi University, Shihezi 832000, China
[2]College of Water Conservancy and Architectural Engineering, Shihezi University, Shihezi 832000, China
*Email:ChenWJ513@163.com

In order to understand spatial and temporal aspects of salt accumulation outside film in farmland that is installed with mulched drip irrigation in Xinjiang, indoor physical simulation and field observations were carried out. The horizontal and vertical distribution of soil salinity and the process of salt accumulation were followed under different soil texture and temperature treatments, and each treatment was repeated three times. Field observations were carried out all year round. The salt content in the surface layer of both texture classes showed exponential relationship with the horizontal distance from the emitter. The salt content in the vertical profile of the soil outside the film showed an obvious "Γ" type distribution, and the salt was mainly concentrated in the surface soil layer. The average salt content in the surface layer (0-2 cm) of sandy soil was 7.3 times greater than in the soil layer below 2 cm; but in the loam soil it was 8.4 times greater. Field observations showed that the average salt content of the vertical profile of the soil outside the film was 1.3 times greater than under the film. Surface salt content of both soils positively correlated with temperature and negatively correlated with soil water content, and the effect of soil water content was greater. When the temperature is low, the rate of surface soil salt accumulation is not affected by soil texture and soil water content; but when the temperature is high, it changes abruptly in sandy soil surface at temperatures above 30 ℃, while in loam soil it accelerates above 35℃. Results can help to understand the movement of water and salt in the field under plastic-mulched drip irrigation.

Keywords: plastic-mulched drip irrigation, soil texture, salt accumulation, accumulation rate

Remediation of sodium-rich oilfield produced water-impacted soils

Thomas DESUTTER

North Dakota State University, United States

Email: thomas.desutter@ndsu.edu

Much of the oilfield produced waters in the Williston Basin (USA), and many shale-oil formations around the world, are composed of NaCl concentrations at or near its saturation level. Thus, when accidental releases and spills occur onto soils there is a need to clean up the chloride to protect surface and groundwaters, but there is also a need to reduce the concentration of sodium within the soil to prevent any unwanted swelling and/or dispersion, which will likely occur as the total salt level of the soil is decreased. Soils that have had releases and spills onto them are often void of any vegetation, mostly due to the plants within the region not being tolerable to the imposed salinity and toxicity conditions. For example, in North Dakota (USA) the establishment of glycophytes, the dominant plants in the region, within the spill sites to remove salts is complicated by establishment, growth, precipitation, toxicity, periods of violent weather, and overall maintenance of the site. Currently, the physical removal of the contaminated soils, its disposal into approved landfills, and its replacement with non-contaminated soil is the most common remediation strategy. However, this approach leads to further remediation due to compaction, soil mixing, plant establishment, and ensuring that the topsoil has similar texture and soil carbon levels as did the original soil, and this soil is free of noxious weeds. This talk will cover some alternative remediation methods (gypsum application, leaching, electrokinetics, wicking, washing) for reducing salinity and sodicity from soils impacted by produced waters.

Keywords: remediation, brine, sodicity

Composition of microbial communities, soil aggregate stability and organic carbon stock under different land uses in saline–sodic soil

Haojie FENG[1,2], Xuejun DU[1], Zideng GAO[1], Xueqin REN[1], Shuwen HU[1*]*

[1]China Agricultural University, College of Resources and Environment Sciences
[2]Shandong Agricultural University, College of Resources and Environment.
Corresponding authors:Xueqin Ren, renxueqin@cau.edu.cn, Shuwen Hu, shuwenhu@cau.edu.cn

Considerable attention has been paid to the establishment of an appropriate land use type for the reclamation of saline–sodic soils. The microbial community structures, soil aggregate stability and soil organic carbon (SOC) stock and their relationship under various land use types, however, remain elusive in the western Songnen Plain of China. This presentation is firstly focused on the changes of bacterial and fungal abundance and community patterns under six various land use types: (a) forest, (b) sorghum, (c) paddy, (d) wetland, (e) wasteland, and (f) meadow, with a–c considered to be 'managed systems' and d–f to be 'unmanaged systems.' The results indicated that the abundance and community structures of both bacteria and fungi were similar in paddy and wetland soils, suggesting drying–rewetting alternations played a much greater role in shifting soil microbial communities than other agronomic measures (e.g., fertilization and tillage). The redundancy analysis combined with phylogenetic investigation of communities by reconstruction of the unobserved states and FUNGuild analyses indicated that bacteria predominated in nutrient cycling, whereas *Ascomycota* and *Basidiomycota* fungi were largely responsible for the restoration of aggregate stability in saline–sodic soils.

The second part of this presentation concentrated on the effects of land use change and soil properties on soil aggregate stability and SOC stock in saline-sodic soils. Soil samples were collected from four major land use areas (meadow, forest, sorghum field, paddy field) in Northeast China. Our results in paddy field had the highest SOC stock indicating its potential to sequester SOC more than other land use types. Silt + clay fractions sequester more organic C storage over the other size aggregates in saline-sodic soil, which was mainly influenced by soil texture and clay minerals. Spearman's rank correlation analysis showed that binding agents (SOC, Ca^{2+} and poorly crystalline Fe/Al oxides) had significant positive ($p < 0.01$) effects on soil aggregate stability. Meanwhile, the redundancy analysis (RDA) showed that all soil parameters resulted in 85.1% variation; but regarding soil aggregate stability chemical characteristics of saline-sodic soil (i.e., pH, EC) contributed 23.1%, binding agents contributed 20.6%, and their interactions contributed 39.5%. The interactions between binding agents and clay manifested its importance for promoting soil aggregate stabilization in saline-sodic soil.

Sodicity and the soil-plant system: Current assessment

S.R. GRATTAN

Department of Land, Air and Water Resources, University of California, Davis, CA USA
Plant Environmental Science Bldg. UC Davis
Email: srgrattan@ucdavis.edu

Soil sodicity adversely affects the soil-plant system which impacts the productivity of agricultural lands across the globe and can be found where salinity is high or low (Wallender and Tanji, 2012). First, sodium (Na^+) itself is a potentially toxic ion for many crops especially avocado, citrus, beans and many fruit and nut crops. This is particularly important in sodic soils that are also saline. Second, the high Na^+/Ca^{2+} or Na^+/K^+ ratio can promote nutritional disorders such as a sodium induced Ca^{2+} or K^+ deficiency. Third, sodic soils have deteriorated soil physical conditions, which affects the crop in a number of ways. It increases soil strength affecting root growth, reduces water infiltration and promotes soils crusts making seedling emergence more difficult. And it can cause hypoxia and anoxia conditions which reduces soil gas diffusion rates affecting root respiration, can produce toxic constituents, reduce nutrient availability and promote water-borne root diseases.

Brief History:

More than 65 years ago, researchers at the US Salinity Laboratory classified soils as "sodic" when the exchangeable soil percentage (ESP) exceeds 15 (USSL Staff, 1954). The sodicity of the soil water, on the other hand is characterized by the sodium adsorption ratio (SAR) which is derived from Gapon exchange reactions. SAR is defined as

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{2+} + Mg^{2+})}} \qquad (1)$$

where concentrations of all cations are molarities. The ESP and SAR of the soil extract are closely related to one another and, for most practical purposes, are numerically equivalent in the range of 3 to 30 (USSL Staff, 1954) which makes it convenient to assess sodicity. Since that time, much has been learned about the many factors affecting crop response to salinity and differences in sensitivity to salinity among crop species (Läuchli and Grattan, 2012). Similarly, much has been learned about the complexities of soil mineralogy, clay content, organic matter, ionic strength and composition of irrigation waters on aggregate stability and soil physical conditions (Suarez and Jurinak, 2012; Oster *et al.,* 2016; Sposito *et al.*, 2016; Smith e*t al.*, 2015). As such, this historical classification of sodic soils holds little value because many other factors must be considered to assess whether irrigation water can have negative impacts on crops or soils.

Moving from SAR to CROSS:

For decades, SAR has been the standard for predicting the potential permeability hazard an irrigation water of a given quality would have on soil structure (US Salinity Laboratory Staff, 1954). But the heightened interest in waste waters as a supplemental source of irrigation water have inspired scientists to re-examine the appropriateness of SAR as the best expression for characterizing the 'sodic' effects on aggregate stability. Many waste waters are being considered for irrigation including municipal waste waters, agricultural drainage waters, waste waters from agricultural processing plants, wineries, animal feed lots, and dairies. The concentration and composition of waste waters can vary quite dramatically where some waste waters may have usually high concentrations of K^+, Mg^{2+} and/or organic carbon.

While the impact of the different dominant cations in the soil solution on hydraulic properties has been known for decades (Quirk and Schofield, 1955), such distinction has not been quantitatively incorporated into water quality assessment criteria. That changed a decade ago when Rengasamy and Marchuk (2011) proposed a modification of the SAR by incorporating the less dispersive effects of K^+ and diminished flocculating power of Mg^{2+} into the expression. The generalized parameter, the Cation Ratio of Soil Structural Stability (CROSS), was proposed as a better predictor of potential soil permeability hazards. This new expression modifies the traditional SAR formula by incorporating a numerical coefficient (0.56) for K^+ that reflects a lower dispersing effect than Na^+ and a numerical coefficient (0.60) for Mg^{2+} that diminishes its flocculating power relative to Ca^{2+}.

This new expression has since been refined by others to optimize the coefficients for practical application. Investigators have since modified the coefficients for K^+ and Mg^{2+} by equating CROSS as the weighted sum of SAR and PAR (potassium adsorption ratio). Their goal was to replace the SAR parameter with this new $CROSS_{opt}$ parameter which was found to better predict soil stability and permeability over a wide range of waste water compositions (Oster et. al., 2016; Smith et al. 2015; Sposito et al. 2016). While this expression is valuable regardless of water quality, it was introduced to provide more confidence in potential soil structural problems when using waste waters that contained considerable quantities of K^+ and Mg^{2+}. The $CROSS_{opt}$

expression below is a modification of the SAR expression to include coefficients that were optimal using the soils tested by Oster et al. (2016).

$$Cross\ opt = \frac{Na + 0.335\ K}{\sqrt{(Ca + 0.0758\ Mg)}} \quad (2)$$

In addition, experiments currently underway at UC Davis (Kisekka et al., 2021, ongoing research) are finding that CROSS far better predicts the reduction in water infiltration in strawberry pots filled with soil, than does SAR. It is important to note that while this expression is likely better that the SAR expression, factors such as soil texture, dissolved organic carbon (DOC), clay composition, pH, calcite, and Al and Fe oxide content affect soils response to sodic conditions so there is still room for improving this expression (Sposito et. al., 2016.)

References

Lauchli, A and S.R. Grattan. 2012. Plant responses to saline sodic conditions. In: *Agricultural Salinity Assessment and Management* (2nd edition). W.W. Wallender and K.K. Tanji, eds. ASCE pp 169-205.

Oster,J.D., G. Sposito and C.J. Smith. 2016. Accounting for potassium and magnesium in irrigation water quality assessment. Calif. Agric. 70(2):71-76.

Quirk, J.P and RK Schofield. 1955. The effect of electrolyte concentration on soil permeability. J. Soil Sci. 6:163-178.

Rengasamy P, Marchuk A. 2011. Cation ratio of soils structural stability (CROSS). Soil Res 49:280–285.

Smith CJ, Oster JD, Sposito G. 2015. Potassium and magnesium in irrigation water quality assessment. Agriculture Water Management 152:59–64.

Sposito, G., J.D. Oster, C.J. Smith, and S. Assouline. 2016. Assessing soil permeability impacts from irrigation with marginal water. CAB Reviews 11(015)

Suarez, D.L. and J.J. Jurinak. 2012. The chemistry of salt-affected soils. In: Agricultural Salinity Assessment and Management (2nd edition). W.W. Wallender and K.K. Tanji, eds. ASCE pp 57-88..

U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook 60. Washington, D.C. USA

Wallender, W.W. and K.K. Tanji. 2012. Agricultural Salinity Assessment and Management. ASCE Manuals and Reports on Engineering Practice No. 71 (2nd Edition). American Society of Civil Engineers. Reston, VA USA 1094p

Biochar application improves soil nutrient content, soil enzyme activity, cell membrane permeability, rice grain yield and quality in saline–sodic paddy fields

Feng JIN[1]*, Xiwen SHAO*[1]

[1]Faculty of Agronomy, Jilin Agricultural University,
Changchun 130118, China

Salinity–sodicity is one of the most severe limitations for crop production. Biochar application could alleviate the adverse impacts of salinity–sodicity stress in crops. Since its effect in the reduction of Na^+ uptake and improvement of soil nutrient status in rice is unknown, the study evaluated the effect of biochar on soil nutrients, soil enzyme activity, rice ion composition, cell membrane permeability, leaf water status, grain yield and quality in saline–sodic paddy soil during a 2-year field experiment conducted in Jilin province in the northeastern part of China. The soil was amended with the following biochar rates: zero-biochar, 33.75 t ha^{-1}, 67.5 t ha^{-1}, and 101.25 t ha^{-1}. Results show that addition of biochar significantly increased availability of soil total N, available P, and available K content, while it remarkably reduced the alkali-hydrolysable nitrogen content, among which NH_4-N and NO_3-N were reduced significantly in both years. Biochar application significantly increased soil organic matter and soil C/N ratio. Soil Na^+ /K^+ ratio was significantly reduced after biochar application in both years. All biochar application treatments improved the soil catalase, alkaline phosphatase, urease, and sucrose activities. Biochar addition significantly reduced Na^+ concentration and Na^+/K^+ ratio, while it remarkably increased K^+ concentration in rice plants. Furthermore, biochar application significantly decreased relative electrical leakage of leaf and increased leaf water status, plant height, and chlorophyll content index. The rice biomass, grain yield, harvest index and quality were significantly increased. Therefore, biochar applications can improve soil nutrient status, decrease Na^+ /K^+ concentration in soil, promote rice growth, and increase rice yield in severely saline-sodic paddy soils. It is anticipated that the study results will be useful for formulating novel management models for improving rice cultivation on saline-sodic soils.

Keywords: biochar, salinity-sodicity stress, ion accumulation, osmotic stress, soil nutrients

Long-term monitoring of a degrading alkaline sodic lake in Hungary

Zsuzsanna. LADÁNYI[1], Katalin CSÁNYI[1], Tibor TÓTH[2], Gyöngyi BARNA[2]

[1]Department of Physical Geography and Geoinformatics, University of Szeged, Szeged, Hungary

[2]Institute for Soil Sciences, Centre for Agricultural Research, Eötvös Loránd Research Network, Budapest, Hungary

Corresponding author: Zsuzsanna Ladányi: ladanyi@geo.u-szeged.hu

There were many soda lakes in Hungary, the number of which has drastically decreased over the last few decades. These were very valuable habitats, including for birds. It is necessary to examine how they can be preserved and maintained, and to do this we need to know the ongoing processes. This is why we started this monitoring. These soda lakes are located in a dune region, where the level of saline groundwater has been already dropped, therefore the supply of salt to the surface is limited at several places.

Long-term changes of a small degrading soda lake (13.5 ha) were investigated from a cenological and soil perspective to support its future preservation (Ladányi et al. 2009; 2011; 2016). The lakebed has no surface water cover since decades, steppification, desalinization and leaching became dominant processes mostly due to anthropogenic interventions and the impact of climate change, the more frequent drought years contributed to the lowering of the groundwater table.

In this study we discuss the results from the 2018 soil and vegetation survey campaign and describe the decade-long-changes between 2009 and 2018. As a result of the experienced changing water (and salt) regime and mostly the lack of wise water management, the wet inland halophytic vegetation of alkaline sodic lake started to change: reed spread and steppification, thus degradation of the naturalness could be observed. There is a decrease in the extent of the natural *Puccinellia* swards, and more salt meadow (and in humid year salt marsh) – *Puccinellia* sward transitional stands can be observed. There is an increase in the number of patches and extent of the annual salt pioneer swards. There is a spread of reed - especially in humid years. Increasing salt/soda content and decreasing calcium carbonate content and pH was observed in the lake bed. The highest increase of soda content in soil was observed at the annual salt pioneer swards, but it was also characteristic on the *Puccinellia* swards. The lowest decrease of calcium carbonate content was observed in the sand steppe grassland and salt marsh points.

References

Ladányi Zs, Blanka V, Deák JÁ, Rakonczai J, Mezősi G. 2016. Assessment of soil and vegetation changes due to hydrologically driven desalinization process in an alkaline wetland, Hungary. *Ecological Complexity* 25: 1–10.

Ladányi Zs, Rakonczai J, Deák J Á 2011. A Hungarian landscape under strong natural and human impact in the last century. Carpathian Journal of Earth and Environmental Sciences 6/2: 35-44.

Ladányi, Zs, Rakonczai, J, Kovács, F, Geiger, J, Deák, JÁ 2009. The effect of recent climatic change on the Great Hungarian Plain. *Cereal Research Communications,* 37/4: 477–480.

Influence of different gypsum application methods on the distribution of water and salt in soil profile

Mingzhu LI[1], Wenchao ZHANG[2], Zhentao SUN[2], Yonggan ZHAO[2], Shujuan WANG[2]*

[1]Shanxi Clean Energy Research Institute, Tsinghua University, Shanxi Taiyuan 030032 China
[2]Department of Energy and Power Engineering, Tsinghua University, Beijing 100084, China)
*E-mail:wangshuj@tsinghua.edu.cn

In order to characterize the distribution of soil water and salt under different gypsum application methods, we chose the Kuiboyuan area of Wuyuan County, Bayannaoer City, Inner Mongolia Autonomous Region as the research area. In an oil sunflower field, where desulfurization gypsum was applied the vertical changes in water content, pH, EC and water-soluble cation concentrations were followed. Compared to the unreclaimed soil, the pH and alkalinity in the gypsumed treatment decreased and strip application reduced soil pH and EC values, increased surface soil water content, reduced soluble Na^+ content and increased Ca^{2+} content. In contrast, hole application had the least reclamation effect. Strip application and hole applications, both applied to the roots of crops, showed better reclamation effect near the roots, but there was no significant difference between the salinity index values at the midpoint between rows and in the original soil. Spreading application significantly changed soluble cation concentrations in different layers, in surface soil (0 -20 cm) Na^+ content was significantly reduced, Ca^{2+} content was significantly increased, but soluble ion content in deeper soil (≥20 cm) showed no significant change.

Keywords: desulfurization gypsum, hole application, strip application, spreading application, water and salt distribution

Research on large scale secondary soil salinization and high efficiency water saving in cotton fields

Hongbo LIU[1,2], Bin WU[1], Yungang BAI[2], Jianghui ZHANG[2], Ming ZHENG[2], Jun XIAO[2]*

[1]College of Water Conservancy and Civil Engineering, Xinjiang Agriculture University, Urumqi 830052 ;

[2]Xinjiang Research Institute of Water Resources and Hydropower, Urumqi 830049

*E-mail：lhb090@163.com

With the rapid development of large-scale and efficient water-saving farmland constructions, secondary soil salinization has become the core issue of sustainable utilization and development of water and soil resources. Based on the review of a large number of domestic and foreign technical publications on secondary soil salinization, this paper summarized the influence of high-efficiency water-saving irrigation, leaching and large-scale irrigation area construction on secondary soil salinization, and put forward the problems that need further study and attention in order to provide reference for high-efficiency water-saving and sustainable land use.

Keywords: scale, high efficiency water saving, cotton field, secondary soil salinization

Improvement of land productivity in dry farming conditions in the saline-alkali lands of Songnen Plain

Huitao LIU, Yunyun SUN, Yushan GAO, Fangming LIU, Jingang DOU, Zhonghua HOU

Jilin Academy of Agricultural Sciences, Changchun 130033, China

In Songnen Plain, the salinized lands cover an area of 25 thousand km^2, which is one of three largest concentrated contiguous areas of soda-containing salinized and alkaline land in the world. In the southern Songnen Plain, saline-alkali farmlands under dry farming cover the territory of several counties/cities, such as Changling, Qian'an, Qianguo, Tongyu and Taonan, with a total area of about 6 thousand km^2, which play important role in grain production. Saline-alkali dryland farmlands have salinity and sodicity stress, often barren patches and seasonal drought, therefore the yield there is a typically medium or low. Long term corn yield is between 4.8 and 6 t/ha. Salinization and the decreasing productivity have seriously restricted the development of ecological environment and rural economy in this region. In this study, the improvement of land productivity, such as cultivating fertile plough layer and application of amendments was studied. In field experiments, the effect of deep application of organic fertilizer to break the bottom of the plough layer and cultivate the fertile plough layer, and the effect of soil amendments for reducing sodicity and increasing yield were tested. Results showed that deep application of organic fertilizer to break the bottom of the plough layer improved soil structure and created healthy plough layer. The deep application of 30 m^3/ha organic fertilizer had the largest effect. Compared with conventional planting methods, in the treatment of deep application of organic fertilizer soil physical properties of cultivated layer were improved, bulk density decreased obviously, solid and liquid phase decreased, gas phase increased, soil water content increased, and soil hardness decreased, corn yield increased by 36.22 percent. The positive effect of both soil amendment and peat was remarkable. The application of amendment improved soil physical and chemical properties, decreased soil pH value, increased soil nutrient content, and improved soil nutrient adsorption and supplying ability. When amendment was applied corn plant height, leaf area index, ear characteristics and other indexes increased significantly. Corn yield increased by 16.3% with amendment and 8.2% with peat application.

Microtopographical variation of soil water and salt transport as well as plant response in the saline-sodic region of the Songnen Plain, northeast China

Jianbo LIU, Fan YANG, Zhichun WANG

Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun, 130102, China

In arid and semi-arid regions, microtopography is one of the important factors affecting the soil properties and plant distribution in saline-sodic soils. In order to understand the microtopographical variation of soil physical and chemical properties as well as plant response, classical statistics and geostatistics were used to evaluate relative elevation, soil physical and chemical properties as well as plant biomass. The results from classical statistics showed that the coefficients of variation of soil physical and chemical properties were smaller than 0.7, indicating moderate and weak spatial variation, while geostatistical analysis showed that the nugget variation of soil physical and chemical properties was smaller than 75%, indicating moderate and strong spatial autocorrelation. In addition, soil physical properties (such as gravimetric soil moisture content) have stronger spatial autocorrelation than soil chemical properties (pH, electrical conductivity, sodium adsorption ratio). The interpolated map showed that the spatial distribution of soil properties showed streaks and patches. The measured soil physical and chemical properties were significantly correlated with relative elevation ($P < 0.01$), there was a significant negative correlation between plant biomass and relative elevation ($P < 0.05$). The correlation coefficient of microtopography with soil moisture is larger than that of soil physical and chemical properties. The correlation coefficient between elevation and plant biomass is the least. Therefore, it is suggested that the microtopography leads to the difference in soil moisture at different elevations on the slope, and then alters the soil physical and chemical properties, which indirectly affect plant growth. The regression analysis showed that there was a quadratic relationship between the soil physical and chemical properties and the relative elevation, that is, the relative elevation was 50-60 cm when soil salinity reached the highest value, and plant biomass was lowest. The finding of elevation threshold provides a theoretical basis for site specific remediation and tillage management of saline-sodic soils.

Keywords: saline-sodic soil, microtopography, soil physical and chemical properties, plant response

Distribution of fluorine in a saline sodic soil and the effect of aluminum sulfate amendment on fluorine migration in paddy field

Jinhua LIU, Hongbin WANG, Xingmin ZHAO, Biao SUI

The college of Resource and Environment Jilin Agriculture University Jilin Changchun 130118

As an amendment, application of aluminum sulfate has been theoretically and practically proved as an effective way of improving saline sodic soil in paddy field development in the west of Jilin province, which not only decreases pH in surface soil and water, the content of CO_3^{2-}, HCO_3^-, CEC and alkalization degree, but also improves the physical properties of saline sodic soil, such as promoting the aggregation of micro-aggregates, increasing soil porosity and the degree of expansion, decreasing soil bulk density, improving rice growth in a favorable environment to obtain higher yield. Since the area is also the main endemic fluorosis area, the fluorine distribution characteristics and its adsorption and desorption characteristics in the soil as well as the effect of aluminum sulfate on fluorine migration and rice F uptake were studied. The results provide theoretical support for reducing the bioavailability of fluorine from a new aspect. The following main results (1-6) were obtained.

1. The total fluorine content in surface soils is 200 - 450 mg/kg with an average of 266.17 mg/kg, which is lower than the background value of China and the control treatment of black soil, but the average water soluble fluorine and exchangeable fluorine contents are 13.73 mg/kg and 8.49 mg/kg, higher than the control. Fluorine moves upward with soil water and accumulates in the surface soil layer in spring, which makes its bioavailability higher.

2. There is a significant positive correlation between exchangeable fluorine and other fluorine fractions, which indicated that exchangeable fluorine is the transitional fraction. pH showed significantly positive correlation with water soluble fluorine, organic fluorine and Fe/Mn oxide-bound fluorine concentrations. Nevertheless, it showed significantly negative correlation with exchangeable fluorine content. Significantly positive correlation is observed between $CaCO_3$ and water soluble fluorine content, CEC and exchangeable fluorine. Moreover, available P shows significantly positive correlation with exchangeable fluorine content. Soil organic matter shows significantly positive correlation with water soluble fluorine, Fe/Mn oxide-bound fluorine and organic fluorine contents. Free iron oxide and free iron aluminum content show

significantly positive correlation with exchangeable fluorine and Fe/Mn oxide-bound fluorine concentrations, respectively. Decreasing soil pH is the best method to reduce biological effectiveness of fluorine in saline sodic soils.

3. The isothermal adsorption process of F in saline sodic soil can be well described by Langmuir equation with the equilibrium time of 48 hours. Dual constant equation fits the process of fluorine adsorption without the influence of initial fluorine content. pH affects the capability of saline sodic soil to adsorb fluorine with more adsorption and less desorption rate at decreasing pH values. Al shortens the equilibrium time of fluorine adsorption. With the addition of Al amendment fluorine adsorption is increasing and desorption rate is decreasing. As anion content increases, the amount of adsorbed fluorine first decreases and then increases, its desorption rate is higher than that of single fluorine. When F-Al-anions coexist in the solution, the amount of adsorbed fluorine is higher and desorption rate is less compared the situation when F-anions coexist, and desorption rate is higher compared the previous case. The amount of adsorbed and desorbed fluorine in $H_2PO_4^-$treatments is higher than with other anions.

4. Adding Al decreases fluorine leaching rate in soda-containing saline-alkali soils compared with the treatment without Al. But the magnitude of reduction is different according to the relative Al and F content, which is probably ascribed to pH change after $Al_2(SO_4)_3$ application, the change of the aluminum oxide/hydroxide content, the change of soil colloids and Al release by fluorine adsorption. The total fluorine leaching rate is lower in 1:1 treatment because of higher adsorption and lower desorption rate.

5. Pot experiment shows that the concentration of fluorine in rice plant is increasing with increasing fluorine application. The order of fluorine content in each part of mature rice is husk > brown rice > root > stem and leaf. As the $Al_2(SO_4)_3$ application dose is increasing, the fluorine content in rice plant decreases first and then increases. A suitable Al to F ratio lowers fluorine content in rice plant, but it doesn’t change its distribution characteristics in each part.

6. 1:1.9 - 1:8.5 Al to F mole ratio in saline sodic soil is better for reducing the bioavailability of fluorine as water soluble and exchangeable fluorine in soil and fluorine content in plant is relatively low, Fe/Mn- and organic matter-bound fluorine content in soil is relatively high, fluorine adsorption is higher and its desorption rate is lower than that of the control, which inhibited fluorine migration to the ground water.

Innovations in the efficient utilization of saline-alkali land resources

Xiaojing LIU[1,2], Kai GUO[1,2], Xiaohui FENG[1]

[1]Key Engineering Laboratory for Efficient Utilization of Saline Resources, Center for Agricultural Resources Research, Institute of Genetics and Developmental Biology, CAS, Shijiazhuang 050021, China

[2]University of Chinese Academy of Sciences, Beijing 100049, China

Email: xjliu@sjziam.ac.cn

Currently, all over China there are about one million km^2 saline-alkali lands, out of which recently salinized soils cover about 333 thousand km^2. As important cropland resources and ecological protection areas, the development and utilization of saline-alkali lands have always been important in the development of agriculture and ecological industry. Since the sixth Five-year Plan of China, lot of work has been carried out on the reclamation of saline-alkali land, and remarkable achievements have been obtained. Based on these, a mature technical system has been developed for the improvement of saline-alkali soils, especially in the Huanghuaihai Plain, where the application of well irrigation and a drainage system resulted in the improvement of large areas. However, restricted by regional water resources and climate conditions etc., the area of saline alkali land that have development and utilization potential is less than 133 thousand km^2. The limitations of the traditional saline-alkali land reclamation through water conservancy project measures with groundwater regulation is becoming increasingly prominent, which causes insufficient and unbalanced development in saline-alkali areas. Backward agricultural production, poor ecological environment and concentration of poverty zone are still the main problems confronted in the saline-alkali areas, which puts forward new propositions and challenges for land reclamation. In recent years, the implementation of the strategy of Rural Revitalization has put forward new requirements for saline-alkali land reclamation, and points out a new direction. The development and utilization of saline-alkali land should adhere to the harmonious coexistence of humans and nature. The development of agriculture and ecological industries must be based on the particular characteristics of saline and alkali areas, saline water and plants. In future, the local resources of saline-alkali soils, saline water and salt tolerant biological resources should be considered in an overall way in saline-alkali land utilization. It is required to follow the principle of "accepting the situation in a favorable way and adapting to local conditions", and correcting the disadvantageous characteristics of the saline-alkali land as the dominant resource; and the research on efficient utilization of the resources should be strengthened. The main development directions can be summarized as follows: Firstly, overall planning of water saving irrigation, saline water utilization, precise salt control in the root zone and cropping salt tolerant plants, thereby saving water in accordance with the regional soil and water resources; Secondly, introducing advanced industries including up-to-date agricultural technology, photovoltaic industry, salt water desalination plants, etc., to capitalize on the space, light and heat resources of saline-alkali lands, thereby enlarging the industry on saline alkali lands, utilizing space by following the principle of "occupying space without land, occupying land without soil"; Thirdly, deeply tap the potential of crop salt tolerance and local characteristic plant resources and develop new technologies for the cultivation and processing of high-quality agricultural and ecological products, thereby efficiently utilizing the characteristic plants by following the principle of "adaptation to saline land through using saline resources”; Fourth, cultivate new business forms, develop seed industry, special planting, grass husbandry, vegetation construction and other industries, cultivate and strengthen the brand of the characteristic cultivations, thereby promoting high-quality and green agricultural development.

Keywords: saline-alkali land resources, saline-alkali soils, saline water, salt tolerant plant, efficient utilization

Role of academic and research institutions in reclamation of sodic soils in Sub Saharan Africa

Henry Tamba NYUMA

College of Agriculture and Forestry, University of Liberia P.O.BOX 9020 Monrovia, Liberia
Email: tnyuma@gmail.com

The consequences of soil sodicity pose serious limitations to agricultural productivity and effective ecosystem functions of soils in semi-arid and arid regions across Sub Saharan Africa (SSA) in the wake of climate change and the increasing demands for food and basic ecosystem services rendered by these agro ecological zones. Despite the potential threats of soil degradation due to sodicity, there are scanty literature from research highlighting the current challenges and future consequences of sodicity on agricultural systems in SSA.

Academic and research institutions in most SSA countries are established with the mandate to train soil scientists equipped with the needed skills intended to address issues affecting soil nutrient dynamics, hence low productivity. The lack of funding, limited man power and soil specific research programs in most SSA countries affect research agenda of academic and research institutions within the region. This is evidenced by the distribution of soil scientists across the region, with 37% of soil scientists located in West Africa, 37% in Eastern Africa and 27% in Southern Africa. However research on reclamation of sodic affected soils is yet to come under the spotlight in the region as most of the current research are focused on macronutrient replenishment based on national development agenda, mostly dependent on donors funding.

This paper highlights the role of Academic and Research institutions in reclamation of salt affected soils and the future of agricultural production in the arid regions of SSA.

It is evident that more than 75% of soil research in the SSA is focused on soil fertility, yield improvement and nutrient use efficiency, with 37% of soil specialists based in West Africa, considered as one of the largest tropical arid regions. Given the current development, soil reclamation due to sodicity should be declared a new frontier in soil research as well as exploiting the potential of arid regions.

Keywords: academic institutions, reclamation, sodicity, soil science, Sub Saharan Africa

History of the roles of gypsum in soil reclamation and establishment of SAR/EC water quality guidelines

J.D. OSTER

Emeritus Soil and Water Specialist
University of California, Riverside
Email: James.oster @ucr.edu

The first published paper about the use of gypsum for reclamation of sodic soils may have been written by De Sigmond published in 1924. Its use as a soil amendment in the U.S. dates to about 1800: President Jefferson is known to have used gypsum as a soil amendment to improve crop yields on his farm in Virginia. In California (Mediterranean climate), W.P. Kelley conducted several long-term reclamation projects with a calcareous sodic soil near Fresno starting in the 1920s. The treatments were gypsum, gypsum in conjunction with cropping, and only cropping (phytoremediation). Cropping was as effective as gypsum in conjunction with cropping in achieving reclamation throughout the rootzone, and cropping was a common method used to reclaim sodic soils in the San Joaquin Valley of California. In the 1970s, Abrol and Bhumbla obtained similar results in the monsoonal climate of India. Possible roles for cropping in soil reclamation will be described in the presentation and paper.

During the 1920s in Australia, gypsum when applied to soils with exchangeable sodium percentages of less than 10 % was found to increase crop yield under dryland conditions. Gypsum reduced soil crusting and maintained soil infiltration rates. Similarly, in the 1950s farmers in the Bakersfield area of California, who irrigated with Friant-Kern irrigation water (EC < 0.1 dS/m), found that gypsum improved and maintained infiltration rates. Bob Ayers promoted this practice in the 1950s while advising these farmers, and his experience with this water quality issue influenced the criteria he and Westcot published in the FAO Irrigation and Drainage paper #29 Rev. 1.

The Ayers and Westcot water quality criteria are based on considerably more information. Fireman and Bodman (UC Berkeley) were probably the first to document experimentally that there was no single level of EC or SAR of the irrigation water that could be linked to soil permeability. The two were always linked: permeability increased with increasing EC and with decreasing SAR. Quirk and Schofield introduced the concept of “threshold concentration,” or salt concentration at which a 10 – 15 % decrease in hydraulic conductivity may occur for a given SAR. Fred Schorer – in whose lab I washed the glassware while an undergraduate student at North Dakota State University – irrigated undisturbed soil columns of a loam soil that were cropped with waters of different quality. He obtained a considerably better correlation of final infiltration rates to the SAR and EC of the applied water than to the SAR and EC of the soil solution averaged over the total length of the soil column, or for the surface soil. Infiltration rates are especially affected by SAR and EC of the irrigation water, because of dispersion of soil aggregates on the soil surface that decreases porosity and infiltration rates. Additional findings that underpin the SAR/EC water quality guidelines of Ayers and Westcot will be addressed in the paper and presentation

In 2011 Rengasamy and Marchuk posed to modify SAR to account for deleterious effects of Mg and K: the new index is Cation Ratio of Structural Stability (CROSS). The presentation and paper will address recent findings published in several papers that support the substitution of CROSS for SAR in irrigation water quality guidelines of Ayers and Westcot.

Phytoremediation of Sodic Soils

Manzoor QADIR

United Nations University Institute for Water, Environment and Health, 204-175 Longwood Road South, Hamilton, L8P 0A1, Ontario, Canada (E-mail: Manzoor.Qadir@unu.edu)

Sodicity induced soil degradation is a major environmental constraint with severe negative impacts on agricultural productivity and sustainability in arid and semi-arid regions. As an important category of salt-affected soils, sodic soils are characterized by excess levels of sodium ions in the soil solution phase as well as on the cation exchange complex, exhibiting unique structural problems because of certain physical processes (slaking, swelling, and dispersion of clay) and specific conditions (surface crusting and hardsetting). Saline-sodic soils, another category of salt-affected soils, are generally grouped with sodic soils because of several common properties and management approaches. Sodic and saline-sodic soils occur within the boundaries of at least 75 countries, and their extent has increased steadily in several major irrigation schemes throughout the world. The use of these soils for crop production is on the increase as they are a valuable resource that cannot be neglected, especially in areas where significant investments have already been made in irrigation infrastructure. It is imperative to find ways to improve sodic soils to ensure that they can support highly productive land-use systems to meet the challenges of global food security.

Nearly a century-old record reveals amelioration of sodic soils through the provision of a readily available source of calcium to replace excess sodium on the cation exchange complex, the displaced sodium subject to leaching from the root zone through the application of excess irrigation water in the presence of a drainage system. Many sodic soils do contain inherent or precipitated sources of calcium, i.e., calcite at varying depths within the soil profile. However, due to its negligible solubility, natural dissolution of calcite does not provide enough calcium to affect soil amelioration with routine management practices. Consequently, amelioration of these soils has been predominantly achieved through the application of chemical amendments. However, amendment costs have increased prohibitively over the past two decades due to competing demands from industry and reductions in government subsidies for their agricultural use in several developing countries. In parallel, scientific research and farmers' feedback have demonstrated that sodic soils can be brought back to a highly productive state through a plantassisted approach generically termed ‘phytoremediation’. Typical plant-based strategies for contaminated soils, such as those containing elevated levels of metals and metalloids, work through the cultivation of specific plant species capable of hyper-accumulating target ionic species in their shoots, thereby removing them from the soil. In contrast, phytoremediation of sodic soils is achieved by the ability of plant roots to increase the dissolution rate of calcite, thereby resulting in enhanced levels of calcium in soil solution to effectively replace sodium from the cation exchange complex. Phytoremediation has shown to be advantageous in several aspects: (1) no financial outlay to purchase chemical amendments, (2) accrued financial or other benefits from crops grown during amelioration, (3) promotion of soil aggregate stability and creation of macro-pores that improve soil hydraulic properties and root proliferation, (4) greater plant nutrient availability in soil after phytoremediation, (5) more uniform and greater zone of amelioration in terms of soil depth, and (6) environmental considerations in terms of carbon sequestration in the post-amelioration soil. Phytoremediation is particularly effective when used on moderately saline-sodic and sodic soils. It is a viable solution for resource-poor farmers through community-based management, which would help in strengthening the linkages among researchers, farm advisors, and farmers. These linkages will continue to be fostered as the use of sodic soils become more prevalent. The success of phytoremediation of sodic soils requires a greater understanding of the processes fostering phytoremediation, the potential of phytoremediation species to withstand ambient salinity and sodicity levels in soil and water, and of the uses and markets for the agricultural products produced. Strategic research on such aspects would further elucidate the role of phytoremediation in the restoration of sodic soils for sustainable agriculture and environmental conservation.

Decisive factors in the reclamation of sodic soils: A reappraisal

Pichu RENGASAMY

School of Agriculture, Food and Wine, The University of Adelaide, Waite Campus, Adelaide, Australia.

Email: pichu.rengasamy@adelaide.edu.au

Introduction

Crop production in dispersive sodic soils is limited because of the solid phase chemistry leading to poor soil physical conditions hindering air, water and nutrient movements and soil solution chemistry enhancing elemental toxicity and nutrient deficiency (McDonald *et al*. 2020). Sodic soils adversely affect the geotechnical behaviour of clay soil under buildings and other infrastructure. Different types of soil erosion such as gully and tunnel erosions commonly occur in these soils. Physical breakdown of the particle aggregates and swelling of clays reduce the shear strength of the soil sediments resulting in structural failure and initiation of landslides (Baldermann *et al.* 2021). Estimates (Page *et al*. 2020) show that approximately 618 million ha of land globally are sodic (dispersive) soils.

Traditionally, the focus was on exchangeable sodium as the main factor causing swelling and dispersion of soil clays. Hence, commonly, the choice of parameters to identify swelling and dispersion in soils and to define soil sodicity is either exchangeable sodium percentage (ESP) of soils or sodium adsorption ratio (SAR) of soil solutions. These parameters remained as decisive factors in the reclamation of sodic soils. However, recent studies show that many factors other than ESP or SAR influence the behaviour of sodic soils (Rengasamy *et al.* 2016).

Impact of clay dispersion on soil behaviour

The swelling and eventual dispersion of clay particles from soil aggregates by the interaction of water molecules with clay surfaces, destroy all the hierarchical orders of soil structure and worsen soil physical properties. Dispersive soils have conditions favourable for plant growth and function within a very limited soil water content range compared to a wider range in normal soils. Depending on the degree of clay dispersion, active porosity, aeration porosity and hydraulic conductivity are severely reduced. Increased soil strength at low water contents and crust formation affect seedling emergence and root growth. Transient waterlogging in these soils leads to the accumulation of salts and consequently, nutrient toxicity and deficiency occur (Rengasamy 2010).

Factors influencing clay dispersion during soil and water interactions

Experiments have shown that sodic soil aggregates when immersed in non-polar solvents such as hexane and benzene, neither slake nor disperse. Sodic clays when heated above 300 ^{0}C, do not swell or disperse because of the loss of ionic charge during heating. Based on these observations, Rengasamy *et al.* (2016) concluded that swelling and clay dispersion occurred only when polar water molecules reacted with ionic charges on soil particles.

Source of ionic charge on soil aggregates

The net electrical charge depends on the type and amount of clay minerals, organic matter, and other inorganic constituents. While the charge originates from the individual components, the charge available for hydration changes because of the different types of bonding among these components. For example, soil clays are complex intergrowths of different clay structures intimately associated with inorganic and organic molecules and biopolymers; as a result, they do not have the same charge characteristics as the pure clay mineral counterparts. Further, the charges on broken bonds of clays change with soil pH.

According to thermodynamic principles, these charges have to be balanced by oppositely charged elements or molecules in order to be in a stable equilibrium.

Generally, most agricultural soils (except perhaps some of Ferrosols, equivalent of Oxisols) have net negative charge, and exchangeable cations, most commonly by Na, K, Mg and Ca. Exchangeable Al, Fe, and Mn can be involved in acidic soils. In soils with net positive charge (as in Oxisols), the charge is balanced by exchangeable anions, such as chloride, sulphate, and phosphate.

The bonds between exchangeable cations and clay particles (clay-organic complexes) are a mixture of covalent and ionic character. Marchuk and Rengasamy (2011) derived ionicity index of a cation indicating the ionic character of a clay-cation bond.as below:

$$II = 1- (I_z / I_{z+1})\ Z^{0.5} \qquad (1)$$

where Z is the valence of the cation whose ionization potential is I_z and I_{z+1} is the ionization potential when the valence of the cation changes to Z + 1.

Decisive factor causing clay dispersion

The degree of ionicity of clay-cation bonding indicates water interaction, but swelling and dispersion depend on the dispersive power of cations. Rengasamy *et al*. (2016) defined the 'dispersive charge' of a soil as:

$$\text{Dispersive charge} = (Ca) + 1.7\,(Mg) + 25\,(K) + 45\,(Na) \qquad (2)$$

where concentrations of exchangeable cations measured at the given soil pH are expressed as $cmol_c\ kg^{-1}$ and the coefficients of each cation are their respective dispersive powers relative to Ca and are derived from the ionicity of clay-cation bonds.

The flocculating effects of cations present in electrolytes in soil solutions will reduce the dispersive charge. Rengasamy et al. (2016) defined the 'flocculating charge' as follows in Equation (3):

$$\text{Flocculating charge} = 45\,(Ca) + 27\,(Mg) + 1.8\,(K) + (Na) \qquad (3)$$

where the concentration of soluble cations in the dispersed (or flocculated) soil-water suspension is expressed as $cmol_c\ kg^{-1}$ (on soil basis). The weighting factors of the cations are based on the flocculating powers of cations (Rengasamy *et al.* 2016)), and they are inversely proportional to the coefficients of the dispersive powers.

In dispersed suspensions, the 'net dispersive charge' (Dispersive charge – Flocculating charge) determines the amount of clay dispersed. The Zeta potential of the dispersed clay is highly correlated with the net dispersive charge, indicating the importance of electrostatic forces involved in clay dispersion and flocculation processes. At zero point of dispersion (the point of complete flocculation), dispersive charge equals flocculating charge.

Constraints caused by solution chemistry of dispersive sodic soils

Soil pH varies depending on the composition of cations and anions. Acidic pH caused by Fe and Al, and alkaline pH caused by carbonate species interfere with plant growth by both nutrient toxicity and deficiency (Rengasamy 2016). The physical condition affected by the solid phase chemistry can also lead to transient waterlogging leading to changed redox status of the soil. Under anoxic and suboxic conditions, solubility of nutrient elements are altered and consequently nutrient toxicity and deficiency occur (more details in Rengasamy 2016).

Conclusions

1. As discussed above, because several soil factors control the effects of ESP or SAR on adverse soil physical conditions, they are not suitable factors in diagnosing and amending the adverse soil physical conditions observed in sodic soils.

2. Measurement of clay dispersion is the first step in diagnosing soil physical constraints. The amount of clay dispersed is highly correlated with net dispersive charge on soil particles.
3. Net dispersive charge is the decisive factor that will guide in the decision of the type and quantity of amendments.
4. Reduction of dispersive charge can be achieved by changing the composition of exchangeable cations, using organic matter producing molecules that combine covalently with soil particles, utilizing thermal and biological processes, which reduce ionicity of clay bonds, and introducing flocculating agents.
5. Soil management is necessary to maintain soil solution chemistry as conducive for optimal plant growth. Correcting soil pH with amendments and reducing waterlogging by changing solid phase chemistry are essential for the reclamation of sodic dispersive soils.

Acknowledgements

I acknowledge the help of my students and colleagues over the past three decades leading to the development of the new concepts discussed in this presentation, and the financial support given by GRDC, Australia, during these years.

References

1. Baldermann, A. Dietzel, M. and Reinprecht, V. 2021. Chemical weathering and progressing alteration as possible controlling factors for creeping landslides. *Science of the Total environment*, https://doi.org/10.1016/j.scitoenv.2021.146300.
2. Marchuk, A. and Rengasamy, P. 2011. Clay behaviour in suspension is related to the ionicity of clay-cation bonds. *Applied Clay Science* **53**, 754-759.
3. McDonald, G.K., Tavakkoli, E. and Rengasamy, P. 2020. Commentary: Bread wheat with high salinity and sodicity tolerance. *Frontiers in Plant Science* **11,** article 1194.
4. Page, K.L., Dang, Y.P., Dalal, R.C., Kopittke, P.M. and Menzies, N.W. 2020. The impact, identification and management of dispersive soils in rainfed cropping systems. *European Journal of Soil Science. 2020; 1-20. https://doi.org/10.1111/ejss.13070.*
5. Rengasamy, P. 2010. Soil processes affecting crop production in salt-affected soils. *Functional Plant Biology* **37(7),** 613-620.
6. Rengasamy, P. 2016. Soil chemistry factors confounding crop salinity tolerance- a review. *Agronomy* **6**, 53. Doi:10.3390/agronomy6040053
7. Rengasamy, P., Tavakkoli, E. and McDonald, G.K. 2016. Exchangeable cations and clay dispersion: net dispersive charge, a new concept for dispersive soil. *European Journal of Soil Science* **67,** 659-665.

Management of *Eucalyptus camaldulensis* plantation for bioenergy production, carbon sequestration and phytoremediation of saline landscapes of Punjab Pakistan

Zulfiqar Ahmad SAQIB[1,2*], *Javaid AKHTAR*[1,2], *Riaz Hussain QURESHI*[1,3], *Saeed IQBAL*[4]

[1]Saline Agriculture Research Centre, University of Agriculture, Faisalabad, Pakistan
[2]Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan
[3]Higher Education Commission (HEC) of Pakistan, Islamabad
[4]Engro Fertilizer Pvt Limited, Pakistan
Corresponding Author: E-mail: zulfiqar.dasti@uaf.edu.pk Ph: +92 41 9201304

In Pakistan, around 30-40% of cultivated lands cannot yield to its full potential because of high salinity/sodicity status. Also abandoned salt-affected wastelands can pose a constant threat for the neighbouring quality lands. But using such lands for normal agricultural purpose is not a profitable preposition, because of poor growth of crops under such conditions. However, using halophytic woody perennials are best adapted to nutrient deficient and toxic ion salt-affected environments. The trees not only give cover to soil to reduce evaporation (the basic cause of development of dry land salinity) but improve soil organic matter and other soil physical and chemical properties thus leading to improved soil health and ecosystem. Apart from playing a key role in mitigating effects of salinity/sodicity in salt-affected wastelands, tree plantation has proven to be directly profitable to growers as well. It also has aesthetic value in landscape and is important for ecological resurgence.

Keeping above facts in mind, a study was carried out on naturally salt-affected wastelands of Faisalabad district in Punjab with the objective to assess the plantation strategies, plantation duration and other plant biophysical determinants in improving soil health, wood biomass production and carbon sequestration potential. *Eucalyptus* seedlings (40 days old) were planted on salt-affected wasteland (at three sites simultaneously) using ridges. Canal water was used for irrigation for establishment of plants. After one month, number of dead plants was counted from a given population and mortality was expressed in percentage. Plants were categorized into good, medium and poor plants, (on visual observation basis) six months after transplantation and were tagged for all subsequent plant and soil sampling. Soil samples were collected from within the root vicinity of tagged plants. Soil sampling and observation of soil physical parameters were carried out at 6, 12, 18, 24 and 36 months and 5 years after transplantation. Non-experimental (without tree plantation) fields were also selected along all these experimental sites. Soil samples were collected twice from the non-experimental sites, i.e., before the commencement of the experiment and at the termination of the experiment. These soil samples were analysed for ECe, SAR and pHs and other soil parameters like, bulk density, infiltration rate and soil organic matter content, SOC both at the start and end of experiment. These results were then compared with 'before' and 'after' experimental results of the plantation sites to validate the extent of physicochemical changes in salt-affected soil through *Eucalyptus* plantations.

The different plant spacings (density) significantly influence both plant and soil parameters. Higher stem girth was observed in plots having widely spaced plantation block, while changes in soil physical and chemical properties were significantly different in closely spaced plantation blocks when compared with wider spacing blocks, due to higher number of plants per unit area of land. Tree plantation improved the soil physical properties like infiltration rate, organic matter content and bulk density. Tree plantation also influenced the chemical properties of soil. A reduction in soil pH, EC and SAR was observed during experiment which progressed with time. In general, there was a gradual decrease in EC_e at all the three experimental sites. A reduction of 36-40% at the time of final sampling was observed at all the experimental sites, compared to EC_e values recorded before the start of the experiment (Table-1).

Table-1: Effect of *Eucalyptus* plantation on soil EC_e (dS m^{-1}) in natural salt-affected sites

Sites	**Sampling times (months after transplantation)**				
	6 months	12 months	18 months	24 months	**36 months**
I	22.42	20.72	18.19	17.45	**14.86**
II	27.85	26.02	23.52	20.79	**17.42**
III	23.84	22.66	20.01	18.45	**15.31**
SED*	**0.323**	**0.329**	**0.347**	**0.395**	**0.427**

*** Standard error of difference between two means** **(Sites, n = 160; Depths, n =96)**

The comparison of experimental and non-experimental sites indicated a progressive deterioration in all physical and chemical properties of soil in non-experimental field, whereas improvement in the soil physical and chemical properties was observed under tree plantation.

Tree plantation was directly profitable to farmers apart from non-tangible benefits like mitigation in salinity/sodicity and ecological improvement.

It is concluded that salt-affected wastelands which otherwise have ‘zero opportunity cost’ can be brought under *Eucalyptus camaldulensis* plantation, which will not only bring improvements in physico-chemical properties of soil, but also additional (financial) benefits for the growers. Non-tangible benefits like aesthetic value of tree plantation, ecological improvement and biological diversity will be over and above.

SALEACH: a new web-based Soil Salinity Leaching Model for improved irrigation management

*Hossein SHAHROKHNIA, Laosheng WU**

Department of Environmental Sciences, University of California, Riverside, CA 92521, USA

* Corresponding author. Tel.: +1 951 827 4664; E-mail address: laosheng.wu@ucr.edu

Introduction

When saline irrigation water is applied to croplands, adding excess water to soil greater than the crop evapotranspiration demand is necessary to maintain rootzone salinity in an appropriate range for crop growth. The current soil salinity management models can be classified into two broad categories: steady-state models and transient-state models. Steady-state models, such as the Rhoades (1974) and WATSUIT models (Wu et al., 2012), are easy to use and provide information about the long-term effects of a given change, e.g., to assess soil salinity resulting from a change in irrigation water quality. In contrast, transient-state models, such as HYDRUS (Simunek et al., 1998) and UNSATCHEM (Suarez and Simunek, 1997), are more complicated and require more input data, but they can provide specific, detailed information on soil and water temporal variations to reflect the continual-changes occurring in natural systems (Suarez, 2012).

The traditional steady-state models, such as Rhoades (1974) and WATSUIT (Oster and Rhoades, 1990), use different levels of simplicity and have their respective strengths and weaknesses, but a significant deficiency of these models is that they do not account for soil types and irrigation systems that also affect soil salinity management. The objective of this study was to develop a simple and web-based steady-state model to simultaneously account for crop, soil, water, and irrigation system types and to test the model performance by comparing the results with those of existing models.

Materials and Methods

The leaching requirement (*LR*) was defined by Rhoades (1974) as the amount of excess water that is required during irrigation so that the average rootzone salinity does not exceed the salinity (electrical conductivity, *EC*) threshold of a particular crop ($EC_t \cong EC^*_e$). Rhoades (1974) proposed the following model to estimate LR:

$$LR = \frac{EC_{iw}}{5EC_e^* - EC_{iw}} \qquad (1)$$

where EC_{iw} (dS m^{-1}) is the EC of the applied irrigation water, and EC^*_e is the average of EC_{iw} and EC_{dw} (EC of drainage water) when it is multiplied by a soil water content ratio and a coefficient (K).

Our new model is based on the above traditional model by also considering soil type and irrigation system factors:

(1) *Soil type effect* is considered by using a modified soil water ratio (M factor) to account for differences in soil water holding capacity and maximum allowable depletion (MAD):

$$M = \frac{(1 - \frac{MAD}{2})(\theta_{FC} - \theta_{PWP})}{(\theta_S - \theta_{PWP})} \qquad (2)$$

where θ_s is saturated soil water content, θ_{FC} is soil water field capacity, and θ_{PWP} is permanent wilting point water content. Depending on the specific MAD value for a crop, the M factor varies with soil types. For example, considering a MAD of 50%, the resulting M factor values fall approximately in the range of 0.12 to 0.44, in which the lower and higher values are associated with light soils and heavy soils, respectively.

(2) *Irrigation system effect* is considered by two factors: the K coefficient and leaching zone effect (C_{lz}). The original K coefficient was defined as the ratio of the average soil salinity at different depths, which is affected by root water uptake pattern and the leaching fraction; and the leaching zone effect (C_{lz}) is to account for the differences in salt accumulation patterns and the soil leaching zone in various irrigation systems (flood and sprinkler, furrow, and drip). The final modified leaching requirement equation simultaneously considering water, crop, soil, and irrigation system is:

$$LR = \frac{EC_{iw}}{\left(\frac{2}{(K)(M)}\right) EC_t - EC_{iw}} . C_{lz} \qquad (3)$$

Results from the new model (*www.UCR.EDU/Salinity*) were compared with the simulation results of 27 combinations of water, crop, soil, and irrigation types from HYDRUS and WatSuit.

Results and Summary

SALEACH broadens the applicability of the traditional approach with the purpose of providing a simple, web-based decision support tool for practitioners to estimate the LR, irrigation water amount, soil salinity, and crop yield by considering irrigation water quality, crop tolerance to salinity, soil texture, and irrigation system. The new model was evaluated by comparing its simulations with a more established steady-state model (WATSUIT) and a transient-state model (HYDRUS-1D). Statistical analyses showed that the SALEACH-estimated LRs, drainage water salinity values (EC_{dw}) and soil water salinity values (EC_{sw}) were closely correlated with the results derived from the traditional steady-state model (WATSUIT) and the transient-state model (HYDRUS-1D) tested in 27 combinations of crop, soil, water, and irrigation types. Thus, we conclude that SALEACH is reliable for practical applications, and it is a useful tool for better irrigation management to improve water use efficiency and sustain agricultural production, while reducing groundwater pollution in irrigated croplands.

References

Oster, J.D., Rhoades, J.D., 1990. Steady-state rootzone salt balance, in: Tanji, K.K., (Ed.), Agri. Salinity Assessment & Management, ASCE Manuals & Reports on Engineering No. 71. ASCE, Reston, VA, pp. 469-481.

Rhoades, J. D., 1974. Drainage for salinity control, in: van Schilfgaarde J. (Eds)., Agronomy Monographs, Drainage for agriculture. 17: 433-461.

Šimůnek, J., Huang, K., Van Genuchten, M. T., 1998. The HYDRUS code for simulating the one-dimensional movement of water, heat, and multiple solutes in variably-saturated media. US Salinity Laboratory Research Report No. 144. USDA/ARS, Riverside, CA.

Suarez, D.L., 2012a. Modelling transient rootzone salinity (SWS model), in: Wallender, W. W., Tanji, K.K., (Eds.), Agricultural Salinity Assessment and Management, 2nd Ed. ASCE Manuals and Reports on Engineering Practice No. 71, ASCE, Reston VA, pp 855-897.

Suarez, D. L., Šimůnek, J., 1997. UNSATCHEM: Unsaturated water and solute transport model with equilibrium and kinetic chemistry. Soil Science Society of America Journal. 61(6), 1633-1646.

Wu, L., Amrhein, C., Oster, J.D., 2012. Salinity assessment of irrigation water using WATSUIT, in: Wallender, W. W., Tanji, K.K, (Eds.), Agricultural Salinity Assessment and Management, 2nd Ed. ASCE Manuals and Reports on Engineering Practice No. 71, ASCE, Reston VA, pp 787-800.

Impact of saline soil improvement measures on salt content in the abandonment-reclamation process

Xiaoyan SHI[1,2], Haijiang WANG[1,2], Jianghui SONG[1,2], Xin LV[1,2], Weidi LI[1], Baoguo LI[3,4], Jianchu SHI[3,4]

[1]College of Agriculture, Shihezi University, Shihezi 832000, China
[2]The Key Laboratory of Oasis Ecological Agriculture of Xinjiang Production and Construction Group, Shihezi University, Shihezi, Xinjiang 832003, China
[3]China Agricultural University, College of Land Science and Technology, Beijing 100193, China
[4]Key Laboratory of Arable Land Conservation (North China), Ministry of Agriculture, Beijing 100193, China

Understanding the impacts of desalination treatments on salt migration in saline soil during the farmland abandonment-reclamation process has significance for saline soil development and utilization. In this study, the soil salt content of severely salinized land in Xinjiang, China, was monitored over seven consecutive years using electromagnetic induction (EMI) rapid measurement technology. The experiment involved three different soil desalination engineering treatments and one control in the newly reclaimed, highly saline land (T1: salt isolation treatment at root area with conventional planting; T2: underground tube salt drainage with conventional planting; T3: conventional planting; CK: a natural control). A profile salinity prediction model was built based on the EMI to simulate the three-dimensional spatial distribution characteristics of soil salinity in the test area. The effects of the different saline soil improvement treatments on the distribution of salt content in the soil profile and the effect of desalination were analysed. The results demonstrated the following: (1) the soil salt content in the test area showed an obvious trend of surface salt accumulation. The salt content in the 0-100 cm layers under the different treatments showed decreasing, increasing and decreasing trends with the process of cotton planting, abandonment and reclamation, respectively, with a greater decrease in salt content associated with a longer planting period. (2) The soil salt content obviously decreased under the T1 treatment in the 0-40 cm and 80-100 cm soil layers and in the 20-60 cm soil layers under the T2 and T3 treatments. After the implementation of salinized soil improvement measures and tillage abandonment, a trend of increased salt content was

evident in the plough layer under the different treatments; however, engineering improvement measures were able to inhibit salt migration to a certain degree. Under engineered drainage and salt isolation at the root area in combination with agricultural cultivation, irrigation could effectively reduce the soil salt content in the plough layer. These results provide a theoretical basis for soil improvement and utilization in arid areas.
Keywords: saline-sodic soil, improvement measures, electromagnetic induction, desalination rate

Synergistic interpretation of soil salinity by electromagnetic induction under different landform types

Jianghui SONG[1,2], Xiaoyan SHI[1,2], Haijiang WANG[1,2※], Xin LV[1,2], Jianhua CHEN[1]

[1]Agricultural College, ShiHezi University, ShiHezi 832000, China;
[2]The Key Laboratory of Oasis Eco-agriculture, Xinjiang Production and Construction Group, Shihezi 832000, China

Accurate and rapid measurement of spatial distribution of soil salt content and its change are essential for preventing land degradation and improving the ecological environment. Electromagnetic induction technique provides soil apparent conductivity (ECa) values efficiently and quickly by overcoming several shortcomings of traditional sampling methods at reduced costs. However, the differences in soil properties among different geomorphologic landform types may lead to the decrease in the accuracy of EM38 in predicting soil salinity. In order to clarify the effect of soil properties on apparent conductivity in different geomorphologic landform types, three typical landform types (alluvial-proluvial fan edge, alluvial plain and dry delta) in Manas River Basin of Xinjiang were taken as the research objects. The apparent conductivity data of two measurement modes (horizontal mode EMh and vertical mode EMv) were obtained by using EM38 at different heights from the ground, i.e., 30 cm, 50 cm, 70 cm, 90 cm, 110 cm and 130 cm, respectively. Moreover, in each landform type, 20 representative sampling points were selected for soil sample collection, with sampling depth of 0-20, 20-40, 40-60, 60-80, 80-100 cm. Soil salt content (TS), soil moisture content (θ), soil clay mass fraction (γ), soil cation exchange capacity (CEC) and soil organic carbon content (SOC) were determined. Firstly, path analysis method was used to analyze the influence degree and contribution rate of these variables at different depths on ECa measured at different heights. Next, by selecting non-salinity factors with high contribution rate of ECa as auxiliary variables, a multi-factor collaborative interpretation model of soil salinity was established, and compared with the model established only with ECa as independent variable. Finally, the optimal interpretation model of soil salinity was established and the accuracy of the model was evaluated. The results showed that among the three landform types, soil salt content was the most important factor affecting the contribution rate of ECa, and there were significant differences in the factors affecting ECa of each soil layer under different landforms. Water content of the upper soil (0-60 cm) contributed most to ECa, whereas soil CEC value and organic carbon content of the bottom soil (60-100 cm) in the alluvial-proluvial fan edge. A high contribution was provided by soil salt content at 0-20 cm layer and 40-80 cm layer, whereas CEC value and clay mass fraction for 20-40 cm layer in the alluvial plain. ECa can be significantly affected by CEC value of the upper layer (0-60 cm) and soil organic carbon content of the lower layer (60-100 cm) in the dry delta. According to the accumulative contribution rate of more than 80%, non-salt factors were selected to establish the collaborative interpretation model of layered soil salt content under different landforms. The R^2_{adj} of different soil layers under three types of landforms improved in the following ranges from 0.81-0.86, 0.57-0.87 and 0.27-0.47 to 0.83-0.91, 0.63-0.93 and 0.48-0.70, respectively. The validation results showed that the R^2 of salt prediction models for different soil layers under the three landform types were 0.61-0.81, 0.48-0.85 and 0.35-0.66, respectively. Results can provide theoretical basis and technical guidance for rapid and effective monitoring of saline soils.

Keywords: soils, salt, models, electromagnetic induction, influence factor, landforms

Hemp production and demonstration model on slightly-moderately saline-sodic land

Yufeng SUN

Daqing Branch of Heilongjiang Academy of Sciences, Daqing, Heilongjiang 163319, China
E-mail：sunyf888@163.com

Inside the calcareous black soil (pH 7.8-8.2) region of western Songnen Plain, but focusing on the soda-containing saline-sodic soils, research was carried out on 1) the introduction of high-quality and highly resistant industrial hemp germplasm resources; 2) breeding of new varieties; 3) the promotion and application of supporting planting technology; 4) integrating key technical solutions to obtain high quality seeds; 5) to establish efficient production model and 6) to form a large-scale industrial demonstration project.

Through the use of excellent resources and own selected varieties as parents, different breeding techniques and continuous multi-location varietal adaptability studies were run during many years. As a result three excellent slightly-moderately salt tolerant varieties were selected, and two excellent lines were obtained. Through the combination of these varieties and soil conditions, we carried out a series of studies on the germination characteristics, growth and development under sodicity stress, but also in reclaimed land and developed the appropriate agronomic techniques for the varieties. After five consecutive years the project team has established 252 hectares demonstration area, 80 hectares high quality seed breeding area, and 1,334 hectares extension area, thereby effectively contributing to local economic growth and poverty alleviation. By cooperating with leading domestic industrial enterprises and exploring raw material development and application, we contributed not only to maximization of the benefits of saline agriculture, but also to the development of a series of products such as yarn and short fiber, and successfully established an industrial economic model for hemp in saline land.

Keywords: industrial hemp, saline-sodic land, industrial economic model

Phosphorus accumulation, utilization and translocation characteristics of rice under saline-alkaline stress

Zhijie TIAN[1,2], Jingpeng LI[1], Fu YANG[1], Zhichun WANG[1]

[1]Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun 130102, China;

[2] Xinzhou Teachers University, Xinzhou 034000, China

Phosphorus is important for crop development and resistance to saline-alkaline stress. A pot experiment was conducted with two contrasting saline-alkaline tolerant (Dongdao-4) and sensitive (Tongyu-315) rice varieties. Plant growth, dry weight and phosphorus accumulation, utilization and translocation on slightly (pH 8.27, ESP 9.7%) and severely (pH 9.09, ESP 21.56%) saline-alkaline soils, combined with phosphorus application (0, 50, 100, 150, 200 kg ha^{-1}) was tested. The effects of two rice varieties to P application under saline-alkaline stress were significantly different with various optimal phosphorus applications. Phosphorus application did not have significant effect on rice growth and phosphorus nutrition characteristics under slight saline-alkaline stress. Moreover, both rice varieties showed relatively high dry matter yield without phosphorus application due to the high content of available phosphorus in soil. Under severe saline-alkaline stress, however, phosphorus application significantly increased grain yield, phosphorus accumulation and phosphorus translocation of rice, especially of Dongdao-4 variety. For attaining the greatest grain yield, Dongdao-4 had the optimal phosphorus application at 150 kg ha^{-1} and 200 kg ha^{-1} in slightly and severely saline-alkaline soil, respectively, and Tongyu-315 had the optimal phosphorus application at 100 kg ha^{-1} in both soil types. Thus, the saline-alkaline-tolerant rice variety was more sensitive to phosphorus application, especially in severe stress condition with greatly reduced Na^+/K^+ ratio and increased biomass, phosphorus assimilation and phosphorus translocation. While the saline-alkaline-sensitive rice variety was more insensitive to phosphorus application with consistently higher Na^+/K^+ ratio and then suffered more serious damage from severe saline-alkaline stress. Consequently both varieties and soil conditions should be considered when identifying the optimal phosphorus application.

Keywords: saline-alkaline soil, phosphorus application, dry matter translocation, phosphorus translocation

The effect of alkaliphile bacteria on diminishing soil salinity and sodicity stress in GN15 almond rootstock growth parameters and nutrient concentrations

Mehrnoush Eskandari TORBAGHAN[1], Gholam Hossein Khalili TORGHABEH[2]

[1]Researcher, Soil and Water Department, Khorasan Razavi Agricultural and Natural Resources Research and Education Center, AREEO, Mashhad, Iran
[2]M.Sc. student of Horticultural Science, Ferdowsi University of Mashhad, Iran
Corresponding Email Address: mehrnoosh.eskandary@gmail.com

Eighteen alkaliphilic isolates were isolated and purified from different almond grove rhizospheres in Khorasan Razavi province, Iran to alleviate the soil salinity and sodicity stress for 15GN-rootstock almonds cultivation. Production of 3-indoleacetic acid, the quantitative solubility of mineral phosphates, and exo-polysaccharide production in all isolates were investigated in the laboratory to select the most tolerant strains. The superior strains were tested in the vicinity of 15GN-rootstocks to identify the effect of them on some growth characteristics, biochemical parameters, and soil and plant nutrient concentrations under both open-air and potted conditions in saline-alkaline soils (2, 4, 8, and 16 dS m^{-1} ECs and 10, 15, 15, and 20, SAR values respectively). The average of IAA, PSB, and EPS was 587.1, 127.5, and 213.9 mg L^{-1} respectively in the alkaliphilic isolates. Soil salinity and sodicity increase caused a reduction in the fresh and dry weight of shoots and roots, height, stem diameter, chlorophyll content, and leaf area, but the moisture content of roots increased. Sandhu et al. (2020) indicated that Na^+ and, to a lesser extent, Cl^- were the most toxic ions to almond rootstocks. With the alkaliphilic bacteria application chlorophyll index, the number of leaves, and leaf loss showed opposite and unexpectable trend at the highest salinity level (16 dS m^{-1}). The use of alkaliphilic strain (A7) improved all growth parameters in the rootstocks compared to the control. Eskandari Torbaghan et al. (2017) showed that the application of alkaliphilic bacteria increased wheat yield about 43.6% by the production of ammonia (0.055%) and IAA (0.0001%). With increasing salinity and sodicity of the soil, the amounts of EC, Cl, Na, K, P, and Fe in the soil as well as Na, Cl, Fe, Zn, and Mg content of the plant increased. However, the plant N, P and K concentrations decreased. The concentration of macro nutrients (N, P, K and Mg) at 16 dS m^{-1} salinity showed less reduction than at 8 dS m^{-1}. Proline content increased with increasing salinity, but soluble,

insoluble, and total sugar contents decreased. Only soil K and P as well as plant Mg concentrations with 148.6, 511.7 ppm, and 0.4063%, respectively, were higher in A11 than in A7 (138.1, 485.7 ppm, and 0.3054 %). Proline and three types of sugars were not significantly different under the influence of alkaliphiles bacteria. In general, the results showed that compared to A7 strain the A11 had more positive effect on the 15GN rootstock growth, which showed opposite results compared to the PGPR characteristics measured of the strains in vitro, which indicated the complex interactions of soil, plant, and bacteria in the saline and alkaline soils (Gamalero et al.,2020). The 8 dS m^{-1} salinity acted as a turning point for almond rootstocks under the influence of alkaliphilic bacteria. When salinity was above 8 dS m^{-1}, the use of alkaline strains improved growth characteristics, biochemical parameters, and soil and plant elemental composition.

Keywords: sodicity stress, exo-polysaccharides, extremophilic bacteria, turning point

References

Eskandari Torbagha, M., Lakzian, A., Astaraei, A. R., Fotovat, A., Besharati, H. (2017). Quantitative Comparison of Ammonia and 3-Indoleacetic Acid Production in Halophilic, Alkalophilic and Haloalkalophilic Bacterial Isolates in Soil. Quarterly Journal of Experimental Animal Biology. 6(1(21), 41-58. DOI: 10.4314/jfas.8vi2s.80.

Gamalero, E., Bona, E., Todeschini, V., & Lingua, G. (2020). Saline and Arid Soils: Impact on Bacteria, Plants, and their Interaction. Biology, 9(6), 116. https://doi.org/10.3390/biology9060116.

Shultana, R., Tan Kee Zuan, A., Yusop, M.R., Mohd Saud, H., Ayanda, A.F. (2020). Effect of Salt-Tolerant Bacterial Inoculations on Rice Seedlings Differing in Salt-Tolerance under Saline Soil Conditions. Agronomy, 10, 1030. https://doi.org/10.3390/agronomy10071030.

Review of research on sodic soil reclamation

Tibor TÓTH

Institute for Soil Sciences, Centre for Agricultural Research

Budapest, Herman Ottó 15, Hungary 1022.

Email: tibor@rissac.hu

Since centuries, reclamation of sodic soils is an essential part of cropping practices in several parts of the world. Parallel to increasing population, the need for new cropland constantly re-evaluates land suitability concepts. Therefore the importance of sodic soils as potential croplands is increasing worldwide. Although theoretically farmers can choose a wide variety of reclamation options according to the profitability, business plan, human and financial resources; in practice few reclamation methods are applied at large scale.

The presentation touches on early history, 20 century intensive research and current trends of sodic soil reclamation. New approaches, such as leaching, chemical amendments, addition of organic material, biological and microbial improvements will be discussed, and also brand new approaches will be reviewed.

Early history is reviewed using historical books, the achievements of last hundred years using basic technical literature, mostly books, and the current approaches of our time with fresh publications, mostly papers.

Keywords: mixing fertile subsoil, liming, chemical reclamation, new technology

Effects of soil texture on soil leaching and cotton growth under irrigation and drainage

Dongwang WANG[1,2]，*Zhenhua WANG*[1,2*]，*Tingbo LV*[1,2]，*Jinzhu ZHANG*[1,2]，*Wenhao LI*[1,2]

[1]College of Water Conservancy and Architectural Engineering Shihezi University， Shihezi 832000，Xinjiang，China

[2]Key Laboratory of modern water saving irrigation of Xinjiang Bingtuan，Shihezi 832000，Xinjiang，China

*Email:wzh2002027@163.com

Irrigation and drainage linkage technology is a kind of combined water-saving technology. In order to further explore the effect of different soil texture classes on soil leaching and cotton growth under irrigation and drainage linkage, and to provide theoretical basis for saline-alkali soil improvement in Xinjiang, soil pH, salinity, permeability, cotton yield and water use efficiency (WUE) were investigated under irrigation and drainage linkage (T1) and conventional drip irrigation (T2) in three soil texture classes (clay, loam and sandy soil) by pit test. Results showed that the 0-60 cm average pH value of clay, loam and sandy soils under T1 treatment decreased by 5.02%, 5.85% and 3.27% respectively compared with that of T2 treatment, that is, the pH value of shallow soil was reduced by irrigation and drainage treatment. Compared with T2, the average 0-60 cm salt content in clay, loam and sand soils decreased by 14.09%, 14.21% and 12.35%, respectively; Under T1 and T2 treatments, the K/K_0 ratio of different soil texture classes in different cotton growth stages followed the order sandy soil > loam soil > clay. Under T1 treatment, the K/K_0 ratio of different soil texture classes in different growth stages of cotton was greater than 1, and irrigation and drainage improved the soil permeability; The yield and WUE of seed cotton under T1 and T2 treatments with different soil textures followed the order loam> clay> sand, and were significantly different. Under loam texture, cotton yield and WUE in T2 treatment were 94.02% and 87.96% of T1, respectively. Irrigation and drainage have obvious effects on soil pH value, salt content and soil permeability. Adjusting irrigation and drainage to soil texture can effectively improve the root growth

environment of crops, thereby improving water and fertilizer use efficiency and enhancing cotton growth.

Keywords: irrigation and drainage linkage, soil texture, soil pH, soil salinity, permeability, cotton yield, WUE

Advances in the identification of soil constraints in salt-affected soils

Mingming WANG[1], Zhengwei LIANG[1], Pichu RENGASAMY[2], Shuyu WANG[1], Jiani XUE[1]

[1]Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun, Jilin, China

[2]The University of Adelaide, Waite Campus, PMB1, SA 5064, Australia

Identification of the most limiting factors of optimum crop yield is an important pre-requisite to implement sustainable site-specific soil management and to improve crop yield. In the horizons of salt-affected soils, such physical, chemical and biological constraints as salinity, sodicity, hardsetting, crusting, compaction, acidity/alkalinity, nutrient deficiency and boron-, carbonate- and aluminum-toxicity are frequently reported as the major factors. In practice, identification of the most limiting factor based on soil analysis is often complicated by many interacting root-zone constraints, such as salinity, sodicity, alkalinity, nutrient deficiency and toxicy that occur simultaneously in soils. Likewise, temporal and spatial variations of soil constraints frequently make the diagnosis of the limiting factors difficult. Consequently, there is a gap in our knowledge for the optimum approach to identify the predominant factor when different issues can cause constraints to crop growth in different soil layers. Future studies should emphasize the contribution of the multiple constraints, especially during the sensitive stages of crop growth, in the salt-affected soils.

Keywords：salt-affected soil, soil constraints, sensitive stages of crop growth, crop yield

Study on the suitability of forage cultivation in soda-containing saline-sodic cultivated land

Jiabin WU[1,2,], Hexiang ZHENG[1,2], Tianzun PAN[3], Weilesi BIAN[4], Wei WANG[4]*

[1]State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, China Institute of Water Resources and Hydropower Research, Beijing 100038, China; zhenghexiang.29@163.com (H.Z.); mkswjb@163.com (J.W.); tiandelongnnd@sina.com (D.T.); 125046277@qq.com (P.M.)

[2]Institute of Water Resources for Pastoral Areas, China Institute of Water Resources and Hydropower Research, Hohhot 010020, China

[3]Agricultural Technology Extension Center of KeZuoZhong Banne, Tongliao 029300, China

*****Correspondence: mkswjb@163.com; Tel.: +86-13847115086

[4]Inner Mongolia Hengyuan Water Conservancy Engineering Co., Ltd, Hohhot 010020, China

*****Correspondence: 18306390807@163.com; Tel.: +86-18306390807; 237831207@qq.com

In the eastern part of Inner Mongolia, represented by the KeZuoZhong banner, the salinization of cultivated land is serious, and the type of salinized soil is mainly sodic salinized soil, which is the main obstacle factor limiting the yield of farmland. At the same time, with the sustainable development of animal husbandry in agricultural areas, the traditional corn stalk storage based feed supply cannot fully meet the needs of animal husbandry development, and the contradiction between grass and livestock is prominent. In view of the present situation and existing problems of soda-containing saline-alkali farmland, four forage varieties suitable for soda-containing saline-alkali farmland were selected from eight common forage varieties, including silage corn, Gaodancao, Zhaomu No.1, and sweet sorghum. The results showed that the above four forage varieties could achieve high yield and good effect on soda-containing saline-alkali cultivated land through suitable high-yield forage cultivation techniques and field management mode. The research results have good application value and scientific significance for the management, utilization, and improvement of soda-containing salinized farmland.

Effect of substituting chemical fertilizers with organic fertilizers on secondary soil salinization at a Tianjin solar greenhouse facility

Zhaohui WU[1,2], *Li ZHANG*[1,2]

[1]College of Life Sciences, Tianjin Normal University, Tianjin 300387, China;
[2]Tianjin Key Laboratory of Animal and Plant Resistance, Tianjin 300387，China

With the gradual increase of the length of continuous cropping at Tianjin, and the continuous application of a large number of chemical fertilizers, many problems such as secondary soil salinization have been caused, and the ecological function of the soil has been degraded. This study intends to evaluate the effects of different remediation techniques on vegetable yield, quality and environmental pollution; and to explore the mechanism of secondary soil salinization when chemical fertilizers are substituted by organic fertilizers. In this study, during five-year continuous vegetable cropping was carried out in the main production area of Tianjin solar greenhouse facility. There were eight experimental treatments, and the substitution of chemical fertilizers with organic fertilizers is realized by ensuring equal nitrogen content of the two approaches. Taking no fertilized, single application of chemical fertilizers, and farmers' habitual fertilizer application as controls, we focus on the effects of organic fertilizer replacement, half replacement, organic fertilizer combined with straw and soilless organic substrate cultivation on tomato yield, quality, and soil water and salt dynamics. The results of the study showed that compared to control, in the organic substrate cultivation treatment the quality of tomatoes was significantly improved, including vitamin C, total soluble sugar, and titratable acidity increase by 30.7%, 35.4%, 32.6%; 32.1%, 35.2%, 32.6%；35.9%, 35.7%, 38.2%, respectively in the mentioned experimental treatments. The organic fertilizer treatment gave significantly higher tomato yield than the control treatment, by 9.8%, 15.3%, and 5.9% respectively. The soil moisture and salt content in the organic fertilizer combined with straw treatment showed relatively stable trend, between 15% and 20%, and was significantly lower than in other treatments. Combining straw addition with the organic fertilizer treatment, the salt content was reduced by 50.3%, and water content by 40.7%. The substitution of chemical fertilizers with organic fertilizers reduced secondary soil salinization, and the combination with straw had the best effect.

Keywords: solar greenhouse facility, substituting chemical fertilizers with organic fertilizers, secondary soil salinization, straw addition, organic cultivation

Estimating soil salinity with a digital camera

Lu XU[1], *Zhichun WANG*[2]

[1]School of Geography, Geomatics and Planning, Jiangsu Normal University, Xuzhou, 221116, China

[2]Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun, 130102, China

Determining soil salt content (SSC) rapidly and simply is important for various environmental and agricultural applications. Recently increasing attention has been focused on the color analysis to detect soil properties with digital cameras. Based on the fact that soil salinity affects soil color, this study investigated the feasibility of utilizing digital camera observations as an alternative tool for SSC estimation. In this study, field measurements were first conducted in the farmlands and wastelands in the inland river basin of Northwest China, and soil photographs were captured within the random-selected spots that were sampled for SSC measurements in laboratory. Then, four color components, red (R), green (G), blue (B) and gray (Gr), were extracted from the raw photograph, and the digital number (DN) value of each pixel in each color component was calculated and counted. Each number of DN value was differently correlated with SSC. To find out certain DN ranges that are mostly sensitive to the variation of SSC, the whole DN value range (0-255) was separated equidistantly into several partitions (from 2 to 10, 16 and 32), and the pixel number of each partition were recounted while the portion of every partition was computed for all pixels in each color component. After that, SSC and these portions of four color components were regressed by partial least squares regression to find the best partitions according to the best determination coefficient (R2) and the ratio of performance to deviation (RPD). To obtain a better fit, we trained the models based on random training dataset for 100 times. Finally, SSC inversion model was built and evaluated with excellent accuracy (R2=0.9, and RPD=3.11). We conclude that it is viable to apply digital cameras to estimate SSC. Findings from this study provide a base for research that can maximize the potential of digital cameras in estimating soil attributes under field conditions.

Keywords: soil salt content, digital camera, soil color, image processing, PLSR

Ecological management of saline land and high quality agricultural products in Yinchuan Plain of Hetao Basin

Xing XU

Ningxia University

Email: xuxingscience@126. com

The Hetao Basin, which is located in the Yellow River Bend resembling the Chinese character "几" is an important ecological barrier and the supply area of high-quality agricultural products. There are more than 8667 km^2 salinized lands (accounting for 45.1% of the arable land) in the Hetao Basin, threatening seriously the ecological security of the oasis and limiting the sustainable agricultural development. In Ningxia one third of the arable land area has become saline-sodic, forming three types, i.e., cracking sodic soil, saline soil and secondary saline soil. The project addresses the problems of unclear obstacle factors, recurrent improvement effects and poor integration with special industries in Yinchuan Plain saline soils and builds a research technology line with the idea of resource utilization, ecological integrated management and follow-up measures of special industries, and applies new methods such as visible spectrum analysis, remote sensing image diagnosis and big data platform analysis to carry out research and demonstration on the spatial and temporal pattern of salinity in the Yinchuan Plain, the mechanism of salt tolerance and the development of high-quality agricultural products in saline soils.

Results show that (1) the salinity has been alleviated in Hetao Basin saline-sodic land generally, of which the territory of slightly saline-sodic arable land has increased, moderately-severe saline-sodic arable land and saline-sodic wasteland areas have decreased; elevation, groundwater, and irrigation amount being the main driving factors of the temporal and spatial dynamics. (2) *Echinochloa frumentacea* (a salinity-sodicity tolerant forage grass species) can be planted in sodic soil at pH 8.5-9.5, while oats can be planted in saline soil, up to 0.3-0.5% salt content. After growing *E. frumentacea* and oats, the diversity of soil microorganisms and soil enzyme activities have increased. (3) Within a certain range, there is a correlation between soil salinity and the quality of *Lycium barbarum*, rice, and alfalfa. The polysaccharide and flavonoid content of *L. barbarum* is positively correlated with soil pH, total salt, Na^+, and Cl^- content. Compared to the control, on average organic calcium content of *L. barbarum* increased by 25%-35%, while polysaccharide content by 19.3%. (4) An ecological improvement technology system for saline-sodic land, so-called “six in one”, has been proposed, including the supporting machinery and special fertilizer application technology, salt-tolerant pioneer plant pattern and biological improvement. Furthermore ecological restoration and industrial techniques, such as "rice-fishing", "grass-livestock" and high-quality wolfberry, have been created. (5) Three core experimental demonstration bases and 16 demonstration sites were established in cracking sodic, saline, and secondary saline-sodic areas. After ecological improvement, the water production efficiency increased by 21%-39%, pH decreased by 10%-16%, total salt content decreased by 32%-55%, organic matter content increased by 22%-36%, land productivity increased by 50% on average, vegetation cover increased by more than 35%, and the landscape diversity index has increased by one grade on average.

The relevant results were included in the State Council's Soil Pollution Prevention and Control Action Plan, and have been widely applied in Inner Mongolia, Jilin, Xinjiang, Heilongjiang and other provinces (regions).

Keywords: Yinchuan Plain of Hetao Basin, saline-alkali land; ecological management, high-quality agricultural products

The coefficient of linear extensibility of saline-sodic soils and its relationship with other soil physico-chemical properties in Songnen Plain, northeast China

Hongtao YANG[1,2], Fenghua AN[2], Fan YANG[2], Zhichun WANG[2]

[1]Yichun University, Yichun 336000, China
[2]Northeast Insitute of Geography and Agroecology, Chinese Academy of Sciences, Changchun 130102, China

The coefficient of linear extensibility (COLE) of soils that undergo volumetric changes due to soil moisture fluctuation; is an inherent property that is used to estimate soil swelling and shrinking. Many papers were published on the COLE value of Histosols, Stagnosols and Vertisols, however, there is limited information regarding the COLE of saline-sodic soils. In this study, soil samples from undisturbed, uncultivated saline-alkali grasslands were collected from a severely saline-sodic soil region in the Songnen plain, northeast China, to determine the COLE value of this soil and its relationship with soil physico-chemical properties. The results showed that the COLE value of saline-sodic soils ranged from 0.04 cm cm^{-1} to 0.20 cm cm^{-1}, with an average of 0.18 cm/cm. Moreover, significant correlation coefficients ($|r| = 0.50 \sim 0.80$, $P < 0.01$) were determined between the COLE and soil $pH_{1:5}$, $EC_{1:5}$, Sodium Absorption Ratio, silt content, clay content, soil compaction and soil bulk density. Since 86% of the variance in the COLE can be attributed to soil EC and clay content, its value can be predicted with $EC_{1:5}$ and clay content.

Keywords: saline-sodic soils, coefficient of linear extensibility, soil physico-chemical properties

Impact of cultivating rice on regional climate on saline-alkali lands in western Jilin province

Lingxue YU[1], Tingxiang LIU[2], Kun BU[1], Jiuchun YANG[1], Shuting BAI[1], Shuwen ZHANG[1]

[1]Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun, China

[2]College of Geography Science, Changchun Normal University, Changchun, China

Studying land-use change and its associated climate effects is important to understand the role of human activities in the regulation of climate. By coupling remote sensing measurements and regional climate simulation, this study evaluated the land-use changes and corresponding climate impact, caused by the presumed saline-alkali land cultivation in western Jilin. Our results showed that the paddy field expansion has become the dominant land-use change in western Jilin province from 2015 to 2019, 25% of which was converted from saline-alkali land, and this percentage is expected to increase in the near future. We found that cultivation of rice on saline-alkali lands significantly increased Leaf Area Index, particularly in July and August, while decreased albedo mainly in May and June. Our simulation results showed that saline-alkali land conversion to paddy fields can help to decrease air temperature and increase relative humidity. During the growing season, the coolness and humidity effects showed different magnitude, being most significant in July and August, followed by September and June. Instead of albedo, evapotranspiration (ET) played dominant role in the regulation of regional climate, and the counteraction between ET and albedo determined the variations of the temperature and relative humidity responses during the growing season.

Keywords: saline-alkali land cultivation, paddy field, regional climate, Weather Research and Forecasting Model, western Jilin

Reclamation effect of gypsum and organic fertilizer on saline-alkali soil in Inner Mongolia

Jing ZHANG[1], Wenchao ZHANG[2], ZhentaoSUN[2], Yonggan ZHAO[2], Shujuan WANG[2]*

[1]Shanxi Clean Energy Research Institute, Tsinghua University, Shanxi Taiyuan 030032 China;
[2]Department of Energy and Power Engineering, Tsinghua University, Beijing 100084, China)
*E-mail:wangshuj@tsinghua.edu.cn

In order to develop the most suitable local reclamation variant in Inner Mongolia and gradually establish and improve the technical support for flue gas desulfurization (FGD) gypsum reclamation of saline land, from 2012 to 2013, we designed the application of gypsum alone (0.45, 0.9, 1.35 and 1.8 t/ha), FGD gypsum with organic fertilizer (0.6 t/ha gypsum with 2, 4, 6 and 8 t/ha organic fertilizer) and FGD gypsum with humic acid (1.2 t/ha gypsum alone; 1 t/ha humic acid with 0, 0.6, 0.9 and 1.2 t/ha organic fertilizer), and FGD gypsum with humic acid (1.2 t/ha gypsum alone; 1 t/ha humic acid with 0, 0.6, 0.9 and 1.2 t/ha gypsum) to reclaim saline land. The results showed that all three reclamation variants were effective in desalination and alkalinity reduction, seedling emergence and yield increase, among which the effect of single application of FGD gypsum was best. Compared with the original soil, the total soil salinity decreased by 29.18%~66.67%, 0.52%~68.59% and 4.82%~43.82% in the treatments of gypsum alone, gypsum combined with organic fertilizer and gypsum combined with humic acid, respectively; the alkalinity decreased by 19.42%~64.46%, 14.9%~61.84% and 17.13%~26.17%, respectively. Compared with the original soil, the seedling emergence rate of gypsum alone and gypsum combined with organic fertilizer increased by 23.1% and 20.5%, respectively, the yield of the three treatments increased by 293.5%, 233.4% and 130.1%, respectively. Among the treatments with amendments, the effect of yield increase by alkali reduction and salt removal was best with the application of FGD gypsum alone. With time, the reclamation variants applying FGD gypsum alone and FGD gypsum with organic fertilizer could further reduce soil salinity and improve the effect of preserving seedlings and increasing yield. The experimental results showed that the reclamation effect of FGD gypsum alone or with organic fertilizer and humic acid applied to saline land was significant, and the best

reclamation effect was achieved under the three variants when FGD gypsum was applied alone, and when the application rate of 1.35 t/ha was more beneficial to the development of local agriculture.

Keywords: desulfurization gypsum, organic fertilizer, humic acid, saline-alkali soil, yield increase

Salinity fractionation of saline-sodic soils reclaimed by calcium chloride-amended brackish ice

Lu ZHANG, Fan YANG, Zhichun WANG, Fenghua AN

Northeast Institute of Geography and Agroecology, Changchun 130102, China

Salinization is a serious soil degradation problem, which affects the quality of ecological environment and the development of agricultural economy. In recent years, the improvement of degraded soil resources and the utilization of water resources have attracted a lot of attention. In order to study the water-salt dynamics and reclamation effects of calcium-amended brackish ice on saline-sodic soils, we conducted a laboratory soil column experiment with 3 levels of exchangeable sodium percentage (ESP) under four salinity levels (1, 1.6, 2.2 and 2.8 g/L) of brackish ice. Based on the analysis of soil pH, electrical conductivity (EC), sodium adsorption ratio (SAR), alkalinity, infiltration depth and ionome, it was found that soil with low ESP (ESP 20) required a higher salinity (2.2 g/L, Na/Ca $\leq$ 1.14) of brackish ice to keep the soil flocculated. However, for high ESP soils (ESP 40 and 70), there was no significant difference in stabilizing effects among brackish ice treatments of 1, 1.6, 2.2 and 2.8 g/L, these 4 treatments of brackish ice can all realize desalination of 0-12 cm soil layers. But the 1.5 pore volume of brackish ice will accumulate more salts in 12-20 cm soil layer of the soil profile. Therefore, we recommend that the amount of irrigation brackish ice be increased for the soil with high ESP. We further determined an optimal brackish ice concentration for different ESP soils: 2.2 g/L brackish ice for ESP 20 soil, 1.6 g/L for ESP 40 soil and 1 g/L for ESP 70 soil. This study provides a comprehensive understanding for the reclamation of saline-sodic soils and utilization of underground saline water in arid and semi-arid areas.

Effect of different amendment application rates on sodic soil reclamation

Wenxin ZHANG[1,2]*, Wenchao ZHAN*[1,2]*, Rongrong TIA*[1,2]*,* [1,2]*, Yonggan ZHAO*[1,2]*,*
Shujuan WANG[1,2]*, Yan LI*[1,2]*, Lizhen XU*[1,2]

[1]Beijing Engineering Research Center for Ecological Restoration and Carbon Fixation of Saline−Alkaline and Desert Land, Department of Energy and Power Engineering, Tsinghua University, Beijing 100084, China
[2]Center for Ecological Restoration of Saline−Alkali, Shanxi Research Institute for Clean Energy, Tsinghua University, Taiyuan 030032, China

Efficient sodic soil reclamation has great significance for the ecological restoration of saline-alkali land in China. In order to quickly reclaim the sodic soil in Da'an, Jilin Province, nine application rate treatments of flue gas desulfurization gypsum combined with ferrous sulfate and citric acid were designed by orthogonal method to test the effects of different rates on pH, total dissolved solids (TDS), soil sodium adsorption ratio (SAR) and rice yield of sodic soil. Results showed that pH was significantly reduced in 2017, and then decreased smoothly. Total dissolved solids of sodic soil increased first and then decreased. The experimental amendment could greatly reduce soil SAR, the maximum reduction value was 92.4%. In the third year (2019), there was no significant difference between soil TDS and SAR in the treatments. Compared with the control, rice yield increased in each treatment by an average of 63.80%. Based on the influence of different amendment application rates on the mentioned four indexes, the optimal rate was decided as 1.5 t/ha flue gas desulfurization gypsum +750 kg/ha ferrous sulfate + 375 kg/ha citric acid. These experimental results provide theoretical support for selecting optimum amendment application rate in sodic soil.

Keywords：flue gas desulfurization gypsum, ferrous sulfate, citric acid, sodic soil

Effect of carbon addition on soil microbial community diversity in saline-alkali farmland

*Jingyi ZHAO, Yuxin GUO, Zhonghui YUE**

College of Life Science and Technology, Harbin Normal University/Heilongjiang Province Key Laboratory of Plant Biology, Harbin 150025, China

E-mail：yuezhonghui@163.com

Soil organic carbon sources have high biochemical stability and strong adsorptive capacity, therefore have important role in the enhancement of soil quality, increasing the number of soil microorganisms and maintaining the stability of soil carbon pool. Consequently, studying the effects of the addition of straw, biochar and nanocarbon on the composition, diversity and abundance of soil bacterial communities in saline-alkali farmland can provide theoretical references for soil improvement and the rational use of carbon sources. The results of the study were as follows: (1) At 97% similarity level, the Chao1 index, Observed species and Shannon indexes of the saline-alkali soil bacterial community increased after straw treatment. The Chao1 index, Observed species indexes increased and Shannon index decreased after biochar and nanocarbon treatments. (2) The addition of the three carbon sources all increased the species abundance of the saline-alkali soil bacterial community, and the species abundance after straw treatment was higher than that of biochar and nanocarbon treatment. (3) In terms of community composition, the dominant bacterial phylae (relative abundance> 10%) for different treatments were *Acidobacteria*, *Actinobacteria*, *Proteobacteria*, and *Chloroflexi*. After nanocarbon and biochar treatments, the relative abundance of *Acidobacteria* and *Chloroflexi* was higher, while the relative abundance of *Proteobacteria* was lower than after straw treatment. The dominant bacteria classes for different treatments were Subgroup 6, *Alphaproteobacteria*, and *Blastocatellia*. After the addition of three carbon sources, the relative abundance of Subgroup 6, *Blastocatelli*a showed the following order nanocarbon>biochar>straw, and the relative abundance of *Alphaproteobacteria* changed in the opposite way. The results of hierarchical clustering and principal component analysis showed that the bacterial community structure of saline-alkali soil was the most significantly different after nanocarbon treatment. Pairwise cases of significant difference were most frequent in the *Acidobacteria*, *Planctomycetes*, *Latescibacteria* phylae in the nanocarbon treatment and *Nitrospirae*, *Tectomicrobia* phylae in

the in straw treatment. However, there was no significant difference between the control and the biochar treatment at the phylum level. These results showed that the effects of straw, biochar, and nanocarbon on the microbial community in saline-alkali farmland were different. The addition of straw had a great influence on the bacterial community structure and diversity; and straw and nanocarbon had specific influence on the composition and abundance of bacterial community.
Keywords: saline-alkali soil, carbon addition, microbial community diversity, high-throughput sequencing

The sponsors of the conference

- The IUSS Commission 3.6 Salt-affected Soils
- Saline-alkali Soil Commission of Soil Science Society of China
- UNESCO Beijing Office
- FAO/Global Environmental Fund
- The Chinese Academy of Sciences (CAS)
- The Northeast Institute of Geography and Agroecology, CAS
- The Center for Agricultural Resources Research, Institute of Genetics and Developmental Biology, CAS
- Engineering Lab for salt-affected land resources use, CAS
- College of Resource and Environment, Jilin Agricultural University
- Resource & Environment Institute, Jilin Academy of Agricultural Sciences
- Jilin Academy of Forestry Sciences
- Fengheng Bio-tech Co. Ltd. Heilongjiang Province
- Huaqing Agricultural Development Co. Ltd.
- BIOGREEN AGRO Co. Ltd.