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FINAL REPORT

COMMERCIAL CROPS UNDER SALINE CONDITIONS

USING ADVANCED SAND CULTURE METHODS

Principal Investigations - Prof. Meier Schwarz
- Prof. Salomon Helfgott

September 1987-December 1990

The following reports were presented:

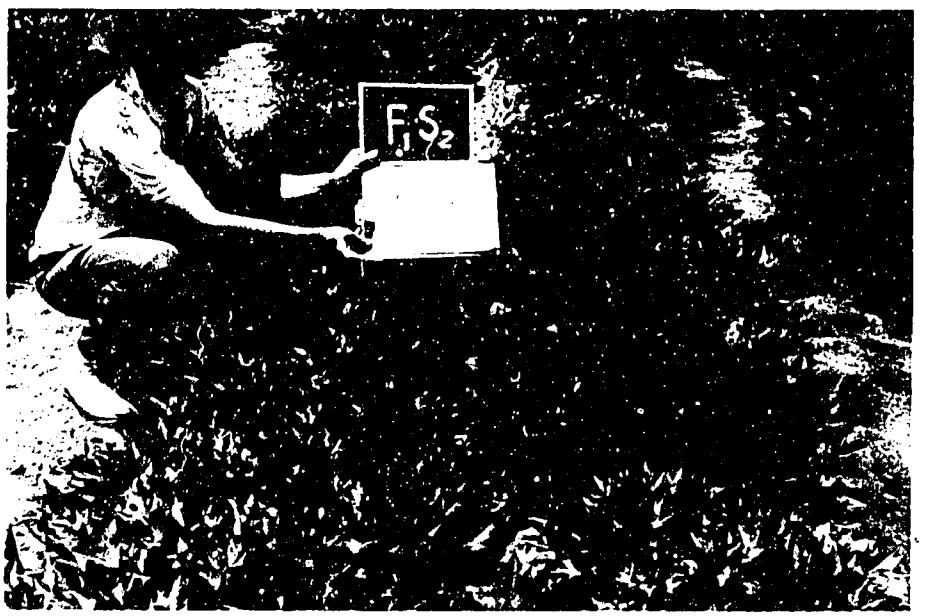
December 1986	- 2 pages
November 1987	- 9 pages
June 1988	- 6 + 3 pages
February-March 1989	- 5 + 11 pages
May-June 1989	- 3 + 12 pages
Final Report	- 10 + 32 pages

The final report includes:

- Short Summary
- Expectation (Work Plan) and Fulfillment
- Final Report - Peru
- Seasonal Report - January - December 1989
- Final Report on Lettuce
- Reprint of Past Summary-lecture held by ISOCC
- Nutrient Solution in Salinity
- Abstract of Pre-Proposal for Root:Shoot Relation in Salinity
- Root:Shoot Ratio in Salinity to Hyd. Soc. (draft)
- Reduced Root:Shoot Mass and Respiration
- Recent Publication

Rec'd in SCI APR 18 1990

Cover



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SHORT SUMMARY

The two-year research was extended to a three-year period, due to a delay in receiving and transferring funds and mainly as a result of Peru's local, political and financial conditions.

All the main aims of the research have been achieved and our work is continued in Peru, partly with local funds.

The experimental units in LaMolina University - Lima now in use for three years have been recently extended and will serve further research. This includes the equipment and research facilities supplied by AID.

The pilot plant unit in Lurine, now operating for two years, is extended as well and will serve in the future as a demonstration unit for farmers.

Two large farms are now planned (both in the northern part of Peru), where our research results will be used commercially; one a private initiative and one governmental, operated by small individual farmers.

Four local agriculture advisers have been trained to instruct farmers on how to use saline water successfully in sandy areas.

Six M.Sc. students are involved in our research program; three of them have presented their theses and the others are in advanced stages of their research. We have been able to involve more students than previously thought and this was a very prosperous achievement. One of the students has received a grant to study for a short term in Israel - a continuation of our work. Another promoted student is now active in field work, as a senior instructor.

Prof. Salomon Helfgott and his colleagues and staff (Plant Protection, Plant Breeding, Vegetable Department, Water Department, Laboratory Department) were deeply involved in the various research stages and this team was the basis for the good and prospective research achievement. Prof. Helfgott, the Peruvian team and research leader, was able to lead the creative atmosphere and most of the success of this research in such a difficult situation in Peru is to his credit.

Three local university reports in Spanish have been published. At each of my five visits to La Moline, seminars, lectures and courses were given (by M. Schwarz and S. Helfgott) to the staff members and higher-grade students.

The visit of Prof. Helfgott to Israel results in close contact with Israeli Agriculture and Research Institutes, which leads to new development ideas.

The experimental, environmental and nutritional controlled experiments in Israel have been accomplished in close connection with the Technion Institute in Haifa and recently, with the Bar Ilan University in Ramat Gan. These institutes provide all the requirements for the basic researcher. The first year's work was to determine the best nutrient solution for the Peruvian saline water and compared with local observation. The further work was concentrated in the root:shoot ratio and root aeration problems under salinity (recently continued under "field" conditions in Peru) and related problems.

The reduction of the first investment (low-cost irrigation dripper) and promotion of this subject was investigated during the last years.

This research period - provided by AID - was exciting for all the scientists involved and we thank the AID officials and the US Government for involving us in promotion of a new practice in a developing country and with the people of Peru.

EXPECTATION (WORK PLAN) AND FULFILLMENT

The main purpose (page 18 of the research proposal):

"the combining of the research knowledge recently obtained in laboratory plant growth experiments for carbon (energy) balance and ionic balance, under medium and high saline conditions, with the field experience in gravel and water culture under low salinity, while during sand culture methods and the use of sand dunes for agricultural purposes, using saline water sources.

The purpose will be to arrive at a formula for root environment (water-nutrients-air) and other agrotechnical possibilities for optimizing plant growth.

The aim of the present proposal is to undertake engineering, plant growth and part of the economic feasibility studies, in a pre-pilot plant unit. The main research study will be at the D.C. facilities, where the pre-pilot plant unit will be erected."

- has been achieved.

The experimental units - 15 X 10 m^2 = 150 m^2 unit - have been erected and are in full use for three years and will be used in the future (in the proposal, 5 X 20 m^2 = 100 m^2 units) (page 20). This includes automatic controllers, fertilizer-proportioners, irrigation pumps, etc.

Sand culture techniques - the sand from two different areas is used in 0.5 and 1.5 atm pressure and two salinity levels (1,500 and 2,500 TSS) and control (page 20).

The plants used have been mainly tomato, cabbage, lettuce and sweet potato (page 21).

Three to six daily irrigation regimes have been used, according to plants (varieties-plant growth stage-season) and a primary irrigation schedule has been prepared (page 21).

The main pilot plant unit (page 20) in Lurin of 300 m^2 was recently enlarged to 600 m^2, divided into 50 m^2 units and is now the main field observation unit.

The standard nutrient solution (mentioned in page 11) has been adjusted to local available fertilizers (reports 1 and 2).

We have not found differences while lowering the P-Phosphorus level and changing the iron levels (page 22, no. 1) but this will require a further study. Similar experiments made in Israel (Bar Ilan University) have not shown significant differences.

Lowering the calcium nitrate and iron to half the standard solution and lowering total nutrient solution to half and irrigation more frequently (nos. 2 and 3, page 22) has been tried for several crops, for four seasons (part of the M.Sc. work of our two first students in La Molina, which is included in their M.Sc. theses). The general answer is: reducing concentration and more frequent irrigation, which is

recommended in all salinity regimes. This observation has been received as well on the pilot plant unit (Lurine).

The root aeration (page 21) (controlled experiments) observation could not be accomplished in La Molina and was studied first at Bar Ilan University. A summary of this experiment is in App. and will be presented for publishing during this year.

The general observation is that controlling root aeration during some critical hours (light hours, including the first two dark hours) will be one of the limiting factors of growth control and root:shoot ratio.

The fertilizer proportional units (page 22) and the nutrient (including micronutrient) solution was used and found suitable, according to the proposal (page 22). The use of unpurified fertilizer standards allows ommission of Molybdenum and no deficiency symptoms have been observed.

Nutrient solution tests of watering and used nutrient solution has always shown a sufficient amount of Cu, Zn, Mn and B (and no toxic amount of B) (page 22).

The "best" irrigation schedule (page 23) is part of the M.Sc. theses of two students (in La Molina), according to our basic instructions (page 23) and will be summarized soon.

The general main observations - for tomatos, lettuce and sweet potatos - are that night irrigation is not required (night includes two hours before darkness).

(The full root:shoot ratio regime - root aeration influence and the related harvest index - especially for root harvest crops like potatos and carrots, is a separate research project and seems to be of great importance under saline conditions!)

The nutrient solution tests (page 23) have been developed to a standard routine in La Molina by our students. We helped to replace and renew some of the missing equipment and used also field measurement equipment, supplied through our research funds.

The field routine tests are pH, total salinity and D.O. Routine laboratory tests are $N-NO_3$ and $N-NH_4$, P, Ca + Mg and Cl (page 23).

The root:shoot ratio (page 24) and root harvest index has received special attention during the last year, while successfully growing sweet potatos and, recently, salt-tolerant potato species in saline water. The first experiments have been very successful. Good quality and good yields have been received using saline water, under reduced shoot (leaf) volume of over 40% (often, darker green leaves).

These observations are the main part of the research of two M.Sc. students (started recently) in La Molina and Lurine.

We found these directions of research (sweet potato and potato) more applied and important than the proposed winged-bean (page 24) and concentrated in this direction.

Some primary observations of beans in salinity (as practised in Peru) have not shown prospective results.

Regular water-timers and solenoid control of proportioners have been found satisfactory for timing and irrigation schedules and the program of mini-computers has been delayed (page 24). On large-scale operations (two large units are now in preparation in Peru), some worker will always be on the farm and no remote control is required. Even at our experimental and pilot plant unit, this proposed remote control requirement was not found to limit development and experiments.

We find it more important to reduce equipment and to make the units as simple as possible, not to add more sophisticated equipment, as described in "new developments".

The economic feasibility (page 26) of the use of saline water in sand was one of the important purposes of the projects. This was not only for use of local available fertilizers and equipment but also to reduce the first investment cost

We encouraged the development of low-cost, thin-walled irrigation trip-pipes, which may be used for up to three years (if properly restored) but are calculated for only two to three seasons (one to two years). The development of these pipes has been carried out at two factories in the U.S. and especially in a new process (and more accurate), as in an integrated unit in Israel (Gilead process) and a sample is included. The price per "running meter" is reduced, from 40-50 U.S. cents, for the standard pipes, to about 6-8 cents. This reduction may be the "breakthrough" to open this kind of controlled irrigation, even for poor farmers. Those pipes (the Israeli version) could be produced in Peru and, with government help, may be a push for successfully controlled farming.

All these achievements and developments have been presented and discussed with the heads of various agriculture departments and the Vice-Minister of Agriculture in Peru.

The first large unit to use these systems (including our information and experiments in applied sand culture and salinity) will be at the new development area, 300 km north of Lima, where some thousand acres of sand and sandy soil will be developed for irrigation. This project will be start ed at the end of this year. We have been requested to inroduce our systems and we have current contact with the main instructors. The full development of our research, the combination of advanced techniques with basic and applied plant growth researchers, will be demonstrated at this unit. The economic consideration (page 26) will become the final proof in this area.

Our first M.Sc. student finished his thesis last year. He has recently been responsible for development at the agriculture instruction center in the tropics in the Upper Amazonas Valley. In this area, he will try to develop our findings in a sandy area (he has no problem of salinity but problems of unbalanced nutrition). We are in permanent contact with him.

The use of our findings in the higher mountain regions has been considered several times. The yields in the green valleys of the Sierra and on the terraces are very poor, especially of the main crops: corn, potatos and beans. In several places, the light soil can be enriched successfully, according to our findings. Water supply is irregular and

water quality is variable during the season, which is one of the main limiting factors. We may overcome some of these problems. It was often discussed whether the high altitude and lower atmospheric pressure may be one - or the main - limiting factor. We have not found precise answers to this point. This is not the primary goal of our work! As we have so often asked, whether our work and findings would be used in the higher mountainous regions, we started some experiments in this direction. It is clear to us that any positive answer may have, in the future, an important influence - not only in Peru. Many areas in this upper level in Peru are not so secure (militarily) and no work (primary observation) could be established. As this problem was so often brought up and at least primary consideration was requested, we prepared some experiments under controlled conditions, in specially prepared growth chambers, at the Bar Ilan University. We got some help for these experiments from the university and the Jerusalem College of Technology.

On page 4 of the proposal for the research, it was stated that:

The hypothesis is based on the assumption that if it was possible to grow successfully certain culture plants, using high salinity, under fully controlled conditions in water culture method, similar results should be obtained in partly controlled sand culture methods, for practical use in sand dunes. This was proven.

Expected contributions of research to the D.C. countries and Israel:

Secondary contribution:

1. Increase the understanding of the physiological and nutritional basis of salt tolerance (partly fulfilled).

2. Enable selection of crops suitable for productive growth, under high saline and arid conditions (partly fulfilled).

3. Supply important parameters as tools for breeding of new salt- and aridity-tolerant cultivars (partly fulfilled).

4. Provide important information concerning management of other controllable environmental factors (partly fulfilled).

5. Evaluate the possibilities of extending crop longevity and vitality under saline conditions (partly fulfilled).

Main contribution:

6. Increase the quantity of water available for irrigation, due to the possible use of high saline water (yes).

7. Increase the area of cultivated land and especially sand dunes, due to the availability of additional water sources and greater use of arid regions (yes).

8. Provide local consumption of vegetables in some D.C. areas and provide outlooks for export (only partly).

UNIVERSIDAD NACIONAL AGRARIA LA MOLINA

TELEFONO 35-2035 - APDO. 456 - LA MOLINA LIMA PERU
FAX 51-14-368681/315747

COMMERCIAL CROPS UNDER ARID CONDITIONS WITH SALINE WATER

US-ISRAEL CDR , USAID

FINAL REPORT (Peru)

Salomon Helfgott, Ph.D. 1/

Increasing requirements for food production demands the exploitation of marginal resources for agriculture. Prominent among such resources in Peru are the use of saline irrigation water in the large sand areas surrounding important cities along the coastal region.

It has recently been demonstrated that successful growth of some crops under high saline conditions in sand or gravel is possible using applied soilless culture methods

Our main objective was to determine crop management techniques in arid coastal sand areas of Peru using saline water and ion nutrition in trickle irrigation.

The expected contributions of the Project were:

a) Increase the area of cultivated land due to the availability of additional non-potable water sources and greater use of arid zones.
b) Enable selection of crops suitable for productive growth under saline and arid conditions.
c) Increase the understanding of plant growth under special stress conditions.

Main activities

Work was conducted during approximately 24 months (end of 1987 until February 1990) at La Molina National Agrarian University (UNALM) and in an open sand area in Lurin, 40 km south of Lima. Both areas have high level sunshine, good climatic conditions and no rain.

Preliminary work and observations took place during the first six to eight months and most of the research and demonstration was done in the last 16-18 months.

a) La Molina (UNALM)

During the first three months we collected sand and water samples, planned the construction of a Pilot Unit and prepared the nutrient solutions. In the next three months, the Pilot Unit was constructed. Initially, it consisted of 12 experimental 10x1.2x0.4 m beds.

1/ Faculty of Agronomy, UNALM, Apto. 456, Lima, PERU.

During the second year, a new similar 12 bed group was constructed. Black plastic was put in the bottom of the beds before adding the sand. After installing the drip irrigation system, tomato and lettuce seedlings were transplanted for preliminary observations.

When the experimental beds were in good operation and the irrigation and nutrient solution systems were functioning adequately, research was started first with lettuce and then with tomato (three trials) and sweet potato (two trials). Work with these crops was the thesis of six graduate students. Variables that were studied included three salinity levels up to 5.0 mmhos/cm, two irrigation frequencies:twice daily (7 am and 1 pm) and three times daily (7 am, 11 am and 3 pm) and two fertilization levels.

Regular plant observations were registered and the evaluations included root:shoot ratio, harvest index and total yields. In addition, in one of the tomato and one of the sweet potato experiments, we determined net photosynthesis and transpiration rates as well as stomatal diffusive resistance, leaf temperature and photon flux density. We used a photosynthesis micro-chamber, an infrared gas analyzer (ADC, England) and a Porometer LI-1600 (Licor, USA). Measurements started one month after transplanting and were made every two weeks.

Plant growth as well as yields of the three species were satisfactory thus confirming that successful growth and crop production is possible in sand with high water salinity levels and ion nutrition in trickle irrigation.

The salary of the students as well as the printing of their thesis was paid according to our budget. We are preparing scientific papers based on part of the work and they will be submitted for publication in spanish in "Anales Cientificos", a scientific journal of the UNALM.

b) Lurin

This place was selected for the Demonstration Unit because it was a virgin sand area near Lima, water is saline (5.0 mmhos/cm) and there are many small farmers. The Unit consisted of eight 10x4 m plots in the middle of a new asparagus plantation.

Our crops included asparagus, lettuce, tomato, sweet potato and cabbage. We had two students that after doing some preliminary observations, started their ...

...thesis work in order to evaluate the response of the abovementioned crops to saline water present in the area and two irrigation frequencies (two and three times daily) with ion nutrition in trickle irrigation.

Results under these conditions have also been satisfactory and farmers are enthusiastic about the system.

Other activities

Since the Project started, Professor Meier Schwarz from Jerusalem College of Technology (JCT) was in Peru four times : November 1987, May 1988, February 1989 and January 1990. During each visit we discussed our work "on site" and decided about changes to improve the system.

Professor Schwarz gave several conferences at the University, visited farmers and had important meetings at the Ministry of Agriculture in order to explain authorities the importance of our work. They promised us, through the University, a 50 has piece of land (sand area) with saline water for demonstration purposes.

On the other hand, in accordance with the approved work plan and the objectives of the Project, I spent two weeks in Israel near the end of the first year (Oct 88). I visited with Professor Schwarz soilless culture laboratories and greenhouses, experimental facilities and commercial plantations under greenhouse or field conditions, with ion nutrition in trickle irrigation, in order to make contact with israeli researchers and farmers. The visit included Institutions such as JCT in Jerusalem, the Negev Arid Zone Research Institute in Beer-Sheva, the Experimental Station at Chavat Habsor and the Volcani Institute in Bet-Dagan and Rehovot. We also spent some time looking at commercial crops in Arav (Dead Sea Valley) and in the Western Negev.

Concluding remarks

We have been able to demonstrate that it is possible to grow and obtain reasonable good yields of various commercial crops(tomato, sweet potato,lettuce,cabbage, asparagus) under sand conditions with saline water up to 5.0 mmhos/cm with ion nutrition in trickle irrigation in the coastal area of Peru.

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A total of eight graduate students participated working for the Project doing research for their th thesis. Their salaries as well as the printing of their thesis were paid according to our budget. Several scientific papers will be published in "Anales Cientificos" (UNALM). The participation of USAID as well as JCT will be mentioned in all the thesis and scientific papers as well as in the extension leaflets that will be prepared.

People at the Ministry of Agriculture are very much interested in our work and promised us, through the University, a piece of land (sand area) for demonstration purposes.

We already spent or have allocated the final funds that were available for our Project. Peru is in a bad economic situation and the outlook for the future is not good. Thus, the continuation of our work and the maintenance of the equipment will depend on outside financial help.

Lima, February, 1990.

Salomón Helfgott, Ph.D.

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COMMERCIAL CROPS UNDER ARID CONDITIONS WITH SALINE WATER

US-ISRAEL CDR, USAID

REPORT (JAN-DEC 89)

Salomon Helfgott, Ph.D. 1/

In accordance with the approved work plan and the objectives of the Project, we continued with our research in the Pilot Unit at La Molina National Agrarian University (UNALM) and in the Demonstration Unit in Lurin, 40 km south of Lima.

La Molina

The 12 experimental beds were in good operation and the irrigation and nutrient solution systems were functioning satisfactorily. In addition, another 12 bed group was constructed and started operating in September.

At the beginning of the year, research with lettuce was completed and this was the thesis of our first MSc. student, Mr. Julio C. Rivas Plata who received an A . Part of his work has been submitted for publication in "Anales Cientificos", a scientific journal of the UNALM.

After the lettuce was harvested, we initiated work with tomato in order to evaluate the response of this crop to three water salinity levels: 1.25 (S1), 3.0 (S2) and 4.5 (S3) mmhos/cm. This was the thesis of our second MSc. student, Mr. Freddy Casas. He determined root: shoot ratio at various growth periods as well as yields when the crop was harvested in June. Yields were equivalent to approximately 22 (S3), 38 (S2) and 52 (S1) ton/ha. The first draft of the thesis is now ready and is being reviewed by his Committee.

In August, sweet potatoes were planted in the same 12 experimental sand beds. This was the thesis of our third MSc. student, Mr. Miguel A. Polo and as far as we know, this is the first time that research is conducted to evaluate the response of this crop to different water salinity levels (same as above) under sand conditions and drip irrigation. Plant growth was excellent and root:shoot ratio was determined every 15 days, starting three months after planting. Harvest will take place in mid-January 1990.

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A fourth student, Mr. Rommel Estrada, was interviewed and accepted in September. He first performed preliminary work in the new 12 bed group and in December transplanted tomato. He is now evaluating the response of this crop to three water salinity levels (1.25, 3.0 and 5.0 mmhos/cm) and two irrigation frequencies: two times daily (7 am, 1 pm) and three times daily (7 am, 11 am and 3 pm).

Lurin

The Demonstration Unit is in the middle of an asparagus plantation. We have eight 40 m^2 (10 x 4 m) plots in an open sand area and our crops included asparagus, lettuce, tomato and sweet potato. A graduate student, Mr Maximo Ramirez, did some preliminary work from July to October and obtained good results with the four crops. He is now conducting his thesis work in order to evaluate the response of the abovementioned crops to saline water (5.0 mmhos/cm) present in the area and two irrigation frequencies (two and three times daily) with ion nutrition in trickle irrigation.

Other activities

Professor Meier Schwarz from Jerusalem College of Technology spent eight days in Peru from the end of February to the beginning of March. We discussed our work "on site" and decided about changes and further objectives. We also had an important meeting with the Vice-Minister of Agriculture. He was informed about our work and also promised us, through the University, a 50 has piece of land (sand area) with saline water for demonstration purposes.

Lima, December 31, 1989.

Salomon Helfgott, Ph.D.

UNIVERSIDAD NACIONAL AGRARIA LA MOLINA

TELEFONO 35-2035 - APDO. 456 - LA MOLINA LIMA PERU

La Molina, 22 de enero de 1990
N° 154/90-SH

Señor Ing.
Santos Galarza B.
Vice-Ministro de Recursos
Naturales y Desarrollo Rural
Presente.-

De mi consideración:

Me es grato dirigirme a Ud. para agradecerle por el apoyo que nos brindó en relación a la reunión sobre riego por goteo que se efectuó en la Sala de Conferencias del Vice-Ministerio el pasado miércoles 17.

La reunión fué presidida por el Ing. Ramírez y asistieron los Directores Generales de Irrigación (Ing. Lecca) y Agua y Suelos (Ing. Cruzado) así como los Directores y/o representantes de PRONADET (Ing. Guerrero), PRONASTER (Ing. Linares), PRONAPEMI (Ing. Arias) y de la Administración y Operación de Distritos de Riego (Ing. García).

La exposición sobre el proyecto Producción de cultivos en arena utilizando riego por goteo con agua salina y fertilización incorporada" estuvo a cargo del Dr. Meier Schwarz del Jerusalem College of Technology, el Ing. Lorenzo Chang-Navarro y el suscrito. Se puso énfasis en las nuevas cintas para riego por goteo cuyo costo es equivalente a 1/10 en comparación al de las tuberías convencionales. Este hecho hará posible su mayor difusión y uso para producir alimentos y generar mayores ingresos para la población de áreas marginales o para aquellos que produzcan para exportación.

El Ing. Ramírez nos ofreció que coordinaría con nosotros a la brevedad posible para hacer realidad la transferencia de esta tecnología que no dudamos será de gran beneficio para el país.

Atentamente,

Dr. Salomón Helfgott
Coordinador Proyecto

c.c._ Decano Fac. Agronomía
Jefe Dpto. Fitotecnia
Ing. L. Chang-Navarro
Archivo

DRAFT

Anales Científicos U.N.A.
Univ. Nat. Agr. La Molina, Peru

Sept. 89.

EFECTO DE LA SALINIDAD Y FERTILIZACION EN EL RENDIMIENTO DE LECHUGA (*lactuca sativa*) CULTIVADA EN POZAS DE ARENA Y UTILIZANDO RIEGO POR GOTEO

S. Helfgott,[1] L. Chang-Navarro,[1] A. Casas,[1] M. Schwarz,[2] J. Valcarcar[3]

INTRODUCCION

A lo largo de la árida costa peruana se encuentran grandes extensiones dd suelo de arena que no son aprovechadas para la agricultura y son difíciles de cultivar y regar por los métodos convencionales por el peligro de erosión, por la baja eficiencia de aplicación del agua de riego y por la baja disponibilidad de agua no salina que se requiere normalmente y que se presenta en la época de estiaje.

En varios países del mundo se aprovecha los suelos de arena empleando el riego por goteo y aún agua salina para regar los cultivos que se realizan en estos arenales, aunque todavía en pequeña escala. Estas prácticas se basan en trabajos de investigadores como Shalhevet (1968), quien reportó que la tolerancia de las plantas a las sales que se presentan al usar agua salina depende de una serie de factores tales como la variedad, el grado de desarrollo, la adición de aquellos nutrientes que no se encuentran en dicha agua y la frecuencia de los riegos. También indicó que las cosechas de lechuga y pepino se redujeron de 10 a 15% y, de 20 a 25%, respectivamente, cuando éstos se desarrollaban en agua que contenía 3000 ppm de sales. Asimismo, mencionó que las plantas cultivadas en soluciones tienen aparentemente una mayor tolerancia para niveles de zinc y cobre que normalmente podrían considerarse tóxicos. Finalmente, señaló que las presiones osmóticas extremadamente altas (mayores de 10 atmósferas) de soluciones nutritivas, durante largos periodos de tiempo con presiones osmóticas moderadamente altas (4-5 atmósferas).

Resh (1987) mencionó que para cultivos hortícolas dos riegos por día son suficientes en verano cuando se usa soluciones nutritivas y arena fina como medio de cultivo. Sin embargo, Schwarz (1987) encontró que regando tres veces por día se obtenían las mejores cosechas en Israel,

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1. Profesores Principales y Asociado, UNALM, Lima, Perú
2. Jerusalem College of Technology, Jerusalem, Israel
3. Ingeniero Agrícola

cuando se usaba arena como medio de cultivo. Los riegos deben darse una hora después de la salida del sol, a las 10 a.m. y las 3 p.m.

No hemos encontrado referencias sobre investigaciones para encontrar los criterios de manejo de suelos de arena utilizando agua salina en el Perú. En lechuga se riega por gravedad y los rendimientos promedios llegan a 50 ton/ha de materia fresca comercial (Delgado et al, 198) aunque Fernández (1977) obtuvo 72 ton/ha de lechuga en suelos de textura franco arenoso.

El presente trabajo tuvo por objerivo principal evaluar el efecto de tres niveles de salinidad del agua de riego en combinación con dos niveles de fertilización líquida aplicados con riego por goteo en lechuga cultivada en pozas de arena.

MATERIALES Y METODOS

La investigación se llevó a cabo en un campo del Programa de Hortalizas de la Universidad Nacional Agraria La Molina, ubicada en el distrito de La Molina, provincia de Lima y Departamento de Lima. Geográficamente, el lugar se encuentra a 12°05' latitud sur y a 76°57' longitud oeste y a una altitud de 238 m.s.n.m. El clima corresponde a desierto subtropical árido caluroso y durante la ejecución del experimento no llovío. Los datos climáticos de los meses (octubre a diciembre 1988) en que se realizó el experimento fueron los siguientes:

Mes	Horas de sol	Temperaturas (°C)			Humedad Relat. (%)			Evap. Tanque A
		Max.	Min.	Promedio	Max.	Min.	Prom.	mm/día
Oct.	6.00	20.60	13.50	16.20	96	66	86	2.90
Nov.	6.53	22.70	11.60	18.00	98	61	84	4.41
Dic.	5.47	24.60	16.80	20.30	98	61	83	4.47

Los tres niveles de salinidad del agua de riego proveniente de pozo que se estudiaron fueron los siguientes:

	Clave
- Salinidad del agua de pozo presentando 1.23 mmhos/cm a 25°C	SI
- Salinidad del agua de pozo con adición de 1,2oo ppm de ClNa presentando 3.30 mmhos/cm a 25°C	S2
- Salinidad del agua de pozo con adición de 1,800 ppm de ClNa presentando 4.30 mmhos/cm a 25°C	S3

Los dos niveles de fertilización que se estuaron fueron los siguientes:

- Solución Schwarz (ver Cuadro 1) F1
- Doble concentración de la solución Schwarz en lo que respecta a macronutrientes pero normal en micronutrientes F2

Cuadro 1. Fórmula de Fertilización de Schwarz

		g/1000 l
Sulfato de Potasio	(52% K_2O)	600
Nitrato de amonio	(33% N)	700
Fosfato di amónico	(18% N, 45% P_2O_5)	350
Sulfato magnésico		200
Sulfato cálcico		10
Sulfato de fierro		2
Acido bórico		1
Sulfato de manganeso		0.5
Sulfato de cobre		0.1
Sulfato de zinc		0.1

Nota: A esta solución se le agregó 0.1 g de quelato de fierro (Fe-EDTA) cuando las plantas estuvieron grandes.

La fertilización y el riego se realizaron en forma conjunta de modo que las combinaciones de los niveles de los dos tratamientos mencionados resultaron en ocho combinaciones de tratamientos cuyas soluciones tienen las características mostradas en el Cuadro 2.

Cuadro 2. Salinidad y pH de las combinaciones de tratamientos

Tratamientos	Salinidad del agua (mhos/cm a 25° C)					pH
	pozo	pozo+ClNa		pozo + ClNa + fertilizantes		
Clave			incr(%)		incr(%)	
F1S1	1.23	1.23	0	3.38	0	7.36
F1S2	1.23	3.3	168	5.22	54	7.33
F1S3	1.23	4.3	249	6.50	92	7.30

F2S1	1.23	1.23	0	5.18*	53	7.27
F2S2	1.23	3.3	168	7.10	110	7.26
F2S3	1.23	4.3	249	8.00	136	7.24

* Sin adición de ClNa

Las características químicas del agua de pozo para el riego figuran en el Cuadro 3.

Cuadro 3. Características químicas del agua de pozo

pH	7.10
C.E. (milimhos/cm a 25°C)	1.23
Ca^{++} (m.e./L)	10.40
Mg^{++} (m.e./L)	0.36
Na^{+} (m.e./L)	1.60
K^{+} (m.e./L)	0.10
Suma de cationes (m.e./L)	12.46
CO_3^{--}	0.00
SO_4^{--}	2.26
Suma de aniones (m.e./L)	12.36
Boro (ppm)	0.00
Relación de Adsorción de Sodio	0.68
Clasificación	C 3 S1*

* Agua altamente salina y bajo peligro de sodio

Se empleó el diseño estadístico de bloques completamente al azar en disposición factorial de 3 x 2 con dos repeticiones. Las unidades experimentales consistieron de 12 pozas de 10m de largo y 1.20 m de ancho, 10 de las cuales fueron de piso de tierra y paredes de ladrillo revestido con una capa de arena cemento y dos pozas fueron excavadas en tierra. La altura de las pozas varió de 30 a 45 cm. Al piso de cada poza se le dió una pendiente longitudinal de 1% y en el extremo más bajo se instaló un tubo de desagüe de PVC de 2" de diámetro y 20 cm de longitud.

Las pozas fueron cubiertas por láminas de polietileno negro de 20 milésimas de pulgadas de espesor para aislarlas del suelo. En medio y a lo largo de cada poza y encima del plástico se instaló un sistema de drenaje hecho con tejas superpuestas y conectada al tubo de desagüe de la poza (Fig.1). Finalmente, se llenaron las pozas con una capa de arena de 30 cm de altura. Colindando con las pozas y para el lado de los desagües de las pozas se hizo un pequeño canal para recibir los escurrimientos que salían por los tubos de desagüe. Se hizo un lavado de sales de la arena, la cual finalmente presentó una conductividad eléctrica de 3mmhos/cm a 25°C. La arena presentó un 98%de arena propiamente dicho y 2% de limo y su capacidad de retención de agua fué de 13%. La densidad seca del suelo fue 1.4 g/cm^3. El sistema hidráulico para el riego consistía de una cisterna para almacenar el agua de pozo, una bomba de agua para impulsar el agua, un filtro de agua, un sistema de inyección de la solución fertilizante y de ClNa al agua de pozo y un regulador de presión del agua. El sistema de tubería de conducción consistió de:

a) Una tubería principal enterrada de PVC de 1" de diámetro;
b) Una tubería secundaria de polietileno negro de 16 mm de diámetro conectada a un elevador de tubería principal mediante una válvula de compuerta que permite independizar el riego de las pozas que pertenecen a un determinado tratamiento;
c) Una tubería terciaria también de polietileno negro de 16 mm de diámetro conectada a la secundaria por una conexión en T.
d) Por las tuberías laterales también de polietileno de 16 mm de diámetro que llevan los goteros de riego incorporados y autoregulados de jpred delgada que dejan salir el líquido de 1.2 a 3.5Lph a una presión de trabajo de 0.8-4.2 atmósfera de presión. En cada poza hubieron 3 líneas laterales distanciadas 40 cm entre ellas.

La variedad de lechuga empleada fue la americana Great Lakes 659. Las plántulas provenientes de un almácigo se trasplantaron a los 31 días en las pozas de arena, en hileras distanciada 40 cm entre ellas. El distanciamiento entre plantas fue de 30 cm alcanzándose una densidad equivalente a 84,183 plantas por hectárea.

Durante 14 días las plantas de todas las pozas recibieron el mismo tratamiento de riego y fertilización: los siete primeros días se regaron sólo con agua de pozo y los siguientes siete días se regaron con la solución correspondiente al tratamiento F1S1. A partir de la tercera semana se implementaron los diversos tratamientos. Los riegos se dieron diariamente, de 1 a 4 veces por día.

Los goteros funcionaron emitiendo un caudal de 2.7 Lph y para una presión de trabajo de 19.5 m de columna de agua. El número de goteros por poza fue de 80. El tiempo de riego era aquel que demoraba en salir las primeras gotas de agua por el desagüe de las pozas. El rango de aplicación de agua fluctuó entre 1.6 y 6.7 mm/riego. Para dos pozas (un tratamiento con sus dos repeticiones) se aplicaba un caudal de 5.52 L/min.

Los riegos se dieron hasta 7 días antes de la última cosecha para evitar la pudrición de las plantas. En total, cada poza recibió riego equivalente a unos 188 mm, es decir, casi 4 mm por día.

Para el análisis se consideraron el rendimiento total de lechuga al estado fresco y como materia seca, rendimiento de lechuga comercial al estado fresco, la productividad media del agua o sea la eficiencia del uso del agua por las plantas en relación al peso fresco de las lechugas y considerando el rendimiento total. Se hicieron también observaciones sobre el color y apariencia de las hojas.

RESULTADOS Y DISCUSION

En el Cuadro 4 se presentan datos sobre la influencia de los tratamientos de salinidad y fertilización sobre el rendimiento total de lechuga fresca. Observamos que para ambos niveles de fertilización, el rendimiento disminuyó con el aumento de la salinidad, pero el porcentaje de reducción del rendimiento fué menor en F1 que en F2. Asimismo, para un mismo nivel de salinidad del agua de riego, el doblar la fertilización no significó incremento de rendimietto sino una reducción debido a que se aumentó la salinidad. A nivel de S1, F2 mostró una reducción cercana a 22% con respecto a F1, pero a nivel de S2 y S3 las reducciones fueron mucho mas notorias. Es decir, el aumento de la fertilización no compensó el efecto depresivo de la salinidad sino por el contrario lo agravó.

CUADRO 4. Influencia de los tratamientos de salinidad y fertilización sobre el rendimiento total de lechuga fresca.

Salinidad del agua	Fertilización	F1		F2	
		t/ha	% reducción	t/ha	% reducción
	S1	69.8	0	54.7	0
	S2	59.8	14	16.6	70
	S3	54.7	22	16.0	71

En el Cuadro 5 se observa que el efecto de los tratamientos sobre el rendimiento de lechuga fresca comercial sigue la misma tendencia anterior pero con la diferencia de que a nivel F2 no se obtuvo lechuga comercial con S2 y S3. Las hojas con S2 F2 y S3 F2 mostraron síntomas típicos de quemaduras debido a la salinidad.

CUADRO 5. Influencia de los tratamientos de salinidad y fertilización sobre el rendimiento de lechuga fresca comercial.

Salinidad del Agua \ Fertilización	F1		F2	
	t/ha	% reducción	t/ha	% reducción
S1	69.7	0	51.9	0
S2	55.9	20	0.0	100
S3	51.9	26	0.0	100

La misma tendencia se observó en cuanto al rendimiento de materia seca (Cuadro 6) y la productividad del agua o sea la cantidad (toneladas) de lechuga fresca producida por m^3 de agua (solución nutritiva) empleada (Cuadro 7).

CUADRO 6. Influencia de los tratamientos de salinidad y fertilización sobre el rendimiento de materia seca de lechuga.

Salinidad del Agua \ Fertilización	F1		F2	
	t/ha	% reducción	t/ha	% reducción
S1	3.84	0	2.95	0
S2	3.00	22	0.68	77
S3	2.20	43	0.62	79

CUADRO 7. Influencia de los tratamientos de salinidad y fertilización sobre la productividad media del agua

Salinidad del Agua	Fertilización	F1		F2	
		t/ha	% reducción	t/ha	% reducción
	S1	0.037	0	0.029	0
	S2	0.030	19	0.009	69
	S3	0.029	22	0.008	72

Nutrient solution in salinity

The ion contents in the saline water sources used in our experiments (report II and III) are different than those in Israel. These differences have not been too extreme, and the general formula (page 11 on research proposal) was--on most occasions--the basic formula. During the first year we prepared, in Israel, saline water matching Peruvian salinity and compared continuously the growth and development (tomato seedlings and lettuce) with common Israeli salinity (approx. 2600 ppm) (Schwarz 1968). No significant differences were found.

A few primary trials in Peru concentrated on the same problem, trying 3 and 5 mM - P, raising the Fe level to double the amount, and revising total microelements to double the amount. All these experiments are summarized in the Peruvian publication, and no significant changes have been observed. The pH level was always reduced to be below 6.5-7.

The general summary in "The Use of Saline Water in Hydroponics" (Schwarz-1985), App. 5, was found suitable in all our work.

A study was conducted in the National Agrarian University (Peru) to investigate lettuce growth in sand using saline water and drip irrigation. Lettuce plants (var. were transplanted in sand culture units (12 x 1.1 m) at the beginning of spring 1988. Three salinity levels, 1.23 (S_1), 3.3 (S_2) and 4.3 (S_3) mmhos/cm at 25°C and two fertilization levels, Schwarz formula (F_1) and double strength of the same formula only in macronutrients (F_2), were tested as a 3x2 factorial. With the addition of nutrients, final water salinity was 3.38, 5.18, 5.22, 6.5, 7.1 and 8.0 mmhos/cm at 25°C for F_1S_1, F_2S_1, F_1S_2, F_1S_3, F_2S_2 and F_2S_3, respectively. The sand units were irrigated four times ~~per day~~ daily during the first two weeks and then only once daily. Each irrigation lasted not more than 27 minutes.

Highly significant differences were found between treatments. Fresh yields were 69.8, 54.7, 58.9, 54.7, 16.6 and 16.0 ton/ha for F_1S_1, F_2S_1, F_1S_2, F_1S_3, F_2S_2 and F_2S_3, respectively. An increase in macronutrient concentration did not compensate the depressive effect of salinity. On the contrary, yield reduction was greater.

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OXYGENATING OF NUTRIENT SOLUTION IN NORMAL AND STRESS CONDITIONS

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SUMMARY

Energie supply by respiration for root functioning is related to maintenance and growth storage and translocation activities.
Maintenance respiration may require up to 30 % of the available oxygen under stress conditions. During high root activity hours, oxygen demand is up to 10 times higher than at low activity hours.
Part of the oxygen may be translocated from shoot to root part.
Night aeration or continuous air saturating of the nutrient solution, stimulates - often uneccessarily - root formation, and requires plant material and increasing yield. Extremely high aeration stimulates large root volume production. Controlled aeration may reduce the shoot:root ratio which will be a benefit in soilless culture conditions.

INTRODUCTION

Oxygen concentration in root environment, in saline condition and sewage is often very low (below 0.5 mg/l), a situation also existing in tramped soil, and flood conditions.
In recent work (Schwarz, M. & Gale, J. 1981) the reduction in growth under low salinity could be related to the increase of

maintenance respiration. The energy cost of maintenance is greater under salt stress conditions as a result of requirements for compartmentation, secretion and for repair of cellular damage. More plant assimilate resources are required for maintenance with less being left for growth, which is thus reduced.
In saline conditions, this higher respiration (carbon) requirement necessitates high oxygen supplementation, especially to the roots, and oxygen could be the limiting growth factor.
Oxygenating of the nutrient solution during the critical hours may overcome this limitation.

BASIC ASSUMPTION

The synthesis of plant dry matter from glucose and mineral nutrients requires the input of energy. The energy is supplied by the respiration process, the growth respiration. In shoot parts, a portion of the required oxygen could be supplied from oxygen released from the photosynthetic process. In root parts almost all the required oxygen would come from air. The growing tissues of the root and the root tips would require the majority of the root oxygen requirements.
The non-growing tissue additionally requires respiratory energy, the maintenance energy or maintenace respiration. The growing tissues require maintenance respiration during non-growth periods, and even parts of the measured growth respiration will be required for maintenance of the growth tissues. It is assumed that the same amount of maintenance respiration is required during photosynthetic active hours as during non-active hours (Szaniawski 1981).
Maintenance respiration will include energy requirements for compartmentation, secretion, repair of cellular damage,etc.
The amount of maintenance respiration requirements measured per dry matter of living plant tissue could be different in plant species, as some researchers found a higher respiration rate in

shoot parts than in root parts, others found higher rates in root parts, and some found equal amounts (Lambers et al. 1983). Different methods of measuring maintenance respiration could explain some of these differences. Maintenance repiration will be higher in young and active tissues than in other tissues. The energy cost of biochemical reactions and the conservation of energy in the respiratory pathway - the conversion efficiencies - (ADP: O ratio) of roots and shoots differ considerably (Lambers et al. 1983).
The third important requirement for the ion and water uptake - the ion uptake respiration, was measured first by Veen (1980).
A fourth component of respiration-energy requirements will include the translocation energy requirements including the phloem activities, which will be be relatively high during those active photosynthetic hours.
Where does all the root oxygen required for those respiration processes come from, and is oxygen availability a main limiting factor?
If the amount of available energy for all the required processes is not sufficient, which respiratory process will be preferred? Is this a simple automatic process, "first-come first-served", or is the plant able to calculate and control the energy balance and first supply maintenance requirements, using only surplus energy for other activities?

ROOT FORMATION IN SOIL AND SOILLESS CONDITION

A plant supplied with all the nutritional and environmental requirements will have the same growth development patterns and yield in soil and soilless conditions. The main known difference between soil and soilless culture developed plants is, that in soilless conditions no root hairs develop. This phenomenon is found especially in water-culture methods, as well as in all sand and gravel culture (inert media culture) methods. No sound expla-

nation was given for this basic difference. Who "told" the plant that it is growing in soilless conditions? Apparently, plants grown in soil grow just as well in soilless conditions as the water film around the roots supplies the required water, nutrients and oxygen.
The requirements of the enormous combined-length of the root hairs for plant growth mentioned in text books (which may reach thousands of kilometers for a single plant) is not required in soilless conditions. Why? This greatly reduces the amount of root material required for plant growth, and a normal ratio of 1:2 or 1:3 in shoot /root soil condition, can in good soilless condition be reduced to 1:10.

MAINTENANCE RESPIRATION IN ROOTS UNDER TEMPERATURE AND SALINE STRESS CONDITIONS

Root functioning, apparent bottle-neck in plant production in most situations, is controlled by the interplay between shoot and root and respiration rates are influenced accordingly. Reduction of root functioning, as a result of oxygen deficiency, probably connected to energy deficiency, was observed expecially in saline conditions. The energy cost of maintenance respiration in salinity-stress was calculated for Xanthium Strumarium (-5 x 10^5 Pa NaCl salinity) to be 30 % of the decreased growth (Table 1). It has been suggested that the salt-induced increase of respiration during the day is a result of the plant being unable to use assimilates for growth. It was found that CO_2 fertilization stimulates growth more in salized than in control plants. This supports the hypothesis that at low salinity the plants suffer from a shortage of assimilates due to reduction of photosynthesis and an increase of maintenance respiration.
The carbon fixation efficiency (carbon remaining in plant after 24 hours = carbon fixed-maintenance respiration) was found to be about 0.75 for all plants and is not affected by salt.

Table 1 Daily root requirements for oxygen (i.e. µmol) in salinized and controlled plants (for 5 g fresh weight roots) (Schwarz & Gale 1983)

	Salinity in mmol NaCl	Salinized plants day 14 h	Salinized plants night 10 h	Control plants day 14 h	Control plants night 10 h
Xanthium strumarium	130	191	65	176	50
Phaseolus vulgaris	140	202	98	180	75
Atriplex halimus	170	127	55	117	45

Morphological disorders under low saline conditions, e.g. reduction of leaf thickness, leaf area and internode distances, are expected to be amongst the reasons for reduced growth. Recent research indicates clearly that these disorders are also a result of reduced available energy in salinized plants for plant structure, and not a result of salinity per se, as most of these disorders could be alleviated by increasing the CO_2 level.
Maintenance respiration increases with rising temperature (Schwarz & Gale, 1983). An increase from 16 - 28 °C in Xanthium strumarium increases the maintenance respiration requirements by 100 % (from 200 to 400 µmol CO_2/gdw/day) under control conditions and in low saline stress conditions by 65 % above the saline stress maintenance respiration requirements.
In saline conditions, when the photosynthetic activity is already reduced, and the salt maintenance respiration is high, the temperature stress maintenance respiration will put an extra burden on the carbon balance in the plant.

THE DAILY ROOT RESPIRATION COURSE

A "typical" daily respiration course of a tomato plant is seen in

Fig. 1. After light was turned on, root respiration rose. Photosynthesis reached maximum rates after approximately 90 minutes. The beginning of maximal rate of root respiration is delayed about 130 minutes. The same delay of a 130 minute period, is the decline in root respiration after the light was turned off.
Salinized plants require more energy for their maintenance respiration in shoots and roots, and their overall carbon balance is affected (Schwarz & Gale 1981). The relationship between photosynthesis under saline condition and the root respiration is shown (lines marked x-x-x and 0-0-0). Salinity delays the beginning of maximum photosynthesis, and accordingly root respiration was delayed.

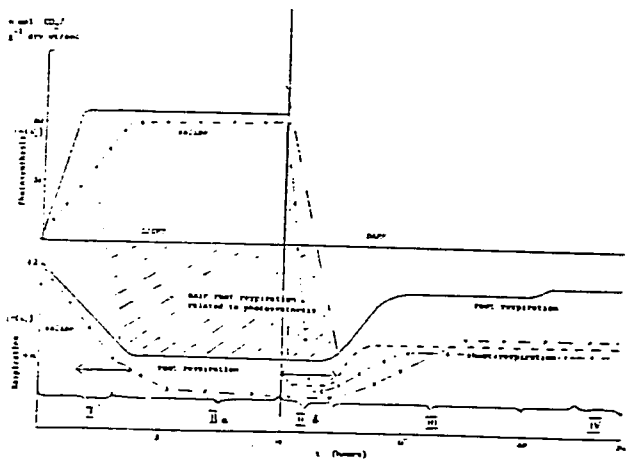

Fig. 1 Daily course of uptake and efflux of CO_2 in normal and salinized tomato plants

x-x = salinized root respiration

0-0 = salinized shoot respiration

—— = normal root respiration

--- = normal shoot respiration

The following periods may be observed in root respiration:

Day, period I
Gradually increasing; shortly (minutes) after starting photosynthesis until (minutes to hours) maximum photosynthesis.

Day/Night, period IIa
Constantly high, equivalent to maximum photosynthesis.
Continuing IIb at night (related also to accumulation and storage of photosynthesate).

Night, period III
Gradually steep decreasing, and continuing several hours (related to reduced accumulation and storage of photosynthesate).

Night, period IV
Contant rate.

With increasing salinity the increase in maintenance respiration requirements (Schwarz and Gale 1981) will leave less free energy for the root, and full root respiration rate will be obtained later. Root respiration in dark was always found to be higher than in shoot.
Root respiration of beans was found similar to tomato. In maize maximal root respiration occurred approximately half an hour after beginning of photosynthesis and this rate remained constant. This rate was reduced shortly after the dark period began. The knowledge of the daily course of the energy used, the respiration rate of the roots in regular and saline conditions, may help to understand the root requirements and open a possibility to control and/or supply adequate O_2 for this respiration rate.
The deficiency of oxygen, or the excess of CO_2 in roots will greatly reduce root activity, especially in saline conditions (Brouwer, 1979). Metabolic activities of roots are unaffected by lowering O_2 concentration, until it is very low (Greenwood 1969). The knowledge of these low rates, in regular and saline conditions, may help to supply only the required oxygen amount and saving of energy in recycling nutrient solution as in water culture method, or in drip irrigation conditions, and to add amount of air or oxygen only, when requested by the roots.

It is generally accepted that root growth occurs mainly in "night time", when the roots are free from other - more primary - "obligations", as intake and uptake of ions, translocation and storage of phyotosynthesate. The energy requirements for those more primary functions may not leave enough free energy for growth processes during day time. It is a general rule in life science that an organism uses its energy and sources first for maintenance and then for other productive plant requirements.

According to Fig. 1, day time root respiration will continue into night - depending on plant species - 60-120 minutes. It seems that root aeration will not be required during the subsequent night hours. Root aeration will increase during these hours causing some unnecessary root formation.

In some plants, part of the oxygen requirements of the roots could be supplied through the leaves and stem (Greenwood 1969). Since saline conditions require relatively large quantities of oxygen for root functioning, it was suggested that among the features of low salt-resistant plants will be the ability to transfer oxygen from shoot to root. Primary observations support this idea.

In Table 1 the amount of oxygen requirement, day and night in three salt resistant plants are presented.

During night hours (night hours starting 120 minutes after dark) all the oxygen was removed from the nutrient solution by bubbling nitrogen. No difference in growth was observed. This controlled root aeration will be examined in further experiments.

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PROPOSAL

Life Sciences Department
Bar Ilan University, Ramat Gan

and

Title: Effects of and control of root:shoot ratio toward harvest index ratio under saline conditions

(Israel) Principal Investigator: Prof. Meier SCHWARZ
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Objectives

1. To determine and control the root:shoot ratio toward increasing harvest index ratio under saline conditions.

2. To determine the plant carbon (energy) balance as the maintenance respiration of roots and shoots under saline conditions and their daily course.

3. To evaluate the phytohormone balance under these conditions.

4. To evaluate these findings for economic purposes, especially for root harvest plants such as potato, sweet potato and tomato.

Summary of the Research Concepts

Exploitation of marginal water resources for agriculture is one of the main requirements for increasing food production in many countries. Important resources are saline and brackish water in warm semi-arid and arid areas.

In recent work (Schwarz and Gale, 1981) the reduction in growth under salinity could be related to the increase of maintenance respiration. The energy cost of maintenance increases under salt stress conditions as a result of requirements for compartmentation, secretion and for repair of cellular damage. More plant assimilate resources are required for maintenance, leaving less for growth, which is thus reduced. The energy cost of maintenance respiration in salinity was calculated to be responsible for 30% of the decreased growth in some C4 salt resistant plant species. The carbon fixation efficiency (carbon remaining in plant after 24 hours) is 0.75, and was not affected by salt.

Root functioning, often an apparent bottleneck in plant production, is controlled by the interplay between shoot and root. Respiration rates are influenced accordingly. Reduction of root functioning, as a result of oxygen deficiency, was observed especially in saline conditions (Armstrong, 1981).

The root/shoot ratio is influenced by nutrition as observed in soilless culture conditions. High yields could be obtained in tomatoes on a 1:5 root:shoot ratio as compared to the regular 1:3 ratio.

The root/shoot ratio is affected especially in salinity, on the oxygen level available to the roots. There are strong indications that oversupply of oxygen to the roots--especially at night time, will produce high root volume which will be a ballast (increase?) on plant-yield productivity. A too low oxygen level, especially during photosynthetic active hours will have well known deleterious effects.

The root oxygen level and the day-night fluctuation control the carbon balance and the root to shoot ratio.

Optimal oxygen supply and distribution for respiration processes in roots and shoots and the ratio between them are of primary importance for economical crop production in salinity. Better knowledge of these basic processes will lead to understanding of the mechanism of plant tolerance to salinity and its economics.

Root development also depends on media and environment: for example, many hydroponically-grown plants have no rootlets, and shoot-to-root ratio varies to extremes in the same plant under different growth conditions. These basic differences may influence yield. The waste of energy for producing unnecessary plant tissues and organs and the extra energy required for maintenance respiration of this "unimportant" plant material, may be of high economic value.

Controlling root:shoot ratio will be important, especially when growing root-harvest plants such as potato and sweet potato using saline water.

Indications of the effects mentioned have been observed under controlled conditions at Bar-Ilan University and Phyto-tron, Duke University (North Carolina), and under pilot plant conditions at La Molina University, Lima, Peru.

This research will open the possibility of using more efficient saline water sources, to be found in arid areas, especially using sand and sandy soil.

Methods

The basic research program will be conducted in Israel at the Life Sciences Department of Bar-Ilan University and the Jerusalem College of Techology, Jerusalem.

The Phyto-tron Engineering facilities and controlled-environment units (growth cuvettes and chambers) available in both laboratories will be used.

The study, to be conducted under pilot plant (200 m^2) conditions will employ sand culture methods and saline water (2500, 5000 ppm).

Duration: 3 years Starting Date: January 1991

Estimated Budget:

Personnel	$125,000
Supplies, equipment	25,000
Pilot plant	40,000
Travel	18,000
Overhead	32,000
Total	$240,000

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Draft to be presented at
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May, 1990, Vancouver

ROOT SHOOT-RATIO AND PLANT GROWTH UNDER SALINE CONDITIONS

The basis for successful growth under high saline conditions is a good aerated growth medium such as sand, and supplying the media with a fertilizer nutrient solution.

Accurate control of water-ions-air (oxygen) in the plant's root volume is critical, due to the low capacity of sand to retain these components. In deep sand areas the excess solution will drain to the lower levels, and each irrigation replaces the nutrient-water content in the root-holding sand-medium level.

Scientific background of the special problem

In recent work (Schwarz, M. and Gale, J. 1981. Carbon balance of plants growing under saline conditions), the reduction in growth under low salinity could be related to the increase of maintenance respiration. The energy cost of maintenance is greater under salt stress conditions as a result of requirement for compartmentation, secretion and for repair of cellular damage. More plant assimilate resources are required for maintenance with less being left for growth, which is thus reduced. The energy cost of maintenance respiration in salinity was calculated to be 30% of the decreased growth in some C4 salt resistant plant species.

The photosynthetic mechanism, per se, was not affected by salinity. The carbon fixation efficiency (carbon remaining in plant after 24 hours) is 0.75, and was not affected by salt. CO_2 supplementation increased plant tolerance of salinity levels, and morphological changes under salinity were counteracted by high ambient CO_2. The root-to-shoot ratio was raised.

In saline conditions, this higher respiration (carbon) requirement necessitates high oxygen supplementation, especially to the roots, and oxygen could be the limiting growth factor.

Root functioning, an apparent bottleneck in plant production, in most situations, is controlled by the interplay between shoot and root, and respiration rates are influenced accordingly. Reduction of root functioning, as a result of oxygen deficiency was observed especially in saline conditions.

The waste of energy for producing unnecessary plant tissues and organs and the extra energy required for maintenance respiration of this "unimportant" plant material, may be of high economic value.

The root/shoot ratio is influenced partly by nutrition as observed in soilless culture conditions. High yields could be obtained in tomatoes on a 1:9 root:shoot ratio as compared to a regular 1:3 ratio.

The root/shoot ratio is affected especially in salinity on the oxygen level available to the roots. There are strong indications that oversupply of oxygen to the roots--especially at night time--will produce high root volume which will be a ballast to plant-yield productivity. A too low oxygen level, especially during photosynthetic active hours, will have well known deleterious effects.

The root oxygen level and the day-night fluctuation control the carbon balance and the root to shoot ratio.

Optimal oxygen supply ard distribution for respiration processes in roots and the ratio between them are of primary importance for economic crops in salinity.

It should be mentioned that the highly active hours of the root respiration continue in many C4 culture plants 60-90 minutes after darkness and start at a similar timespan after reaching morning maximum photosynthetic activity. These are the critical hours of controlling oxygen level in roots for root:shoot influences and carbon balance.

The problem investigated was

a) on field conditions and pilot plant facilities in Peru;
b) on controlled environmental conditions in Israel--Bar Ilan University

Objectives:

a. To study the root/shoot ratio and energy (carbon) balance in plants growing in saline conditions.

b. To control root/shoot ratio for improving harvest index in saline conditions.

c. To demonstrate the practice of growing semi-salt tolerant culture plants in the near inert sand of the arid coastal area of Peru, while using the only available saline water sources.

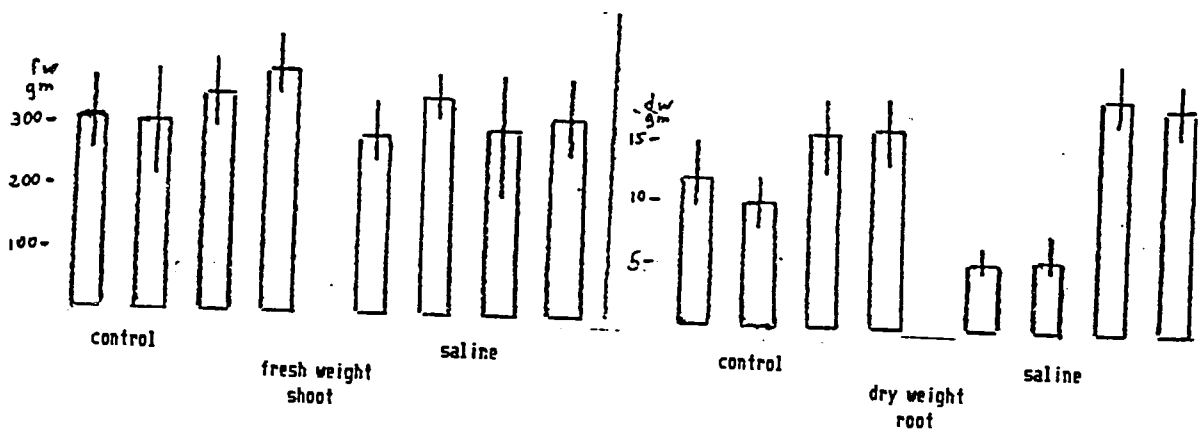
The beginning experiments include:

1. Optimal oxygenating day and night.
2. Optimal oxygenating only at day.
3. Optimal oxygenating only from 60-90 minutes after daylight until 60-90 minutes after darkness.
4. Control, no oxygenating.

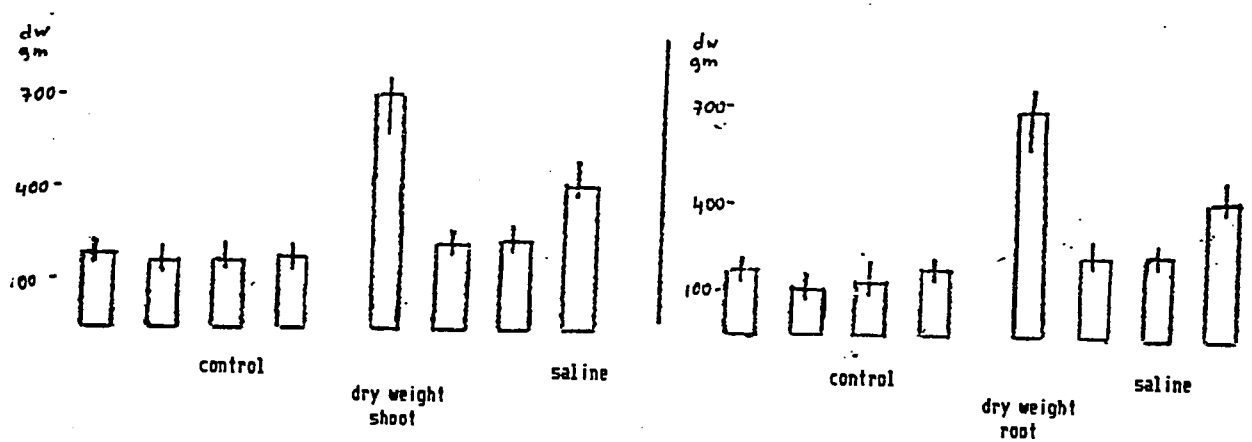
The above in saline level of 3000 TDS and control.

Plants used are local varieties of tomato (var. Faculty 38), lettuce (var. x22), and cabbage (var. Tasty). Plant tests include the regular plant observations, root:shoot ratio and yield consideration.

Shoot (fw) and root (dw) of tomato (var. Fac. 38) plants in saline and control conditions with additional root aeration at night (N), day (D), continually (F), and no additional aeration (C).



Shoot (dw) and root (dw) of lettuce (var. 163) plants in saline and control conditions, with additional root aeration at night (N), day (D), continuously (F) and no additional aeration (C).



Short Discussion:

Under saline conditions in tomato plants increased root and shoot volumes are observed under continuous aeration; when no additional aeration occurs, or in circumstances of interrupted aeration--day or night--there is reduced root and shoot mass. This lower root and shoot volume will reduce the carbon (energy) loss by respiration. To determine if this reduced plant mass production will affect plant yield--fruits--will require further investigation.

In lettuce plants, under saline conditions, an increase in root and shoot mass was determined when there was night time aeration. This increases the yield--the lettuce head--as well.

Day and/or night root respiration certainly plays an important role in plant development under saline conditions, as demonstrated in this experiment. Reduced or additional root aeration may be the key for economic crops in salinity, and the best aeration schedule will differ according to whether the root, the shoot or the fruit alone is the product whose yield needs to be increased. This root:shoot balance under salinity requires further and primary investigation, including plant hormone balance.

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ROOT AND SHOOT RESPIRATION WITH HALF ROOTS AND SHOOTS UNDER SALINE CONDITIONS

Meier Schwarz

The root:shoot ratio and their carbon balance influences have received minor interest in recent years, compared to the literature 20 years ago. Some of the older "findings" should be reviewed and re-examined, while growing under controlled environmental conditions. The carbon balance (changes and losses (respiration)) under high light and CO_2 conditions will affect the root:shoot ratio.

A first observation was made to determine the influence on respiration of root:shoots under full and half roots and shoots grown under high light and high CO_2 conditioning, under saline stress.

Methods:

Tomato plants (var. red cherry) were grown in greenhouse conditions, in growth media gravel:vermiculite 2/3:1/3 (v:v), using half-strength modified Hoagland nutrient solution.

Plants were transferred to aerated water culture (: modified Hoagland nutrient solution) in glass cuvettes. The plant stems passed through holes in 3-cm thick rubber bungs, sealed with plasticine.

Conditions were: 12 h light at 600 μ mol m^{-2} S^{-1} photo flux density (400-700 nm), with mercury growth lamps. 25/18 ± 0.5°C day/night air temperatures and 60% ± 5% relative humidity; 1000 ppm CO_2 in the shoot chamber.

Root and shoot respiration were measured with IRGA instruments. Fresh and dry weight of root and shoot parts were weighed and respiration (μg O_2) per gram dry weight per second-calculated.

Day measurements were taken three hours after light start and night measurements - 90 minutes from beginning of darkness.

Salinity level of a total of approximately 2,500 ppm received after three days and stepwise increasing salinity (Schwarz, 1968).

Results:

Root respiration of 10-week-old tomato plants in Ng O_2/g dw/sec.:

		full shoot	half shoot	full root	half shoot
root	day	12	10.5	11	12
respiration	night	3.1	3.4	3.1	3.6

no sign. diff.

THE INFLUENCE OF ROOT AERATION ON ROOT:SHOOT RATIO IN SALINITY ON TOMATO AND LETTUCE

Tomato plants (var. F[illegible]) and lettuce (var. [illegible]) were grown under saline (3,000 TDS/1,500 TDS) and control (600 TDS) nutrient solution conditions, in 1/2-3/4 cm particles of tuff (porous vulcanic ash from the Golan Heights) gravel. Plastic growth containers, 30 cm diameter and 35 cm depth, were aerated through perforated plastic pipes from underneath. Aeration occurs in the daytime (from sunrise to two hours after sunset) or at night (from two hours after sunset to sunrise) or continuously, and control (no additional aeration).

Four-week-old plants were adapted gradually to the salinity levels within seven days and then, the aeration treatment started. Six replications for each treatment in three treatment series have been studied.

Tomato treatment continues for six weeks; lettuce treatment for three weeks.

Root and shoot fresh and dry weight was taken.

The results of one of the experiments is summarized below.

In lettuce plants (salt-sensitive), no differences have been found in the various aeration treatments. Lettuce head (shoot) yield was, in non-saline condition, average 35% higher and 40% in root weight. The taste of the saline-treated plants was more bitter, compared to control plants.

Short Discussion:

"Night-time" for roots starts approximately 90 minutes after darkness, when shoot-to-root translocation is reduced and root maintenance respiration is near the minimum (Schwarz and Gale, 1984). Aeration during these "non-requested" root activity hours may induce production of new roots, mostly not required and a burden on the carbon balance in the plant under salinity.

Primary Results and Discussion:

The main conclusion of these first experiments is that the root respiration - per gram weight - is not influenced by the amount of roots or shoots. If the half-root or shoot produces the same root activity, the other half can be a waste for the plant productivity - a burden on the carbon balance. The respiration and maintenance respiration of this non-required plant material could be free for other plant activities and may raise te harvest index ratio , under saline conditions!

Suggestions for Further Observations:

The primary observation was with a C_3 salt-tolerant plant (tomato). Similar observations are important with salt-sensitive plant, C_4 plants and control conditions.

Is root volume production influenced by root aeration (day or night)? Where is the border between too much and too little aeration?

FURTHER SUGGESTIONS:

Root:Shoot Ratio and Harvest Index in Salinity:

This ratio will be of primary importance under salinity and controlled conditions.

The influence of root aeration - oxygen control - and at various day and night hours - has to be determined and their balance calculated.

The economic consideration will be for root-harvest plants such as sweet potatos, potatos (saline resistance varieties), carrots and fruit plants (such as tomatos), as a result of the carbon balance in the plant and hormone transport.

Basic research will include determining the carbon balance (maintenance respiration) of shoot and root, day and night, reduce non-required plant mass for most of the roots (a burden on the carbon balance!).

Culture Plant-Growing at Higher Altitudes (low atm. pressure):

The influence of growing culture plants under low atm. stress conditions (high Andian location) under fully controlled nutritional conditions and various controlled environmental conditions (light, CO_2) should be studied, to find the limiting growth factors in this environment and to improve yields and adapt varieties to this area.

Recent Publication

The main field information obtained in recent years, including the work in Peru, will be published (in print) by the Food and Agriculture Organization (U.N.) in Rome in the next few months. It is proposed, by the same organization, to prepare a "Simple Technologies for Small Scale Soilless Culture Vegetable Production Systems in the Tropics" to be published in 1991, based as well on our findings in Peru. In all these publications AID work will be mentioned accordingly.

In the "Oxygenating of Nutrient Solution in Normal and Stress Conditions" in Soilless-Culture, 5:1, 45-53 (Schwarz, 1989) some of our primary assumptions during the last period of research are included (App. 6). The coming report, "Oxygenating of Growth Media in Normal and Stress Conditions" includes our recent findings.