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COORDINATED USE OF MARGINAL WATER RESOURCES IN ARID AND DESERT AREAS , Stage II

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Section I

A. Executive summary

The Turkana region of Kenya exhibits traits that are typical of South-Saharan Africa: low and very variable precipitation (200-300 mm) and a continuous increase in population. The area was traditionally only used for very low density rangeland and new approaches are necessary in order to ensure the livelihood of the local population and that of displaced refugees from the neighboring countries. A good example of this situation is exemplified by the Kakuma Refugee Camp in Turkana, with eighty thousand inmates. The estimated daily consumption of firewood is 80 ton (1 kg per day per inmate). It is obvious that in order to meet this demand, massive tree felling activities are necessary, in whose wake desertification will spread. It is clear that in order to solve this problem an innovative approach based on locally available sources is essential. Results of the AID/CDR program C11-133 (the first stage of the current project) confirmed that it is possible to use runoff water to cultivate multi-purpose fast growing trees (MPSGT) in arid zones, and supplement the sometimes erratic runoff events by irrigating with locally available brackish water. These conclusions are based on the results obtained in filed trials and pot experiments studying the biomass of *Acacia saligna* a leguminous tree. In order to be able to implement this technique on a wide scale further research is necessary on the following key issues:

I. Seedling establishment when irrigated with brackish water – Proper fertilization may ensure seedling survival and development during the early growth stages and new fertilization approaches will be tested.

II. Rate of re-growth after felling- Tree lopping or felling is mandatory in order to produce the necessary firewood. Within this phase of the project we study the effect felling height above the ground or lopping have on shoot re-growth and water use.

III. Root and shoot development - the effects that the potential use of brackish water and its rate of application rates may have on the development of the above (shoot) and below (root) parts of the tree are being evaluated.

IV. Intercropping -The possibility of intercropping between the trees in the aftermath of runoff event are being studied, in view of the fact that the provision of grain is as well a critical issue in this area.

During the period covered by this report the following activities were carried out: trees were pruned to 3 different height treatments and irrigation trials with different water qualities were continued. Above and below ground development patterns of *A. saligna* are being monitored as well as the relevant ancillary soil, atmosphere and physiological conditions.

Dr. Ephrath from BGU and Prof. Nyabundi from Maseno University visited Turkana, examined the sites of the field trials, discussed plot arrangements and technical matters. Prof. Nyabundi visited the experimental site in Israel and discussed with Drs. Berliner and Ephrath the results obtained so far.

B) RESEARCH OBJECTIVES:

The main objective is to expand the areas of agroforestry in arid and desert areas of Africa by supplementing erratic runoff floods with brackish water irrigation, thus stabilizing the supply of fuelwood and forage to the local population. This activities will contribute to decrease the risk of desertification, set the basis for sustained food and firewood production and contribute to decrease migration to deprived urban slums.

SPECIFIC RESEARCH OBJECTIVES.

I. Fertilization (pot and field trials)

(b) To test new fertilization techniques with Mo, bicarbonate and nitrogen. Previous trials carried out in pots showed that the addition of Mo resulted in a considerably diminished salt sensitivity, enhanced biomass production and nutritional value of leaves.

(c) To study the effect of selected mycorrhiza which stimulate nutrient uptake by roots under saline conditions. These effects were observed in a previous AID/CDR project.

(d) To carry out screening tests for salt tolerant species of N_2-fixing microorganisms living in symbiosis with Acacia roots in affected salt and drought affected areas in Israel and Kenya.

II. Re-growth patterns (field trials)

a) Assess the effect felling (or lopping) height above the ground of shrubs that are being irrigated with runoff water only have on:
   - I. shoot regrowth
   - II. root development

b) Monitor the effects that different levels of soil salinity, quality and quantity of water application have on the behaviour of *Acacia saligna* shrubs after lopping them at 1.5 m. height. The following key aspects will be monitored:
   - I. shoot regrowth
   - II. shrub water relations and biomass production characteristics
   - III. soil moisture absorption patterns of the shrubs
   - IV. photosynthesis
   - V. in situ spatial and temporal distribution of roots with the aid of minirhizotron system

III. Intercropping (Field trial in Kenya)

To evaluate the possibility of intercropping between the trees in the aftermath of runoff events. Sorghum, a highly versatile and popular grain crop in Turkana, will be used as an intercrop.

B-2 Research Accomplishments:

In the following we use the sub-titles and indexing as they appeared in the Technical Work Plan of the approved proposal.

B-2-1 Supplemental Irrigation trials (ISRAEL)

I. Lopping height treatments

The experiment is being carried out at the Israeli Negev Desert at Wadi Mashash farm. The site is about 20 Km North of Sede-Boqer at an elevation of about 350 m above sea level. The plot, at the size of 0.5 ha, was planted with *Acacia saligna* in 1993 and is surrounded by walls from three sides forming a leveled catchment's basin (Liman). The trees were planted at four meters distance between rows and one meter within the tree row (2500 trees ha^{-1}). The central four trees in each plot are being measured. At the end of the winter, after a runoff event and prior to the pruning (during February 2003) soil samples from two representative points in the basin were taken at 30 cm increment up to the depth of 210 cm for determining gravimetric soil moisture content. Three pruning heights (0.5, 1 and 1.5 m) and a non-pruned treatment are being studied. Each treatment is replicated 3 times in a completely randomized block design. The re-growth of the four selected shrubs within each plot is being monitored by carefully mapping foliage emergence and equivalent diameter at 0.2 m. height

II. Irrigation trials

This field trial was set-up during the previous AID project and we present in the following a brief description of the layout and the techniques used.

Experimental design: Completely randomized block design with eleven treatments and three replicates. A description of the treatments is presented in Table 1

Table 1 Description of treatments, irrigation frequency and codes

Treatment Number	Description	Code
1	Runoff	R
2	Runoff and irrigated thereafter with fresh water at high frequency	HFR
3	Runoff and irrigated thereafter with fresh water at low frequency	LFR
4	Runoff and irrigated thereafter with brackish water at high frequency	HBR
5	Runoff and irrigated thereafter with brackish water at low frequency	LBR
6	Irrigated with fresh water at high frequency	HF
7	Irrigated with fresh water at low frequency	LF
8	Irrigated with brackish water at high frequency	HB
9	Irrigated with brackish water at low frequency	LB
10	Well watered using fresh water	WWF
11	Well watered using brackish water	WWB

Descriptions of irrigation treatments:

Runoff Flooding once a year (during winter)

High Irrigation frequency:	irrigation once a week
Low irrigation frequency:	irrigation twice a month
Well Watered.	irrigation twice a week.

Each of the thirty-three plots has an area of 75 m^2 and is planted to 16 shrubs of *A. saligna*. The central four trees are used for measurements and access tubes for soil moisture measurements and rooting patterns are located between them.

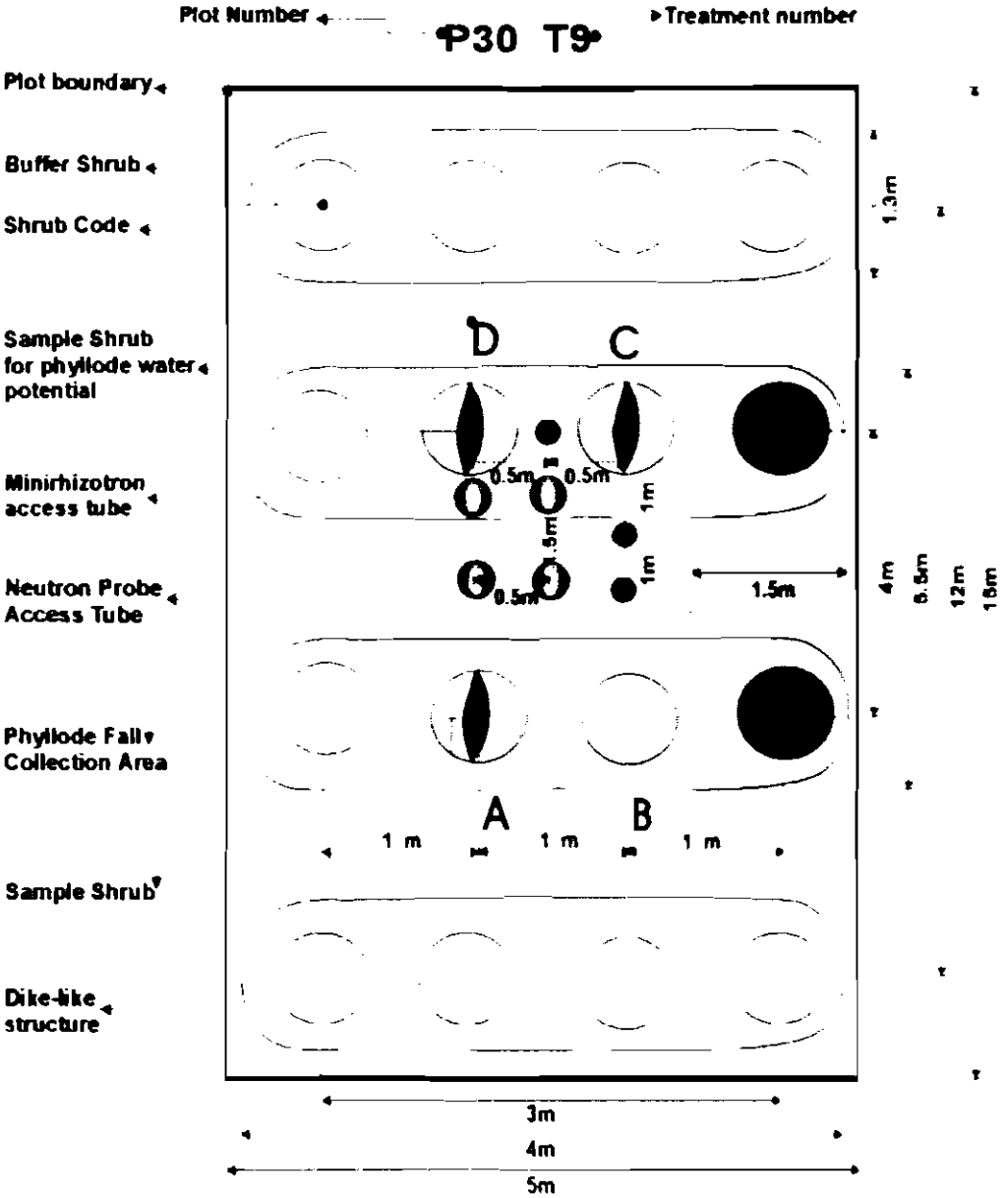

Fig. 1 Schematic description of plot layout

Measurements and technical details

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Irrigation volumes: The volumes of water to be added to each plot (irrespective of irrigation frequency) were determined as follows: on the day prior to the irrigation the depletion from Field Capacity was determined in each plot (Fig. 1) from Neutron probe data (to a depth of 1.2m), and the appropriate volumes computed. The water was applied via a drip irrigation system. A dike around each row of shrubs limits the water spread and minimizes the wetting of the inter-row area.

Brackish water: The brackish water is artificially prepared using a concentrated salt solution (70 gr of NaCl per liter of fresh water). This solution is injected into the irrigation system at a rate of 5% of the fresh water flow using a proportional injector pump (model DI-210, Dosatron, France, injection rate range of 2% to 10% with an operating flow range of 10 lh^{-1} to 2.5 m^3/h). Thus, an electric conductivity of 6 dS m^{-1} is obtained for the brackish irrigation water (based on the average electrical conductivity of 1 dS m^{-1} of the fresh water from the National Water Carrier)

Cross sectional area: Was computed from the equivalent trunk diameter measured at a height of 20 cm above the ground in each plot on each of the four central shrubs (Fig 1). These measurements were carried out at bi-weekly intervals.

Phyllode Fall Collection The phyllode fall is collected on all plots every 15 days, immediately prior to the irrigation of the low frequency treatment from a 4 m^2 area (Fig. 1). Water content of the fresh PFC was determined on sub-samples

Predawn and mid-day Phyllode Water Potential (PLWP and LWP) were measured using a pressure chamber (ARI II Arimad , Kfar Haruv, Israel). The phyllodes for predawn measurements were sampled before sunrise (between 5:00 – 6:00 hours). During the afternoon on the day previous to the measurement, mature fully developed phyllodes were selected and covered with aluminum foil. A total of 99 phyllodes (3 phyllodes/plot) were covered for each measurement date. On the morrow, phyllodes were cut gently, and immediately placed in a cool-box. The time interval between covering and sampling was 12 h. After sampling, the aluminum cover was removed and the phyllode placed in a plastic bag with wetted paper. The petiole-like extreme of the phyllode was cut again with a razor blade in order to obtain a uniform cut surface, prior to its insertion into the pressure bomb. The pressure was applied a rate of 0.5 bar/sec. The PLWP and LWP's were routinely measured every 15 days, prior to irrigation.

Results

During the first year of this project (fifth growth year of shrubs planted during Project CI1-133, of which the present project is a continuation) the trees were not pruned and a detailed assessment of their response to the various treatments was carried out. The rationale for this approach was that that even though more than three years had elapsed since the end of the previous phase of the project, irrigation had not been discontinued during this period and salts had continued to accumulate in the soil profile. It is reasonable to assume that this fact influenced shrub behaviour and that it had to be quantified prior to the radical pruning.

We assessed the production of biomass during the fifth growth year of the shrubs by monitoring the Cross Sectional Area (CSA). In Fig. 2 the evolution of CSA for treatments without runoff addition during the fifth growth year is presented. Well-watered shrubs performed better in comparison to all other treatments. Until Day of the Year (DOY) 120 no changes were apparent. Thereafter a linear increase could be observed which was more marked for the well-watered plots. The slope decreased after DOY 280.

The CSA evolution for treatments that received an application of runoff water during winter is presented in Fig. 3. The change in CSA for LFR, LBR, HBR and HFR appear to show a smaller increment than their counterparts without runoff addition. It is however worth noting that the CSA at the beginning of this season was higher for the treatments that received runoff when compared to the same irrigation treatments that did not receive runoff during the winter. A detailed statistical analysis will be carried out

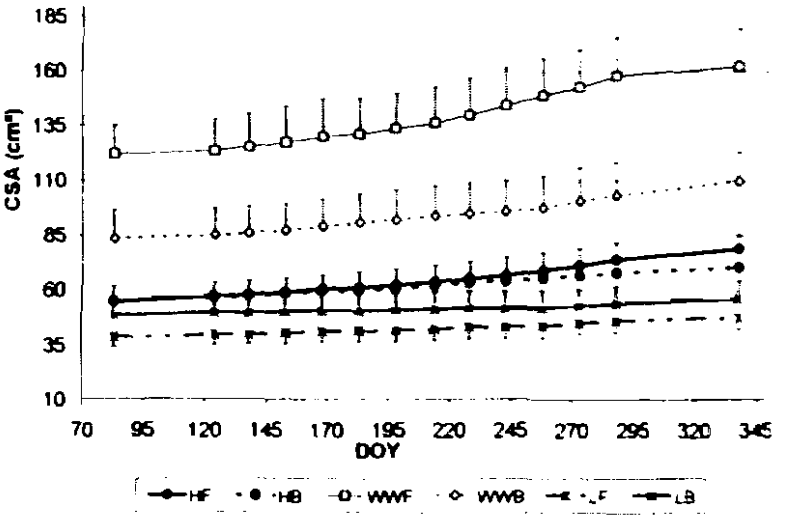

Fig. 2. CSA during the fifth growing season for treatments that received no supplement of runoff. Bars indicate one S.D.

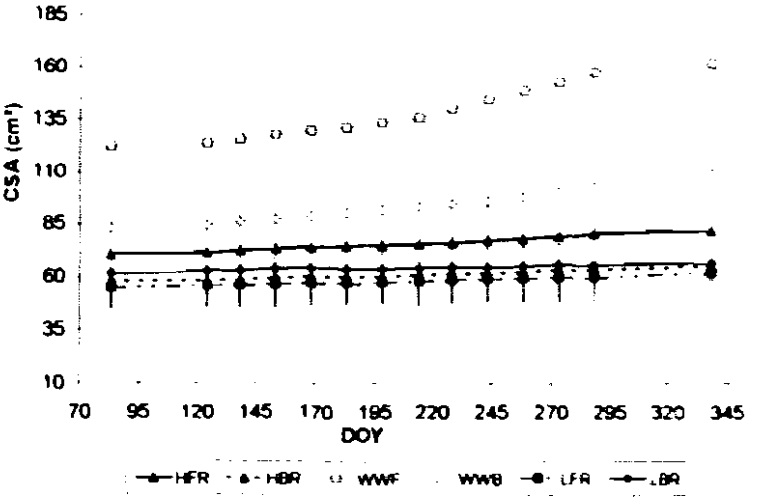

Fig. 3. CSA during the fifth growing season for treatments that received a supplement of runoff. Bars indicate one S.D.

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Table 1. CSA's of *Acacia saligna* at the beginning (DOY 83) and end (DOY 338) of the fifth growth year and the difference between them. Similar letters indicate that the corresponding treatments are not statistically different (Tukey test, α=0.01)

	CSA										
	R	HFR	LFR	HBR	LBR	HF	LF	HB	LB	WWF	WWB
DOY	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
83	22.51 d	70.86 bc	55.49 bcd	58.33 bcd	61.88 bcd	54.70 bcd	38.50 cd	54.74 bcd	48.69 bcd	121.8 a	83.43 ab
338	26.86 d	82.94 bc	63.12 bcd	66.16 bcd	67.56 bcd	79.03 bc	47.64 cd	70.60 bcd	56.19 cd	162.3 a	109.7 b
Difference	4.35 d	12.08 b	7.63 d	7.83 d	5.69 d	24.33 b	9.14 d	15.86 d	7.50 d	40.46 a	26.28 b

The increment in biomass is linearly related to the increment in CSA. In Table 1 the increments observed during the fifth growth year (first year of the present project) are presented. The results indicate that no statistically significant differences due to the use of brackish water were observed for the Low Frequency treatments

B.2.3 Fertilization techniques (Israel)

The goal of this section of the research is to determine optimum growth conditions for *Acacia saligna* growing under conditions of salinity in the greenhouse. Specifically, it is planned to test how the concentration of essential nutrients such as nitrogen, type of nitrogen (NO_3^- vs NO_3/NH_4^+ mixture) and molybdenum in the fertilizer regime affect the ability of *A. saligna* seedlings to tolerate high levels of salt

Plant growth conditions

Our first task has been to find the best conditions for germinating and growing *A. saligna* in the greenhouse so that a high percentage of germination and uniform and healthy plant growth are achieved.

a) Germination

A. saligna seedlings have been germinated by immersing seeds in deionized water at 80 °C, allowing the water to cool and leaving the seedlings overnight before transferring them to moist filter paper. Previous work at BIDR has proven this to be an effective means for germinating *A. saligna* seeds. Initially, imbibed seeds were incubated in a growth room at 24 °C under a low light intensity of 50 μE m^{-2} s^{-1}. However, only 50% germination was achieved and germination was not uniform. Uniformity of germination as well as percentage germination (75% to 80%) improved when seeds were incubated in the greenhouse under a maximum daily light intensity of 1000 μE m^{-2} s^{-1} and temperatures ranging from 28 °C during the day and 18 °C at night.

b) Growth

When seedlings exhibited a root length of about 2 cm and the first two cotyledons were visible, seedlings were transferred to 25 ml plugs containing 1:1:2 loess: sand: perlite (No. 2) mixture. When seedlings were transferred before this stage approximately 30% of the seedlings did not survive whereas 90% survived at this later stage. Seedlings were irrigated with 20:20:20 N:P:K + micronutrients and transferred to half-liter pots when 3 to 4 cotyledons/leaflets (?) had emerged

However, growth was extremely non-uniform and it was found that placing the seedlings directly into the half-liter pots greatly improved uniformity of growth. One other problem that emerged was that older cotyledons/leaflets (?) exhibited pale tissue in the interveinal regions, often a sign of nutrient deficiency. In fact, it was observed that the commercial 20:20:20 fertilizer lacked Boron and the fertilizer mixture has been changed to Hoagland's solution.

B-2-4. Stress tolerance mechanisms in *Acacia saligna* (Israel).

Having overcome the problems of germination and growth of *A. saligna* seedlings, a preliminary experiment has been sown to investigate how *A. saligna* responds to salinity at two concentrations of nitrogen in the fertilizer solution. Seedlings will be grown in Hoagland's solution until the first fully expanded leaf stage at which time the plants will be treated with Hoagland's solution containing either 5 mM or 10mM NO_3^- and 0 mM or 100mM NaCl. Plants will be grown for a further two months after which time photosynthesis will be measured as well as various growth and biomass parameters.

B-3-1 Field trial set-up (Kenya)

As mentioned in the Management Report the plots have to be replanted. Two batches of seedlings were prepared at the University of Kisumu and were planted in April, at the end of the rainy season.

C) SCIENTIFIC IMPACT OF COLLABORATION:

A Seminar about the results obtained in Israel during the first year of this project was presented at the Maseno University and attracted a wide audience. A student from Maseno University will pursue her M. Sc. studies at the Blaustein Institute. The topic of her thesis will be one of the topics of the present project.

D) DESCRIPTION OF PROJECT IMPACT:

The Turkana herdsman have showed great interest in the runoff collecting structures and would like to actively take part in the construction of new structures, if required. We expect that once the possibility of using brackish shallow groundwater together with runoff to grow trees and sorghum will have been proven in the field, the local population will implement the technique. The authorities of the Kakuma refugee camp (80,000 inmates and a great consumer of firewood and grain) would be willing to implement the technique, but apparently regulations imposed by the Kenyan Government, don't allow them to do so at the present stage..

E) STRENGTHENING OF DEVELOPING COUNTRY INSTITUTIONS:

A Memorandum of understanding between the Maseno University and the Blaustein Inst. for Desert Research is going to be signed in the near future. This agreement will be the direct result of the cooperation between the PI's of this project.

F) FUTURE WORK:

We will continue the measurement program as detailed in the proposal.

Section II

A) Managerial Issues:

There are no additional issues to be reported

B) Budget:

No changes required at present

C) Special Concerns:

None

D) Collaboration, Travel, Training and Publications:

Dr. Ephrath visit to Kenya and Professor Nyabundi's visit to Israel were carried out as planned

E) Request for American Embassy Tel Aviv or A.I.D. actions.

There is no request for actions to be undertaken by either.