Regional action programme (RAP)-water resources management: water saving irrigated agriculture (WASIA Project)

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REGIONAL ACTION PROGRAMME (RAP)-WATER RESOURCES MANAGEMENT: WATER SAVING IN IRRIGATED AGRICULTURE *(WASIA PROJECT)*

EXECUTIVE SUMMARY

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I. PRIORITY SETTING JUSTIFICATION AND OBJECTIVES

At the beginning of the new century, agriculture faces the challenges to produce more food for inexhaustible population growth, while maintaining almost unchanged land and water input. This challenge becomes particularly important for arid and semi-arid areas of the Mediterranean, where agricultural production is strictly related to irrigation and where, in many places, the maximum employment of resources has already achieved.

The Southern Mediterranean, comprehending the Northern African and Near East countries, is the poorest region in the world in terms of water resources, globally and per inhabitant. In many countries of the region, annual water withdrawal has reached or already exceeded total annual renewable water resources (e.g. Egypt, Libya, Palestine, Israel, Jordan, Syria, Malta, Tunisia) and further employment of resources is unrealistic from both technical, environmental and socio-economic point of view. In the region, population growth is among the greatest in the world (3% per year) and agricultural production relies heavily on irrigation: in the Northern African region, irrigated agriculture consumes in average about 85% of total annual water withdrawal (FAO, 1997), and, in some countries, water use for irrigation approaches even 90% (e.g. Egypt, Morocco, Cyprus). At the same time, average losses of water diverted to agriculture are extremely high and accounts to about 50% (FAO, 2000) due to inefficient use of water at on-farm scale, poor performance of irrigation distribution systems caused by inadequate maintenance and operation, improper irrigation and drainage infrastructures, etc.

The projections of food and water demand in the Mediterranean indicate, for the period 1990-2025, a population increase in the Southern Mediterranean countries of almost 100% with the corresponding increase of water demand of approximately 50%. Irrigated agriculture holds the key to feeding the growing population in the region since irrigated land produces two to three times more crops than rainfed agriculture. At present, the irrigated areas in the Mediterranean account for more than 16 million hectares with a growth rate stabilized, at the beginning of the nineties, to around 200,000 hectares per year. This requires an additional supply of water for agriculture by a rate of 2 km^3/year. However, regardless of these specific causes, existing situation is not amenable to cope with the spiraling increases in food and water demand due to water and land shortage in the region.

Therefore, the solution should be searched not in the increase of land and water input for agricultural use but in better employment of already existing natural resources, i.e. in water saving in irrigated agriculture, and increased use of non-conventional water resources (saline and treated wastewater) which may have adverse impacts on both the environmental and public health.

In the Phase I of the RAP, great efforts had been carried out to cope the above cited problems locally and at the regional Mediterranean scale and, through the collaborative research network, these efforts have resulted in numerous publications, organizations of conferences and workshops as well as the realization of several research projects. That is the time to translate the ideas, conclusions and recommendations developed through these researches to actions on the ground in the Mediterranean region. This is what had been exactly formulated in the Research Project WASIA ("Water Saving in Irrigated Agriculture") which aims at the development of sustainable agricultural production and food security in the Mediterranean region.

The main objective of the WASIA research project is to develop a conceptual framework for ***water saving in irrigated agriculture*** of the Mediterranean region through the integration of the activities which represent major topics of the three Collaborative "Water Resources Management" Research Networks and aim to:

Improve water use efficiency in irrigation practices (WUE_Net),
Improve performances of irrigation distribution systems (CIS_Net), and
Promote safe and sustainable use of non-conventional water resources (NWRM_Net),

Specific objectives of the project are addressed to the development of 8 (eight) research themes to be carried out at eight different locations in the Mediterranean Region:

1. Deficit Irrigation of orchards with low quality water, (Tunis, Tunisia)
2. Deficit Irrigation of pistachio with different fertigation practices (Southeast Anatolian Region, Turkey)
3. Hydraulics performances of irrigation systems under different irrigation practices (Ghezala-Teskraya, Tunisia)
4. Innovative approach for energy saving in irrigation systems (Souss Massa, Morocco)
5. Reuse of treated wastewater for irrigation of cereals, forage and vegetables by means of different irrigation methods (Agadir, Morocco)
6. Re-cycling of drainage water for sustainable irrigated agriculture (Nile Delta, Egypt)
7. Sustainable use of highly saline water for irrigation of crops under arid and semi-arid conditions: new strategies (Tarsus, Turkey)
8. Development of screening legumes and forage nursery for salinity tolerance (Aleppo, Syria)

The proposed research themes cover some of the most important aspect of water saving in the Mediterranean agriculture and represent the continuation of the collaborative research network activities carried out during the first phase of the RAP. Therefore, it is expected that the outputs of the project should provide a substantial contribution in achieving sustainable agricultural production and food security in the Mediterranean region.

II. METHODOLOGY

In the realization of the WASIA project, 8 local institutions (one for each experimental site) were involved along with the CIHEAM-IAMB and the National Water Research Center (Cairo, Egypt). The programmed duration of the project was 24 months, while the approved budget was Euro 300,000.

According to the Working plan, four Work Packages are established. Three of them are tightly related to the three Collaborative Irrigation Networks of IAMB (WUE, CIS and NWRM) with the task of coordinating and carrying out the major activities under specific research themes, while the fourth is related to the overall scientific and administrative coordination of the Project, the exchange of information and interactions between the first three Work Packages.

Two meetings, related to preparation of activities and organizational aspects of the WASIA project, were carried out in the 1st year of the Phase II of RAP, while the third and fourth meeting, related to the monitoring of activities and presentation of results, were held in the 2nd phase of the RAP. The last meeting is scheduled for the end of the program in May 2003.

The first meeting was organized at IAMB, in October 2000, before the initiation of the experimental work at eight selected pilot sites included in the WASIA project. The scientific coordination of the Project is assigned to the Chairperson of the National Water Research Center (NWRC), Cairo (Egypt), in cooperation with the CIHEAM-IAMB Research Network coordinators and local coordinators of different pilot sites. It is agreed that the Project should be financially administrated, along the whole duration, by the Administration Division of the CIHEAM-IAMB in cooperation with the person nominated by the NWRC, Cairo (Egypt). In this occasion, the working plan of WASIA project was fully discussed between the local coordinators and IAMB scientific coordinators. A part of discussion was dedicated to the definition of the way of communication among the partners, the contribution of each local site and the division of the EU budget among the sites, to be allocated to the equipment and consumable material needed to improve the experimental work on the fields and in laboratories and to facilitate the communication between the partners.

The second meeting was held at Bari Institute from 23 to 25 February 2001 with the participation of the representatives from NWRC (Cairo, Egypt), local coordinators and IAMB staff included in the project. In this meeting, the working plan was revised and approved. Moreover, it was agreed to distribute equally among the experimental sites the EU budget allocated for the project, with the exception of ICARDA site which had to receive only a part of budget for travel expenses and consumable material.

The third meeting of the local co-ordinators and scientific co-ordinators of work packages was held at the National Water Research Center (Cairo, Egypt) from 13 to 15 January 2002 following the invitation of the Chairperson Dr. Mona El Kady. In that occasion, the local co-ordinators presented the activities related to each pilot site and agreed the completion of the program with the scientific co-ordinators. It was decided to interrupt the activities at the Souss Massa experimental site in Morocco due to difficulties to establish the contacts with the coordinators of the pilot area.

The fourth meeting was held in Cairo (Egypt) at the NWRC from 10 to 11 October 2002, where the complete presentation of the outcomes and research findings from 7 experimental sites was done. Moreover, the way of preparation of the final report and other deliverables of the project are discussed and agreed according to the formulated working plan for each site.

The last meeting is scheduled for the end of May 2003 when the research results of the project will be presented and discussed during a regional seminar with the participation of numerous irrigation experts and researchers from the Mediterranean region. In that occasion, the level of exchange of information and interaction between different themes and working packages will be assessed. Furthermore, this meeting should trace the guidelines for the further actions on water saving in agricultural sector to be taken in the Mediterranean region.

III. RESULTS AND OUTPUTS

Detailed reports related to the eight research themes, describing the experimental site, measurements methods and procedures, and giving the results and outputs are presented as separate documents, while a summary of the activities with results and conclusions is reported here bellow.

Research theme 1: "Deficit irrigation of orchards with low quality water"
Pilot area: Mornag-Tunis, Tunisia
Partner: Institut National Agronomique de Tunisie (INAT), Tunisia
Objectives:

save water in irrigated agriculture through deficit irrigation practices,
monitor and reduce salt input to the soil and consequently diminish environmental degradation
improve irrigation water productivity in orchards.

Programmed Activities:

Meteorological data collection and regional climate characterisation: rainfall frequency distribution, ten-days T°C averages and ETo
Characterization of the soil of the selected region: sampling of typical soil, determination of Field Capacity, Permanent Wilting Point (PWP), Soil Moisture Release Curve
Surveys on irrigation practices in representative orchards
Collection and analysis of existing research data and development of phenological calendars for the selected tree species.
Implementation of demonstration plots (amount of water usually delivered by the farmer will be used for reference). Restrictive treatments consist in irrigation water cuts of 33% at selected growth stages.
Quantification of saved water volumes and salt-input reductions
Preparation of “Deficit Irrigation Guidelines”
Dissemination of results

Deliverables:

Deficit irrigation guidelines for peach growers to save water
Indications on irrigation criteria to control excessive salt accumulation in the root zone

Results and Conclusions:

A continuous water restriction seems to give a better yield than restrictions during just the vegetative growth phase or during the final fruit growth stage: 1) irrigation water saving during the whole season of 33% has resulted in the yield losses of 10%; 2) irrigation water saving of 33% during the vegetative growth stage (10% saving over the whole season) has resulted in the yield reduction of 15%; 3) irrigation water saving of 33% during the final growth stage (22% saving over the whole season) has resulted in yield reduction of 22%.
Water restriction during the whole growing season seems to improve sugar content and the dry weight of fruits.
Salts are mainly concentrated near the trunk and that soil salinity evolves in the same manner for different treatments.

Predawn water potential showed an increasing difference between the control treatment and restriction treatments. During the period June-July its value varied from 0.21 to 0.27 MPa for the control while it dropped from 0.25 to 0.53 for the less watered regime. Midday xylem water potential was respectively 1.0 and 1.5 MPa for the control and restriction (I-II-III) treatments.
The extrapolation of the results obtained at the Mornag region to other Mediterranean regions is possible through the measurement of the water status of trees.
At Mornag-INAT, a reference station is established for the continuation of experimental work on deficit irrigation practices.

Research theme 2: "Deficit irrigation of pistachio with different fertigation practices"
Pilot area: Southeast Anatolian Region, Turkey
Partner: Çukurova University, Faculty of Agriculture, Adana, Turkey
Objectives:

save water in irrigated agriculture through deficit irrigation practices,
optimize nitrogen use and fertigation practices
improve irrigation water productivity of pistachio.

Programmed Activities:

Collection of available climatic data
Characterization of the soil of the selected region
Experiment on a pistachio orchard with restrictive irrigation treatments, having water cuts down to 30% and different fertigation programs
Monitoring of the soil-water status, plant growth, morphology, phenology and gas-exchange
Quantification of water savings
Preparation of "Deficit Irrigation Guidelines"
Dissemination of results and "Guidelines" and meetings with pistachio growers held by the "Pistachio Research Institute" Extension-Service of the Region

Deliverables:

Project Reports
Deficit Irrigation Guidelines related to Fertigation Practices

Results and Conclusions:

Although pistachio is traditionally cultivated under rainfed conditions, it significantly increases yield even under deficit irrigation. The response to deficit irrigation is enhanced by the use of fertilizers in the irrigation water (fertigation).
Irrigation and fertigation decreased the shedding of reproductive bud compared to traditional practice in 2001. It can be expected that higher yields can be obtained in the irrigated treatments in the following year.
There were significant statistical interaction between irrigation and nitrogen both affecting yield in 2001. The maximum yield was taken from $I_{f2}N_3$ treatment. In 2002 it could not be found significant relation between yield and nitrogen amount.
Stomatal conductance of *Pistachio* does not respond to VPD of the atmosphere while shows a response related to leaf water potential;
Although potential rates of net photosynthesis of 50 mol m^{-2} s^{-1} were observed under full CO_2 and light saturation, actual values of no more than 20 mol m^{-2} s^{-1} were measured for the treatments receiving high nitrogen and high water applications ($I_{f1}N_390$);
the net photosynthesis of the "Traditional" leaves was at least 32% lower than $I_{f1}N_390$;
the rate of photosynthesis was strictly linked to the stomatal conductance which ranged between about 0.1-0.2 mol m^{-2} s^{-1} of the "Traditional" treatment and about 0.4 mol m^{-2} s^{-1} of the $I_{f1}N_390$ one;
irrespective of the treatments date of measurement and leaf sampled the sub-stomatal CO_2 partial pressure remained significantly constant around 200-220 mol mol^{-1}. This is an indication of the *Pistachio* ability to maintain an optimum balance between stomatal opening and photosynthetic rate;
Due to the inference reported in the previous two points, the photosynthetic WUE of *Pistachio* was always held constant in average around 2 mol $mmol^{-1}$ irrespective of treatments date of measurements and leaf sampled.
The results of this experiment highlighted that pistachio can achieve the maximum yield with 30% less water than the full irrigation requirements provided that fertigation is applied.

Research theme 3: "Hydraulics performances of irrigation systems under different irrigation practices"
Pilot area: Ghezala - Teskraya Irrigation District, Tunisia

Partner: Institution de la Recherche et de l'Einsegnement Supérior Agricoles (IRESA)

Objectives:

to understand the farmers behaviour by monitoring the irrigation system and by applying models able to simulate different scenarios;

to develop a tool aiming at identifying the failure areas in the system and the importance of such a failure;

to improve the capabilities of managers and operators of irrigation systems in identifying the problems and related solutions for improving the irrigation system performance.

Programmed Activities:

Data collection on climate, hydrology, irrigation network characteristics, demand hydrograph, cropping pattern.

Analysis of data and realization of relevant thematic maps.

Development of models for the performance analysis of the irrigation scheme.

Application of models for performance analysis of the irrigation scheme

Identification of possible improvement of the system performance

Development of criteria for improving management of irrigation system.

Dissemination of results.

Deliverables:

Quantify the degree of performance of the irrigation system.

Define criteria for the identification of critical zones

Developed criteria for management of irrigation system.

Results and Conclusions:

The degree of performance of the Ghezala system has been defined in respect to the relative pressure deficit and reliability. The following criteria for identification of the critical zones were adopted: no risk when relative pressure deficit > 0 and reliability >90%; failure risk at the farm level when relative pressure deficit is between -1 and 0 and reliability between 50 and 90%; failure risk at the water distribution network level when relative pressure deficit <-1 and reliability<50%.

1000 demand hydrographs flowing through the network have been analyzed corresponding to the discharges from 200 to 750 l/s. The best performances were observed with the discharge of 200 l/s when 20 hydrants out of 147 had reliability lower than 50% and 61 out of 147 had relative pressure deficit lower than -1 indicating permanent dangerous failure of the system. The worst performances were observed with the discharge of 750 l/s when about 50% of hydrants had reliability lower than 50% and almost all hydrants (139 out of 147) had permanent pressure deficit problems.

In order to improve the performances of the water distribution network, new technology for the delivery system can be used ("ACQUACARD") allowing irrigation only during the night when discharges are lower than 200 l/s. Also, the rehabilitation of the network (by increasing pipe diameters) may be considered.

The application of the software "Analyse du reseau" for the analysis of pressurized irrigation systems (developed during the realization of the project) and the integration of the results of software analysis in GIS demonstrated the usefulness of these tools in the performance analysis of irrigation systems with large number of data.

Research theme 4: "Innovative approach for energy saving in irrigation systems"

Pilot area: Souss-Massa Irrigation District, Morocco

Partner: Ministère de l'Agriculture, du Développement Rural, des Eaux et Forets (MADREF - Morocco)

Objectives:

set up an innovative methodology for reducing energy cost for the operation of the system;

quantify the energy saving; and

improve the social conditions of farmers by reducing the water price.

Programmed Activities:

Data collection on the demand hydrograph, on the energy consumption and on the physical characteristic of the network

Set up a data-base on the demand hydrograph, on the energy consumption and on the physical characteristic of the network

Development of a methodology (including a software package) for the energy saving in irrigation districts serving by pumping station

Application of such a methodology to the “Ait Amira” irrigation scheme
Quantification of the energy saving
Dissemination of results.

Deliverables:

A software package
Data-base on energy consumption and on the physical characteristic of the network
Quantification of energy saving

Results and Conclusions:

Unfortunately, during the Cairo meeting in January 2002, it was decided to interrupt the activities at this site due to difficulties to establish the contacts with the coordinators of the pilot area Souss-Massa in Morocco.

Research theme 5: "Reuse of treated wastewater for irrigation of cereals, forage and vegetables by means of different irrigation methods"

Pilot area: Drarga, Agadir, Morocco

Partner: Institut Agronomique et Vétérinaire Hassan II, Agadir, Morocco

Objectives:

To promote the use of treated waste effluents as an additional water source for irrigation;
To set new strategies for management to reduce risks for degradation of environment;
To establish an association of users of treated wastewater;
To establish an irrigation network to supply each farmer or a group of farmers with treated effluent;
To demonstrate water and nutrient saving and productivity of irrigated forage, vegetables and cereals crops and to convince the farmers on the safety of treated water.

Programmed Activities:

Collection of meteorological data (rainfall, temperature, ETo)
Plant productivity and product quality
Monitoring of nitrogen balance for each crop.
Evaluation on the performance of the different irrigation systems (water distribution efficiency, clogging, etc.)
Quantification of water and nutrient saved for each cropping system.
Evaluation of alternated use of freshwater and treated effluent water.
Development of guidelines on the use of epurated water for different cropping systems.
Dissemination of results

Deliverables:

Guidelines for optimal use of non-conventional water resources in irrigation
Setting strategies for the recycling and re-use without any environmental and health hazards
Water saving potentiality through reuse of non-conventional water resources
End-Users participation and creation of water user association for non-conventional water resources
Cost benefit analysis for the use of Non-conventional water resources

Results and Conclusions:

Yields were doubled for almost all plants when irrigated with treated wastewater (tomato, maize, green beans). The WUE was the highest for the plants receiving 120%ETM.

The alternation of saline water with treated wastewater has increased the WUE and has reduced by 50% the total nitrogen lost under treatment irrigated with treated wastewater.

The economic analysis of the reuse of treated wastewater allows farmers to reduce the cost of the fertilizers inputs saving up to 350 Euro/ha depending on the crop. This could be a great incentive for the promotion on recycling treated wastewater in agriculture.

The amount of water saved is estimated to 185,500 m^3/year for the community of Drarga. This water saving could reach up to 20 millions m^3/year at the regional level of Agadir which is about 10% of the conventional water resources.

The studies on cereals demonstrate that supplemental irrigation stabilizes bread wheat yield under arid condition of Morocco - there is a three times increase of grain yield of wheat when the amount of water increase from 100 mm to 300 mm. Plants growing under rainfed condition yielded almost zero production. If water is the limiting factor, and land is available, it appears more effective to use treated waste water as supplemental water source at a rate of 200 mm.

The nitrate concentration in the groundwater is reduced by 70% when sewage water is treated before used for agricultural purposes. The percentage of diarrhea in the rural community of Drarga is reduced by 80%.

Tertiary wastewater treatment could meet the environmental goals, but didn't match the crop nutrition requirement.

Research theme 6: "Recycling of drainage water for sustainable irrigated agriculture"
Pilot area: Harris- Behira Govenorat, Western Nile Delta, Egypt
Partner: NWRC - Cairo, Drainage Research Institute, Delta Barrages, Egypt

Objectives:

To test different management practices by using recycled drainage water for irrigation;

To monitor the impact of drainage water reuse options on crop yields and characteristics, soil salinity and salt distribution, groundwater quality and water use efficiency; and

To develop a drainage water reuse guidelines.

Programmed Activities:

Collection of meteorological data (rainfall, temperature, ETo)

Plant productivity and product quality

Physiological data related to photosynthesis, evapotranspiration, water potential and osmotic potential under different treatments.

Evaluation of the performance of the different irrigation treatments with non-conventional water.

Impact on soil characteristics, soil physical properties.

Quantification of water and nutrient saved for each cropping system.

Development of guidelines on the use of drainage water for irrigation.

Dissemination of results

Deliverables:

Guidelines for optimal use of drainage water resources in irrigation

Setting strategies for the recycling and re-use without any environmental and health hazards

Water saving potentiality through reuse of drainage water resources

End-Users participation and creation of water user association for drainage water resources.

Results and Conclusions:

Using of drainage water (EC=4.3 dS/m) and available saline water in the experimental area (mixed water with EC=3.5 dS/m), did not result in any significant difference in the yield of both crops under investigation. However, the yield was about 40% lower than under conditions of irrigation with the fresh Nile water of 1.2 dS/m.

The leaching fraction used in the pilot area is very large (about 0.4) to overcome salinity problems. The proper leaching fraction has to be determined for each area according to its irrigation water quality and soil characteristics (salinity-drainage condition).

Salinity distribution along the soil profile showed no trends and no significant changes. Sometimes there is salinity build up on the top soil layer rather than the lower layers, which may be explained by the fact that salts are moving up from lower layers to the top soil layer during the dry period between irrigation intervals and during the non-irrigation period at the end of the season.

The drawbacks of use of non-conventional water in irrigation could be accepted if we consider the social impact, since without irrigation with drainage water and/or available saline water source, at least 50% of this area would be without any agricultural activity.

New strategies to overcome negative effects of the use of non-conventional water resources should include an appropriate crop rotation with the crops of different salt tolerance degree.

There is a high potentiality of using drainage water successfully in irrigation assuring the presence of a good quality water source to meet the leaching requirements and to be alternated with the low quality one according to the salt sensitivity of the crop growth stage. This could lead up to 60 to 70% saving in the fresh water and in elimination of negative impacts on soil productivity. Those are crucial conditions to get benefits of each drop of drainage water in irrigation particularly under Egyptian conditions, where drainage water is present in enormous quantities (around 15 billion m^3) - nearly one-third of the fresh water allocated for agriculture.

The process of development of the water user association at the experimental area is going on, but, this requires time and support of different agencies.

The guidelines for drainage water reuse consists of agricultural, environmental and socio-economic parts which recognizes different aspects of use of non-conventional water in irrigated agriculture.

Research theme 7: "Sustainable use of highly saline water for irrigation of crops under arid and semi-arid conditions"

Pilot area: Experimental Station of Agricultural Structures and Irrigation Department of Çukurova University, Adana,

Partner: Çukurova University, Faculty of Agriculture, Adana, Turkey

Objectives:

to investigate new strategies of using saline water for crop production under arid and semi-arid conditions;

to obtain the characterization of the plant growing parameters of investigated varieties as a function of irrigation with saline water of different salt concentration levels;

to evaluate the yield production and yield loss in relation to the salt concentration level of irrigation water;

to assess the salt balance under different irrigation programs;

to classify the investigated crops with respect to their salt tolerance degree;

to obtain the suitable leaching fractions for getting high yield from investigated crops and non-salinisation of soils irrigated with saline water.

Programmed Activities:

Collection of meteorological data (rainfall, temperature, ETo)

Plant productivity and product quality

Physiological data related to photosynthesis, evapotranspiration, water potential and osmotic potential under the different treatments

Evaluation on the performance of the different irrigation systems (water distribution efficiency, clogging, etc.)

Impact on soil characteristics, soil aggregate stability using “Henin” method.

Quantification of water and nutrient saved for each cropping system

Evaluation of alternating freshwater with Non-conventional water during the sensitive stage

Development of guidelines on the use of epurated water for different cropping systems

Dissemination of results

Deliverables:

Guidelines for optimal use of saline water in irrigation

Setting strategies for the recycling and re-use without any environmental and health hazards

Water saving potentiality through reuse of saline water resources

End-Users participation and creation of water user association for Non-conventional water resources

Cost benefit analyses for the use of saline water resources

Results and Conclusions:

There is no statistically significant difference between the irrigation of wheat with waters with EC of 0.5 (fresh water), 3.0, 6.0, 9.0, and 12.0 dS/m: grain yields ranged from 5940 to 6484 kg /ha, dry-matter yields varied from 1154 to 1349 g/m^2 and harvest index varied from 0.36 to 0.42.

Highest soil salinity was observed in the 0-10 cm soil layer in treatments with ECw of 12 dS/m and 12 dS/m+10% leaching as ECe=4.3 dS/m.

Highest average SAR was determined in the top layer of soil as 9.74 in the treatment irrigated with water of 9.0 dS/m, followed by 12.0 dS/m treatment as 7.53 and 7.11 dS/m in the treatment irrigated with 12 dS/m +10% leaching. SAR values increased with increasing salinity of irrigation water.

WUE ranged from 1.286 to 1.444 kg/m^3. As the salinity level of irrigation water increased WUE values also increased slightly.

Saline irrigation water can safely be used for irrigation of wheat crop in the Mediterranean region because of effective winter rainfalls leach the salts out of the root zone as long as an efficient drainage system is provided.

Research theme 8: "Development of screening legumes and forage nursery for salinity tolerance"

Pilot area: ICARDA, Aleppo, Syria

Partner: International Center for Agricultural Research in the Dry Areas (ICARDA)

Objectives:

to screen lentil and chickpeas varieties available at ICARDA and National Programs for salinity tolerance;

to test 10 to 20 varieties of each under greenhouse condition for plant characterization and yield quantity and quality;

Programmed Activities:

Phase 1: Bench screening, available varieties of lentil, chickpeas, and at least one selected forage legumes will be test for three salinity levels 3, 4-5, 8 dS/m. This test will be conducted with three treatments:

Dry seed with three salinity levels and control

Pr-soaked seed with fresh water and then with three salinity levels

X-rated seed to study the impact of x-ray on plant salinity tolerance as dry seed and pre-soaked seed with three salinity levels and control.

Phase 2: Greenhouse screening study: top 10 to 20 (upon availability of varieties) varieties will be tested with the same above treatments under greenhouse (controlled condition).

Phase 3: (continuation of research at the field level depends on availability of funds) Top 3-5 varieties to move for field-testing at the farmers field

Dissemination of results

Deliverables:

Salt tolerance of lintel, chickpeas and some forage crops.

Tested varieties of lintel, chickpeas and some forage crops and their appropriate agronomic practices in cotton- and wheat-based rotations.

Degree- and/or non degree-training opportunities in the field of crop and water salinity management in collaboration with the CIHEAM-IAMB.

Results and Conclusions (concerning the phase 1):

The in-vitro screening of 200 lentil and 205 chickpea varieties indicated that the chickpea varieties were more saline tolerant than the lentil varieties. Pre-soaking of the seeds in water with a very low salt content (EC 0.5 dS/m) substantially improved emergence, shoot growth, and survival of the species at the higher salinity levels.

Chickpea showed a reduction of the emergence percentage between the control and the most saline treatment of respectively 13 % and 18 % for chickpea and 10% for vetch.

During early seedling, salinity affected the development of the seedlings that showed symptoms of water stress. These symptoms could be observed in the form of leaf water potential, pod number and weights, and water content.

Chickpea varieties F.89-74, F.87-59 and ICCV2 may be categorized as ion excluders or includers depending on their responses to salinity. However, these properties varied according to the cultivar when subjected to the different levels of salinity. Generally, salt tolerant varieties are capable of growing at relatively higher salinity levels as compared with the salt-sensitive cultivar F.97-265 (Flowers et al., 1977). Cultivars F.97-74, F.87-59 and ILC 3279 were found to have higher salt tolerance and produced more dry matter than F.97-265.

Vetch has a more severe reaction to salinity than chickpea, which is confirmed by growth and yield. The effect on growth and yield was more pronounced for vetch than for chickpea.

To better understand the difference of responses on osmotic adjustment and water use efficiency, additional greenhouse experiments in sand and soil need to be conducted for chickpea; vetch and lentil genotypes. The top 2 genotypes of each crop should susbequently be tested in the field. Similar observations should be made in the field as in the greenhouse. Soil salinity, the EC and average chloride concentration of soil water, and the chemical composition of soil water should also be analyzed.

IV. COMMENTS

The programmed activities are realized at 7 out of 8 experimental sites. They were not completed only at the site of Souss-Massa (Morocco) due to continuos problems to establish contacts with the local coordinators. The WASIA research project focussed on the integration of know-how, research finding and experiences gained in the three research networks of IAMB (WUE, CIS and NWRM), through which possible water saving in irrigated agriculture could be achieved. At each experimental site, the activities are carried out allowing for the interaction between different aspects of water saving elaborated by each of research networks. E.g. in the case of the research themes 1 and 2, water saving strategies have included deficit irrigation at different growing stages (WUE-Net) together with the use of low quality (saline) water (NWRM-Net) and its impact on the performance of irrigation systems (CIS-Net). In the case of research theme 5, the use of treated wastewater (NWRM-Net) is analysed considering the alternation of different irrigation strategies during the growing season (WUE-Net) and application of furrow, sprinkler and drip irrigation systems (CIS-Net), etc. The overall scheme of integration of activities concerning to three research lines of the collaborative research network is presented in Figure 1 which illustrates different

layers of interaction for each research themes. The implementation of the project as such integrated approach has allowed for the creation of a conceptual framework which takes into consideration different aspects of water saving in irrigated agriculture of the Mediterranean region.

The research project WASIA has contributed in the integration of the collaborative research network activities under one umbrella at different sites in the Mediterranean region which has resulted in an increased exchange of research findings and available information, development of new data-bases, different research techniques and application of updated technologies. Such outcomes, along with wide experiences and ample information available at the institutions involved in the research program, will certainly increase the competence of decision makers and research staff in the developing countries of the Mediterranean and help in the setup of comprehensive strategies for water saving in irrigated agriculture.

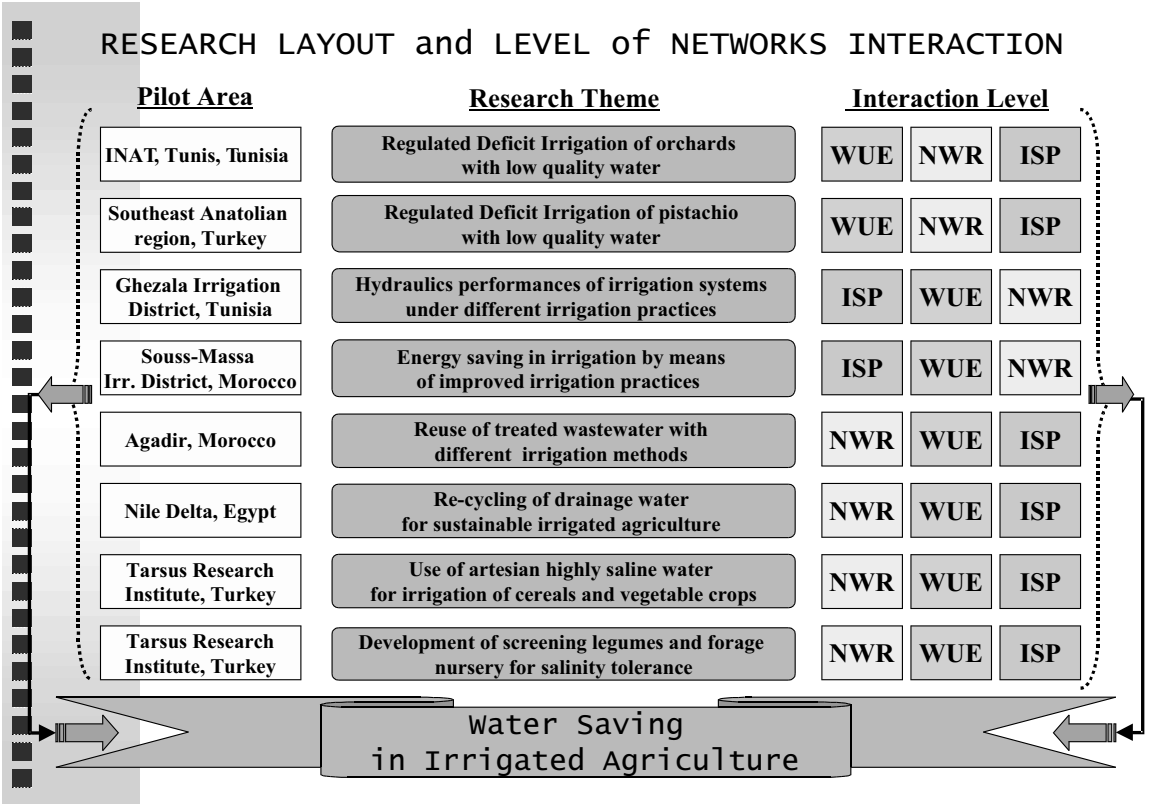

Fig. 1. Conceptual framework for water saving in irrigated agriculture

The deliverables of the project include many important tools which were missing in the most of developing countries in the region (e.g. guidelines for deficit irrigation strategies, guidelines for optimal use of treated wastewater, saline water and drainage water in irrigation, new databases on water demand, software packages, geo-referenced databases, etc.). Moreover, at some sites (Morocco, Egypt and Tunisia), the experiments were carried out in cooperation with the farmer's associations and also at the private farms which is of particular importance because it facilitates the transfer of the research findings to the direct water users and contributes to the implementation of new management strategies on the ground. In Tunisia, at experimental site of Mornaq (INAT), a reference station has been established for the continuation of experimental work on deficit irrigation practices. At the Ghezala - Teskraya Irrigation District (Tunisia), the first test of a new technological tool ("ACQUACARD") for improvement of the performances of pressurised irrigation systems has been done. In Turkey, at the "Pistachio Research Institute", several meetings with pistachio growers were held presenting the deficit irrigation strategies with different fertigation practices. In Egypt, at Harris-Behira Governorat (Western Nile Delta), the process of development of the water user association has initiated. All these achievements and outputs of the project should represent a strong basis for the setup of a new policy and an integrated program on water saving in the region focusing not only on technical but also on socio-economic and environmental aspects of water management. Certainly, it should contribute in better management of land and water resources as well as the development of sustainable agriculture production and food security in the Mediterranean region.