3.7 Activities of Foreign Researchers

(1) Associate Professor Salih, A. A.

from Gezira Research Station, Agricultural Research Corporation, Sudan
(December, 1996 - November, 1997)

General

I graduated from Khartoum University in 1975, and obtained a Ph.D. from University of California at Riverside in 1984. My major field of study was soil physics. I joined the Agriculture Research Corporation of Sudan from 1976. Now I am associate Professor at the Land and Water Research Center, Gezira Research Station, Wad Medani, Sudan.

My stay at the ALRC was really fruitful. This prestigious center of excellence is devoted to research pertaining to arid environments. It is well equipped and with Scientific cadre of high caliber. Actually I learned a lot during my stay here, and I owe it to the ceaseless help from all; scientific and administrative staff, the provision of research facilities and the reliable cooperation with fellow scientist.

Abstract of Seminars

During my one year stay at the ALRC I presented 5 seminars covering some of my research activities which are related to some problems pertaining to arid environments like water conservation, compaction and field water management.

1) Effect of Sowing Method and Microcatchments on Sorghum Yield and *Acacia* Establishment in Eastern Sudan

The effect of sowing method and microcatchments on sorghum and *Acacia* seedlings was investigated over two seasons in the traditional rainfed agricultural sub-sector in Eastern Sudan, with the objectives of increasing sorghum yield and improving the survival rate of *Acacia* seedlings in a sorghum-*Acacia* rotation. It was found that planting sorghum in the furrow, or within tied ridges improved soil water storage significantly and increased sorghum yield by 60 and 90% over traditional flat sowing on heavy soils in a dry year, but the increase was not significant in a wet year. L-shaped or semicircular microcatchments improved soil water storage and the survival rate before the subsequent rainy season of *A. senegal* and *A. seyal* significantly over flat sowing. Addition of fertilizer nitrogen to the seedlings improved the survival rates of both tree species.

2) Relationships of Tillage Systems to Soil Physical Properties, Cotton Root Growth and Yield in Gezira Scheme, Sudan

The cracking behavior of Vertisols is assumed to fracture tillage pans that may develop due to tillage, and thus subsoiling is not a common practice on these soils. This field study evaluated the relationships of 3 tillage systems to some soil physical properties, root growth and yield of cotton (*Gossypium barbadense* L.) grown on Vertisols. The tillage systems used included disc harrowing (DH), three bottom disc (DP) and subsoiling (SS). Root and shoot growth were studied during the growing season. Soil properties evaluated included infiltration rate, bulk density, soil penetration resistance and moisture status.

The results indicated that infiltration rate was improved by SS over the other two tillage systems. Plant height and shoot dry matter were significantly higher with SS at latter growth stages. A regression analysis showed that bulk density of the plough pan at 135 days after sowing accounted for 90% of the

observed variation in subsoil root dry weight while soil penetration resistance accounted for 59% of the variation. Subsoiling increased the irrigation production efficiency 25 and 13% over DH and DP respectively, and improved cotton yield. From these results, it appears that subsoiling may be necessary to improve cotton yields in some parts of the Gezira Scheme.

3) *Prosopis chilensis* Root and Shoot Growth in Response to Soil Impedance and Soil Matric Potential

The suitability of *Prosopis chilensis* for reforestation under conditions of high soil bulk density and high moisture stress was examined in a green house study. Root growth was greatly reduced at high bulk density (2.1 Mg/m^3) and high moisture stress (-1.0 MPa). However, adverse effects of high bulk density were greatly reduced at low moisture stress. Rate of root growth was adequate for good tree establishment in soils with medium bulk density (1.7 Mg/m3). *Prosopis chilensis* could be successfully grown on dense soils provided good moisture conditions were available for sufficient time.

4) Response of Wheat to Irrigation Skipping at Different Growth Stages in a Tropical Environment

Three semi-dwarf wheat (*Triticum aestivum*) varieties; Condor, Nielain and Wadi Elniel were subjected to moisture stress by skipping one irrigation at two growth stages in a field study at the Gezira Research Station Farm, Sudan, during season 1995/96 (FS) and 1996/97 (SS). In both seasons, irrigation skipping during early to mid-stem elongation reduced grain yield by 14% compared to the no irrigation skipping treatment. Irrigation skipping during anthesis to dough stage reduced yields by 33% in the warm FS and by 12% in the cooler SS, while combined irrigation skipping at both growth stages reduced grain yields by 38% in the FS and 25% in the SS compared to no skipping treatment. The reduction in yield was mainly due to reduced number of grains per unit area and reduced grain weight. Differences between varieties were not significant. A significant correlation was found between amount of water applied from anthesis to maturity and harvest index (r= 0.64), which indicate the importance of the pattern of supply of irrigation water rather than the amount. Days to reach maturity and irrigation production efficiency (IPE) were reduced by late skipping. In both seasons good correlation was found between biomass production and IPE (r= 0.84 and 0.78 for FS and SS respectively). The study suggested that, large amounts of irrigation water could be saved with acceptable yield loss by irrigation skipping during early stem elongation. The best strategy under this tropical environment is to avoid moisture stress during anthesis through to dough stage.

5) Soil Moisture Balance Studies at the Gash Delta, Sudan

The Gash delta stretches around 100 km in a north-westerly direction from the town of Kassala in Eastern Sudan. Annual rainfall varies from 200 to 400 mm and reference evapotranspiration from 175 to 300 mm per month from winter to summer. Comparing the rainfall amounts and ET, it is clear that drought stress will occur unless irrigation water is applied. The Delta is irrigated by "spate irrigation", where water is diverted from the river into the field for 3-4 weeks. Water that infiltrated and stored in the soil profile is used for production of different summer crops, without further irrigation. To improve the management of this system, a soil moisture balance study was carried for two seasons on two soil types (sandy loam and clay loam) on 6 commercial crops. Preliminary results indicated that more available water was stored in the sandy loam soil and all crops have better root growth than in the clay loam soil. the duration of flooding of the fields could be reduced to 2 weeks in the sandy loam soil without reduction in yield in both soils by simple manipulation of the soil surface with the disc harrow. This finding might help reduce loss of scarce irrigation water by evaporation and deep percolation. The improved sorghum variety

Wad Ahmed has higher water use efficiency and deeper prolific root system compared to the local varieties and is more suitable when stored water in the rooting zone (0-200 cm) is less than 400 mm.

Abstract of Research Results at ALRC

During my one year stay I conducted collaborative research with scientists from ALRC and visiting professors. The results of these studies is summarized below.

1) Effect of Fertilizer Placement and Moisture Stress on Two Sorghum (*Sorghum bicolor* L. Moench) Cultivars

Increased depth and intensity of roots is a major mechanism of improving water uptake and sorghum grain yield. This study was conducted to determine response to fertilizer placement under limited moisture conditions of two sorghum cultivar with different response to drought. in pot and field experiments. Deep placement of fertilizer gave rise to more uniform root distribution in the non tolerant cultivar Tabat, whereas surface application resulted in a higher concentration of roots near the surface. Root distribution in the drought tolerant cultivar Gadambalia was not affected by fertilizer placement or soil moisture condition. In both cultivars, nutrient uptake was improved with fertilizer placement, the effect was more pronounced under low soil moisture because of the rapid drying of the surface soil. Surface nutrient concentration resulted in shallow root proliferation and caused rapid soil drying in the surface soil, which might have limited nutrient uptake from this zone especially under dry conditions, compared to more uniform soil water extraction patterns. The improved root growth associated with deep fertilizer placement improved moisture extraction of Tabat under limited water availability. The increase in water use efficiency with 5 and 10 cm fertilizer placement in Tabat was higher under limited soil moisture. Grain yield of Tabat was significantly increased with 15 cm fertilizer placement with limited soil moisture under field condition. Water extraction from a given zone was directly related to the root density in that zone. Fertilizer placement under dry conditions is more important with management systems which cause a significant positional variation than systems which result in uniform distribution.

2) Rooting, Water Uptake and Xylem Structure in Adaptation to Drought in Two Sorghum Cultivars

Several mechanisms have been reported to explain the high tolerance of sorghum (*Sorghum bicolor* (L.) Moench) to drought. The objectives of this study were to identify the role of root distribution, transpiration rate and root and stem anatomy in determining the response of two sorghum cultivars, with high and low drought tolerance, to soil moisture stress. Two levels of water stress were used -0.02 MPa (wet) and -0.75 MPa (dry). In the non-tolerant cultivar, Tabat, root length density (RLD) was highest in the wet and lowest in the dry treatments. In the tolerant cultivar, Gadambalia, RLD was not affected by stress. Total leaf area of Tabat was twice that of Gadambalia, but transpiration per unit of leaf area was higher in Gadambalia. Late metaxylem vessels (LMX) capacity in the stem in both treatments was twice in Tabat as compared to Gadambalia. Drought tolerance in Gadambalia is associated with fewer nodal roots, LMX per nodal root and smaller leaf area. In Tabat, nodal roots per plant were reduced by soil moisture stress from 35.3 to 24.5. The diameter of LMX in stem and root was not affected by stress in both cultivars. The total area of all LMX in the stems of both cultivars was not affected by soil moisture conditions and in Tabat it was twice Gadambalia. In roots, however, this area was reduced by stress in Tabat. Genotypic differences in response to soil moisture stress in transpiration rate were consistent with anatomical structure of the stems and roots.

(2) Associate Professor Lux, A.

from Comenius University, Slovakia
(May, 1997 - October, 1997)

Summary of the Seminars

Following seminars were held:

① Biology and in vitro cultures of Karwinskia species - plants from semi-desert areas of Mexico producing toxins with antitumoural effects
② Investigation of protein bodies in cereals at the Dept. Plant Physiology, Faculty of Natural Sciences, Comenius University, Bratislava
③ Perspectives of agriculture in Northern Mexico - personal opinion
④ Some structural adaptations of plants to environmental conditions (ecological anatomy of plants)

The contents of the seminars are summarized as follows:

1) Biology and In Vitro Cultures of Karwinskia Species - Plants from Semi-Desert Areas of Mexico Producing Toxins with Antitumoural Effects

Shrubs and small trees of genus *Karwinskia* (family *Rhamnaceae*) are native in America. Some of the species growing in semi-arid conditions are known to be toxic with paralytic effects. However, use of some of these anthracenone toxins in medicine was shown and particularly toxin T-514 was included into a screening program of the National Cancer Institute in Bethesda, Maryland, U.S.A., and there is a patent granted by the EC.

Screening of Mexican species showed great variability in toxin composition and two species were found to be the most suitable for isolation of T-514, *K. humboldtiana* and especially *K. parvifolia*. The content of this compound is not only species specific, but there is also a great individual variability as well as great local variability, dependence on external conditions. The present source for T-514 production - collected fruits from natural conditions is not satisfactory. Study of the biology: structure, physiology and in vitro cultivation of *Karwinskia* species was conducted at the Dept. Plant Physiology, Comenius University, Bratislava and in Institute of Chemistry, Slovak Academy of Sciences, Bratislava in collaboration with Faculty of Medicine , U.A.N.L. Monterrey, Mexico.

Chemotherapy in general and cancer chemotherapy in particular, is designed to be selectively toxic. Studies on plants of the genus *Karwinskia*, as well as on the characteristics and effects of their toxins in mammalian cells brought some new aspects in this field of research. Preliminary investigations showed selective toxicity of T-514 for certain types of malignant cells *in vitro* and *in vivo* (Velazco-Campos et al. 1993, Piñeyro et al. 1994). T-514 was always more toxic to all neoplastic cells than to the most sensitive normal cells. These findings encourages the effort to explore further potential of anti-neoplastic effects of these compounds on other types of tumoral cells of human origin. Peroxisomicine A_1 (T-514) for its potential anti-neoplastic effect is currently under preclinical screening in Mexico.

In *in vitro* conditions there were established tissue, as well as organ cultures (*K. humboldtiana* and *K. parvifolia* - shoot and root cultures), and after multiplication of shoots and their rooting a successful transfer to glasshouse conditions was achieved (Liskova et al. 1994, Lux et al. 1997). This allows clonal propagation of highly toxin producing individuals. Screening of conditions for satisfactory production of toxins demanded *in vitro* is of great interest. Besides T-514 there are also other compounds with similar effects, or they show other possible uses for their antioxidant or antimicrobial characteristic.

2) Investigation of Protein Bodies in Cereals at the Dept. Plant Physiology, Faculty of Natural Sciences, Comenius University, Bratislava

Protein bodies (PBs) are distinct membrane-bound subcellular compartments regularly present in mature seeds, plant storage organs and the parenchymatous cells of the wood during the winter period. The PBs represent the place of deposition of major storage proteins, phytate, lectins and hydrolytic enzymes. Phytate (*myo* -inositol 1, 2, 3, 4, 5, 6-hexa*kis*phosphate) has long been known as the storage form of phosphorus in seeds (Maga 1982), representing from 60% to 80% of total seed phosphorus (Raboy 1990). Phytate is often present in the complex with various physiologically important cations and the mixture of phytate salts is called phytin. Although the majority of the stored reserves in mature cereal grains is present in the endosperm, significant quantities are deposited in the embryo, including the embryonal axis. When seeds germinate, storages are degraded to supply the embryo with amino acids, carbohydrates, inorganic phosphate and cations to support post-germinative growth of the seedling. Utilization of carbohydrates and proteins precedes that of lipids, and it starts earlier in the axis compared to the rest of the grain. Thus the storage reserves located within the cells of the embryonal axis play a crucial role during the early growth stages prior to the onset of metabolite supply from the endosperm.

Ultrastructure of PBs was investigated in epidermis and cortex of radicle, epidermal and parenchyma cells of coleorhiza and scutellum from mature grains of barley (*H. distichon* L.) and maize (*Zea mays* L.) - Lux et al. 1992, Mikus et al. 1992, Lux et al. 1997. The PBs varies in size and structure and considerable variability was observed between different tissues. PBs often contained more than one type of reserve, mostly protein and phytin and additionally, they often contained more than one type of protein, judging from differences in the structure of PBs matrix. This was most evident in case of PBs from embryonal cells, where heterogeneity in PBs structure was observed even within one cell. PBs in epidermal cells of the radicle were smaller in size and simpler in their structure than those from the cortex. They contained a homogenous proteinaceous matrix and no globoid crystals - the place of phytin deposition. PBs of radicular cortex, coleorhiza and scutellum differed in the structure of their matrix and contained globoid crystals of variable size. The size of globoid crystals reflected a tissue specific distribution of phytate. In maize and teosinte (*Z. diploperennis* Iltis, Doebley and Guzman) grains the majority of phytate is localized in scutellum and in the embryo, however, the phytate concentration was significantly higher in teosinte than in maize Mikus et al. 1995. Elemental composition of phytin, determined by EDX analysis revealed considerable amounts of P, K and Mg in globoid crystals from all embryonal tissues of investigated species. Less than half of the globoid crystals contained detectable amounts of Ca, Fe and Zn, present especially in globoid crystals of radicle and coleorhiza. The potential significance of observed variability in the structure of protein bodies for dry and germinating seeds is discussed.

Another possible practical outcomes of this study are connected with the fact that phytate if present in food can induce deficiency of some elements mainly Fe and Zn, forming insoluble non-digestible complexes.

3) Perspectives of Agriculture in Northern Mexico - Personal Opinion

Coahuila is one of the states of Mexico located in the Antiplane with low precipitation and high evaporation. The types of natural vegetation are different forms of matorral. Agriculture is of a temporal type or of irrigation, there are places with induced grasslands. The soil is mainly of xerosol and regosol types.

To solve the difficult problem of the lack of water in Coahuila and especially in the region of Saltillo is definitively the principal program of all inhabitants of the state Coahuila in the present time.

The solution must be found in a complex form, including management of ground and superficial

waters and economical use of obtained and distributed water. The important part of water use is agriculture. In the same time the agriculture can influence - and in the present time it is already influencing - the quality and quantity of available water in Coaxial. For this reason it is very important to evaluate the price of water in agriculture. This price must be calculated not only as a price needed for the construction of wells, the distributing system and the system of irrigation. The price is in fact much higher.

In the present time the whole area of Saltine is limited in quantity of available water and this quantity is decreasing. This means, that the same water which is lost for the bad management in agriculture is missing for the use in industry - and even worse - as drinking water. The bad management of water in agriculture means the cultivation of inadequate plants, ineffective irrigation resulting in high evaporation etc.

The other side of the present water management, resulting in continuous decrease of water, available in the area, is the environmental aspect. In the corridor between the towns Saltine and Monterey (Nuevo Leon) there is expected formation of an industrial zone before the year 2000. This governmental program started several years ago. this perspective requires to start with changes in a great scale in the different spheres. One of the principals is to provide water for this zone. Related to this, it is necessary to include various other programs.

The principal is to understand and to explain to the people that reserves of available water in the region of Saltillo are not sufficient for the planned perspectives, especially under the present way of water management. The another importance is the protection of ground water aquifers in the limestones and recharging of these aquifers. Related to this program it is indispensable and necessary to evaluated the present and future agriculture in the zone and in the surroundings. This includes:

a/ utilization of water of the best quality only as a drinking water

b/ changes in the present structure of agriculture

c/ reduction and subsequent elimination of the whole ineffective agriculture from the zone

d/ evaluation of the use of treated waste waters in agriculture

e/ stimulation of more effective irrigation

4) Some Structural Adaptations of Plants to Environmental Conditions (Ecological Anatomy of Plants)

Environment affects structure of plants and many of the structural differences of plants from different habitats can be interpreted as evolutionary adaptations to the specific conditions. (Discipline studying relationship between plant structure and environmental conditions is ecological anatomy). The ways of adaptations to the particular environment differ between the species. The water availability is the principal factor affecting the structure of plants. Species adapted to dry habitats are classified as xerophytes.

Xeromorphy is the most clearly visible in leaves. This include usually the small ratio of the external surface to its volume resulting in small and compact leaves. Changes in the internal structure are often the reduction in cell size, the increase in the thickness of the cell walls, thick mesophyll, small intercellular spaces and dense network of veins. However, not all plant from the dry conditions posses clear evidence of xeromorphy. In *Karwinskia humboldtiana*, one of Mexican medicinal plants growing in areas with low precipitation, the leaves were found to be of “mesophytic character”. The only structural adaptation to dry conditions with high light intensity is a thick wax and cuticular layer on the leaf surface (Lux and Earl 1989). The wax was almost absent in plants grown in vitro with a high relative humidity (Hanackova et al. 1997).

Another way how some plants survive extreme drought is succulence, development of water storage tissues in some organs. One of the species with extreme stem succulence studied by us is *Echinocactus*

platyacanthus. Three years old seedlings of this species were found to be able survive 18 month without water. Even small seedlings, three month old, with the stem size ca 10 mm and fresh weight only 0.2 g were able to survive total drought of three month in temperature 40 ^{o}C day / 20 ^{o}C night. The water lost during this time was approximately 87%. This result prove the survival power of these plants. The structural characteristic of these plants is extensive water storage parenchyma in the stem cortex. Another feature is abnormal development of xylem, segmented by radial parenchyma sectors. This xylem structure was found to be present in both stem and root and it is believed to allow volume changes connected with dehydration without a danger of mechanical injury of tissues during shrinking.

Structural difference were studied also in sorghum cultivars (*Sorghum* bicolor) differing in drought tolerance. Tolerant cv. Gadambalia had more developed sclerenchyma in stems and roots than non-tolerant cv. Tabat. The most prominent was the thick sclerenchyma sheath surrounding vascular bundles in the stem. Late metaxylem vessels in stems and roots the principal structure delivery water and solutions in these organs were compressed also. The vessel diameter in both varieties was similar, however, their number per plant being higher in cv. Tabat. The different soil water conditions almost did not effect the drought tolerant variety Gadambalia. In non tolerant variety Tabat the number of vessels in stem and root has increased in well watered conditions, increasing also the total vessel area in these plants. The increase of relative capacities to deliver water and solutions in these plants under favorable conditions might be advantageous if the water supply is not limited. The "conservative" strategy of drought tolerant variety, not changing these parameter in differing conditions is supposed to be advantageous if the water supply is limited or suddenly decreased.