J Intl Cooper Agric Dev 2017; 15: 48–53

Journal of
International Cooperation for
Agricultural Development

Field Report

Development of Core Agricultural Researcher for Promotion of Rice Production in Sudan

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Received: February 16, 2017 Accepted: March 15, 2017

Abstract. Sudan is the third largest country in Africa that depends mainly on agricultural activities. Among major crops, rice is recently contributing as the fourth source of food after sorghum, millet and wheat. Rice production is very important to fill the gap of food consumption in the country, wherein a total estimated potential area of production is more than 300,000 hectares. In addition, rice produced from the country is being exported. In the White Nile State, rice production plays the major economic activity and a source of employment for the rural population. The national average yield of rice has increased to 5 t/ha during the last ten years as a result of introducing newly released technologies. The research plan for rice in Sudan (2015–2019) consisted of: rice enhancement and evaluation, crop husbandry development, dissemination and out scaling of released varieties, cultural practices and establishment of innovation platform.

Key words: Rice, research, technology, promotion and production

I. Outline of agriculture in general in Sudan

1. Statistics of major crops and rice

Sudan with an area of 1.8 million square kilometers is third largest country in Africa. The country has great-untapped potentialities for agricultural development. About one third of the total area is suitable for crop or pastoral production, but only small fraction of this land is under intensive use. Despite this fact, the country is heavily dependent on agriculture. The agriculture sector dominates the economy. It provides the livelihood for over 80% of the population and also provides a big share of inputs for the country agro-industries. Main agriculture products are sorghum, sesame, cotton, Gum Arabic, livestock and other products.

Sorghum (*Sorghum bicolor* (L) Moench) is an important food and feed crop. Semi-arid tropical Asia and semi-arid tropical Sub-Saharan Africa grow about 60% of the world area[1], while Sudan grows about 24% of Africa area and produces 17% of its production. Sorghum is grown annually throughout the country on an area of about 5.25 million hectares, representing 45% of total cultivated land. About 90% of the area is rainfed, while only 10% is under irrigation, floods and basins. The main growing areas are the central rain lands, particularly Gedarif, Sinnar and Blue Nile States, and it is also grown in Southern Kordofan and Southern Darfur states. The national average yield is 595 kg/ha. The total production is estimated as 3.5 million tones[2].

Sesame (*Sesamum indicum* L) is an important oil seed crop, grown extensively in the tropical to subtropical semi-arid zones in the world. Sesame is grown mainly for its seeds which contain about 50% edible oil and 20% protein. Sudan is one of the main sesame producing countries. It is almost exclusively produced under rain-fed conditions, by both the mechanized sector and the traditional farming system in a belt characterized by summer rainfall of 300–800 mm in about four months during June to September. The cultivated area is about 1.1 million hectares; with av-

erage yield of 357 kg/ha. The total production is estimated as 405,000 tones[3].

Cotton is one of the most important cash crops produced in Sudan. Cotton is grown in Sudan under various topographical and environmental conditions, utilizing various methods of irrigation, and using different applications of chemical inputs. It is cultivated in clay soil in Gezira scheme, in silt soil in Tokar of Eastern Sudan and in heavy clay soil in Nuba mountain, Blue Nile and Gedarif areas. Categorized by system of irrigation it is grown by gravity and pumps in Gezira, Rahad, New Halfa, White Nile, Blue Nile and Suki Scheme, by Flood in Tokar Delta and by rain in Nuba Mountain, Blue Nile and Gedarif areas.

Cotton farming is a livelihood issue and a way of life for more than 300,000 Sudanese farmers. The intensive labor demand in cotton farming and cotton- based industries provides employment, reduces poverty, improved lives and encourages settlement in rural areas. Commercially cotton had been grown in the Eastern Sudan (Tokar Delta) since 1867 where traditional organic farming is still in practice. Sudan produces five types of cotton; namely the Extra-fine, Fine, High-Account, Medium and Course-count cotton. The Sudan as one of the cotton producing countries produces both irrigated and rain fed cotton over large areas fluctuating between 0.5 million hectares in 1970th dropping to 192,780 hectares in 2010th. The production fluctuated widely between 713,000 tons in 1970th to below 100,000 tons in 2000th. The national average yield is about 1,428 kg/ha.

Rice is one of the most important food crops in the world and the second largest cereal crop. It is the staple food of nearly one-half of the world's population. Sub Saharan African countries produce about 21.6 million tons of rice and they introduce 32% of the global rice market to fill the gap between their production and their demand[4]. This was a result of population growth and the increasing of consumer preference in favor of rice in urban area[5, 6]. Rice is one of cereal crops which is recently contributes as four food source in Sudan after sorghum, millet and wheat. Rice production is very important to fill the gap of consumption and then to export for Arabic gulf countries to catch hard currency. Sudan has a total estimated potential rice area of more than 300.000 hectares. If this area properly utilized, it would suffice the local consumption demand to fill the gap for non-course food grain. In the Gezira, the crop was introduced by the technical assistance of China in 1973 through 1980. During this period 12.000 hectares were cultivated under irrigation system attaining 3.5 to 7.6 t ha^{-1}. Rice production constitutes the major economic activity and a key source of employment for the rural population at White Nile State in the Sudan; the crop is cultivated as irrigated and flood ecosystem in this State. Low yields of (0.98−1.2) t ha^{-1} were produced due to the using traditional varieties with low inputs that are not adequate to enhance productivity. The average yield of rice in the Sudan has been increased to 2−5 t ha^{-1} during the last ten years as a result of introducing and releasing new varieties but it is still far less than other leading rice-growing countries. The total cultivated area of rice in Sudan during the last ten years is about 8000 ha. The total production is about 25,000 ton. The annual consumption increases during the last ten years from 40−60 thousands metric ton, although Sudan import about 40,000 metric ton, Annually[7].

Aerobic rice is a production system where rice is grown in well-drained, non-puddle and non-saturated soils. Water requirements can be lowered by reducing water losses due to seepage, percolation and evaporation. Aerobic rice is specifically developed rice, combining drought tolerance of upland rice and yield potential of lowland rice. Therefore, aerobic rice is "improved upland rice" in terms of yield potential, and "improved lowland rice" in terms of drought tolerance. Aerobic rice varieties have the ability to maintain rapid growth in soils with moisture content at or below field capacity, and can produce yields of 4−6 t/ha with a moderate application of fertilizers under such soil water conditions. Aerobic rice can save as much as 50% of irrigation water in comparison to lowland rice. An aerobic rice varieties (Kosti 1, Kosti 2, wakra and Umgar), new released varieties were recommended for commercial production for aerobic rice areas in the Sudan[8]. In 2010, the Government of the Sudan and government of Japan signed the agreement for Capacity Building Project for the Implementation of the Executive Program for the Agricultural Revival by Japan International Cooperation Agency (JICA) with Federal Ministry of Agriculture. The project duration was 6 years. Through the experimental activities of the project, a model system of human resource development and organizational capacity development of the ministry of Agriculture has been developed. Planning, implementation, monitoring and evaluation for promotion of rice production enhanced (Fig. 1).

2. Cropping system

Cropping systems vary among farms depending on the available resources and constraints; geography and climate of the farm; government policy; economic, social and political pressures; and the philosophy and culture of the farmer. A cropping system refers to growing a combination of crops in space and time.

An ideal cropping system should:

- Use natural resources efficiently
- Provide stable and high returns

Fig. 1. Agricultural Research Corporation (ARC) action in collaboration with JICA project in the area of rice research.

- Do not damage the environment.

Benefit of cropping systems:

- Maintain and enhance soil fertility.
- Enhance crop growth.
- Minimize spread of disease.
- Control weeds.
- Inhibit pest and insect growth.
- Increase soil cover.
- Use resources more efficiently.
- Reduce risk for crop failure.
- Improved food and financial security.

The cropping systems followed in dry lands differ from those followed under normal conditions, only those crops can be grown under dry land conditions which require less water to complete their life cycle or which can stand or yield under drought conditions. This can include both drought resistant and drought tolerant plants. In addition, plant can be to sustain the growth of plants.

Commonly practiced cropping systems are:

- Monocropping (practiced in large area in the rainfed sector)
- Crop rotation practices (practiced in the irrigated schemes)
- Intercropping systems (irrigated and rained areas)
- Mixed cropping systems (small scale area under rainfed conditions)
- Ratoon cropping (Sugar cane schemes)
- Agro-forestry (savanna)

Growing the same crop year after year in the same field is called monocropping. In contrast to monocropping, in crop rotation practice crops are grown in a planned sequence from season to season within a year or from year to year.

This planned crop rotation sequence could be:

- Three-year period i.e. three-year crop rotation, e.g. Year 1: sorghum; Year 2: groundnut; Year 3: cotton; Year 4: will be sorghum again.
- Four course rotation (cereal crop, legume, cotton, fallow)
- Five course rotation (cotton, wheat, fallow, groundnut, sorghum)

Intercropping or mixed cropping:

Adverse weather conditions like delay in the onset of rains and/or failure of rains for few days to weeks some time or other during the crop period is very common in the rain-fed sorghum growing areas. Such situation results in economic losses to the farmers due to the partial or total failure of sorghum crop. To overcome this situation, following sorghum based cropping systems like intercropping or mixed cropping in rain-fed sorghum growing areas is adopted. With particular reference to dry land agriculture, an intercropping system needs to be designed in such a way that in the case of unfavorable weather, at least one crop will survive to give economic yields, thereby providing for the necessary insurance against unpredictable weather. In case the year happens to be normal with respect to rainfall, the intercropping system, as a whole, should prove to be more profitable than growing either of the crops alone.

Intercropping refers to growing more than one crop in the same land area in rows of definite proportion and pattern. Mixed cropping refers to simultaneously growing more than one crop in the same land area as a mixture. Unlike in intercropping system, in mixed cropping the crops are grown without any definite proportion or pattern. Mixed cropping of Sorghum-pigeon pea is most common. Mixtures with pigeon pea, bambara, cowpea and even with pearl millet and other cereals, vegetables, etc. during Autumn are practiced under different situations.

Agro forestry is an integrated approach of using the interactive benefits from combining trees and shrubs with crops and/or livestock. It combines agricultural and forestry technologies to create more diverse, productive, profitable, healthy and sustainable land-use systems.

3. General constraints

- Climate change and drought
- Marketing (infrastructure)
- Finance
- Low yield of crop

- Poor cultural practices and crop management
- Mechanization
- Pests (insects, diseases and weeds)
- Research capacities: shortage in laboratory equipments, chemical and spare parts is a problem
- Seed production system
- Biotechnology
- Technology transfer
- Scarcity of funding for research

II. Outline of rice cultivation and marketing

1. Planting method

Rice crop is cultivated as irrigated and flood ecosystem in rice growing areas in the Sudan (upland and lowland). Most of cultivated area is traditional under flooded conditions in the White Nile state. The method of cultivation is direct sowing under rain fed conditions with an annual average rain fall of 280 mm from July to end of August. The areas cultivated by rice are then subjected to floods from the White Nile River till the time of harvest in late November or early December. Harvesting the crop is practiced in the water and then transferred by small boats to outside the field. Other methods of planting were:

- Directly by the hand (broadcasting + ridging)
- Directly by hand (on flat in holes- 25 × 25 cm, 5–10 seeds per hole)
- Planter (seed drill) in rows, 20 cm apart.

2. Management till harvesting

Under submerged conditions in the White Nile state, the area was cultivated by rice directly in the rainy season (July–August) and then subjected to floods from the White Nile River till the time of harvest in late November or early December. Harvesting the crop is practiced in the water and then transferred by small boats to outside the field.

Under aerobic (upland) conditions in the Gezira state and other rice growing areas, the land is well prepared by disk harrow and leveling. The planting time was first to mid-July. The crop was sown in rows (seed drill), 20–30 cm apart, using a seed rate of 70 kg/ha. The fertilizers were applied at the rate of 86 and 43 kg/ha^{-1} in of the form of urea and triple super phosphate, respectively. The triple super phosphate was applied as a basal dose during final land preparation and the urea was top dressed in two equal split doses one at 21 days after sowing and the other before panicle initiation. Hand weeding was performed three-four times per season. The irrigation was scheduled every 5 to 7 day intervals according to weather conditions and crop stage until plants reached maturity. After maturity, the crop was harvested manually, then dried and threshed.

3. Critical problems faced in cultivation

Aerobic rice describes a management adaptation to reduced irrigation water supplies but, due to reduced intervals of flooding in this system, this requires revised weed management approaches to reduce costs and provide effective weed control. Low plant density and high gaps encourage the growth of weeds, and in many cultivars, result in less uniform ripening and poor grain quality. On the other hand, very high plant stand should be avoided because it tends to have less productive tillers, increases lodging, prevents the full benefit of nitrogen application, and increases the chances of pest damage. Also, methods of planting, planting date, row spacing, and seeding rates of aerobic rice have important factors affecting plant competition for light, water, nutrients, and space.

4. Marketing of rice

Up to now there is no problem for rice marketing due to existence of rice production deficit, but by the increase of rice production it became very important to develop marketing methods, that have a link with post harvesting-if we targeting the global markets. It is necessary to encourage cooperation establishment for financing production and marketing that could solve basic problems. Today, there is no problem facing marketing as the local market can accept different types and packs from the local and imported production.

5. Constraints faced to improve rice productivity

- Drought stress (empty seeds)
- Low yield and less quality of local traditional varieties (especially under flooded rice system in the White Nile State)
- Poor crop establishment and management
- High cost of inputs (fertilizer, herbicides)
- Weed competition and lack use of herbicides
- Pest (birds, termites)
- Research capacities: shortage in laboratory equipments
- Biotechnology
- Scarcity of funding for research
- Poor seed production system
- Technology transfer and extension services
- Rice post harvest machines

III. Research for rice development

1. Theme of major researches on rice conducted by ARC

- Released of four aerobic rice varieties namely: Kosti 1, Kosti 2, Umgar and Wakra to grown in rice growing area in the Sudan.
- Variety improvement activities in the White Nile Gezira, Shambat, and Rahad locations includes: Nursery

and field trials for genetic identification, enhancement and evaluation of promising germplasm.
- On station experiments conducted in the Gezira, White Nile and Rahad, Geiniena locations to determine the optimum sowing methods, sowing date, seed rate, plant spacing, herbicides dose, water irrigation and interval and fertilizers doses.
- Demonstration farms of rice technologies conducted in the Gezira, White Nile, Gedarif and other sites under irrigation conditions.
- Transfer of technologies of some rice packages to the farmers in different states.
- Collaboration research program with JICA and other organizations conducted in the Gezira, White Nile and Gedarif States.
- Maintenance and Seed production (foundation and certificate seeds) of released and promising varieties

2. Research plan on rice of ARC

The research plan on rice (from 2014–2018) consisted of the following projects/activities:

a. Genetic enhancement and evaluation of promising germplasm
   - Performance of some upland rice genotypes in multi-location trials under irrigated conditions of Sudan
   - Breeding for high yield and quality in upland rice
   - Evaluation and screening of introduced rice genotypes for yield and adaptation under submergence conditions at White Nile flooded areas
   - Advanced Irrigated rice yield trial
   - National yield and quality upland rice trial
   - Response of Rice germplasm selected under Saline Conditions
   - Physical and chemical mutagenesis for drought and salinity tolerance in aerobic rice
   - Nursery observation of upland, lowland and irrigated rice genotypes introduced from WARDA and IRRI
b. Development and recommendation of improved crop husbandry practices for different eco-logical zones
   - Effect of different tillage systems on the growth and yield of upland rice
   - Effect of different sowing methods on yield and water consumption of upland rice
   - Modification and evaluation of mechanical planting of upland rice
   - Effect of seed rate and/or spacing on growth and yield of lowland Rice
   - Effect of seed rate and/or spacing on growth and yield of upland Rice
   - Response of aerobic rice varieties to planting date under irrigated conditions
   - Response of upland rice to different rates of phosphate and nitrogen fertilizers
   - Response of low land Rice to nitrogen and phosphorus fertilization under irrigated soil condition.
   - Zn-Phosphorus Interaction Effect on upland rice grain yield and Quality under the irrigated conditions.
   - Testing of different types and amount of fertilizer of upland rice
   - Determination of crop water requirement of upland rice
   - Determination of suitable Irrigation scheduling of upland rice
   - The effect of extra and deficit irrigation on yield of upland rice
   - Chemical weeds and weed control of rice

3. Research needs to be conducted
- Biotechnology as the breeding method in rice
- Rhizobium as a crop enhancer and biofertilizer for increasing upland rice productivity
- Post-harvest technologies and processing and value-addition
- Rice insect fauna survey and control
- Monitoring of diseases
- Socioeconomic studies on rice production in the Sudan
- Dissemination and out scaling of released varieties, cultural practices and establishment of innovation platform

4. Financial and/or technical support of donors to ARC for conducting research
- Local finance
- JICA support, (training, equipments, inputs), through the Capacity Building Project for the Implementation of the Executive Program for the Agricultural Revival in the Sudan

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