Sorghum Production under Spate Irrigation Systems

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Practical Note Spate Irrigation

Spate Irrigation Network

Introduction

Sorghum (sorghum bicolor) is the fifth most important cereal globally and feeds around 500 million people. It is especially important for rural people in arid regions. It provides food for household consumption and produces larger amounts of fodder to support their livestock than other grains (Wortmann 2006). Figure 1 shows the global sorghum harvested area (GAEZ 2011).

Sorghum is a type of annual grass with a variation of 0.5 – 5.0 m in height. It consists of fibrous roots growing in the top 0.9 m of soil but can extend to 1.5 m. Sorghum is a physiological marvel. It grows on a large range of soil types and is more tolerant to salinity than maize. It is drought and heat tolerant and more efficient in water and nutrient use than other crops (ICRISAT miscellaneous).

Different varieties are used for different purposes. It is boiled like rice, used for porridge, beer, bread, injera (Ethiopian/Eritrean yeast risen flatbread) and sometimes popped like popcorn. Some types are eaten in the green stage like sweet corn. The whole plant is often used as fodder or the grains as poultry food. The stems are used for building, fencing, weaving or firewood. They yield sugar, syrup and even bio fuel.

The living plants are used for windbreaks or for covering other crops. Further sorghum is used for liquor, industrial alcohol and vegetable oil.

Sorghum can be grown as a ratoon crop. Ratooning is when the stem of sorghum is cut at ground level after the first planted crop reaches maturity. The plant regenerates and a second harvest of the crop is possible.

In this practical note, the focus is on the practices of sorghum production under spate irrigation in Ethiopia, Pakistan, Yemen and Sudan. Sorghum is one of the main crops cultivated under spate irrigation. It is used for human consumption but also increasingly for poultry feed and fodder. In spate irrigated areas sorghum is a major crop but what is remarkable is that yields different enormously between countries. This suggests that there is a large scope to do better in sorghum production. This note serves to make a comparison between spate irrigated areas with the aim of understanding good practices. Table 1 shows the sorghum yield per country.

The wide ranges in yields observed in the different spate schemes are variously attributed to the unpredictability of water supply, degree of control that farmers can exercise over spate flows, farming skills and soil moisture practices and the priority that farmers give to spate irrigation, considering that many of them work in other sectors because of the low return to labour in spate irrigation. This indicates that there are important opportunities to improve crop yields through the adoption of better crop and moisture management practices (Van Steenbergen et al. 2010).

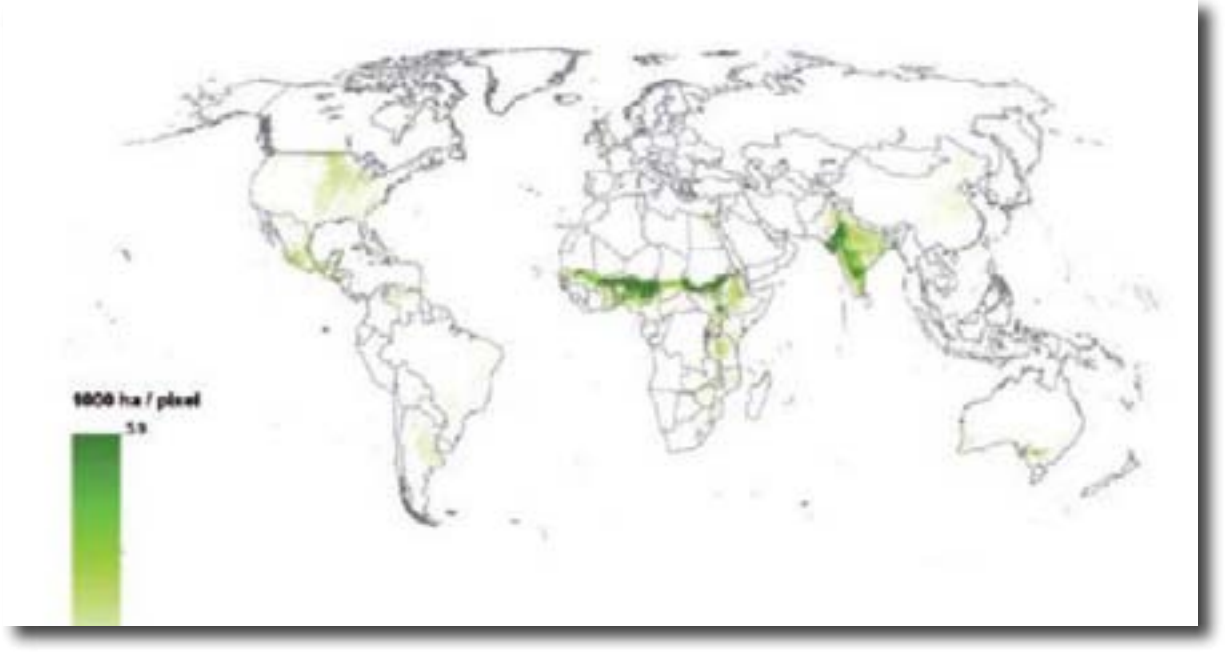

Figure 1: Sorghum harvested area (Source: GAEZ 2011)

Country	Sorghum usage	Yield (kg/ha)
Ethiopia	Sorghum (grain)	1000-1500 (Steduto et al. 2012)
Eritrea	Sorghum (grain)	800-3750 (Van Steenbergen et al. 2010)
Pakistan	Sorghum (grain)	360-550 (Van Steenbergen et al. 2010)
	Sorghum (fodder)	1500-4800 (Van Steenbergen et al. 2010)
Sudan	Sorghum (grain)	600 (Steduto et al. 2012)
Yemen	Sorghum (grain)	600-3500 (Van Steenbergen et al. 2010)
	Sorghum (fodder)	810-11500 (Van Steenbergen et al. 2010)

Table 1: Sorghum yield per country (kg/ha)

Furthermore the potential of sorghum is relatively undeveloped. It has a remarkable array of untapped variability in grain type, plant type, adaptability, and productive capacity, but it just does not receive the attention it deserves (Vietmeyer 1996). The potentials and challenges of this remarkable cereal will be discussed further in the recommendations.

Eritrea

Sorghum is the staple food in Eritrea. Sorghum is locally used for porridge and injera. Sorghum cultivated under spate irrigation is found in the Eastern Lowlands (Sheeb, Wadi Labka, Foro, Bada) and Western Lowlands (Gash Barka region). In the Eastern Lowlands, sorghum yields are high compared to other countries having spate irrigation systems. Sorghum yields of 3750 kg/ha with occasions of 6000 kg/ha are reached. This is due to a highly efficient moisture management (Haile et al. 2008).

In the Eastern Lowlands, land is ploughed before the irrigation season to open up the soil. Ploughing is done by using oxen, camels and in some circumstances donkeys and cows. After the fields are irrigated, farmers plough again and carefully mulch the soil. The sooner this takes place the more moisture will be stored. In some cases the ploughing and mulching is done twice and this assures that soil moisture is preserved for several months (Haile 2003).

Planting takes place in September or if the flood arrives very early, even in August. The command area is relatively compact. This makes it possible to have two or even three spates on the land and to store more moisture in the soil. A fully irrigated field receives at least three irrigations turns of 50 cm depth each. Most of the farmers use seed for planting which is either purchased from the market or from other farmers. Some farmers use their own seed from previous year's harvest. For row planting farmers make use of a method called Jeleb. This is where a wooden bar is attached to the plough and seeds are dropped in rows while ploughing. The seeding rates for sorghum ranging from 24 to 40 kg/ha, which is more than the optimum. This ensures adequate crop stand and fodder (Tesfai & Stroosnijder 2000).

Seeding depth is about 15 cm with a spacing between rows of 30 cm. Sorghum is harvested in December with threshing performed 2 to 3 weeks after harvest when the grain is fully

Figure 2: Sorghum field, Eritrea.

Figure 3: Drying red sorghum, Eritrea.

dried. If enough moisture is available, sorghum can be ratooned for a further two months. Ratooning provides a high return on investment. Unlike new seedlings, a ratoon crop is able to extract remaing moisture that is deep in the soil profile. Because land does not require prepation or sowing, ratooning saves on material and labour. The harvesting period is also shorter for a ratoon crop. After the second or third ratooning the plant is cut and used as feed for livestock (Tesfai 2001).

Farmers criteria in choosing a sorghum variety depends on many parameters. For instance in the Sheeb area, the parameters are germination rate, vulnerability to pest and diseases, vulnerability to water stress, uniformity in emergence, uniformity in size, panicle size and yield, thickness of stalk, palatability of stalk, colour and ease of grinding the grains with stone.

Several varieties with various desirable characteristics have been released by the national and regional research institutions such as wedi-ahmed, arfa-gedemek, tabat, mailo. One of the most popular varieties, i.e. 'tetron' was however discovered by farmers in nearby Sudan. Tetron gives high yields and has shown unexpectedly good resistance to drought and pest infection. Other varieties of sorghum grown in Eritrea are among others `Hejeri'. It was introduced from Sudan. This sorghum has a well-branched root system, high yielding, short stalked and is very efficient at extracting residual moisture from the soil (good ratoonability). It has white grain and a compact head. Other sorghum varieties are:

- Feterita: A white grain variety which produces darker flour. It has a short growing season and short stalks. Farmers prefer it less for consumption than Hejeri but it has less bird problems.
- Hartsetsa: A red grain variety which produces a greyish flour. It has a growing cycle of three months. It has an intermediate stalk, compact head, a high yielding but a poor ratoonability. Good for human consumption.
- Durra: A tall, open headed and early maturing variety. It has a good ratooninability. The seeds are red. However it has a low yielding and is more cultivated as animal feed than for human consumption (Ogba-Michael 2006).

Relatively high yields are obtained in the eastern lowlands of Eritrea. The water management practice there is to divert as many spate flows as possible to a relatively small area; ideally, farmers hope to achieve two or three irrigations before planting. The result of this approach is that in a good year harvests in Sheeb can be larger than in most spate system elsewhere in the world. (Van Steenbergen et al. 2010).

However according to Ogba-Michael (2006) there are still some improvements that could increase sorghum yield in spate irrigated areas of Eritrea:

- Improve row planting: The system of row planting exists but is not done on an efficient way. The row is normally not straight and the spacing between rows is not uniform. Oxen driven row planters can be introduced.
- Reduce plant density: Within row seeding is too dense to permit the plants to perform to their best potential. The farmers do some thinning of the plants for forage but it is done so late that it cannot minimize the effects of intense intra crop competition within the sorghum stand. As a result, the panicles produced are small in size and the shoots are too thin and weak. However, dense planting is done to suppress weeds and farmers also need fodder for their animals. Dense planting can be better achieved by having properly spaced rows of sorghum, with an intercropping crop of fast growing legume in the inter row spaces.

Ethiopia

Ethiopia is the largest sorghum producing country in Eastern and Southern Africa next to Sudan. In Ethiopia, sorghum stands 3rd next to teff and maize in area and the second in total production next to maize. Sorghum production in Ethiopia shows an increasing trend in the past 15 years It covers 16% of the total area allocated to

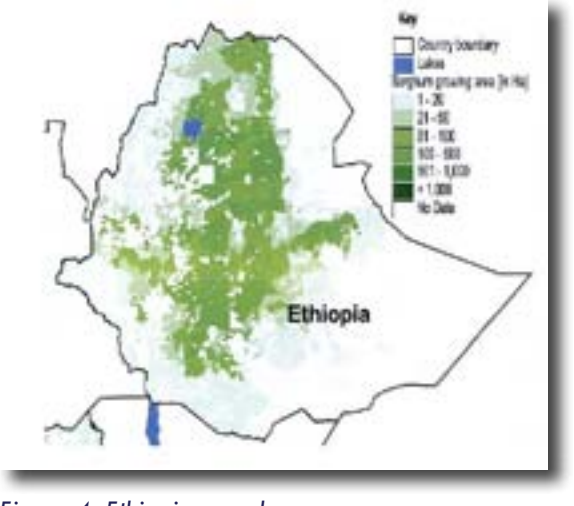

Figure 4: Ethiopian sorghum zones

grains (cereals, pulses, and oil crops) and 20% of the area covered by cereals. It is the second most important crop for injera (staple food of Ethiopians'-thin pan cake) next to teff. The grain is used for the preparation of traditional foods and beverages. Sorghum is cultivated in all regions of Ethiopia in altitude ranges of 400m to 2500m. Oromiya, Amhara and Tigray regions are the three major producers of sorghum covering 86.4% of the total area and 89% of the total production in the last nine years.

In the main agricultural regions in Ethiopia there are two rainy seasons, the Meher (Main) and the Belg (short rainy season), and consequently there are two crop seasons. Meher is the main crop season. The Meher season is overwhelmingly important (96.9 percent of total crop production and 95.5 percent of total cereal production in the country). Only smallholders cultivate crops during the Belg season and yields are smaller in the Belg than in the Meher season. 4.5 percent of national cereal production was produced in the Belg season.

In spate irrigation areas, farmers plough their lands usually with oxen before the flooding takes place. Tied-ridges have been extensively used. For sorghum the spacing of the ridges is 60-75cm. Since tied ridges may result in water logging especially on clay soils when the seasonal rainfall is high, tying ought to be done on every 6m distance whereas in light sandy soils tying every 3 m is practiced.

Sowing in rows and broadcasting are the two common planting methods for sorghum. Moreover, inter-cultivation, weeding and other operations are difficult in broadcasted sorghum. Seeding depth is 3 to 4cm depth. When sowing in rows the row to row spacing range from 60cm to 75cm. Seed rate is 8-10kg/ha and if sowing is by broadcasting a high seed rate of 15-20 kg/ha is used. Sowing dates for sorghum vary depending on the agro-ecology, which in turn depends on the onset of the rainfall and the growing period of the crop (Table 2). In warm and moist soils it takes only 3-5 days for the sorghum seed to emerge, but it may take up to 10 or more days if the soil temperature is cooler.

At some locations, type of sorghum (long/short term varieties) is determined by the timing and volume of the first irrigation. In Gobu for example farmers stock sorghum varieties with growth periods ranging from 60 to 120 days and varied degrees of tolerance to drought conditions. When early signs are good and rainfall already begins in June, they opt for the long duration variety of sorghum while they can still grow as second crop of the short duration varieties. In times of shortage and uncertainty the farmers make use of their short duration varieties and shift the planting period to September.

Harvesting of sorghum is done after observing a black mark on the ear head. The mark is a sign of physiological maturity. The mark can be observed by removing a few seeds from the bottom of the ear head. However, since the physiologically mature sorghum may contain moisture of up to 25-30% the crop is left till the moisture level is reduced before harvesting. If birds are problem in the area or if the farmers want to make the land free for the next crop farmers usually harvest at the physiological maturity and dry it later. Grains are also dried by spreading it in the sun in thin layer. In some areas sorghum is harvested when the crop is matured , but not when it is fully dry . This is done to allow enough time for the ratoon crop to develop.

A large number of pests attack sorghum at various stages both in the field and in the storage. The major pests of sorghum are insects, diseases, striga (parasitic weed spp), and birds. Stalk borers and sorghum shoot flies are the most serious insect pests that affect sorghum in Ethiopia. Angomois grain moth (Sitotroga cerealella) and maize weevil (Sitophillus zeamais (Motschulsky)) are the most common insect pests of sorghum in storage. Furthermore secondary weevils like red flour beetles (Tribolium castaneum) are also a sorghum pest.

More than 40 sorghum varieties with various desirable characteristics have been released by the national and regional research institutions in Ethiopia for commercial production. Of these nearly 20 are on the current recommendation list. The varieties are classified into highland,

Altitude (m)	Growing period	Sowing date	Yield range (Qt/ha)
High (1900-2700 masl)	175-240 days	15 april - 10 may	30-50
Mid (1600-1900 masl)	150-180 days	1-15 may	25-40
Low (<1600 masl)	90-130 days	1-15 june	20-40

Table 2. Sowing dates for different sorghum growing regions

intermediate altitude, and lowland varieties. From the highland, Alemaya 70, Chiro, Chelenko, from the intermediate, Birmash, Baji, and Geremew, from the lowland Gambella1107, Seredo, Meko-1, Teshale, Gobiye, Abshir, Melkam, and different hybrids can be mentioned. Gobiye variety is known for its resistance to striga (a parasitic weed species).

Local cultivars are preferred by the farmers in many parts of the country. This is due in part to their high biomass that makes them good forage sources. In many parts where 'shilshalo' is practiced farmers usually plant thick stand of sorghum and they thin by shilshalo when the plants reach about knee height. The thinned out plants are given to their animals. Lower leaves are also removed as forage especially after the plant reaches its physiological maturity as well. Stalks are used for house construction and as fuel wood whereby it will also aggravate the shortage of animal feed.

Sorghum is thinned out during growth. This is mainly farmers lack other sources of fodder. This affects the total yield which is big problem for poor farmers. Further at the moment most sorghum varieties are late-maturing. The acceptance of short duration and short varieties are facing some resistance from farmer's perspectives, while In spate irrigated areas – especially in the lowlands where there is no supplementary rainfall - short duration varieties could be more useful.

Pakistan

Sorghum is locally called jawar in most of the Pakistan's spate irrigated area. Sorghum is basically used as fodder. It is sown in the lowlands plains after flood irrigation in June-August. One flood before sowing is often enough for sorghum to grow.

Sorghum has many varieties. In the last 40 years institutes under the National Agricultural Research System (NARS) have developed several sorghum varieties (see table 3)

However in the spate irrigation areas two type of sorghum varieties are under cultivation, locally called Ratuk and Chutiali. Ratuk is a red coloured grain type. Chotiali has white coloured grains. A wider majority of the farmers in Dera Ghazi Khan and Balochistan prefer the Chotiali variety. It is more drought resistant and are stronger than the Ratuk.

Sorghum is normally harvested in Nov-Dec. The seed application ratio is 40-50 kg per acre, but some farmers apply high seed ratio in order to get green fodder when the plants are 3-4ft above the ground. The green fodder is normally taken through thinning of the weak plants. Intercropping with millet, Tetak and mung beans is also practiced for additional harvest or in case of failure of the sorghum cultivation.

After harvest, the panicles are collected and dried before threshing. This harvesting technique used is called Lao. Men and women collect panicles by cutting it from the top and put it into a cloth called Jholli. When one Jholli is filled up, it is taken to the collection point until the harvest of one field is complete. Normally, the labor is entitled to 1/20 of the Jholli . The labor is also entitled to take as much fodder as they can carry. After getting dried, the panicles are chopped by bullocks and cleaned through spoon type wooden

Variety	Researchers	Year	Characteristics
DS-75	ARI, DI-Khan	1975	Short Season
Pak SS-2	MMRI, Yousafwala	1976	Fullseason, dual purpose, stay green
Ghiza-3	ARI-DI-Khan	1981	Short season, dual purpose drought tolerant variety
DS-97	ARI, DI-Khan	1997	Short season, stay green, dual purpose, drought tolerant variety
YSS-98	MMRI, Yousafwala	1999	Full season, stay green, dual purpose, drought tolerant variety
DS-2003	ARI-DI-Khan	2003	Short season, dual purpose, drought tolerant variety
Johar	NARC, Islamabad	2006	Short season, stay green, dual purpose, drought tolerant variety

Table 3: Sorghum varieties developed by different institutes under NARS (Source: PARC Miscellaneous)

shawl throwing across the wind. Once the grain are cleaned, they are measured in Kg to certain the quantity of harvest.

The remaining parts of the plants are used as dry fodder. Some farmers leave the panicles on the soil to maintain water quantity in the plant for a longer time period. Majority of livestock keepers chop the dry sorghum and mix it with the green fodder. The reaped plants are normally stored at the field in standing shape looking coon. After harvest, the stubble and left over dry leafs are sold to the pastoralists to feed their small ruminants' sheep and goats. In Kachi Plains of Balochistan and Dera Ghazi Khan, pastoralists from the highlands migrate to the lowlands to avoid winter months. The pastoralists depend on the sorghum to feed their animals during their winter stay.

In most areas of Pakistan, green fodder is sold in kg rates. However in spate irrigated areas, people use local weight measures. For instance in the Taunsa Sharif spate area - Dera Ghazi Khan district - it is sold in camel load called (Baar).

Because the spate irrigated lands are not equally irrigated, some farmers in the neighboring vicinity sell the fodder to each other.
During the winter rains in Feb-March, sorghum roots often rejuvenates. The sorghum is then used as green fodder only. During that time farmers also intercrop sorghum with mustard or chickpea to get the off season green fodder.

Sorghum seeds are normally not available in the shops in spate irrigated areas. Large number of farmers keep the portion of the previous harvest to be used as a seed during the following season. So, the same variety is under cultivation in many areas for centuries.

A local weed called jawar marr (sorghum killer) natural grows with sorghum and attacks the root zones. However it does not cause serious damage. Sometimes porcupines damage the sorghum crops due to its sugary characteristics. Common diseases are not known at the local level.

There has been incidence of animal death when livestock eat green fodder from the Choutiali variety. Young plants including the roots and especially the leaves of sorghum contain a glucoside, which upon breaking down releases the poisonous hydrocyanic acid (HCN). This is locally called zahr poison. Farmers are aware of it and avoid their animal to feed them with young sorghum plants.

Comparing to other countries are the sorghum yields in spate irrigated areas in Pakistan very low. According to PARC (miscellaneous) limited use of improved cultivator, inadequate plant population, lack/low level of fertilizer application, weed control measures, and water conservation practices mainly contribute to low yield levels.

Figure 4: Threshing sorghum, Pakistan

Box 1: The Khan Arid Zone Research Institute (AZRI)

The Khan Arid Zone Research Institute (AZRI), D.I. Khan Pakistan developed production packages of technologies including planting method, sowing times, optimum use of fertilizer, plant density, moisture conservation and quality seed for different crops growing spate areas. Research showed that application of 90 kg N ha-1 in three equal splits through soil appeared to be the best method for obtaining maximum sorghum yield, the nitrogen applied through soil appeared superior than foliar application and intercropping 2 rows of sorghum followed by 2 rows of mung bean gave higher monetary return per hectare than sole cropping.

Yemen

Sorghum is the most cultivated grain in Yemen. The grain is used for human consumption and the vegetative part is used as either green or dry forage. Sorghum yields vary from 600 to 3,500 kg/ha (Van Steenbergen et al. 2010). Under spate irrigation sorghum is mainly cultivated in the western coastline wadis and the south-eastern coastline wadis. The amount of sorghum that is cultivated under spate irrigation varies between wadi. In wadi Tuban for instance 47% of the grain sorghums is planted on spate irrigation while in wadi Zabid this is 80% (Worldbank 2002).

The spates occur mainly in the two rainfall seasons called Seif and Kharif . The Seif season is from half February to half of June. The Kharif season is from July to half October. Usually sorghum is irrigated once per season, except for some upstream areas where farmers have the possibility to give sorghum two irrigations (zahw). Depending on the amount of water coming in Seif and Kharif allows farmers to sow sometimes twice a year on the same land and to harvest several times grain in each season (until 5 harvests of grain, 2 in Seif and 3 in Kharif) (Lionel and Floriane 2006)

Farmers plough the land before irrigation. This is to bury the remains of the last harvest and to increase the water storage capacity of the soil. Some small farmers in the upstream areas choose to grow sorghum in both rainy seasons. They are able to because of the high water availability in their area. The difficulty for those farmers is the short time between the harvest and the sowing time for the next season. To overcome this problem they rent a tractor and some workers. Farmers who grow sorghum in one season do not have any constrain of time between seif and kharif cultivation, since they have six months between the last harvest and the ploughing (Lionel and Floriane 2006)

Figure 5: Sorghum in Orchard, Yemen.

Farmers plough their land either with the use of a tractor they rent or by using bulls when they have little land. Farmers sow one week after the irrigation, when the water is well drained. For sowing they make use of a 5 lines seed drill (Lionel and Floriane 2006)

Fodder production is mainly done 2,5 months after sowing or during growth when the plants are thinned out. The farmer cut the sorghum with a sickle and put it on the soil. After three days drying they make packs of about 15 kg of sorghum and carry it from the field to the farm to be stored (Al-Shaybani 2003).

Sorghum needs 3 months to produces grains. When the sorghum is on the soil, women cut the panicles. The panicles are stored a few days to dry until it can be threshed. The stems are packed and stored on the farm for the animals. However, the packs cannot be stored more than 3 months because of termites. Green sorghum is sold as a high value fodder crop on the market (Lionel and Floriane 2006)

Farmers focus on grains that have a short growth cycle, like a local variety of sorghum called ‘tahf’ (Bin Ghouth 2011). There is evidence that shows that local varieties of sorghum have less growth above ground than improved varieties but can tolerate extremely dry conditions by regulating their water use through surface area. This suggests that local cultivars have slightly faster, deeper-growing root systems than improved cultivars and can exploit moisture held deep in the soil profile (Van Steenbergen et al. 2010).

Sudan

At least one-third of the total cropped area in Sudan annually is sorghum. It produces an average of 75 % of food grains in the country. Sorghum is considered as the most important staple food. Most of the crop is consumed locally. A part is used as fodder. Mainly in the Gash (Kassala state) and Toker delta, sorghum is cultivated under spate irrigation.

In most areas sorghum is planted from mid-June to mid-July to avoid pests. However in the spate irrigated areas in Gash and Toker delta it is planted after the flood. Harvesting usually starts October because many of these varieties reach maturity after 105 days. Sorghum is only planted after irrigation has occurred. For seeding farmers use manual hand tools called Garraia and Salluka or they use mechanical wide-level discs. Practice of plant thinning and weeding is done by using wide-level discs and weedicides. Grain harvest is usually manually done by cutting the heads. After this the sorghum heads are threshed mechanically.

Sorghum in Sudan is characterized by wide genetic variaties. Breeders have produced high quality (hybrid) varieties that suit both the irrigated and the rainfed regions. There are high rainfall varieties such as Wad Ahmed, Hybrid 1, Tabat, Hybrid Banar and Hybrid Rabih and low rainfall varieties such as Gishaish, Arfa Gadamak, Butana, Hybrid 521 and Mayo.

Traditionally seed varieties are selected by the farmers from their production. In the Gash delta for instance farmers use a local type named Aklamoy which is the main staple food for the people. The stalks are used as fodder for their animals. Another more common variety is Durra which is also in use in Eritrea. Its flour is fermented to make a local bread (Kisra) or non-fermented porridge (Assyda). Durra flour is also used in Glucose industry. Durra as a rainy season crop occupy an area of about 10-14 million feddans (approx. 4-6 million hectares) to with a targeted production of 2.2-4.2 million tons according to the variable amount of rainfalls annually.

The main varieties of sorghum used for animal fodder are Abu 70 and Sudan Grass. Abu 70 gives 8-12 tons per hectare per annum. Sorghum as fodder is planted by two methods: either broadcasting and ridging or using planters. The planting is usually done in successive time intervals to provide fodder for animals continuously. Mechanical harvesting (chopping) and hand cutting are both practiced. The fodder is usually harvested at evening to fed the animals after milking for proper lactation. The harvest should be on time so as not to lose the nutritive value of it. Any surplus is left to dry and collected in bundles to be stored for off-season or sold in nearby towns and villages to other livestock owners.

The main diseases of sorghum is the covered and loose smuts in non-treated crop seeds. Beside this the major pests for Durra are stem borers and Buda (Striga hermonthica) as a main destructive parasitic pest which mostly lead to about 100% crop failure.

Recommendations

Sorghum is a neglected crop despite its considerable importance as a food security crop for the vast majority of vulnerable population in spate irrigated areas. Further there is a difference in yields in the different spate schemes due to different cropping practices. To increase sorghums potential, several options for improvement are discussed below.

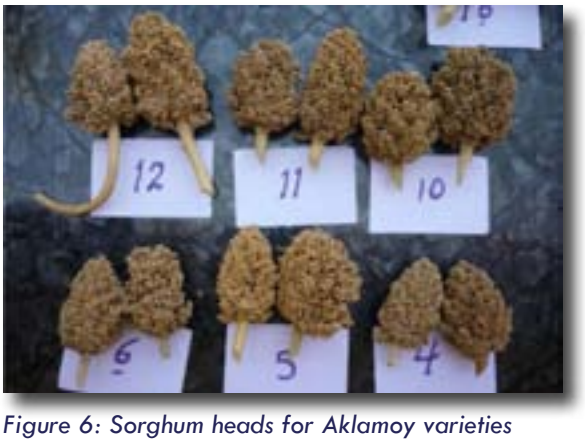

Figure 6: Sorghum heads for Aklamoy varieties produced under spate irrigation Gash, Sudan.

Figure 7: Improved varieties of sorghum for irrigated areas Sudan.

BOX 2: International Crops Research Institute for Semi-Arid Tropics (ICRISAT)

ICRISAT has one of the largest collections of global sorghum germplasm with more than 36,000 accessions in its gene bank. These accessions are maintained under short-term and long-term storage conditions and shared with re- search organizations globally. ICRISAT and National Agricultural Research Systems (NARS) across the sorghum growing areas are working on sorghum genetic enhancement for traits of global and regional importance. During 2010, ICRISAT sent a total of 3,275 seed samples of hybrid seed parents/breeding lines to 21 countries. India received 2,375 samples, followed by Nigeria and other countries. Of the 2,375 samples supplied in India, 888 samples were sent to public sector scientists, 1,380 samples to private sector scientists and the remaining 107 samples to farmers and NGOs. 14 sets of sweet stalk trials consisting of 423 entries were sent for evaluation in India, Philippines, Israel, Mexico, Mozambique and Mali. Further seed samples were also sent to Brazil, Mexico, U.S.A, Australia and China[1].

Sharing varieties

Many different and outstanding sorghums can be found throughout the spate irrigated areas. The varieties have to be made more widely available. Most types are only locally known. These are well proven in the field. Exchanging these varieties could become an important way to improve the long-term stability of the farm production in spate areas.

However there is a need to be very careful in introducing a new variety by external agent, as many factors are important for farmers to assess a variety as successful. It is not just yield but also taste, colour of grain, stalk yield, palatability for livestock, ability to keep, maturing period.

Improving infrastructure seed production

Sorghum production in spate areas is predominantly based on traditional seeds. However sometimes farmers have demand for improved seeds. For instance farmers in Balochistan often buy their seeds. The reason given by farmers is that the viability of sorghum is poor if stored for 2 years or more and there may be years with insufficient floodwater for cultivation. However to non availability of good quality seed, they plant their own local seed (Ian Macdonalds and associates 1987). There should be proper infrastructure for seed production where farmers can get quality seed. There is a need to establish cooperatives among the farmers which will manage the seed production among the farmers and disseminate them from farmer to farmer.

Breeding better sorghum

The objective for improved sorghum breeds is yield reliability. Thus, that farmers can rely every year on a stable yield. Crop-breeding objectives for stabilizing yields include: Raising pest and disease resistance, boosting tolerance to drought and other changeable environmental stresses, improving grain quality in storage and processing. Further it is important to breed multipurpose sorghums. ICRISAT is the main international research institute on sorghum breeds. However table 4 shows some examples of research institutions per country involved in breeding sorghum. In DI Khan in Pakistan and Sheeb, Eritrea, some efforts have been made in improved sorghum varieties in spate areas (Van Steenbergen et al. 2010):

Countries	Research Institutions
Pakistan	PARC, NARC, MMRI, AZRI
Yemen	AREA, ICARDA
Etihopia	INTSORMIL, EARSAM, ECARSAM, EIAR
Eritrea	NARI
Sudan	ARC Sudan

Table 4: Research institutions involved in sorghum breeding.

1) *Ashok Kumar, A., Reddy, B. V. S., Sharma, H. C., Hash, C. T., Srinivasa Rao, P., Ramaiah, B., & Reddy, P. S. (2011). Recent advances in sorghum genetic enhancement research at ICRISAT. American Journal of Plant Sciences, 2(4), 589-600.*

- early-maturing sorghum varieties have been made available to farmers and these give higher yields than local varieties;
- higher-yielding varieties of sorghum have been developed, which are not damaged by birds and which grow better in hot and dry conditions;
- tetron sorghum variety, introduced in Eritrea, has shown better resistance to drought and pest infection.

However although the main focus of research is often on improving crop yield per unit area, the availability and sustainability of a variety is also crucial (Michael, 2000). Local cultivars still fare well in terms of drought resistance, labour inputs, market values, food values and storage, and these factors need to be given more consideration in research (Van Steenbergen et al. 2010).

Strengthening farming methods

Improved farming methods could create higher resistance of sorghum against pests and diseases and could create higher yields . Intercropping with legumes and use of fertilizer, plant density, weed control and water conserving techniques are several examples discussed.

Legume intercropping/ rotations and use of fertilizer

Most spate farmers believe that their soils are naturally fertilized by the fine sediments that are deposited during flood irrigation (Van Steenbergen et al. 2010). However Tesfai (2001) argues that although soils in Sheeb receive inputs of total N, P and K from spate flows, soils are in fact low in N and organic matter. The application of organic fertilizers would thus increase the organic matter content of the soil and improve the water storage and nutrient retention capacity of the soils. This is an argument to intercrop or rotate sorghum with legumes such as guar or mung bean (see figure 8).

Plant density

Plant density is an important factors of yield differences for sorghum. The combination of seed rate for sorghum or a mixture of sorghum with other crops can be very different in similar conditions. A range of seed combinations and plant density should be investigated locally to measure the proportions of grain and fodder yield and to determine whether one particular mix offers distinct advantages and can be recommended in the future.

Weed control

Weed control is essential to have higher yield productivity. Weeds can reduce yields and create harvesting problems. One of the common weed is Striga , which can be eradicated using: deep ploughing before seedbed application, removing Striga before flowering and intercropping with other crops such as sesam, guar or mung bean. Weed control with herbicides (Atrazine, Glyphosate) is less satisfactory in sorghum than in maize for instance, because the sorghum plants are more sensitive to the chemicals. Furthermore input of herbicides and insecticides are beyond the reach of most farmers in spate irrigated areas.

Water conserving techniques

Making productive use of water within the command area through improved field water management and moisture conservation, conjunctive use and improved agronomic practices could increase the sorghum yield in spate areas. Evidence from Eritrea shows that providing adequate moisture helps to double sorghum yields. The secret is a refined system of water management in which the land is ploughed prior to the irrigation season to “open up the soil”. After the fields arewatered they are carefully ploughed and mulched and the sooner this takes place after irrigation, the more moisture is stored. In the Eastern Lowlands the command area is also kept relatively compact. Because of this, it is possible to have two or even three spates on the land, and to store sufficient moisture in the soil to last throughout the season (Van Steenbergen & Mehari 2009).

Figure 8: Legume intercropping; mung bean with sorghum

Research should be conducted in spate irrigated areas on local level to determine the effect of the depth of water stored and infiltrated in a field. Suggested treatments are from 50 to 60 cm of stored soil moisture for a maximum yield of sorghum.

Mechanising farm operations.

In spate irrigated areas, there is often labor shortages in periods which require intense labor (planting, harvesting and threshing). This results in reduced crop yields. Adequate planting, harvesting and threshing can be improved with machinery. A sorghum planter or other types of row planters with special sorghum seed plates can work satisfactory for planting sorghum faster than manually. Harvesting can be done with a mechanical reaper windrower or swather. For threshing small stationary threshers are useful. In overall, these machines are simple in function and operation and not too expensive. However more research have be done for further refinement and modification of the use of machinery in spate irrigated areas.

Figure 9 : Sorghum smut.

Raising pest resistance

Some problems related to pests are caused by nutritional and drought stress. Stalk rot of sorghum and Striga in sorghum are examples. Pathologists, breeders, and agronomists working together could be very effective in developing varieties or techniques for managing Striga and stalk rot in Sorghum. Sorghum that suffer from loose headed smut (see figure 9) could easily be controlled by using an appropriate seed treatment. Vitavax, Ceresan and Agrosan are examples of seed treatment applicants.

Improving bird resistance

There are bird-resistant sorghum types who have seed coats that contain tannins. However those sorghum types are bitter and difficult to digest. The use of physical barriers such as nylon or plastic nets is another method used to protect sorghum. Other more satisfactory solutions have to be found.

Increasing mold resistance

In many spate areas molds destroy grain in the head (panicle) are holding sorghum back. According to Bandyopadhyay (2000), there are three ways to overcome mold:

- First avoidance of the rains. Avoidance can be practiced either by delaying sowing dates or by growing medium- to late-maturing cultivars such that the grain filling and maturity stages occur after end of the rains.
- Second chemical control. However chemical control appears to provide some protection against grain mold, but it is neither practical nor economical except for small fields with valuable sorghum lines that need to be saved.

BOX 3: Striga

Striga is a serious parasitic weed in the lowlands of Wollo, Ethiopia. It limits the production of sorghum, a staple grain crop of lowlanders. However, thanks to intervention from the USAID AMAREW project, use of striga-resistant cultivars as a component of an integrated striga management (ISM) strategy has proved promising. The striga-resistant cultivars Gobiye, Abshir and Birhan released by the Sirinka Research Center for striga-infected fields in the Kobo and Sirinka areas show about a three-fold increase in yield (25-34 q/ha) as compared to control sites. Increased use of the new varieties could produce vastly improved yields in the Kobo area alone. The ISM strategy included an improved striga-resistant cultivar, methods of fertilizer application, and proper crop management practices[2].

2) *USAID AMAREW project: www.oired.vt.edu/amarew/success/striga.htm.*

Box 4: Sorghum market in Ethiopia

The marketing system for sorghum in Ethiopia is poorly developed, and has limited industrial use. In the country, only 11.5 percent of the crop is sold with 74.0 percent being consumed at the local level. The remaining 9.2 percent is retained as seed and the rest is used as payment of wages in kind (1.2 percent) and animal feed (0.9 per cent) (AATF, 2011).

- Finally in most cases, avoidance or chemical control in farmers' sowings is impractical. Host plant resistance is the most preferred method of control and is the backbone strengthened by other methods in integrated disease management strategies.

If cultivars more resistant to mold can be found, then earlier, fast-maturing types could be grown regardless of the humidity during the harvest period.

Grain storage

In spate irrigation areas local storage is most important and serves both local subsistence, trade as well as the conservation of seeds for the next season. In Eritrea traditional grain storage causes 4–14 percent crop loss (Haile et al., 2003), while in Pakistan losses are estimated between 6-20%. (Nawaz 2012)

Improved local storage can serve several purposes (1) protection from high temperature and temperature changes, which can be done by using a roof and insulating material; (2) controlling moisture, which can be done by placing the storage on a dry underfloor, platform, or moisture barrier or by suspending the material; (3) protecting against insects, which may be done by using airtight containers, by smoking and preservatives (many local plants have this function) or insecticides (requiring utmost care in handling); (4) protecting against rodents, which requires securely closing the storage or using rat baffles; (5) protection from domestic animals for instance by fencing off the storage and (6) protection against thieves by locking inflows and outflows to the storage. By bringing grain losses back to 1% improved local storage facilities are a very useful investment (Nawaz 2012)

Marketing

Sorghum production and marketing are affected by lack of government attention and inadequate support from research, agricultural programs and rural development policies. More research and policy decision making have to be done to promote linkages between value chain actors, identify and develop new sorghum products for local, regional and international markets, promote markets for existing sorghum products and alternative uses and improve farmers' knowledge on post-harvest operations. Markets for sorghum flour and foods are undeveloped. These have to be created so that sorghum-based processed foods can be sold in the urban areas such as popcorn, pre or quick cooking sorghum, tannin free sorghum and beer. Further market chains have to be improved to increase the value for sorghum grain that is now sold as chicken fodder. Sorghum from spate irrigated areas is also grown without agro-chemicals usually, which would entitle it to an 'organic' mark-up price.

Drawbacks considered

In Pakistan and Yemen sorghum cannot compete with imported wheat, which is sold at low subsidized prices in the local markets. With increasing prosperity and urbanization, changing taste may lead to deterioration in the position of the local producer compared with that of the importer (Van Steenbergen et al. 2010). Sorghum has lack of status. It is perceived that it is a "coarse" grain, "animal feed" and "food for the peasant classes." Furthermore there are many different preferences for sorghum for different purposes. This means that farmers not always accept/ adapt varieties developed by research institutions.

There is a need - as has been done in India - to repopularize sorghum as a nutritious and tasty crop and promote it as a better alternative to highly water demanding or imported staple crops. Where there are price guarantees and food distribution programs, this should extend to sorghum as well. Sorghum is a crop on which the livelihoods of many poor farmers can depend on, because it is eminently suitable to harsh semi-arid conditions and relatively fail-proof.

Figure 10: Drying red sorghum, Eritrea.

Figure 11: Marketing green sorghum as fodder, Yemen.

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Colofon
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