FOOD SECURITY FOR SOUTHERN AFRICA

Edited by

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CHAPTER TWELVE

SORGHUM AND FOOD SECURITY IN SOUTHERN AFRICA : PRESENT AND FUTURE RESEARCH PRIORITIES of TECHNICAL SCIENTISTS

L. R. House

INTRODUCTION

Maize, sorghum and pearl millet are important summer cereals in the SADCC region. Maize is by far the dominant crop. Generally, maize is grown in good farming environments, sorghum in drier areas and pearl millet in hot dry conditions. The yield potential of maize and sorghum is about the same, but that of pearl millet is less (50-60 percent) when all three crops are well managed and under conditions of no stress. Africa is a traditional sorghum - millet area but maize has encroached over the last 50-70 years and the process is still taking place. The reverse is true in Latin America, particularly Mexico, Argentina, and Brazil where sorghum has encroached into traditional maize growing areas. The Buenos Aires district of Argentina is an example where maize was the dominant crop and it was yielding 1750 kg/hectare. Over a period of years in the early-mid 1970s, the average yield of both sorghum and maize increased to 2250 kg/ha and sorghum replaced maize in the drier parts of the district.

Research on maize improvement in Zimbabwe is well established and has a long history; SR52, a commonly used hybrid, was released 27 years ago. High yielding hybrids have been developed, an efficient seed industry provides quality seed. By contrast, sorghum research has been more limited, with production coming from traditional varieties or imported hybrids. The picture is changing; scientists of Zimbabwe's Department of Agricultural Research and Specialist Services (R&SS) are developing and evaluating

hybrids for farmer use. It is reasonable to expect that locally adapted high yielding hybrids will not only produce higher yields in traditional sorghum areas but will also provide an opportunity for farmers to plant some of their land to maize and some to sorghum in areas marginal for maize.

PRIORITIES FOR SORGHUM IMPROVEMENT

I believe that the exploitation of hybrid vigor is a powerful tool in the plant breeders' hands.A high priority for any crop improvement programme is the production of high yielding varieties and hybrids. These varieties and hybrids are invariably responsive to management inputs and, frequently are superior in yield under harsher growing conditions. Stability of yield is also an important consideration in a breeding programme. Stability of yield can be defined as a consistently good yield over locations and seasons. Stability of yield is an inherent characteristic identified by multilocation testing over seasons. Stability is also achieved from resistance to important biological (disease, insect, weed pests) and environmental stress factors (moisture, temperature, acidic toxic soils, etc.).

An effort has been made to identify and prioritize yield limiting traits in southern Africa (Table 1). We are currently verifying priorities. Progress has been made in developing procedures to screen for resistance to many of these traits. In some instances, ICRISAT's regional programme for SADCC states can adapt techniques developed outside of the region; and, in other cases it will be necessary to undertake developmental research within the SADCC Region.

The priorities for sorghum research at the ICRISAT Center in India for the SADCC Region are spelled out in Table 2.

Table 1: ICRISAT/SADCC Priorities for Sorghum Improvement in the SADCC Region

Trait	BOT	LES	MAL	MOZ	SWAZ	TAN	ZAM	ZIM	SADCC Mean
BREEDING									
Grain yield	10	10	10	10	5	10	5	5	8.1
Fodder yield	6	5	2	2	5	1	1	1	2.9
Crop maturity	7	7	3	3	3	3	3	3	4.0
Plant height	2	2	2	4	2	4	4	2	2.8
Grain quality food	8	8	8	8	8	10	8	5	7.9
Grain quality beer	5	5	5	5	8	5	8	8	6.1
AGRONOMY									
Soil fertility	3	5	4	4	4	4	4	4	4.0
Drought power	7	9	7	7	7	4	4	2	5.9
Weed control	5	5	7	7	5	7	7	7	6.3
Acid soils	3	1	2	2	3	3	4	2	2.5
Water logging	1	1	2	1	1	2	2	1	1.4
PHYSIOLOGY									
Cold tolerance	1	3	1	1	2	1	2	2	1.6
Drought	10	8	5	7	3	8	3	5	6.1
Stand establishment	6	6	2	2	2	4	2	3	3.4
Lodging	3	3	2	-	2	3	3	2	2.6
ENTOMOLOGY STEMBORERS									
Busseola	4	6	2	2	4	4	4	4	3.8
Chilo	6	1	6	6	6	6	6	4	5.0
Sesamia	4	1	2	2	4	2	4	2	2.5
Shoot fly	1	1	2	2	3	2	2	2	1.6
Aphids	5	5	3	3	3	2	4	4	3.6
Midge	1	1	3	3	1	3	3	2	2.1
Head bugs	1	1	1	2	1	2	2	2	1.5
Army worm	1	1	2	4	1	3	3	3	2.3
Locusts	9	2	4	4	2	4	5	5	4.4
Weevils	5	2	5	5	3	6	5	5	4.5
Mites	1	1	1	1	5	1	1	1	1.5
Termites	1	1	3	3	1	2	3	2	2.0
Birds	8	5	7	7	7	6	6	6	6.5
PATHOLOGY									
Grain mold	2	2	5	5	2	5	5	5	3.9
Downy mildew	2	1	4	4	3	3	4	4	3.1
Charcoalrot	3	3	1	1	1	3	2	2	2.0

1 = low priority; 10 = high priority

Table 1: (Continued)

Trait	BOT	LES	MAL	MOZ	SWAZ	TAN	ZAM	ZIM	SADCC Mean
LEAF DISEASES									
Leaf blight	2	1	3	2	3	3	4	4	2.8
Rust	1	1	3	2	2	4	3	2	2.3
Grey leaf spot	1	1	4	2	1	4	4	2	2.4
Anthracnose	1	2	2	2	1	2	2	2	1.8
Sooty stripe	2	1	4	2	1	3	4	3	2.5
Zonate leaf spot	1	1	2	2	1	2	2	2	1.6
Oval leaf spot	2	2	2	2	1	2	2	1	1.8
Bacteria	1	4	2	2	2	2	2	2	2.1
Ergot	2	1	2	2	3	2	2	3	2.1
SMUT									
Head smut	2	2	1	-	1	2	1	2	1.6
Long smut	2	1	1	-	1	2	1	1	1.3
Covered kernel	3	4	2	-	3	3	2	2	2.7
Loose smut	1	2	1	-	1	2	1	2	1.4
STRIGA	4	2	4	-	3	4	4	4	3.6

I feel it is important to have a multidisciplinary team focused on thse problems. It is important to ensure that new varieties and hybrids are not more susceptible to yield limiting traits than those currently in use, but, to cope with changes in the pest complex following use of new varieties, hybrids and management practices.

Quality of food made from the grain of new varieties and hybrids is an important factor in consumer acceptance and market value. Quality traits become important selection criteria. This area of crop improvement will be discussed in detail later in the paper.

Nutritional traits are also of concern both from a nutritional and antinutritional view point. The essential amino acid, lysine, is limiting in the storage protein of sorghum grain. High lysine has been found in some varieties from Ethiopia with shrunken seed, and from mutation studies at Purdue University, in an opaque seed.

Table 2: Sorghum Research Priorities at the ICRISAT Center in India for the SADCC Region

Trait	ICRISAT's Screening Capability at ICRISAT center in India	Research Priority	
		Development Research	Adaptive Research
Stem borer	0.7	0.5	0.5
Midge	0.8	0.2	0.8
Head bugs	0.1	Screening capability poor	
Shoot fly	0.8	0.3	0.7
Grain mold	1.0	0.2	0.8
Charcoal rot	0.2	Screening capability poor	
Downy mildew	1.0	0.3	0.7
Anthracnose	0.8	Very low priority	
Leaf blight	0.0	1.0	0.0
Rust	0.9	Very low priority	
Striga	0.5	0.6	0.4
Weeds		Establish priority	
Birds	0.0	1.0	0.0
Drought Resist.	0.3	Screening capability poor	
Stand est.	0.5	0.3	0.7
Soil fertility	0.8	0.7	0.3
Intercropping	0.5	0.7	0.3
Grain quality	0.8	0.6	0.4
Grain yield	0.9	0.8	0.2
Fodder yield		Establish priority	

* A value of 0.0 or 0.1 is no or poor capability and 1.0 is a very good capability, 0.4 is considered necessary for screening.

A 1.0 in the Development Research Column indicates a high priority for the SADCC Regional Programme.

A 0.8 in the Adaptive Research column implies a low development research requirement, but the adaptation of an existing technique.

The high lysine trait is not as stable in the opaque background as in the shrunken source. However, transfer of the trait to normal seed has been found difficult and expensive and interest still remains academic.

Tannin, is found primarily in brown seeded sorghum grains (with a testa) complex with protein reducing digestibility. There is also a lower carbohydrate digestibility compared to low tannin sorghums. The problem can be avoided by using very low tannin varieties or by detoxifying the

tannin by alkali treatment or malting. The presence of tannin contributes to bird resistance and may have value in sorghum used for brewing. Almost all high tannin grains are soft, resulting in poor recovery following dehulling (pearling). Recently several high tannin lines with hard endosperm have been found in the world collection of sorghum germplasm at ICRISAT Center in India. We will evaluate these as pearling will also reduce the tannin containing testa.

The Tropical Development Research Institute in London is investigating a possible toxic effect from HCN in malts used for baby foods. HCN is a potential problem when sorghum is used for livestock feed. The problem is of particular concern in young sorghum plants - the HCN is basically gone once plants are 45-50 days old.

VARIABILITY - ITS GENERATION AND EXPLOITATION

Except for identical twins, no two people look alike. Differences represent variations among people. Variation exists for all traits in plants and animals. Because of variation a breeder can apply a selection pressure, for traits that he wants in a plant variety. As selection proceeds variability is reduced. It is therefore important for a breeder to both select for and generate variability for traits in which he has interest.

Several steps are important to maintain variability. One is the collection and use of traditional varieties (both local and introduced) and breeding stocks from other breeders.

The ICRISAT/SADCC regional sorghum programme was launched in the 1983-84 season at the MATOPOS research station outside Bulawayo in Zimbabwe. A sorghum breeding nursery was established at the MATOPOS station. Some 5300 sorghum collections (varieties) from southern Africa and from

breeders' lines from 25 breeders around the world were planted at the nursery. The ICRISAT/SADCC nursery is providing a diverse base for crop improvement activities. Introduction of new varieties is a constant process. Recently we have been introducing lines with specific food quality or resistance traits.

Variability is also increased by crossing; selection is applied in generations following the cross. Intermating populations are also genetically manipulated to maintain variability while selection proceeds.

The existence of variability is an important point of this paper. Many overlook this important aspect and undertake research with sorghum - any sorghum. But one variety may differ greatly from another and the value of research can be greatly reduced if this fact is not appreciated. But, of greater importance, is the opportunity for the breeder to select for a desired trait; say a sorghum that makes a good sadza (thick porridge), or produces a flour that blends well with wheat flour, or a sorghum with good malting traits. The opportunity to select for desired traits has been largely overlooked by the food technologist. As mentioned, all to frequently, sorghum is sorghum - all the same.

SURPLUSES

Surplus grain of any kind is expensive to store and to manage. Today grain surpluses exist in Zimbabwe, India, China, USA, Canada, Argentina and Australia. Other countries, such as Malawi and Zambia periodically have surpluses in some crops and/or in some areas. The Sudan currently has a surplus of sorghum.

As crop improvement people we recognize a traditional use of the crop which is important and which can be modified and non traditional uses that might have market

opportunity. A sorghum surplus generates a need for scientists to identify market opportunities that might absorb the surplus. In Zimbabwe, an array of uses of cereals exists, including sorghum. Some ventures using sorghum flour have not succeeded; grain colour has been a factor. ICRISAT's sorghum breeders are in the process of identifying new end uses for sorghum, learning what is known about their quality requirements, and incorporating these traits in our regional breeding programme.

TRADITIONAL USES OF SORGHUM

Traditionally sorghum is used in an array of products:

1. Flat breads, leavened and unleavened, from fermented or nonfermented dough.
2. Porridges, thick and thin, fermented or unfermented, acidic, neutral, or basic.
3. Pasta products.
4. Boiled rice-like products.
5. Pop, parched, snack foods.
6. Fermented and unfermented beverages.

The priority that ICRISAT researchers have assigned to these food types for the SADCC Region is presented in Table 3. The table also lays out a series of quality traits and our capability to evaluate them. The desired nature of each trait is presented for each food type. There are basic traits across food types and traits specific to each food type. Traits of importance in evaluating a grain for a thick porridge are presented in Table 4.

The relationship of grain hardness (texture) and pericarp thickness to various traditional foods is as follows:

> "The specific acceptability of the cultivars was related to endosperm texture and pericarp thickness. Grains with a hard endosperm texture and a thick pericarp had the best hand milling properties while the floury grains exhibited poor milling qualtiy. The thin pericarp pearly endosperm types were not readily accepted by consumers using hand milling, but, they can be mechanically milled to produce excellent products.

Table 3: Basic Series of Tests for Routine Evaluation of Types of Foods from Sorghum and Millets

Grain Trait	Flat Breads	Porridges	Product Composite Flour	Boiled rice-type Prod.	Pasta	Baby Inst.	Malt	Evaluation Capability
	Priority in Southern Africa (1)							
	1	5	4	3	1	3	5	
GRAIN								
Texture	Inter	hard	soft	inter	?	?	not imp	4
Colour	wh	wh	wh	wh	wh	?	not imp	5
TESTA								
(Tannin)	Abs.	abs. present	abs.	abs.	abs.	abs.	absent present	3
Density	Inter	high	low	high	low	?	not imp	5
DEHULLING-MILLING								
Extraction rate	high	high	inter	not imp	inter	high	not imp	4
Dehulling time	short not imp	short	short	short	short	short	not imp	4
Kernel shape	round flat	round	round	round	round	round	not imp	5
Pericarp thickness	thick/ thin			thick/ thin	thick/ thin	thick thin	not imp	5
1000 grain wt.	inter	low inter	inter high	low inter	?	?	not imp	5
Grinding work	inter	inter high	inter low	high	?	?	not imp	4
Particle size dust	fine	course	very fine	not imp	?	?	not imp	4
MALT								
Diastatic power	not imp	?	not imp	not imp	not imp	?	high	4

5 = very high priority; 1 = very low priority

Grains with 60 to 100 percent corneous endosperm were preferred for the preparation of stiff porridges like tû, ugali, bogobe and sangati (sadza), and for rice like products. Soft endosperm (0 to 40 percent corneous) types produced the best quality kisra and injera (flat breads from fermented dough). Kernels with intermediate texture (40 to 60 percent corneous)

Table 4: Additional Tests for Routine Evaluation of Traits Relevant to Production of Porridge (Sadza)

Trait	Evaluation Capability
Gel Spread	3
Water Retention	5
Amylographic properties	4
Starch damage	4
Gelatinization temperature	5
Taste	3
Texture (finger and mouth)	3
Keeping quality	3

were the most suited for producing unleavened breads like roti and tortilla. In general, brown sorghums with a testa were unacceptable or least preferred for all the products evaluated. The presence of a red or yellow pericarp did not adversely affect acceptability of most of the products as long as their taste, texture, and keeping quality were satisfactory. The preferred colour of porridges is either white or yellow; but porridges made from red sorghums were also acceptable. Some sorghums with a sub coat made good leavened breads. Thus, colour is not of critical importance in many of the food systems. However, colour is critical for unleavened breads, particularly tortillas[1/]."

These data and comments clearly indicate that traditional foods can be categorized and that tests for several quality parameters have been identified. These tests are still to be systematically applied in crop improvement programmes.

Lars Hultgren, Biotechnic Lab of the Carlsberg Research Center in Copenhagen has shown that more than one product may be possible following various treatments of the grain; for example, finer flours going to one use and course to another. It is also possible to develop various uses of the stem resulting in total plant use. An increase in the

1/ Murty, D.S., L.W. Rooney, H.D. Patil and L.R. House. A Report on the International Sorghum Food Quality Trials (ISFQT) ICRISAT page 16.

number of marketable products would increase the value of the crop. A range of products has been mentioned, many more could be identified. Multiple end uses of sorghum are a real possibility. A range of quality traits have been identified that can be evaluated. Products from sorghum have ranged from successful (Chibuku opague beer) to moderately or poorly successful (composite flours). The question why can be asked.

Food technologists and industrialists have generally looked at sorghum as sorghum; i.e., all sorghum grains are the same. But if the food technologist works with the plant breeder to develop varieties and hybrids for specific end uses, there might be an expanded market for sorghum for human and industrial consumption. The array of possible new sorghum products is very great, all of them cannot be dealt with. Prioritization is required. To approach this question, ICRISAT/SADCC has commissioned four sorghum study papers on the following topics:

1. Food technology research on sorghum from traditional to industrial.
2. Non food industrial uses of sorghum.
3. Sorghum in livestock feed.
4. Sorghum marketing and trade policy.

These study papers will describe the state of the art, and what can be done to improve short run market opportunities for sorghum and long range market development. These papers should assist in helping ICRISAT scientists establish research priorities. However it is becoming increasingly apparent that some exploratory research and development activities will be necessary to establish ICRISAT's final sorghum breeding priorities for the SADCC region. Once established, it will be possible to derive tests to measure important quality parameters.

One can only hope that the development of sorghum varieties

and hybrids for specific end uses will result in expanded market opportunities for red sorghum in Zimbabwe and expanded use of white sorghum by smallholders in low rainfall areas in the SADCC region. The availability of better market opportunities will encourage production and the availability of sorghum in processed form.