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Evaluation of sorghum technologies for smallholders in a semi-arid region of Zimbabwe (Part I): Production practices and development of an experimental agenda

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Background information and informal diagnostic survey were used to describe the sorghum cropping practice of smallholders in Siabuwa Communal Area in Zimbabwe in the 1984/85 season. Grain yield for the local variety Balala was monitored and found to be low and highly variable depending on rainfall and management. Water deficit during grain filling, low yield potential of Balala, low nitrogen and phosphorus in the soils, shortage of arable land and low plant population were identified as the major problems. Use of improved varieties, construction of soil ridges, use of nitrogen and phosphorus fertilizers and intercropping were suggested as solutions to some of the problems. Experiments were designed to test the solutions and details are given in part two of the article.

The methods of crop production in the Sebungwe region are poorly understood and the agro-ecological potential varies widely (Weinrich, 1977; Scudder, 1982). Empirical data on most production constraints are lacking. Farmers rely on traditional 'varieties' of food crops while most exotic varieties have been introduced through drought-relief schemes without adequate testing. There has been little agronomic research work in the area.

To help improve the production of food crops a problem-orientated agronomic research programme aimed at small-scale farmers was started in Siabuwa Communal Area in the northern Sebungwe in 1984. The aims of the research were: (i) to understand farmer practices in Siabuwa in relation to farmer circumstances of the major food crop sorghum (*Sorghum bicolor* L., Moench), (ii) to identify and understand the most important technical production problems faced by farmers cultivating sorghum, and (iii) to develop and implement an experimental programme to examine potential solutions to the important production problems in sorghum under current local farmer conditions.

The approach was similar to the Farming Systems Adaptive Research methodology described by Collinson (1982 and 1987) and Merrill-Dands (1986). The methods of sorghum production, and problems and their possible causes were used to develop an appropriate experimental programme described in this article. A second article (Chiduza *et al.*, 1995) presents results from experiments that tested appropriate high-priority solutions to some of the technical problems identified.

Diagnostic methods

Three diagnostic techniques were used in Siabuwa: (a) analysis of existing background information, (b) an informal diagnostic

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survey (Collinson, 1987), and (c) monitoring of sorghum grain yields in the farmers' fields.

Background information
Little background information existed for the Siabuwa valley. General information on cropping patterns (Scudder, 1982; Blackie, 1983) and a study on soils (Hungwe and Blackie, 1987) were available. An analysis of daily rainfall data from Siabuwa primary school, summarized into five-day totals (pentads) for 34 years (1951/52 to 1986/87), was done to obtain a preliminary estimate of how rainfall constrains crop production in Siabuwa. Probabilities of obtaining certain levels of rainfall per month were calculated for the 34 years of rainfall data (Fig. 1). Analysis of rainfall per pentad was done to determine the beginning and end of the growing season and the frequency of occurrence of mid-season drought. A rainy pentad was taken as the middle of any three pentads which together had at least 4 mm of rain, provided that not more than one of the three had less than 8 mm (Lineham, 1978). A mid-season drought was defined as a period of a relatively low incidence of rain occurring between 15 January and early February, normally indicated by a marked drop in the number of rainy pentads which may amount to about 50 per cent of the peak value (Zimbabwe, 1981).

Informal survey
An informal survey (Collinson, 1987) of approximately sixty farmers was carried out

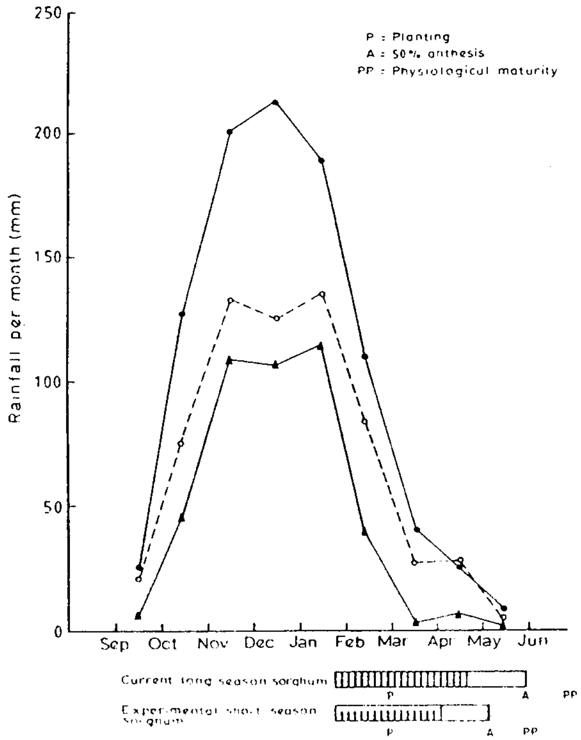

Fig. 1: Probability of rainfall in Siabuwa, between the seasons 1951/52 and 1986/87

in Siabuwa over two weeks in April 1984. Emphasis was placed on involving farmers in understanding the current farming systems, the practices employed and in diagnosing production problems. Little quantitative data could be obtained directly from farmers during this survey; for example, they had little knowledge of cultivated area or yield. A formal survey was not carried out because it was felt that it would provide little further useful quantitative information.

The informal survey revealed that sorghum was the most important food crop for most farmers in terms of area planted, resources allocation and food uses. In addition, research and extension in northern Sebungwe had neglected sorghum; therefore, it was decided to concentrate on examining sorghum production practices and problems.

Measurement of sorghum yields
Because quantitative data gathered during the informal diagnostic survey was insufficient for understanding the technical constraints in the sorghum crop, measurements of grain yield and observations of agronomic practices for sorghum were carried out and recorded during the 1985/86 and 1986/87 seasons.

Grain yield was obtained from harvests at crop maturity on ten farms in each year. Ten sampling points of one square metre were randomly selected within each field, and information on plant population density, weight of panicles, variety and soil type was recorded and grain yield calculated at 12,5 per cent moisture. Farmers were also questioned about inputs and practices employed on the fields sampled.

Planning the experimental programme
The planning process described by Byerlee and Collinson (1980) and Collinson (1987) was used to develop a programme of on-farm experiments that addressed the more important technical production constraints of sorghum. Emphasis was placed on identifying solutions that could result in increased production of sorghum in Siabuwa over the short term, that is, two to five years.

Potential solutions involving policy matters were not considered during planning. Priority was given to solutions of a technical nature. Selection of experimental treatments for the on-farm experiments was based on the identified solutions to the priority problems.

Circumstances and the cropping system

Circumstances
Important circumstances for cropping in Siabuwa are given in Table 1.

Cropping system
The major food crops grown in Siabuwa are sorghum, maize (*Zea mays L.*) and pearl millet (*Pennisetum typhoides*). Cotton (*Gossypium hirsutum*) is the most important cash crop.

Sorghum occupies about 90 per cent of the cropped area for household heads and about 50 per cent for other farmers. Several varieties of sorghum are planted by each farmer.

Current production practices in sorghum

Varieties
The Tonga use two generic names, 'Maila' and 'Lusili' to describe the main divisions among the numerous sorghum 'varieties' they grow in the area. The characteristics of these varieties and grain yields achieved are given in Table 2.

The Maila sorghum is grown mostly on the vertisols as pure stand ratoon crops. This is a strategy to reduce difficulties in the establishment of sorghum plants on the vertisols and to conserve seeds at the same time.

Current management practices for sorghum are shown in Table 3.

Production problems and solutions for sorghum

This section presents the major technical problems relating to sorghum production in Siabuwa, their causes, and relevant solutions subsequently developed into an experimental programme.

Table 1: Important circumstances faced by farmers in Siabuwa Communal Area, Zimbabwe

Circumstance and Observations	
Elevation	• 660–700 m above sea level
Soils as % of arable area (Hungwe and Blackie, 1987)	• 64% deep vertisol clays and siallitic (non-cracking) clays • 20% medium textured alluvial soils and similar upland sandstone derived soils of good arable potential • 4% sandy and 12% sodic
Climate	• Semi-arid with highly variable rainfall, an important constraint on crop production.
Rainfall 34-year mean from 1950/51 to 1986/87 season	• Mean annual; 676 mm • Range; 115–1 188 mm (coefficient of variation = 33%) • Start of rain (first rainy pentad); 28 November (range 7 November–10 January) • End of rain (last rainy pentad); 10 March (range 9 February –15 April) • Duration of rain season; Mean 102 days (range 55–144 days) • Probability of a mid-season drought; 38% in 34 years of rainfall analysed
Temperature (November–April)	• Mean daily max; 31°C • Mean daily min; 22°C
Trypanosomiasis	• Bovine trypanosomiasis means cattle not kept for draft or other purposes.
Input availability	• Fertilizer, pesticides, seeds; Available through Agricultural Finance Corporation

Table 2: Current sorghum 'varieties' used and grain yields[1] obtained by farmers in Siabuwa Communal Area, Zimbabwe

Variety Group	*Characteristics*
'Maila'	Group of up to six long-season (> 130 days to physiological maturity) varieties with varying seed colour. Common names include 'Maila Tong', 'Dong' and 'Mbwende', long stemmed (2–3 m). Grain stored for family consumption. Stems used for housing, and animal fodder in dry season. Grain yield = 1 178 kg per ha (number of fields = 37).
'Lusili'	Group of eight short- to medium-season varieties (90–120 days to maturity). Common names include 'Njamba', 'Nchenta' and 'Chivenda'. Stem lengths range from 1–2 m. Variable grain colour and panicle shape (most have open panicle). Grain yield = 1 714 kg per ha (number of fields = 17) (mixture of local and introduced materials).

[1] Grain yield date from harvests in farmers' fields, 1985/86 and 1986/87.

Table 3: Current management practices for sorghum in Siabuwa Communal Area, Zimbabwe

Practice	*Observations*
Land preparation	• Collect and burn crop residues on field September/October • Planting hills only dug with hand hoe on flat (may be combine with planting)
Planting	• 60% of sorghum fields dry planted in hills October/early November • Exception is Maila Tonga planted just after start of rains • Commonly 20–30 seeds per hill, hills scattered 70–120 cm apart. Seeds placed in holes approx. 5 cm deep and covered with soil • Thinned to 2–6 plants per hill • Practice of planting in rows 100 cm apart, 15–45 cm between plants within row becoming popular • Often replant several times on vertisols, in same hills, to achieve good stand • Tendency to ratoon long season sorghums on vertisols
Soil fertility management	• Rotation — None • Inorganic fertilizer — None on sorghum • Manure — Little organic manure because no cattle
Weeding	• Once with hand hoe after first weeding of maize and cotton • Additional weeding can occur if weed burden severe • Local short season varieties weeded 2–3 weeks after crop emergence • Maila Tonga often not weeded until 5-6 weeks after emergence (tolerant of competition from weeds) • Shortage of labour for timely weeding
Crop residue management	• Residues left on field after grain harvest and grazed by goats. Remainder burned just before planting
Pests	• Birds, especially Quelea (*Quelea quelea*) • Crickets (*Acheta bimaculata*) • Elephants • Bird scaring takes large amount of women's and children's time after soft dough stage of sorghum development • Maila Tonga more vulnerable to bird damage (is last sorghum to mature — May and June)
Harvesting	• Lusili: Cut panicles after physiological maturity and sun dry • Maila: Lodge plants at hard dough stage, then cut panicles up to one week later
Grain storage	• Most shorter season varieties store poorly (less than six months) • Maila Tonga stores well • No control measures taken against storage pests or diseases

Source: Information from an informal survey of 60 farmers, 1984

Problem 1: Current long-season sorghum regularly experiences a water deficit, especially during grain filling

For existing long-season sorghum planted towards the end of November there is a greater than 50 per cent probability of water deficit by the middle of grain filling and the probability increases towards maturity (Fig. 1). Farmers reported drought to be common on their sorghum crops after panicle emergence in some years. Field observations in 1986/87 showed symptoms of water deficit. Gravimetric measurement of soil moisture showed soils in Siabuwa to be below wilting point for most of February and early March (Hungwe, 1987). Analysis of rainfall data indicated a 38 per cent probability of a mid-season drought. Thus, current long-season varieties routinely suffer increasingly severe and frequent water deficit from panicle emergence to grain maturity.

Better conservation of soil moisture was a possible solution to this problem. This could be obtained by better weed control to reduce water loss from the soil profile during the season or by constructing soil ridges before planting (combined with planting in the furrow) to concentrate infiltration of water near plants. Weed control using herbicides was felt to be impracticable for the farmers while increased hand hoeing was not possible because no extra labour was available.

Construction of ridges using hoes would also require labour and would probably conflict with other cultural practices in demand for labour. Use of a donkey-drawn ridger may be appropriate for some farmers. It was decided to work on ridging systems, but as a low priority.

Drought-tolerant longer-season varieties would potentially be useful but are not currently available. In contrast, earlier maturing varieties offer a way of avoiding water deficit, especially during grain filling. Shorter-season pearly-white open-pollinated sorghum varieties such as 321CR and SV-2, suitable for making locally preferred food products, have been developed recently in Zimbabwe (Mushonga, 1983 and 1988) and were available for testing.

There was little doubt that early-maturing sorghum varieties are suitable for the growing season in the area. Scudder (1982) noted that early-maturing sorghum performed better than later-maturing types during the unfavourable 1981/82 season. However, Reid (1982) reported that previous attempts to introduce modern higher-yielding sorghum into the Siabuwa area had failed, with unsuitable taste of porridge and poorer storage abilities probably playing a major part in the rejection of the sorghum. Use of earlier-maturing varieties may help bring earlier relief from a period of food shortage commonly experienced from October to early March.

Problem 2: Low yield potential of current long-season sorghum

Long-season sorghum is 3 m tall and has a low grain yield potential (around 2 000 kg per ha for Maila under good management in Siabuwa). In 1985/86 there was little water deficit during grain filling of the longer-season sorghum. The yield of longer-season types (130 days) such as Balala averaged only 1 418 kg per ha (n = 24) compared with an average of 2 439 kg per ha (n = 16) for introduced shorter-season sorghum grown without fertilizer by some farmers. The use of improved shorter-season open-pollinated varieties of sorghum such as 321CR and SV-2 with a higher yield potential of around 5 000 kg per ha (under adequate soil fertility and moisture) offered a solution to this problem (Mushonga and Appa Rao, 1986; Mushonga, 1988).

Problem 3: Low nitrogen and phosphorus status of the soils

Fallowing to regenerate soil fertility is becoming impossible in Siabuwa because of increasing human population pressure on the land. Sorghum was the crop previously cultivated in 90 per cent of the fields planted to sorghum in 1984/85 season. Table 4 shows that clay soils have marginal levels of phosphorus while levels of nitrogen in the upper 20 cm of soil were medium and levels at 40 cm in the profile were very low (Hungwe, 1985).

It was not clear whether low soil fertility was a problem or not for an environment such as Siabuwa where shortage of rainfall limited production of sorghum and prevented uptake of mineral nutrients. It was decided to test response to fertilizer in a simple experiment involving no application of fertilizer and an application of some nitrogen and phosphorus fertilizer against different varieties. If a large response to fertilizer was obtained, then an experiment with several fertilizer levels could be designed to determine the biological and economic optimum for the area.

Table 4: Chemical characteristics of clay, clay loam and sandy loam soils taken at a depth of 20–40 cm from farmers' fields in Siabuwa Communal Area

	Clay		*Clay Loam*		*Sandy Loam*	
	Mean	(Range)	Mean	(Range)	Mean	(Range)
pH ($CaCl_2$ extraction)	7,50	(7,3–7,6)	6,8	(6,3–7,6)	6,1	(5,4–7,5)
N(ppm), after incubation	32,00	(4–71)	41	(33–46)	38	(26–58)
Available P_2O_5 (ppm) (Resin method)	23,00	(10–44)	30	(8–49)	23	(7–63)
Total exchangeable cations (meq 100 g^{-1} soil)	83,90	(41,4–178,7)	15,6	(14,7–16,2)	10,2	(4,0–41,1)
Ex K (Meq %)	2,02	(1,07–4,50)	0,83	(0,55–1,27)	0,69	(0,37–1,15)
Ex Na (Meq %)	0,52	(0,01–3,34)	0,04	(0,01–0,12)	0,12	(0,003–0,26)
Ex Ca (Meq %	74,05	(35,4–173,0)	11,7	(10,9–12,7)	7,8	(2,8–32,2)
Ex Mg (Meq %)	6,98	(2,25–18,14)	2,99	(2,45–3,57)	1,67	(0,04–6,72)
	n = 7		*n* = 6		*n* = 10	

Source: Hungwe (1985)

Problem 4: Shortage of arable land for sorghum

The Tonga people have one of the highest rates of population increase in the world, in excess of three per cent per annum (Scudder, 1982). People are now compelled to use sodic soils and deep Kalahari sands for growing sorghum. Use of sodic soils poses the danger of high levels of erosion and environmental degradation, while Kalahari sands have a very low mineral nutrient content and water-holding capacity.

A possible technical solution to this problem would be to intensify current production of sorghum on the better soil types.

The intercropping of long-season sorghum varieties with acceptable short-season sorghum varieties was a way of increasing yield for the large area of vertisols where long-season sorghum are grown, mostly as ratoon crops. This was thought of as a way of stabilizing production on the vertisols without a major change in current agronomic practices. However, it was felt necessary first to identify appropriate new shorter-season sorghum varieties.

Problem 5: Low plant population densities for sorghum

Low plant population densities were observed during the 1984 survey. Plant densities measured in 1985/86 and 1986/87 seasons ranged from 22 000 to 160 000 plants per ha with a mean of 58 700 plants per ha. Yet farmers plant 1 200 000 to 1 800 000 seeds per ha. Landsberg (1964) recommended a plant density of around 100 000 plants per ha for parts of Zimbabwe with rainfall similar to Siabuwa. Causes of low plant densities were seed and seedling death owing to inadequate soil moisture, the result of poor infiltration into hard (non-tilled) topsoil. Also guinea fowls (*Numide meleagris*) eat seeds just after emergence, if planted very shallow.

Poor moisture infiltration at the start of the season results from localized and shallow land preparation using a hand hoe. Only planting stations are tilled and weeds are often present.

Possible solutions would be to improve the seedbed tilth either by animal tillage or additional hoeing on the hills just before planting. Weeds could be removed by hoe or

Table 5 : Experimental factors for the research programme in Siabuwa

Experimental Factors	Justification	Priority	Year Trial Started
1. Improved early-maturing pearly-white grain sorghum	Appropriate solution to the current long-season sorghum experiencing water deficit during grain filling and having low yield potential.	High	1984/85
2. Nitrogen (N) and Phosphorus (P) fertilizer	Test response to N and P fertilizer as solution to low soil fertility. Not certain of level of fertilizer to apply if response is positive.	High	1984/85
3. Intercropping short-season sorghum with existing long-season sorghum	Strategy to stabilize production of sorghum on the vertisols. Need to test performance of short-season sorghums in an intercrop.	Low	1985/86
4. Soil ridging systems to concentrate rainfall	Possible solution to water deficit during sorghum growing season. May not be appropriate since farmers have labour shortage for ridging and do not have oxen.	Low	1987/88
5. Plant population densities	To verify that achieved plant densities are low and to determine optimal densities for improved short-season sorghum.	Low	1987/88

pre-emergence herbicide application.

It was not possible to introduce draught animals because of tsetse fly. Additional hoeing was impracticable because labour is in short supply at the time and farmers prefer to plant a larger area before the rains start rather than improve tilth on a small area. Any other forms of tillage were found to be beyond the means of most farmers in Siabuwa at the time of the study.

Although no appropriate solutions to the low plant population stand were identified it was felt necessary to develop a trial to verify that current plant densities are sub optimal and to establish the optimum.

The solutions proposed (and confirmation of the low stand problem) led to five basic experimental factors for investigation (Table 5). Of these, two (nitrogen and phosphorus fertilizer and early-maturing sorghum) were given high priority for experimentation and were placed in experiments for the 1984 /85 season. The remaining factors were of lower priority and it was decided that experimentation on these should wait until the potential benefits from new shorter-season sorghum were confirmed with farmers.

Because the uptake of improved, short-season pearly-white sorghum by farmers (and thus the success of the other experimental factors) would depend on how farmers viewed the cooking and taste properties of the grain from those sorghum varieties, a formal evaluation of food value by farmers was needed before experimentation progressed further. The evaluation took place during the 1985/86 season.

Details of how the high priority experimental factors were developed into on-farm experiments for the 1984/85 and subsequent seasons and the results from those experiments are given in Chiduza *et al.* (1995).

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REFERENCES

Blackie, M.J. 1983 Research design and implementation in the Sebungwe region of Zimbabwe, in P. Matlon, R. Cantrell, D. King and M. Benoit-Cattin (eds.), *Coming full circle: farmer's participation in the development of technology* (Ottawa, IDRC), 51–62.

Byerlee, D. and Collinson, M. 1980 *Planning technologies appropriate to farmers: concepts and procedures* (Mexico City, CIMMYT), 71.

Chiduza, C., Waddington, S.R. and Rukuni, M. 1995 Evaluation of sorghum technologies for smallholders in a semi-arid region of Zimbabwe (Part II): Soghum varieties against fertilizer trials. *Journal of Applied Science in Southerm Africa* **1**, 11–22.

Collinson, M.P. 1982 *Farming systems research in East Africa: The experience of CIMMYT and some national agricultural research service, 1976–1981*. (East Lansing, Michigan State Univ., International Development Paper 7).

Collinson, M.P. 1987 Farming systems research: Procedures for technology development. *Experimental Agriculture*. **23**, 365–86.

Hungwe, A. 1985 A study of the soils of Siabuwa valley, Sebungwe region, and their management for dry-land peasant agriculture (Harare, Univ. of Zimbabwe, Department of Soil Science, mimeo).

Hungwe, A. 1987 A Pedological Study of the Siabuwa Valley, Zimbabwe, and Preliminary investigations into the Water Relations of some *Madumabisa* Mudstone-derived Soils (Harare, Univ. of Zimbabwe, Dept. of Soil Science and Agricultural Engineering. D.Phil. thesis).

Hungwe, A. and Blackie, M.J. 1987 The Sebungwe soil research programme working paper 1 (Harare, Univ. of Zimbabwe, Dept. of Soil Science and Agricultural Engineering).

Landsberg, J.J. 1964 Spacing for sorghum grain production. *Rhodesia Journal of Agricultural Research*. **2**, 23–30.

Lineham, S. 1978 The onset and the end of the rains in Zimbabwe (Harare, Department of Meteorological Services. Notes on Agricultural Meteorology Number 24).

Merrill-Sands, D. 1986 Farming systems research: Clarification of terms and concepts. *Experimental Agriculture* , **22**, 87–104.

Mushonga, J.N. 1983 Sorghum improvement in Zimbabwe, in X (ed.) *Crop improvement in Eastern and Southern Africa, Proceedings of a regional workshop* (Ontario, IDRC).

Mushonga, J.N. 1988 The state of the art of sorghum research for communal farmers in Zimbabwe, in M. Rukuni and R. H. Bernsten (eds.), *Southern Africa: Food Security Policy Options: Proceedings of the Third Annual Conference on Food Security Research in Southern Africa* (Harare, Univ. of Zimbabwe/ Michigan State Univ. Food Security Research Project, Dept. of Agricultural Economics and Extension), 207–16.

Mushonga, J.H. and Appa Rao, S. 1986 Progress in sorghum improvement in Zimbabwe, in X (ed.), *Proceedings of the Second Regional Workshop on Sorghum and Millets for Southern Africa* (Bulawayo, SADCC/ ICRISAT), 103–18.

Reid, M.G. 1982 Crops appropriate to the Sebungwe region, in X (ed.), *Sebungwe regional study. Proceedings of a workshop.* (Hwange).

Scudder, T. 1982 *Regional Planning for People. Parks and Wildlife in the northern portion of the Sebungwe region* (Harare, Univ.of Zimbabwe, Dept. of Land Management, Working Paper 3).

Weinrich, A.K.H. 1977 *The Tonga People on the Southern Shore of Lake Kariba* (Gwelo, Mambo Press).

Zimbabwe 1981 *Climate Handbook of Zimbabwe* (Harare, Dept. of Meteorological Services).