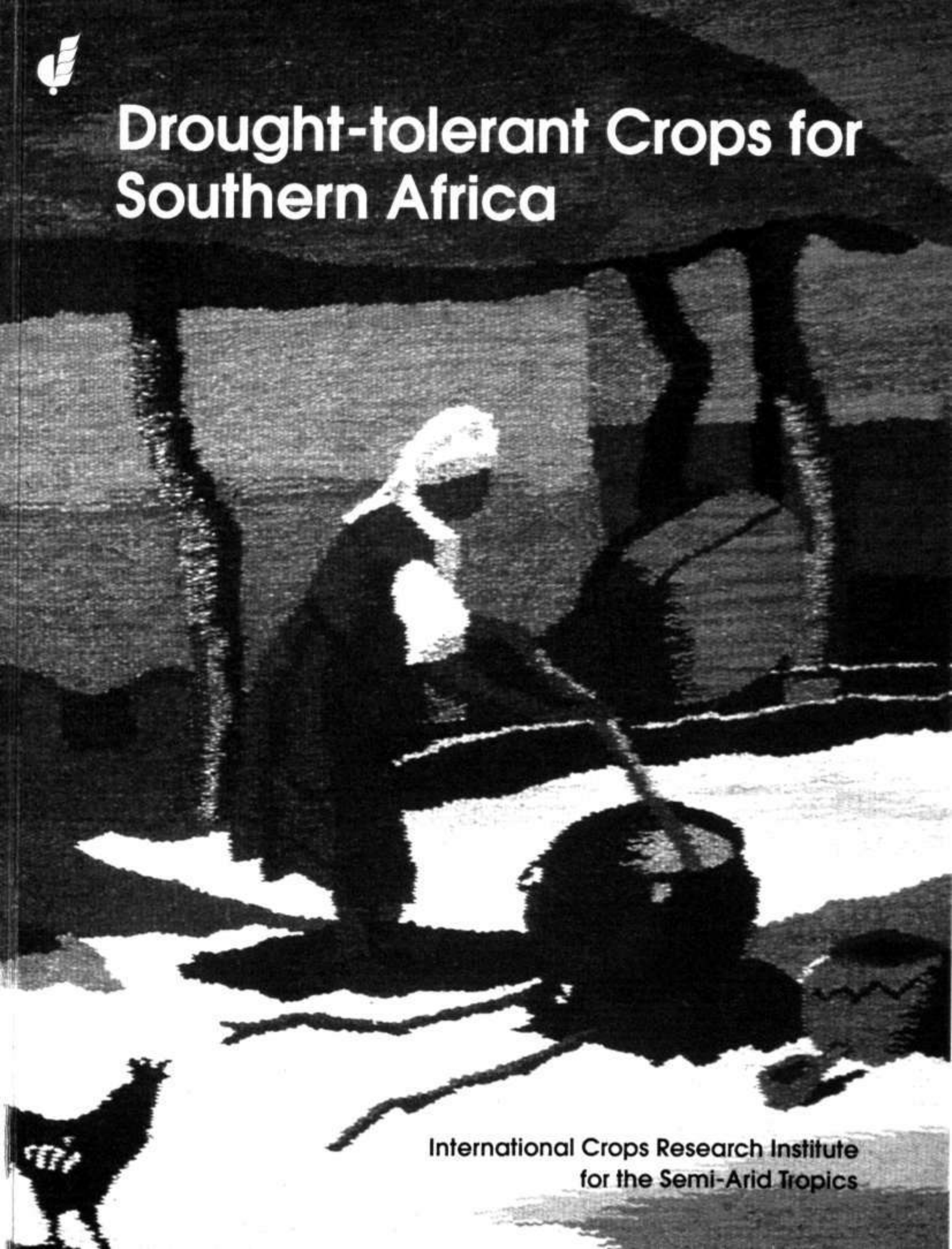
Drought-tolerant Crops for Southern Africa



International Crops Research Institute
for the Semi-Arid Tropics

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Abstract

Small-scale farmers in southern Africa have traditionally relied on sorghum and millet to feed their families. Seventy-five delegates from 17 countries participated in the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop held at Gaborone, Botswana, 25-29 Jul 1994, to discuss ways of improving sustainable food production in semi-arid areas. Recent research on sorghum and pearl millet was reviewed through presentations that discussed the role of three broad disciplines—genetic enhancement, crop protection, and technology transfer—in increasing food security at household level. Priority areas include enhancement of seed production, strategies of crop protection, reliable on-farm trials to identify promising varieties, and more effective technology transfer.

Résumé

Cultures tolérantes à la sécheresse pour l'Afrique australe: comptes rendus de l'Atelier régional SADC/ICRISAT sur le sorgho et le mil, 25–29 juillet 1994, Gaborone, Botswana. Traditionnellement, les petits paysans en Afrique australe dépendent du sorgho et du mil afin de nourrir leurs familles. Soixante-quinze délégués provenant de 17 pays se sont réunis à l'Atelier régional SADC/ICRISAT sur le sorgho et le mil, à Gaborone au Botswana du 25 au 29 juillet 1994 en vue d'examiner des moyens pour améliorer la productivité alimentaire soutenue dans les zones semi-arides. On a passé en revue la recherche sur le sorgho et le mil à travers des communications sur le rôle de trois disciplines—amélioration génétique, défense de la culture et transfert de la technologie—dans l'augmentation de la sécurité alimentaire à l'échelle des ménages. Des domaines de priorités comprennent l'amélioration de la production semencière, des méthodes de lutte contre les maladies et les ravageurs, des essais en champs éprouvés pour identifier des variétés prometteuses ainsi qu'un transfert de technologie plus efficace.

Sumário

Culturas resistentes a seca para à Africa do Sul: procedimentos da Reunião Regional SADC/ICRISAT sobre sorgo e painco, 25–29 Julho 1994, Gaborone, Botswana. Tradicionalmente, os pequenos agricultores no Sul da Africa, tem dependido das culturas do sorgo e painco para alimentar as suas familias. Setenta e cinco representantes de 17 países, participaram nessa reunião para discutir métodos para melhorar a sustentavel producão do alimento nas áreas semi-aridas do Sul da Africa. Investigacões recentes sobre o sorgo e painco perola foram revistas através das apresentacões que discutiram o melhoramento génetico, protecão das culturas, e transferência da tecnologia para aumentar a segurança alimentar ao nível domestico. As recomendacões feitas nessa reunião estão sumarizadas essas incluem melhoramento na producão das sementes estratégias para a protecão das culturas, seguros ensaios nos campos para à identificacão das variedades prometedors, e uma mais efetiva transferência da tecnologia.

Cover photo: Cooking sorghum-detail from a woollen carpet woven in Botswana.
Photography International Consultancies Ltd.

Drought-Tolerant Crops for Southern Africa

Proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana

Edited by

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ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

1996

Editorial Notes

1. The Latin binomials for the principal crops mentioned in this book are:
Sorghum: *Sorghum bicolor* (L.) Moench
Pearl millet: *Pennisetum glaucum* (L.) R.Br.
Finger millet: *Eleusine coracana* (L.) Gaertn.

2. In some papers it has not been possible to cite references with full publication data. Should readers thus have difficulty in identifying sources, staff at SADC/ICRISAT will be glad to assist. Address: Matopos Research Station, PO Box 776, Bulawayo, Zimbabwe. Tel: +263 83 8311. Fax: +263 83 8253 or +263 94 1652. E-mail: icrisatzw@CGnet.com [Dialcom 157:CGI222].

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Foreword

L K Mughogho[1]

This Workshop was an important event for three reasons.

First, it represents one of several longer-term responses to the Drought Emergency of 1991/2 by the scientific community in southern Africa. Even while the initial distribution of improved seeds to farmers was being organized to avoid a repetition of the emergency, it became clear that agricultural research staff would be challenged to answer leading questions about future food security in the region. Specifically, how can particular attention be given to the improvement of staple crops that are known to be drought-tolerant? And how can national, regional, and international researchers most effectively work with farmers, to optimize the exchanges of information and technologies on which up-to-date approaches to agricultural research and development are now based?

It therefore seemed important to bring together leading researchers in the SADC region who could contribute results, experience, and ideas to a debate of these and related issues. The outcome was the convening of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, held in Gaborone, Botswana, in July 1994, the major agenda of which concerned On-Farm Research and Technology Exchange, country by country. This was followed by work-planning meetings and appraisals of the resources for improvement that are currently available.

The second reason for the Workshop's importance is that participants who presented papers were asked to emphasize research findings in the breeding of sorghum and pearl millet, in plant protection, and in economics which could have early application, or which represented significant advances in our knowledge of constraints in producing and marketing these crops. The 47 papers published in this book therefore comprise a benchmark of agricultural research achievement in the SADC region in 1994, providing helpful guidance on strengths and weaknesses.

It is worthy of note that, in editorial consideration of the contents, it was agreed formal topic subheadings should not be used. We felt that this would impose a rigid structure on the publication that might obscure the multidisciplinary nature of the research reported. The papers are therefore loosely grouped by theme, so that readers may focus more readily on actual or potential impacts of research at village level rather than on the scientific and socioeconomic disciplines involved.

Thirdly, the Workshop is the first of its kind in which it has been possible to include papers from participants in South Africa. The SADC research community has thus been considerably strengthened by these additional contributions of experience and knowledge directly relevant to the topics currently demanding our attention.

Since the time of the Workshop follow-up activities in the SADC region have comprised national annual research meetings to discuss technology transfer plans for

1. Executive Director, ICRISAT Southern and Eastern Africa Region, Matopos Research Station, PO Box 776, Bulawayo, Zimbabwe.

sorghum and pearl millet in drought-prone regions. And it is pleasing to note that exchanges between national, regional, and international research workers, so clearly enhanced during the Workshop, have contributed significantly to activities within the new Desert Margins Initiative (DMI) for Africa, launched in Jan 1995. The regional DMI workshop for southern Africa held in Gaborone in Sep 1995, at the same time as regional workshops for western and eastern Africa, endorsed the formation of National Coordination Committees for participating countries (Botswana, Burkina, Kenya, Mali, Namibia, and Niger). Thus the scope and thrust of our earlier Workshop is expected to receive international funding and support for related activities in priority drought-prone areas specifically selected for DMI action.

Opening Remarks

L P Gakale[1]

Distinguished Guests, Fellow Researchers, Ladies and Gentlemen:

It is my pleasure to welcome you all to the 1994 SADC Regional Sorghum and Pearl Millet Workshop. My very warm welcome goes especially to our colleagues from our sister institutions in India and western Africa, who have come here to share their experiences with us in tackling the problems of sorghum and millet production in their regions.

I am aware some of you have been in Gaborone since last week for the planning, monitoring, and evaluating workshop and you have already seen much of Gaborone. I want to urge you, however, to use your spare time to see more of the country and our research facilities.

Let me extend to all of you my Ministry's warm word of welcome. We wish you all a successful Workshop over the course of the week.

Our appreciation goes to our sponsors, USAID, GTZ/BMZ, and CIDA for continued support to the SADC Sorghum and Millet Improvement Project, which has made possible our gathering here this morning. The organizers are to be commended for the arrangements they have made for the Workshop, which I hope you will find adequate for your needs.

Let me now invite our Guest of Honor, Mr Tibi, the Director of Crop Production and Forestry, to officially open our Workshop.

1. Director, Department of Agricultural Research, PO Bag 0033, Gaborone, Botswana

Welcome Address

K S W Tibi[1]

Mr Chairman, Director of SACCAR, Executive Director of SADC/ICRISAT, Director of Agricultural Research, Distinguished Scientists, Ladies and Gentlemen:

It gives me great pleasure to welcome you to Gaborone, Botswana, for the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop. I understand some of you have been in Gaborone since last week participating in a research planning, monitoring, and evaluation workshop that was also sponsored by the Sorghum and Millet Improvement Program (SMIP) of SADC/ICRISAT. These workshops provide an opportunity for scientists to sharpen their skills and exchange experiences in sorghum and millet research. I have great expectations from this workshop, and I wish you fruitful discussions. I hope that the facilities available to you are adequate and conducive to serious work. Equally available are facilities for relaxation and exercise, to help you keep your energy levels high during your 2-week stay here. But remember that too much work makes Johnny a dull boy! In Setswana we say: 'dintsa di bafilwe'. It means 'Come in, the dogs are leashed'.

SMIP became operational in 1984 following a request to ICRISAT by SADC to improve sustainable food production in semi-arid areas of the SADC region that are mostly cultivated by smallholder farmers. Food production and food security in these areas are adversely affected by inadequate rainfall and periodic droughts. The only way to increase food security at household level is through the development of appropriate technologies for drought-tolerant crops. Sorghum and millet are undoubtedly the most important food grains for these areas.

Historically, these food crops were considered poor men's crops, and not enough was done to develop them, even though smallholder farmers have traditionally relied on sorghum and millet to feed their families. But since 1984, when SMIP started its work, we have made great strides in developing and improving sorghum and millet in SADC. The research capacity for sorghum and millet in national agricultural research systems (NARS) has been increased through infrastructural and human resource development. Specifically:

- More than 90 scientists from SADC NARS have been sponsored for training at graduate and postgraduate levels by SMIP.
- A number of improved cultivars of sorghum and millet have been developed and released, and several are now in production.

The training received by NARS scientists has greatly increased sorghum and millet research capabilities across the SADC region. Achieving regional cooperation in agricultural research through the initiative of SACCAR and SMIP is a milestone for SADC. Already many of the released sorghum and millet cultivars are adapted to farming conditions in many SADC countries.

1. Director, Crop Production and Forestry, Ministry of Agriculture, PO Bag 003, Gaborone, Botswana.

Shortfalls in the availability of seed can now potentially be met from regional sources. This year, for example, Botswana will import Okashana 1 pearl millet seed from Namibia for smallholder farmers in drought-affected areas. Similar seed exchange will take place with sorghum.

The most important remaining task for you scientists is to ensure that the technologies you have developed reach farmers. Phase III of SMIP aims to bring new technologies directly to such farmers. The NARS, in collaboration with SMIP, will test available technologies in smallholder farmers' fields away from experiment stations. These technologies should be evaluated carefully for farmer acceptance. Real impact will be realized when food production and security improve at household level. Experience has taught us that domestic food security can be achieved only when consumers of basic food grains are able to produce them at farm household level. Therefore, there is a need to continue to work with smallholder farmers to ensure that available technologies benefit them fully. I call upon government and public-sector institutions and NGOs to work with smallholder farmers in the research, development, production, and marketing of sorghum and millet.

Let me tell you how we in Botswana have been working to establish a sustainable sorghum and millet industry. The development of sorghum grain dehullers by Rural Industries Innovation Center, an NGO, was instrumental in the commercialization of sorghum flour. Because of these dehullers, sorghum is milled in both rural and urban areas. The Botswana Mill Owners' Association continues to provide sorghum flour to all communities in the country. Additional improvements will be needed to continue to make sorghum a commercial commodity. We call on the private sector to continue to find ways of marketing and using sorghum to achieve sustainable growth in the industry. Smallholder farmers stand to reap more benefits from higher production and marketing at household level.

When I was recently talking to a farmer in one of the rural communities, he said 'Hunger has been banished from this household'. He was referring to a favorable sorghum harvest of 50 bags from a 10-ha area. This represents 350 kg ha^{-1} of sorghum grain—a low yield by the standards of commercial farming but very high for a smallholder farmer.

The Department of Agricultural Research has released three sorghum varieties and one hybrid sorghum for production in Botswana. Two pearl millet varieties are in the prerelease phase of their development. The new sorghums are drought-tolerant and will yield more than currently available sorghums. Even a nominal yield increase will mean a substantial increase in sorghum production at household level. This, ladies and gentlemen, will make food security a reality.

In the region there have been impressive successes in the production of sorghum and pearl millet. Zimbabwe and Namibia have each released new cultivars with significant increases in grain production in the past 2 seasons.

The role of the private sector must increase across SADC. Seed companies play a vital role in ensuring that seeds of new varieties and hybrids reach smallholder farmers on time. Market outlets must be strengthened to link national, regional, and international sorghum and millet markets. We must find alternative uses for sorghum and millet in such areas as off-the-shelf consumables and livestock feeds.

Ladies and gentlemen, the Botswana government remains deeply committed to increasing and ensuring food security at household level. Improved sorghum and millet production by smallholder farmers in semi-arid areas of SADC remains the best means to achieve this goal.

On behalf of SADC, I thank the donor community, especially USAID, for continuing to support SMIP. I thank SACCAR and SMIP for the leadership roles they have provided in the development of sorghum and millet in SADC. And, lastly, I congratulate you SADC scientists for your contribution through your NARS.

Thank you.

Workshop Objectives

L M Mazhani[1]

I am pleased to present the objectives of this Workshop as provided for me by the Steering Committee of the SADC/ICRISAT Sorghum and Millet Improvement Project (SMIP). It is very important that the objectives are stated clearly, because they will prescribe the direction of your discussions.

In order to maintain close interaction with national sorghum and millet research programs, SMIP has until now been sponsoring annual workshops attended by research workers in the region. This approach has changed, and SMIP will now maintain working contacts with the national scientists through special workshops. Emphasis will shift from review papers to original research papers, and this is the format that has been adopted for this Workshop, the main objectives of which are:

- To provide an opportunity for sorghum and millet scientists in SADC countries to present papers on any aspect of their original research.
- To exchange information and experience on sorghum and millet technology transfer activities.

It is clear from these two objectives that the Workshop presents an opportunity for you to disseminate your research findings for the benefit of the scientific community in the SADC region. I am sure you will agree with me that this forum is a good basis for collaboration.

I also hope that this Workshop will not be the last, and I look forward to another in the future when you will be able to report new achievements.

Thank you.

1. Deputy Director, Department of Agricultural Research, PO Bag 0033, Gaborone, Botswana.

Full Papers

On-Farm Testing of Prereleased Sorghum Varieties in Botswana

E Makhwaje[1]

Abstract

In the two seasons of data collection during this initial study, there were no significant yield differences either between prereleased varieties alone or between prereleased varieties and the local control. A further comparison between research- and farmer-managed yield results shows a higher yield gap for the prereleased varieties than for the local control. This indicates that, unlike the prereleased varieties, the local control might do almost as well under the worst and the best management conditions.

On a yield basis, there is a strong case for farmers to continue using Segaolane. But, taking color and taste of porridge as indicators, farmers prefer Macia, suggesting that this variety may be used as a food-crop substitute for Segaolane. SDS 2583, a malting variety with red grain and bitter porridge, is the least preferred by farmers as a food crop.

The limited duration of this study means that its results can be regarded as only indicative and, therefore, that more data collection and analysis are needed.

Introduction

This paper presents the results of on-farm trials in Botswana in the 1992/93 and 1993/94 seasons of three prereleased sorghum varieties (Macia, SDS 2583, and SDSL 87019). A local variety, Segaolane, was used as a control. The varieties were evaluated on yield and farmer-perception.

Of importance is the comparison between on-farm and on-station results, and the implications for smallholders.

1. Research Officer, Department of Agricultural Research, PO Bag 0033, Gaborone, Botswana.

Makhwaje, E. 1996. On-farm testing of prereleased sorghum varieties in Botswana. Pages 1-5 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Results

On-farm yields

Figure 1 shows average yields of the 1992/93 and 1993/94 seasons from on-farm trials of the three prereleased sorghum varieties, Macia, SDSL 87019, and SDS 2583, and the local control, Segaolane. The averages are across three agricultural regions (Central, North East, and Southern regions) nine sites (villages), and 108 locations (farmers) within these regions.

Except for SDSL 87019, the other two varieties have slightly lower yields than the local control. However, there were no significant yield differences between varieties. These results indicate that, in terms of yield alone, it is not worthwhile to consider Macia, SDSL 87019, or SDS 2583 as substitutes for Segaolane.

On average, farmers in Botswana plow and sow 5 ha yr^{-1}. Usually, 80% of this is sown to sorghum and the rest to some other crop. Also, the subsistence requirement for an average family of six persons is 1262 kg yr^{-1}. Table 1 compares total yields from each respective variety to the subsistence requirement. Multiplying average yield values given in Figure 1 by four gives total yield figures for each variety (Table 1).

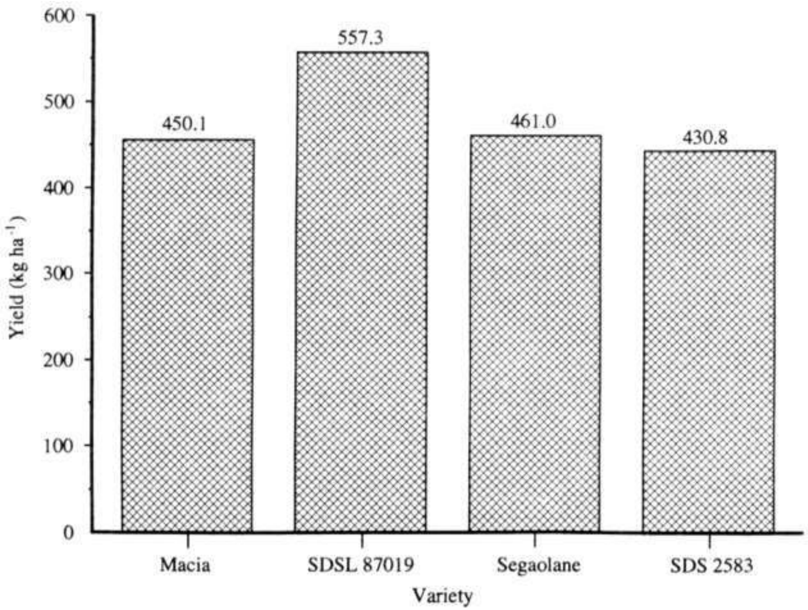

Figure 1. Yield results from sorghum on-farm trials, 1992-94, Botswana.

Table 1. Difference between average yield per year for prereleased sorghum varieties and subsistence grain requirement (1262 kg), Botswana, 1992-94.

Variety	Total yield at 4 ha yr^{1} (kg)	Difference[1] (kg)
Macia	1800	+ 538
SDS 2583	1723	+ 461
SDSL 87019	2229	+ 967
Segaolane	1844	+ 582

1. Refers to total yield at 4 ha yr^{-1} for each variety minus subsistence requirement. The total yield was obtained by multiplying average yield (Fig. 1J for each variety by four.

Table 1 shows that all varieties more than satisfy the subsistence requirement. This implies that, besides the local variety, the alternative varieties, too, have the potential to satisfy the subsistence requirement under farmer-managed conditions. The extra yield could be used for income generation.

Yield gap II

Yield gap II refers to yield differences between potential and actual farm yield. Potential yield was taken to be yield from research-managed and research-implemented (RMR1) trials and actual yield as yield from farmer-managed and farmer-implemented (FMFI) on-farm trials. These yield differences are usually due to biological and/or socioeconomic factors. Figure 2 shows such yield differentials for sorghum varieties for trials conducted between 1992 and 1994.

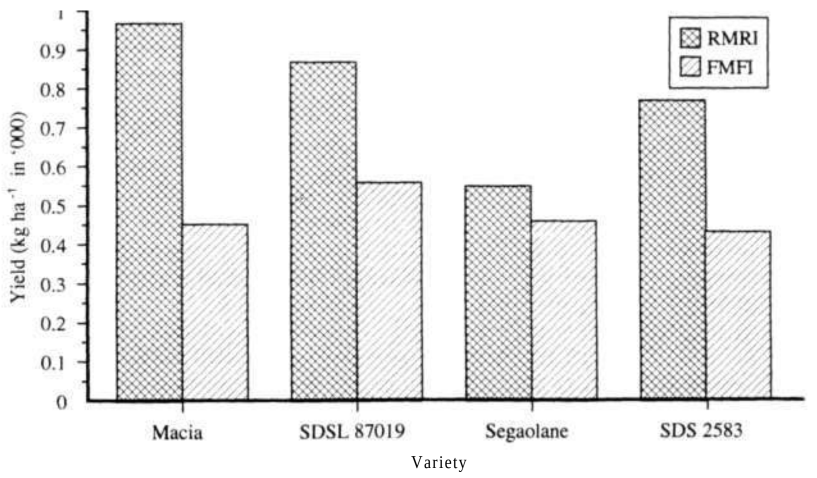

Figure 2. Yield gaps for RMRI and FMFI trials with sorghum, Botswana.

The percentage yield gaps between FMFI and RMRI for the two seasons were: 53.5% (Macia), 36.67% (SDSL 87019), 16.03% (Segaolane), and 44.29% (SDS 2583).

It can be seen that the gap is larger for the alternative varieties—37 to 54% for Macia, SDSL 87019, and SDS 2583— than for Segaolane (16%). Since the only difference between the two trials is the management factor, a high level of management is required for these new varieties to yield as expected. Likewise, a high level of management is not a prerequisite for high yields of the local variety. Hence, under farmer-managed conditions, the local variety is more cost-effective than the three prereleased varieties.

Finally, the results presented in this subsection emphasize the importance of on-farm research in verifying on-station findings. Thus, varieties that might perform well under research management might not perform as well under farmer-managed conditions. We also emphasize the importance of local varieties when considering alternatives. The lower yield gap for the local variety is an indication of a much more stable variety given the worst and best scenarios.

Farmers' preference

Table 2 presents the results of a farmer-perception test conducted in the agricultural regions mentioned earlier. The values for percentage acceptance relate to those individuals who could accept a particular variety rather than the others as a food crop.

Table 2. Farmers' acceptance (%) of prereleased varieties as food crops (total respondents = 48).

	Macia	SDS 2583	SDSL 87019	Segaolane
Acceptance	99.9	25	56	75

Judgment on acceptance was based on color and taste of porridge prepared from *milia* meal of each variety. Although SDS 2583 has red grain, it was the least accepted variety because its porridge has a bitter taste. It is worth noting that this variety was developed primarily for brewing beer. The other varieties with high acceptance percentage have white grains that produce white porridge. The almost 100% acceptance of Macia indicates that this variety could be used as a substitute/complement for the local variety. Farmers liked both the color and taste of the porridge from this variety more than those of the others.

These results indicate that white grain is preferred for porridge over red grain. Taste and color of porridge play a big role in determining whether or not a particular variety will be accepted as a food crop. This implies that it is important for breeders to identify key characters of varieties related to their intended uses.

Table 3 presents farmers' perception of the prereleased varieties in monetary terms. Here, farmers were given a total of P100.00 (US$35.65) and asked to spend it on any of these varieties. Again, taste and color of porridge were used as indicators.

Table 3. Expenditure on prereleased sorghum varieties as food crops, expressed in pula (Botswana currency).

	Macia	SDS 2583	SDSL 87019	Segaolane
Respondents	22	3	9	14
Expenditure (in pula)	16.04	2.50	6.42	10.70

Table 3 indicates that, given color and taste of porridge as indicators, farmers would spend very little money on SDS 2583 as a food crop. Also, farmers would not spend as high a percentage of their funds as the table might imply on only one variety. Thus, when it comes to money, farmers are more cautious and sceptical of new innovations.

Conclusions

Lessons learned from this study, subject to further trials and analysis, are the following.

- Subsistence requirements can be satisfied using the prereleased varieties.
- The yield gap in varieties as one moves from on-station to on-farm results gives the possible variability in yield as one moves from research-managed to farmer-managed situations.

Such information gives a rational basis for determining research priorities if related production constraints can be identified.

It is very important to include farmers in the evaluation of varieties before they are released. Failure to do so may result in developing varieties that society does not want.

Development of and Institutional Support Systems for Sorghum-Milling Technology[1]

M D Mmapatsi and J M Maleke[2]

Abstract

This paper presents an overview of the process of developing technology aimed at answering a felt need in the market and putting in place institutions that support the targeted technology. A small-scale unit for dehulling and milling sorghum was developed by the Rural Industries Innovation Centre, Botswana, for import substitution purposes. It relieves women and children from hand-processing sorghum, thereby releasing their time for alternative productive activities and creating income-earning activities for villagers.

The success of the sorghum dehulling technology clearly demonstrates that, alongside good technology, there should be sound facilitatory and backup organizations and institutions to support the technology.

The paper contends that, where technology is developed to meet a specific need, with total involvement by the concerned target group, such technology is bound to be successful and sustainable.

It is also argued that the development of this unit has led not only to creation of employment in rural food processing, but has also created both backward and forward linkages in the rural economy. As it therefore contributes significantly towards household food security, it is recommended that the Botswana government should continue to support such technology development.

Technology Development Strategy

A major concern constantly being echoed in most developing countries is the slow rate at which these countries' economies grow. Technological progress is one of the important factors that contribute towards economic growth, but unfortunately most of these countries are still lagging behind in terms of technology development and adaptation. Technological progress itself results from improved and new ways of

1. Paper previously presented at the FAO Workshop on Experience Gained in Africa on the Improvement of Post Harvest Technology, 4-8 Jul 1994.
2. Rural Industries Innovation Centre, PO Bag 0011, Kanye, Botswana.

Mmapatsi, M.D., and Maleke, J.M. 1996. Development of and institutional support for sorghum-milling technology. Pages 7-18 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

accomplishing traditional tasks. The development *of* dehulling technology was a new way of accomplishing a traditional task.

Rural Industries Promotion Company (Botswana), which runs the Rural Industries Innovation Centre (RIIC), is primarily a rural development organization and uses technology and rural technological training only as a means to an end. The following are the Centre's specific objectives.

1. To research, develop, transfer, and disseminate technologies appropriate for Botswana.
2. To train and support artisans in the informal sector to get into business.
3. To transfer the manufacture of developed technologies to the private sector.
4. To generate income.

The mandate of this organization dictates that its activities should be those that try to solve problems of rural development. As a result, technology development is to a large extent conceptualized and implemented in a systems perspective.

Clear mechanisms have been put in place that involve all departments of the Centre, namely, the Research and Development, Extension Services, and Commercial Departments. All work together in the development and dissemination of new ideas, products, and services.

The constituency of users is valued and it influences the direction of the product range. This ensures that technology development is not only considered in its totality, but it is also problem- and demand-led.

The process of developing technology recognizes linkages and overlaps that exist in the system. And, in its quest to seek technology-led solutions to rural development, the combination of research, extension, and user linkages is central to the Centre's activities.

The Development of Sorghum Milling in Botswana

Sorghum has traditionally been the main staple food for the majority of Batswana, followed by maize, millet, and pulses. But, during the 1970s, there was growing concern in Botswana that there was a shift away from both production and consumption of sorghum towards maize.

Maize had gradually become more of a cash crop, thereby creating incentives for farmers to grow it, despite the fact that the climatic conditions of the country favor the production of sorghum. Because of the incentives created by the market, sufficient supplies of maize were produced to meet the increasing demand, and small grains such as sorghum and millet remained in the traditional sector (Gibbs 1986).

As a result of the ready availability of maize flour in the market, consumer preference also switched to this commodity. The other contributory factors were the relatively low price and prepackaging of the maize flour. And processing sorghum to make flour, when compared with the processing of maize, requires tedious hand-stamping.

Most *of* the maize flour that came onto the market was from South Africa and, because of its policy of food self-sufficiency, the Botswana government was determined to set in train measures that would persuade consumers to switch back from maize to sorghum. This latter crop is well adapted to the soil and climatic conditions, and has for a long time been the staple food in the country.

Small-scale milling industry

In 1977, the Centre carried out a problem-identification and needs assessment survey in 53 villages. The results showed that one of the major problem areas was the hand-stamping of sorghum grain, a laborious and time-consuming task that is carried out by women and children in traditional households. The Centre therefore began a project to identify, adapt, and develop technologies suitable for the establishment of small-scale sorghum mills for use in rural areas in Botswana. The project had two objectives:

1. To release women's and children's time for more productive or socially rewarding activities, by replacing hand-processing with machine-processing.
2. To encourage increased consumption and production of sorghum, a dryland crop relatively tolerant of drought as compared with maize.

The Pitsane commercial and RIIC service mills

In 1974 the Botswana government established the Botswana Agricultural Marketing Board, primarily to stimulate food production in Botswana, particularly sorghum. Good prices for sorghum and other crops were guaranteed year-round.

The management of the Board approached IDRC in Canada for technical and financial assistance. An agreement was reached for the establishment *of* a pilot sorghum mill in Pitsane.

After the mill was commissioned, profit was realized in a short time, despite the fact that sorghum flour was priced at 23% above maize flour (Gibbs 1986). And when the Pitsane mill was being commissioned, RIIC's National Needs Assessment Report (1977) indicated that there was a need for a technology that could replace hand-stamping in the making *of* sorghum flour. RIIC therefore started work to adapt a dehuller similar to the one used at Pitsane and modified certain components to come up with a better product.

The decortication process in technology development

The development of the dehuller for decortication was carried out by RIIC in collaboration with IDRC.

Adapted from a barley thresher, the machine functions with dry, abrasive wheels. Basically it is a horizontal barrel which incorporates 13 evenly-spaced carborundum wheels that rotate clockwise against the grains at approximately 2000 rev min^{-1}. The barrel has linings of reinforced rubber material to provide greater abrasion and reduce noise level. The principle employed is that of progressive abrasion of the outer layers of grains throughout the length *of* the dehuller barrel. The wheel dimension is 25.0 cm diameter and 2.1 cm thick. Dry sorghum is fed into the hopper (with 25-kg holding capacity) through an adjustable throughput control mechanism. The husks and bran, removed by the abrasive action, are extracted by means of a suction aspiration fan and ducting system located at the top of the barrel, to be collected via cyclone in bags. The dehulled sorghum, being heavier, is extracted either though a side chute for continuous processing, or by a bottom trapdoor in the case of batch feeding. (See the diagrams in Figures 1 and 2 and the diagrammatic representation of the dehulling/milling process in Figure 3.)

Extension and Marketing Strategies

For RIIC, the development of the dehuller technology was not an end in itself, but was rather seen as a vehicle for rural development. The government, on the other hand, supported the development of sorghum milling because this industry could contribute towards both national food security and rural development.

RIIC encouraged and supported the growth of a milling industry that would be decentralized with diverse, rurally-based, and indigenously-owned management. This support was based on the realization that, if service milling prospered, it would offer more sustainable employment in rural areas and raise the labor productivity of women and children by releasing them to engage in alternative activities that have a higher labor opportunity cost (Gibbs 1986; Dinat 1987).

The development of the technology followed the normal extension cycle, which ensured that the research undertaken was demand- and problem-led.

Consumer interests and demand for the product drew RIIC, which had hitherto been more interested in technology development, into product marketing and supply. But, because these are the concerns of the extension and marketing wings of the Centre, these two departments were charged with responsibility for marketing the research and development products (Dinat 1987), and of keeping close contact with users and the opinions of the ultimate consumers.

Thus, from the initial stages, the following steps were taken to market the dehuller technology.

1. In July 1979 the machinery was exhibited as 'state of the art' technology at the agricultural trade fair. Two prototype machines were installed in two villages, and these provided sufficient information to enable production of a limited number of units.
2. To create further awareness of the new product, intensive marketing research was carried out. Meetings were held throughout Botswana in villages at the traditional

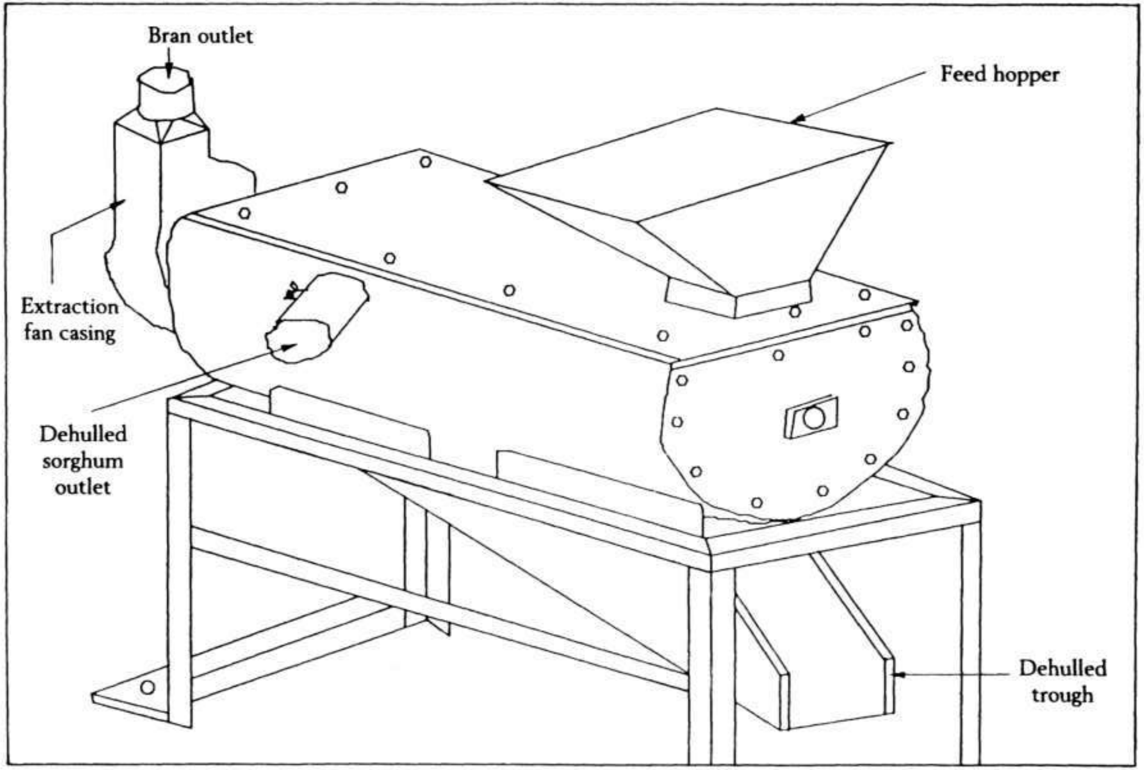

Figure 1. Diagrammatic view of the sorghum dehuller.

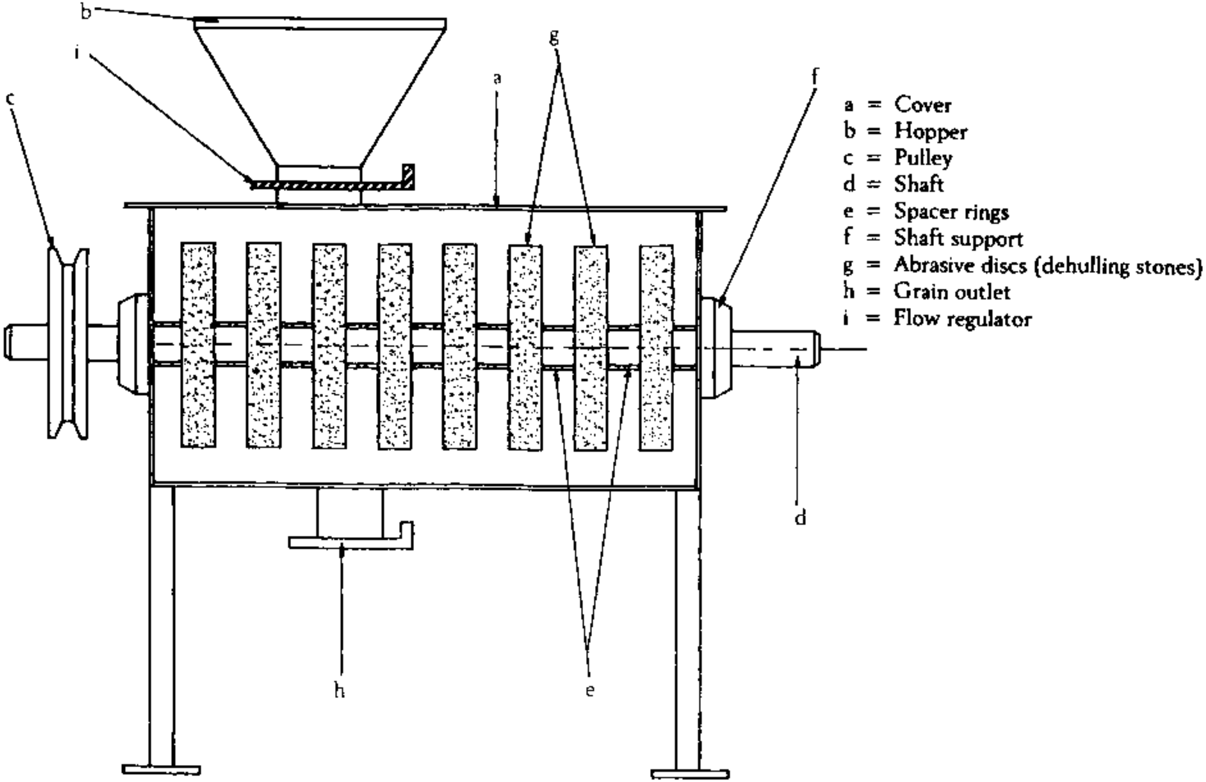

Figure 2. Sectional diagram of the sorghum dehuller to show the dehulling stones.

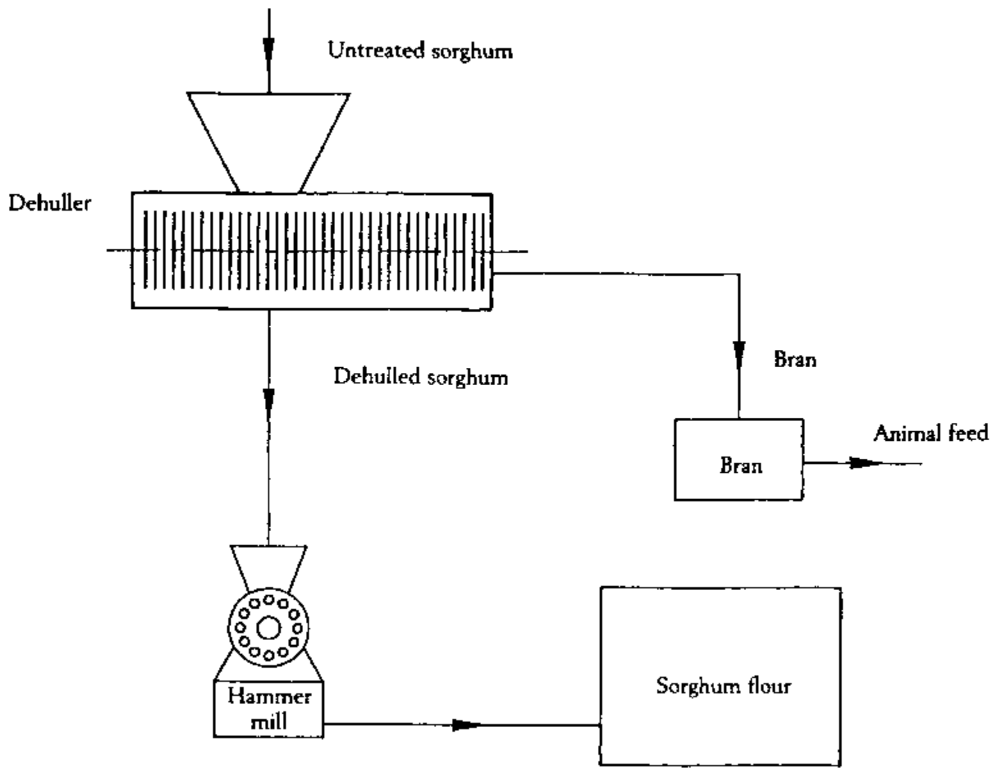

Figure 3. The dehulling/milling processing of sorghum flour.

gathering places (*kgotla*) to brief the villagers about the product. Extension teams were briefed on the socioeconomic feasibility of the milling unit and, as a result of these exercises, villagers were invited to have their crops milled at no charge.

3. The strong interest shown in the milling package encouraged the Extension Department at RIIC to put together an operator's manual, and develop a curriculum for a training course for potential buyers. Seminars were also held with interested buyers, and the curriculum was reviewed during these gatherings.
4. A mechanism was put in place to get feedback from the field, and a database of technical problems was created to address the common ones. As solutions to these problems were worked out, an entire generation of dehullers had to be recalled for modification to improve their performance. Installation procedures were revised to ensure effective backup support.
5. RIIC saw the need for an organized user constituency, and began contacting millers in 1982. This user group later became Botswana Mill Owners' Association, which matured into an independent NGO that concerns itself with mill owners' interests.
6. In order to effectively address demands of the market, resources were organized and regional agents for spare parts were also engaged.
7. Success in the development of the technology and marketing was largely a result of the ability of the organization to match the technology on offer with the need of the user constituency. This also meant that the interlinked elements of objectives, methods, organizational means, and target category had to be adjusted or allowed to self-adjust as any one element changed.

The process flowchart in Figure 4 indicates the steps undertaken from the feasibility study stage to technology transfer.

Targeting and Employment Creation

The National Needs Assessment Report (RIIC 1977) verified that hand-stamping of sorghum has traditionally been a domain of women and children in Botswana.

A study undertaken by Narayan-Parker (1982) revealed that using a dehuller released women's and children's time so that the former now have 41% time to engage in 'productive activities', while children similarly have 50% (Table 1).

Table 1. Saved time redistribution.

Family member	Feed preparation time (h)	Time saved (h)	Household activity (%)	Productive activity (%)	Other (%)
Woman	4-6	2.5	57	41	2
Child	3	2.0	31	50	19

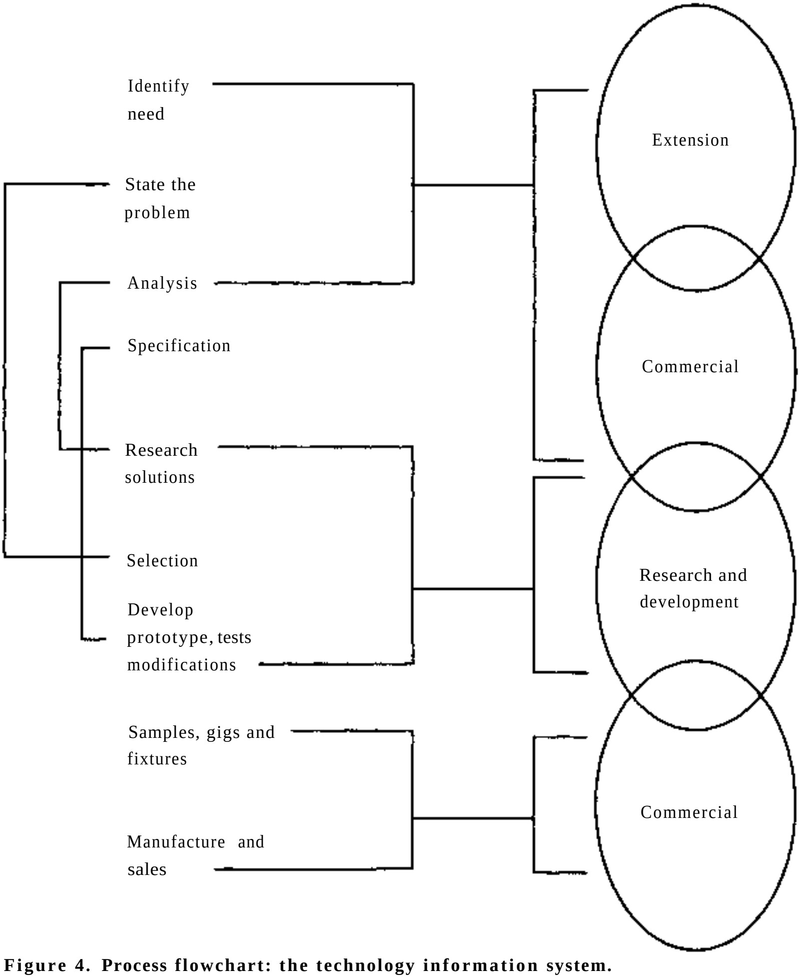

Figure 4. Process flowchart: the technology information system.

A study by Groth et al. (1992) has shown that about 224 jobs have been generated by 56 milling packages that have been set up countrywide, and both males and females registered equal numbers in the mills. Indeed, this could be a sign of equal opportunities in employment in this subsector.

Relationship between Commercial and Service Mills

The service and commercial mills function to service communities in their respective locations and therefore, in most cases, do not compete with each other.

The service mills are generally located in small villages in rural areas, while the commercial ones are situated in urban areas and major villages. However, there are a few mills that do both service and commercial milling, and the targets for such services are different. Financial analysis data for both commercial and service mills and technical data on the dehuller are available from RIIC, if required.

Institutional Support for the Milling Industry

Success in the development and wide distribution of the dehuller technology is largely attributable to the effectiveness and flexibility of the institutions that were charged with various responsibilities. We have adopted the Binswanger and Ruttan (1978) view of institutions as a set of behavioral rules that govern a particular pattern of action and relationships. An organization, however, is a decision-making unit. An organization's activities are guided by the structure and order of institutions, and this indeed shows that there is not much difference between organizations and institutions. The following RIIC units are relevant in this context.

Technology Transfer Unit. This was set up in 1989 to transfer the manufacture of 'qualified' technologies to local engineering workshops, and has been helpful in facilitating, among other technologies, the manufacture of the sorghum dehuller. Through this initiative, RIIC has been able to meet the demand for the sorghum dehullers by its clients and, in the process, has increased local use of sorghum products—in particular, sorghum flour.

Installation Unit. This continues to assist clients in setting up the dehullers for their use, after purchase.

Extension Unit. Staffed by a team of technical officers, this unit continues to maximize the sale of the dehullers through direct contact with the target population.

Marketing Unit. An arm of the RIIC Commercial Department, this unit aims at ensuring the diversification of the Centre's product range by identifying products suitable for local manufacture or distribution. It also markets RIIC's finished products within and outside the country. To this end, RIIC's sorghum dehuller has been disseminated not only in Botswana but also in 10 other African countries: Lesotho, Malawi, Mali, Namibia, Senegal, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe. Other marketing programs are planned.

The associated **Botswana Mill Owners' Association** aims at maximizing the contribution of sorghum milling to economic growth by promoting a decentralized, village-based, and locally-owned industry in the belief that this initiative will maximize employment opportunities and the transfer of skills to rural areas where most people live. Nonetheless, the main objectives of the Association can be summarized as follows:

1. To offer a business advisory service that assists members in both commercial and service milling.
2. To actively promote the consumption of sorghum-based products relative to other grains, and to promote research into new foods from sorghum.
3. To liaise with relevant government ministries and organizations concerning policy issues affecting the industry and representing the interests of member mills.

Summary and Conclusions

The development of the sorghum dehuller by RIIC has proved that technology based on people's perceived needs will be accepted and used, and creates a positive impact on their standard of living. This is particularly demonstrated by time redistribution derived from using the milling technology. In addition, the milling industry has opened up income-earning opportunities through job creation, and thus enhanced food security for a considerable number of people in Botswana. It has also contributed significantly to import substitution and reduced reliance on commercial links with South Africa.

In developing countries with limited financial resources, as in Botswana, there is a need to develop technology along the lines depicted by Holt and Schoorl (1989): to fulfill the search for the end we already" know to be desirable. Given the fact that research and development activities do not readily produce the results that cover their costs, it would always be wise to spend money on development of technologies that meet the identified and felt needs of consumers.

In Botswana, the shift in emphasis from self-sufficiency to food security came about through price incentives that favored cash crops against staple food crops such as sorghum. This directly encouraged producers to switch crops. Consequently, indigenous technical knowledge of sorghum production built up over the years has been underutilized, or could be lost.

Therefore it is recommended that the Botswana government should continue to support RIIC and similar organizations to research and develop technologies geared towards liberating the poor and disadvantaged from hunger. Thus the success of the dehuller and other technologies developed by RIIC is a testimony to the fact that funds from government and other sources have been put to good use.

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Sorghum Variety Release in Malawi: the Case of Pirira 1 and Pirira 2

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Abstract

The major area of sorghum production in Malawi is the Lower Shire. Major constraints to production have been: lack of suitable cultivars, unsatisfactory cultivation practices, drought, and pest damage. Current sorghum breeding work has identified new varieties which are superior to those currently being grown. Two new varieties have been tested on-station between 1984/85 and 1992/93 cropping seasons in replicated trials in six environments, compared with other varieties and controls. Their performances have also been verified in 1992/93 in on-farm trials, compared with farmer varieties, at eight locations in two districts of Chikwawa and Nsanje in the Lower Shire. Results from these 14 environments provide usable data to confirm superiority of the two elite sorghum varieties tested. In the station environments, variety SPV 351 yielded 2.28 t ha^{1} and SPV 475 2.44 t ha^{1}, relative to five other test varieties ranging from 1.5 t ha^{-1} to 1.84 t ha^{-1}, and two controls with 1.41 t ha^{-1} (PN 3) and 1.85 t ha^{-1} (DC 75). In the on-farm locations they also yielded better at 2.03 t ha^{-1} and 2.60 t ha^{-1}, respectively, than the farmers' local landrace variety (LLV Thengalamanga: 1.99 t ha^{-1}). The two varieties also mature earlier (71 and 76 days to 50% flowering) than the control PN 3 (74 days) and other test entries (ranging from 80 to 87 days), and have better storage and grain characters.

Based on significant yield differences (62 and 73% higher grain yield) of the two sorghum varieties relative to PN 3 (in station trials) and (2 and 31% higher yield) relative to LLV Thengalamanga (in on-farm tests), the two varieties from ICRISAT, SPV 351 and SPV 475, were released in Malawi as Pirira 1 and Pirira 2.

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Introduction

Sorghum and pearl millet are important cereals in the Shire Valley (a semi-arid area in Malawi) where approximately 521 000 people live (Venema 1991). In this area, which is marginal for maize production, the two cereals form the main staple food.

Despite their importance as a staple food for 6.5% of the country's population, yields of sorghum and millet in the Shire Valley are limited by several factors such as lack of improved cultivars, unsatisfactory crop production practices, drought, pests, and diseases (Chintu 1985).

Average grain production at farm level is below 600 kg ha^{-1} compared with 2000 kg ha^{-1} at the research level. This yield difference can be attributed largely to the use by farmers of unimproved LLVs and poor agronomic practices. Production is also limited by poor and erratic distribution of rainfall. Crop loss due to pests (birds) and insects (stem borers and weevils) in the field and storage can be quite high.

In view of the above constraints, Chintu and Chigwe (1986) outlined the following strategy for improving sorghum and millet in Malawi:

- screening LLV and exotic breeding material, to develop new and adapted high-yielding varieties;
- improving cultivation practices for soil and water conservation and increased soil fertility;
- using the correct plant population, early sowing, and timely weed control; and
- studying the processing and storage techniques, and the food and other uses of the grain.

The objectives of this paper are to: report the agronomic performance of promising test sorghum varieties in multilocational and replicated trials, and describe the development, quality, and release of the two superior varieties.

Materials and Methods

Seven sorghum varieties were evaluated for grain yield performance, grain quality, pest resistance, and agronomic characters, together with two controls. These varieties were screened at several environments in the Lower Shire for on-station testing (six environments) and on-farm verification (eight locations). The six on-station environments are: 1: Ngabu 1984/85; 2: Kasinthula 1985/86; 3: Kasinthula 1986/87; 4: Ngabu 1990/91; 5: Kasinthula 1990/91; 6: Kasinthula 1992/93. The eight on-farm locations are: farmer fields F1 to F7 and Kasinthula field.

They were arranged in a randomized complete block design with four replications. A gross plot size of 4 rows x 5 m long x 0.75 m between rows was used. Data were collected from a net plot size of 2 rows x 4 m long x 0.75 m between rows. Nitrogen and phosphorus were applied before sowing at the rates of 40 and 17 kg ha^{-1} respectively, from urea and DAP fertilizers. Four seeds were sown per stand at 25 cm between plants. Seedlings were thinned to two plants per stand when about 15 cm high. Data were statistically analyzed using simple ANOVA.

For the purposes of end-use quality, the grains of test varieties, with SPV 351 and SPV 475 as controls, were evaluated using qualitative and quantitative methods for physical and chemical traits. All tests were based on representative samples of harvested and untreated grains from trials, then stored up to the time of analysis at 4°C. Grains were equilibrated to room temperature and humidity standardized to a moisture content of 10.5 ± 0.8% prior to all tests. Quality parameters screened for include: grain color, pericarp and testa presence, endosperm color, grain size, grain visual hardness, % milling yield, % dehulling loss, and tannin content.

Results and Discussion

Significant differences were observed (Table 1) between varieties for grain yield in all six environments. More than 2000 kg ha^{-1} grain yield was achieved in three (1, 2, and 6) out of six environments tested. The other three environments produced poor results due to bad weather.

SPV 346 produced the highest grain yield in environment 1. This yield was not significantly different from SPV 475 and SPV 351, which ranked second and third respectively. These varieties (SPV 351 and SPV 475) ranked first and second in environment 2 and vice versa in environments 4 and 5.

On average, the grain yields of SPV 351 and SPV 475 were 2284 kg ha^{-1} and 2443 kg ha^{-1} respectively, across the six environments. These were 62% and 73% above PN 3, and 24% and 32% above DC 75, respectively.

Table 1. Summary of grain yield (kg ha^{-1}) of sorghum varieties tested with SPV 351 and SPV 475 in six environments in Malawi.

Variety	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Mean
SPV 351	2680	3433	1231	1882	1792	2884	2284
SPV 346	2860	2501	1463	-	521	-	1836
SPV 475	2690	2804	1298	2514	1937	2221	2443
SPV 472	2470	1985	713	-	-	-	1723
SPV 386	2120	1754	1212	-	-	-	1695
SPV 615	1800	2780	426	-	-	-	1669
SPV 245	2040	1961	500	-	-	-	1500
Control							
PN 3 (variety)	990	2355	898	-	-	-	1414
DC 75 (hybrid)	-	-	-	1013	917	3608	1846
Trial mean	2206	2447	967	1316	1112	2081	
	(n=8)	(n=8)	(n=8)	n=15	n=16	n=12	
LSD (P 0.05)	680	1014	595	579	718	1114	
CV(%)	20.9	28.1	35.0	58.7	45.3	37.2	

Table 2. Mean performance of SPV 351 and SPV 475 relative to other test entries in six locations in Malawi.

Variety	Grain yield (kg ha^{-1})	Days to 50% flower	No. of panicles $plot^{-1}$	Grain mass (g)	Threshing panicle (%)	Plant ht (cm)
SPV 351	2284	71	34	36	52	153
SPV 346	1836	80	33	44	56	162
SPV 475	2443	76	32	39	57	149
SPV 472	1723	82	25	29	49	191
SPV 386	1695	81	36	39	44	188
SPV 615	1689	87	10	47	43	155
SPV 245	1500	81	11	59	43	131
Control						
PN 3 (Variety)	1414	74	25	39	48	116
DC 75 (Hybrid)	1846	-	-	-	-	-
Trial mean	1836	79	26	42	49	158
LSD (P 0.05)		7	15	14	14	17
CV(%)		4.8	32.6	18.4	14.4	66.1

Table 2 shows the mean performance for five agronomic traits plus yield. Significant varietal differences were observed in all agronomic characters measured. The earliest varieties to reach 50% flowering in 71-76 days were SPV 351, PN 3, and SPV 475. These varieties were semidwarf, dwarf, and semidwarf, respectively, and 116-153 cm in plant height.

Although the grain weight per panicle of SPV 351, SPV 475, and SPV 346 was not large (36-44 g) compared with SPV 245 (59 g), these varieties had threshing values of more than 50%. The implication is that SPV 351 and SPV 475 have more grains per panicle.

With the exception of PN 3 all varieties tested scored more than 3 out of 5 for grain hardness, including SPV 351 at 3.4 and SPV 475 at 3.2 (Table 3). These grains are thus hard in comparison with the soft grain of PN 3 (scoring 2.5). These observations agree with the observed greater incidence of storage weevil in PN 3 (with an average of 0.26 weevils/panicle) compared with SPV 351 and SPV 475 (with 0.06 and 0.02 weevils/panicle) in the field (pers. comm. Thindwa). Incidentally, PN 3 is white with brown specks while SPV 351 and SPV 475 are creamy-white. The milling quality of the test materials (Table 3) are indicated by the three tests of milling yield, dehulling loss, and grain hardness (score 1: soft; 5: very hard).

The results of grain quality evaluation in Table 3 indicate that SDSL 89420, SPV 351, and SDSL 88298 had the least loss of 12.25%, 15.50%, and 15.75% respectively. The others, such as SPV 475 and two SADC/ICRISAT SMIP varieties, had 20% loss each, while PN 3 had the largest loss of 27%.

The dehulled grain is processed into white flour during milling. The flour is a measured proportion of grain. Varieties SDSL 89420 and SPV 351 produced the

Table 3. Grain quality evaluations of SPV 351 and SPV 475 with other advanced cultivars of sorghum in Malawi.

	Cultivars					
Traits	SPV 351	SPV 475	SDSL 87021	SDSL 89420	SDSL 88298	PN 3
Grain color	Creamy White	Creamy White	Creamy White	Creamy White	Red	White Brown Speck
Pericarp	Thin	Thin	Thin	Thin	Thin	-
Testa	No	No	No	No	No	-
Endosperm color	White Pearly	White Intermed.	White Pearly	White Pearly	White Pearly	-
Grain mass (g/100]	2.64	2.90	2.47	2.48	1.82	-
Visual hardness	3.4	3.2	4.6	4.4	3.4	2.5
% Milling yield	83.00	78.10	74.85	84.70	80.55	71.3
% Dehulling loss	15.50	20.48	22.00	12.25	15.75	26.9
Tannin content	L/N	L/N	L/N	L/N	M	-

highest amount of flour (85% and 83%, respectively) while SDSL 88298 and SPV 475 produced 81% and 78% compared to 71% of PN 3.

Grain weevils were collected from 100 panicles per variety, at hard dough stage. Only at Makoka and in variety control PN 3, did 47% of the panicles collected show signs of weevil attack (weeviling). At Kasinthula and Bvumbwe weeviling in PN 3 was 10% and 20% respectively compared with 1% and 4% in SPV 475 and 5% and 13% in SPV 351. On average, Thengalamanga, the LLV, showed no weeviling symptoms. Relatively, SPV 475 with 2% and SPV 351 with 6% could be moderately resistant. PN 3 was susceptible with a 26% weeviling count.

In addition to carrying out on-farm verification to create awareness and assess the acceptance of the improved varieties among growers, a survey was conducted to determine growers' preferences and choice. Results summarized by Smale (1993) showed that growers ranked SPV 351 first and SPV 475 second, based on grain yield. The two varieties were preferred because of their large grain size and early maturity. Smale reported that the few growers who consumed these varieties said that both varieties produced white flour and that threshing was easier and the flour extraction rate was higher in these, compared with the LLV (i.e., Thengalamanga).

On-farm results shown in Table 4 are from a research-managed and farmer-implemented trial. Complete data for all test entries were obtained only at Kasinthula

Table 4. Grain yield data (t ha^{-1}) of the new varieties in on-farm trials at seven farmer locations and at Kasinthula Station in the Lower Shire in 1992/93.

	Locations								
Varieties	F1	F2	F3	F4	F5	F6	F7	F8	Mean
SPV 351	0.40	1.40	1.79	3.8	5.80	0.78	4.10	2.58	2.60
SPV 475	0.50	1.45	1.54	4.4	-	1.01	3.93	1.40	2.03
Kuyuma	0.35	1.15	0.73	-	-	0.55	-	1.31	0.85
Thengalamanga	-	0.90	-	-	3.29	-	-	1.80	
Seredo	-	-	-	-	2.96	-	2.88	0.18	2.00

Station; where SPV 351 produced 2.58 t ha^{-1}. Good results were also achieved by farmer 7, where SPV 351 and SPV 475 produced 4.10 and 3.93 t ha^{-1} respectively. On average, the yield of SPV 351, SPV 475, and Seredo was above 2 t ha^{-1}. This was similar to research results.

Based on the above research and on-farm results, sorghum varieties SPV 351 and SPV 475 were released in the Lower Shire. The proposed names for these varieties are: Pirira 1 = SPV 351 and Pirira 2 = SPV 475.

Improved varieties of sorghum were selected from the ICRISAT collaborative trials, which were sown at Ngabu and a few other experimental sites in the Lower Shire between 1980 and 1984. Selection of these varieties, namely SPV 351, SPV 346, SPV 475, SPV 472, SPV 386, SPV 615, and SPV 245 was based on grain yield, grain quality, maturity, and agronomic plant aspect scores. After selection, testing of these varieties for grain yield and agronomic characters was done at Ngabu and Kasinthula in several environments, from 1984/85 to 1986/87.

It was shown that varieties SPV 346, SPV 475 and SPV 351 gave the highest grain yields. Although the largest variation in grain yield was observed in 1986/87, the same varieties listed gave the highest overall grain yields during the 3-year period of testing. During the 3rd year in 1986/87 SPV 351 outyielded PN 3 by over 70%.

Without putting much emphasis on 1986/87 data, the experiment was modified and repeated to confirm the above findings during the 1990/91 and 1992/93 seasons, respectively.

The combined Ngabu and Kasinthula results obtained in 1990/91 indicated that SPV 475 and SPV 351 were again top-yielding varieties. These results therefore confirm the previous findings of 1984/85 and 1985/86: that the two improved varieties are adapted and superior to PN 3 in all respects.

However, the best results were obtained in 1992/93 due to favorable weather. Significant varietal differences were observed on grain yield. Varieties such as DC 75, SPV 351, and Thengamalanga produced the highest grain yields at Kasinthula, while SPV 475 ranked 6th.

During the test periods of 1984/85 to 1986/87 and 1990/91 to 1992/93, average annual rainfall in the Shire Valley ranged from 393.9 mm in 1986/87 to 1108.4 mm in 1984/85 with variations between the 5-year period.

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On-Farm Evaluation of Pearl Millet Varieties in Malawi for Farmer Preferences, Grain Yield, and Food Quality Traits

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Abstract

During the 1993/94 season two types of on-farm trials (research-managed and farmer-managed), were conducted in 66 farmers' fields in the Shire Valley to verify crop performance and to expose new varieties to the farming community. Both trials were implemented by farmers. Three new pearl millet varieties (SDMV 89004, SDMV 89005, and ICMV 88908) and two controls (Nigerian Composite-tall [NC-tall], and farmers' local landrace varieties [LLV]) were evaluated for plant and grain traits preferred by farmers, yield potential, and for their acceptability as food.

Variety SDMV 89004 had the highest grain yields: 1.95 t ha^{1} when research-managed and 1.47 t ha^{1} when farmer-managed. Under research-management the three test varieties and NC-tall performed similarly and were superior to the LLV used, whereas, under farmer-managed trials, the three test varieties produced similar yields that were superior to both NC-tall and the LLV.

Of the 164 farmers who evaluated the pearl millet on-farm trials for plant and grain traits, the majority preferred ICMV 88908 as their favorite, followed by SDMV 89004, and SDMV 89005 based on field observations. All the varieties were ranked better than the LLV for grain traits (grain size, dehulling, grinding ease). However, for food taste NC-tall was the most preferred, followed by SDMV 89005, SDMV 89004, and ICMV 88908.

These results, and those from previous years, indicate that farmers prefer the new varieties because of their high grain yield, good grain traits, and acceptability as food (taste). These varieties will therefore be recommended soon for release in Malawi.

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Introduction

Pearl millet is the second most important cereal crop (after sorghum), both in respect of area and production, in the Shire Valley in Malawi. It is grown together with either maize or sorghum, but it is harvested earlier than sorghum and maize and provides food early in the season.

In the Shire Valley where there is the possibility of drought in 1 out of every 5 years (Kumwenda 1993), sorghum and pearl millet are the only crops that can produce grain. Munyenyembe (1993) reported that pearl millet production in the Shire Valley was 58% of the national production during the 1992/93 season. Pearl millet grain yield on the farm has been low, with 600 kg ha^{-1} compared with 2000 kg ha^{-1} at the research station (Chintu 1993). This yield gap has largely been attributed to continued use of local varieties, poor agronomic practices by farmers, and poor and erratic distribution of rainfall. Munyenyembe (1993) also attributed the failure of farmers to take up new technologies, due to social and economic constraints.

Since 1980, researchers in Malawi have evaluated new pearl millet varieties in the Shire Valley at Ngabu and Kasinthula research stations. Through this effort Nigerian Composite-tall (NC-tall) was released in 1983.

Recently the research department has identified three improved varieties for on-farm evaluation. These varieties have been evaluated on the farm with the following objectives: (a) to evaluate the performance of the new varieties under farmers' and improved managements, and (b) to assess farmers' acceptance of the varieties and determine the reasons for acceptance or nonacceptance. This exercise was geared towards involving farmers themselves in selecting varieties according to their preferences.

Materials and Methods

Agronomy

Five varieties—SDMV 89004, SDMV 89005, ICMV 88908, NC-tall, and LLV (farmer's local landrace variety)—were evaluated in research-managed farmer-implemented (RMFI), and farmer-managed farmer-implemented (FMFI) trials. Recommended cultivation practices were followed in RMFI trials, whereas the farmers' local practices were followed in FMFI trials.

In the case of RMFI trials, the gross plot size was 10 rows of 10 m long, 0.75 m apart. The central 8 rows, each 8 m long were harvested. The plot size in FMFI trials was obtained by marking the area which each variety had occupied at the time of sowing and at harvest. Five seeds were sown 40 cm apart and thinned to 2 plants per stand at the 15-cm seedling stage in RMFI trials. In these trials fertilizers were applied per plot at the rate of 810 g at sowing and 540 g urea at the thinning stage. No recommendation was followed for FMFI trials. These trials were sown in 11 extension planning areas (EPA). In each EPA, 3 unreplicated sites (farmers) were selected, for each of the RMFI and FMFI trials. Farmers were treated as replicates (randomized) in each EPA.

The data were analyzed from 22 RMFI sites over 10 EPAs and from 18 FMFI sites over 8 EPAs, following multilocational analysis using the SAS program.

During the season, research and extension staff jointly visited the trials to observe and record the performance of the varieties with the farmer participation. The following data were collected from RMFI and FMFI net plots:

- maturity of the varieties as early (E) medium (M) and late (L);
- plant height at harvest from plant base to tip of panicle;
- plant count: the number of plants per net plot at harvest;
- head count: the number of heads per net plot at harvest;
- grain yield: obtained by multiplying the threshing percentage with plot head weight 1 kg head weight per plot was threshed to determine threshing percentage;
- a sample of 500 g grain was collected from each plot to determine the 1000-grain mass and moisture content. The moisture content was used to adjust the grain yield to 12% moisture. The maturity data were recorded by farmers themselves, and the other traits were recorded jointly with researchers and extension officers.

Before harvest, 31 farmers at Livunzu, 25 farmers at Mitole, 36 farmers at Dolo, 23 farmers at Mpasa, 18 farmers at Dzunde and 31 farmers at Nyachilenda were gathered at the site to evaluate the varieties in the field according to plant and grain traits. For evaluation purposes each individual farmer was asked to indicate whether the new varieties were better, the same or worse than his or her own local landrace variety. They were also asked to rank the varieties according to their preference.

After the trial plants were harvested, the farmer was advised to thresh and store the grain of each variety separately. A 10-kg grain sample of each variety was obtained for evaluation of grain traits and palatability tests. This evaluation was conducted in the six EPAs (Livunzu, Dolo, Mitolo, Mpasa, Dzunde and Nyachilenda) for grain traits and in the three EPAs (Mitole, Mpasa, and Nyachilenda) for palatability tests.

Palatability tests

The 1-kg grain sample was used to prepare flour and food (thick porridge) from each variety. At each site women farmers or farmers' wives dehulled and ground the grain into flour, using pestles and mortars. At Mpasa and Nyachilenda, due to shortage of time, flour was prepared by hammer mill.

Seven women farmers at Mitole, six women farmers at Mpasa, and five women farmers at Nyachilenda were gathered to dehull and prepare flour and food (thick porridge). These farmers were individually asked to indicate whether each of the four varieties was better, the same, or worse than her own LLV. Their responses were recorded. Finally a total of 20 men and women farmers at Mitole, 19 men and women farmers at Mpasa, and 34 men and women farmers at Nyachilenda were grouped at each site to taste the prepared food, with or without beef relish. These farmers were individually asked during tasting to indicate whether each of the four varieties was better, the same, or worse than their LLV. Again, responses were recorded.

Results and Discussion

There were significant differences among varieties in respect of grain yield, 1000-grain mass, plant height, plant count, and head count across 10 EPAs (22 sites) in the RMFI trial (Table 1) and across 8 EPAs (18 sites) in the FMFI trial (Table 2). All the three new varieties produced significantly higher grain yield than the LLV and NC-tall in the RMFI trial (Table 1) and than the LLV in the FMFI trial (Table 2). However, the differences in grain yield among three new varieties were not significant in both the trials.

SDMV 89004 produced the highest grain yield averaged over sites under research-managed (1.95 t ha^{-1}: Table 1) and farmer-managed (1.47 t ha^{-1}: Table 2) trials. These results of on-farm trials from the 1993/94 season are in agreement with the 1992/93 season. SDMV 89004 produced the highest grain yield (1.91 t ha^{-1}) based on the mean data of 22 locations during the 1992/93 season (ICRISAT/SEA Regional Program, 1994). During the 1993/94 season, in both the RMFI and FMFI trials, i.e., under improved as well as farmers' management, the LLV gave the lowest yield.

ICMV 88908 had the largest grain mass, whereas the LLV had the smallest grain under both management systems (Tables 1 and 2). SDMV 89004 ranked 2nd and SDMV 89005 3rd for grain mass.

On farmers' preference, the varieties were ranked in six EPAs by farmers. Seventy-three farmers evaluated RMFI trials whereas 66 farmers evaluated FMFI trials. In both trials, farmers ranked ICMV 88908 as their first choice, followed by SDMV 89004 and SDMV 89005, while NC-tall ranked fourth and and the LLC fifth.

Table 1. Performance of pearl millet on-farm trial varieties averaged over 19-22 farmers under a research-managed system, Malawi, 1993/94 season.

Variety	Grain yield (t ha^{-1})	1000-grain mass (g)	Plant height (cm)	Plant count (ha^{-1})	Head count (ha^{-1})
SDMV 89004	1.95	10.04	215	36510	90602
ICMV 88908	1.87	12.00	191	39683	89452
SDMV 89005	1.84	9.82	214	38700	89287
NC-tall	1.82	9.13	265	35476	78509
LLV	1.26	8.34	294	41771	94178
SE	±0.105	±0.362	±4.7	±990.5	±4256.7
Mean	1.75	9.88	235	38414	88319
CV(%)	28.0	17.2	9.3	11.8	21.0

Table 2. Performance of pearl millet on-farm trial varieties averaged over 16-18 farmers under a farmer-managed system, Malawi, 1993/94 season.

Variety	Grain yield (t ha^{-1})	1000-grain mass (g)	Plant height (cm)	Plant count (ha^{-1})	Head count (ha^{-1})
SDMV 89004	1.47	9.80	212	35139	81417
SDMV 89005	1.44	9.04	217	34583	88069
ICMV 88908	1.38	11.58	184	33750	76819
NC-tall	1.00	8.34	259	30236	65069
LLV	0.93	7.60	280	35114	87064
SE	±0.122	±0.323	±5.6	±1671.4	±6424.5
Mean	1.26	9.35	228	33688	79272
CV(%)	41.0	14.66	10	20	32

There was no EPA by variety interaction for grain yield and grain mass under both managements. The implication of this is that each variety can perform equally well in all the EPAs where varieties were tested.

Responses on grain traits were obtained from farmers at six EPAs (Table 3). At all EPAs, the majority of farmers felt that SDMV 89004, ICMV 88908, SDMV 89005, and NC-tall were better than their LLV in respect of grain size. Similar responses were obtained in respect of grain color at five EPAs (except at Dolo for ICMV). At Dolo, 83% of farmers reported ICMV 88908 worse as compared with the LLV.

Results obtained from three EPAs for food taste are presented in Table 3. All the new varieties and NC-tall were preferred over the LLV by a majority of farmers in all the three EPAs in respect of food taste with relish as well as without relish. By comparing the preference of different varieties over the LLV, NC-tall was preferred most by farmers, followed by SDMV 89004, SDMV 89005, and ICMV 89008.

At Mitole 80% of the farmers felt that NC-tall tasted better than the LLV without relish, while 70% of them felt SDMV 89005 had better taste, followed by SDMV 89004 with 55%. For with relish, 70% of the farmers thought that both NC-tall and SDMV 89004 tasted better than the LLV.

At Mpasa a majority of the farmers felt that all the four varieties were better than the LLV without relish (74-84% preference) and with relish (53-74% preference).

At Nyachilenda, about half of the farmers indicated that ICMV 88904 was worse than the LLV. Fifty-six percent of the farmers thought that SDMV 89004 tasted better, while 53% of them mentioned SDMV 89005.

The differences among varieties were similar with and without relish.

Table 3. Preference rating of on-farm pearl millet varieties over farmers' control (LLV, in %) for gain traits by 164 farmers across six sites, and for food taste by 73 farmers across three sites in Malawi, 1993/94 season.

	No. of	SDMV 89004			SDMV 89005			ICMV 88908			NC-tall		
	responses	Better	Same	Worse	Better	Same	Worse	Better	Same	Worse	Better	Same	Worse
Livunzu													
Grain size	31	100	0	0	97	3	0	100	0	0	71	26	3
Grain color	31	77	-	-	71	-	-	68	-	-	48	23	10
Mitole													
Grain size	25	100	0	0	100	0	0	100	0	0	84	16	0
Grain color	25	56	44	0	76	24	0	72	28	0	84	16	0
Dehulling	7	43	57	0	14	86	0	100	0	0	29	71	0
Food preparation	7	14	86	0	29	71	0	0	14	86	14	86	0
Taste, no relish	20	55	15	30	70	20	5	50	20	30	80	20	0
Taste + relish	20	70	25	5	70	15	15	45	5	50	70	20	10
Dolo													
Grain size	36	78	22	0	81	19	0	81	19	0	-	-	-
Grain color	36	92	8	0	64	36	0	0	17	83	42	58	0
Mpasa													
Grain size	23	100	0	0	96	4	0	100	0	0	91	4	5
Grain color	23	100	0	0	100	0	0	96	4	0	87	4	9
Dehulling	6	67	33	0	67	33	0	100	0	0	33	67	0
Food preparation	6	33	67	0	50	50	0	0	50	50	17	83	0
Taste, no relish	19	79	16	5	74	16	5	74	21	5	84	5	11
Taste + relish	19	68	21	11	74	26	0	53	21	26	74	21	5
Dzunde													
Grain size	18	100	0	0	100	0	0	100	0	0	100	0	0
Grain color	18	100	0	0	83	-	-	83	-	-	72	11	-
Nyachilenda													
Grain size	31	87	-	-	74	-	13	84	3	-	81	3	3
Grain color	31	65	13	6	55	16	13	52	10	26	68	10	10
Dehulling	5	100	0	0	100	0	0	100	0	0	100	0	0
Food preparation	5	20	80	0	0	100	0	0	0	100	0	100	0
Taste, no relish	34	56	21	23	53	35	12	44	12	44	50	38	12
Taste + relish	34	56	24	26	53	35	12	29	18	53	59	41	0

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Farmer Participation in On-Station Evaluation of Plant and Grain Traits: the Case of Pearl Millet in Namibia

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Abstract

This study was initiated to develop information for use in breeding improved pearl millet genotypes for Namibia. A select group of farmers was encouraged to participate in on-station evaluation of varieties under test. Each variety was assessed separately, and both negative and positive characters were recorded.

Five pearl millet varieties which were found promising in the Namibian national pearl millet trial of 1992/93 were sown at the Omahenene Research Station during 1993/94 for evaluation of farmer preferences for plant and grain traits. The five varieties were evaluated against the farmers' local landrace variety (LLV) and Okashana 1. Based on farmers' experience, 15 highly preferred plant and grain traits were recorded. Each of the five experimental varieties was assessed for these traits and compared with the farmers' LLV and Okashana 1.

The study concluded that early maturity, grain size, and resistance to drought are the most preferred traits for pearl millet under Namibian growing conditions. The most preferred grain trait was palatability, followed by ease of processing (threshability, dehulling, and grinding to make flour). Varieties SDMV 92040 and SDMV 90016 were identified as satisfying most farmer requirements. These varieties were as short-duration and drought-tolerant as Okashana 1, produced a better tasting product, and were easier to dehull and grind into flour. They were also superior to the farmers' LLV in all these aspects.

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Introduction

Pearl millet is as important as maize in Namibia in terms of production and consumption, each cereal contributing approximately 25% of the national calorie consumption.

Pearl millet is grown widely in the seven regions of Namibia—Caprivi, Okavango, Oshikoto, Okashana, Ohangwena, Omusati, and Kunene—covering about 355 200 ha of land (Ministry of Agriculture, Windhoek, Namibia, pers. comm. 1994).

The importance of this crop to the Namibian people cannot be overstated. Only 8% of the country's area receives >500 mm yr^{-1} rainfall. About 37% receives 300-500 mm yr^{1} rainfall, and this is where most of the pearl millet is grown. The rest of the country receives <300 mm annual rainfall and is unsuitable for cultivation.

The main objective of this study was to capture the farmers' expertise which represents an extension of the on-farm trial. Farmers were given the opportunity to assess varieties at an early stage of the selection process, and thus were able to share their expertise directly with scientists on the station and select varieties for testing in their own fields. The participatory exercise made the farmers feel more responsible and committed to their on-farm trials. This is essential to instill among the farmers a sense of 'doing something for ourselves' as against 'something being done for us.' This type of participatory research helps in obtaining more specific information for breeders than that generally used.

This participatory approach also enables farmers to contribute their expertise and good judgement early on, which would facilitate identification of varieties for on-farm testing. With better understanding of farmers' priorities for plant and grain traits, breeders can more effectively address concerns of farmers at an early stage of crossing and selection. The risk of using resources on developing a variety which will eventually end up being rejected would therefore be reduced.

Materials and Methods

Five varieties, SDMV 90016, SDMV 92040, SDMV 91018, SDMV 92039, and ICMV-F 86415, and two controls (Okashana 1 and the farmers' LLV) were used in this study.

Women farmers from the Tunetu Women's Cooperative Project at Tsandi participated in evaluating grain size and color, dehulling, grinding, cooking quality, and palatability. The Cooperative derives money from selling pearl millet-derived products (*ontaku* and *oshithima*).

This particular group was chosen because, traditionally, women are closely involved in such activities every day and they are in a good position to evaluate these traits objectively and effectively.

The evaluation process

Grain size and color. Ten women took part in this exercise. Grain samples of each of the seven varieties were kept in numbered jars. Participants were individually interviewed and asked to assess grain size and color in confidence.

Dehulling. A 3-kg sample of grains of each of the seven varieties was dehulled using a mortar and pestle. The maximum time allowed for this activity was 9 min. Five judges and a time-keeper supervised the evaluation of dehulling.

Grinding. Assessment criteria and methods were the same as those used for dehulling.

Cooking quality test. Each of the seven varieties was cooked in a 2-L pot in a traditional manner: *omahangu* flour is added to boiling water, and the porridge is continuously stirred till it reaches the desired consistency. Time taken to cook and ease of cooking were carefully recorded. The fire was kept at the same level for all varieties. Farmers were particularly interested in obtaining a smooth porridge without lumps.

Palatability test. After cooking, each participant tasted the porridge prepared from each of the seven varieties. A housekeeper was appointed to make sure that each participant tasted all the samples.

After the sample tasting session, a panel discussion was held to rate and evaluate the varieties.

Results and Discussion

Farmers in Namibia always prefer short-duration, drought-resistant varieties with large, bold grains. Other preferred traits include good grain yield, good seed-set, pleasing color (mainly cream or light gray), high tillering ability, and ease of threshing. This is why the farmers interviewed selected Okashana 1 and SDMV 92040 (Tables 1-4). Okashana 1 is light gray in color, and SDMV 92040 is cream-colored. Both varieties have all the qualities described above.

SDMV 90016 is not bold-seeded but is cream-colored and has very good tillering ability. It has medium-sized seed (1000 seed mass 10-12 g compared to 12-14 g for Okashana 1). The varieties classified as "worst" by the farmers (Table 1) were characterized by either (long duration farmers' LLV), poor seed-set mainly due to drought, (ICMV-F 86415, farmers' local and SDMV 92039), or unpleasant color (ICMV-F 86415). These varieties performed particularly badly in poor, sandy soils. The farmers also pointed out that these varieties would be difficult to thresh because the glumes completely surround the grain, and the grain itself was not fully developed. This is a manifestation of drought.

Table 1. Evaluation priority plant and grain traits in on-station trials, Namibia, 1993.

Farmer rating	Selection criteria
High	
Okashana 1	Resists drought
SDMV 92040	Short duration
	Large grain size (Okashana, SDMV 92040)
SDMV 90016	Good seed-set
	Pleasing color (SDMV 90016, 92040)
	High tillering (SDMV 90016)
	Easy to thresh
Low	
ICMV 86415	Small grain size
LLV	Long duration
SDMV 92039	Poor seed-set
	Succumbs to drought
	Not a pleasing color
	Does poorly in poor soils

Women farmers from the Tunetu Women's Cooperative Project evaluated grain color and size, ease of dehulling, and grinding, food preparation qualities, and taste of the seven varieties. Each of these varieties was compared to the farmers' local variety and Okashana 1.

Only two varieties (SDMV 92040 and Okashana 1) had larger grains than those of the farmers' local variety. Seventy percent of the women farmers identified SDMV 92040 as superior to Okashana 1 in terms of grain size, while the remaining 30% thought the two varieties had similar grain size. Similarly, 90% of the farmers rated Okashana 1 superior to their LLV, while only 10% thought they were similar (Table 3). With regard to grain color, two varieties were identified as better than the farmers' local variety: SDMV 92040 (80% classified as better) and SDMV 90016 (40% classified as better and 40% as identical) (Table 3).

The Tunetu Women's Cooperative ranked three of the varieties—SDMV 92040, Okashana 1, and SDMV 90016—as "excellent" in terms of grain traits. With the exception of Okashana 1, they were all easy to dehull and grind (all took <9 min to process 3 kg grain). All three were also rated "very good" with regard to food (*mahangu pap*) preparation qualities.

Okashana 1 was identified as particularly difficult to dehull and grind. It normally required 2-3 runs to process Okashana 1 properly. Food preparation quality was evaluated according to the tendency of the flour to form lumps, and ease of breaking these to make a smooth porridge during cooking. The farmers' LLV was rated "very good" in terms of ease of dehulling, grinding, acceptable product color, and cooking quality. All the three varieties above, plus the farmers' LLV control were rated as having good taste and "very acceptable" by the panel.

Table 2. Farmer rating of grain traits and reasons for their choice, and grain yield, Namibia, 1993.

Variety/ rating	Grain yield ($kg\,plot^{-1}$)	Farmer score[1]	Reasons
SDMV 92040	3.0	5	Easy to dehull Easy to grind Acceptable color Large grain size
Okashana 1	3.6	5	Large grain size Acceptable taste Difficult to dehull Difficult to grind Acceptable cooking quality
SDMV 90016[2]	2.2	5	Easy to dehull Easy to grind Resists storage pests Good cooking qualities Good taste
Farmers' LLV	2.2	4	Acceptable color Easy to dehull Easy to grind Very good cooking quality Good taste
SDMV 91018	2.0	3	Small grain size Difficult to dehull Difficult to grind Taste unacceptable
ICMV-F 86415	2.0	2	Poor seed-set Not a pleasing color Difficult to dehull Difficult to grind Unacceptable taste

1. Scored on a 1-5 scale, where 1 = poor, and 5 = excellent.
2. Some farmers thought that the wedge-shaped grains of SDMV 90016 would discourage storage pests.

SDMV 91018 was rated "average", and ICMV-86415 "poor". Both had small grains, and were difficult to dehull and grind into flour. Their taste was also scored as unacceptable, and ICMV-86415 was particularly noted as having an unpleasantly colored product. This variety is deep gray and the flour from it was very dark when compared with the others. All the varieties except ICMV-F 86415 and SDMV 91018 were rated as having better food preparation qualities than the farmers' LLV (Table 3). With regard to taste, only SDMV 90016 was rated better than the LLV control. However, SDMV 92040 was rated similar to the local, while on Okashana 1

Table 3. Overall grain preference ratings (%) of elite cultivars compared with the farmers' LLV, Namibia, 1993.

Grain trait	No. of responses	SDMV 92039			SDMV 92040		
		Better	Same	Worse	Better	Same	Worse
Grain size	10	10	10	80	70	30	0
Grain color	10	0	20	80	80	20	0
Dehulling	25	0	100	0	100	0	0
Grinding	25	0	100	0	100	0	0
Food prepn.	25	100	0	0	100	0	0
Food taste	25	0	0	100	0	100	0
		SDMV 90016			ICMV-F 86415		
		Better	Same	Worse	Better	Same	Worse
Grain size	10	10	20	70	0	10	90
Grain color	10	40	40	20	0	30	70
Dehulling	25	100	0	0	0	0	100
Grinding	25	100	0	0	0	0	100
Food prepn.	25	100	0	0	0	100	0
Food taste	25	100	0	0	0	0	100
		SDMV 91018			Okashana 1		
		Better	Same	Worse	Better	Same	Worse
Grain size	10	0	10	90	90	10	0
Grain color	10	0	40	60	20	30	50
Dehulling	25	0	0	100	0	0	0
Grinding	25	0	0	100	0	0	100
Food prepn.	25	0	100	0	100	0	0
Food taste	25	0	0	100	20	40	40

the farmers were split, with 20% rating it better than the LLV, 40% the same as the local and 40% worse than the LLV. SDMV 92039, ICMV-F 86415, and SDMV 91018 were rated by all panel members as worse than the LLV in terms of food taste. It is worth noting here that two of the varieties, SDMV 91018 and ICMV-F 86415, are currently under farmer verification in on-farm trials. If the above information had been available before sending them for large-scale demonstration and verification with farmers, a lot of resources could have been saved. This is how farmer participation early on in the breeding process becomes very useful.

In similar comparisons with Okashana 1, only SDMV 92040, and SDMV 90016 were identified as superior in terms of food taste. These varieties, plus the farmers' LLV were also rated superior to Okashana in terms of dehulling and grinding ease.

Table 4. Overall grain preference ratings (%) of elite cultivars compared with Okashana 1, Namibia, 1993.

Grain trait	No. of responses	SDMV 92039			SDMV 92040		
		Better	Same	Worse	Better	Same	Worse
Grain size	10	0	10	90	40	60	0
Grain color	10	0	30	70	60	40	0
Dehulling	25	0	0	100	100	0	0
Grinding	25	0	0	100	100	0	0
Food prepn.	25	0	100	0	100	0	0
Food taste	25	0	100	0	0	100	0
		SDMV 90016			ICMV-F 86415		
		Better	Same	Worse	Better	Same	Worse
Grain size	10	0	40	60	0	0	100
Grain color	10	50	20	30	10	20	70
Dehulling	25	100	0	0	0	0	100
Grinding	25	100	0	0	0	0	100
Food prepn.	25	0	100	0	0	100	0
Food taste	25	100	0	0	0	0	100
		SDMV 91018			Farmers' LLV		
		Better	Same	Worse	Better	Same	Worse
Grain size	10	0	0	100	0	0	100
Grain color	10	10	20	70	20	70	10
Dehulling	25	0	0	100	100	0	0
Grinding	25	0	0	100	100	0	0
Food prepn.	25	0	100	0	0	0	100
Food taste	25	0	0	100	40	40	20

However only SDMV 92040 was rated better than Okashana 1 in food preparation quality though SDMV 90016 was rated the same as Okashana 1.

The farmers' LLV was rated worse than Okashana 1 in this aspect, though SDMV 90016 was rated on a par with Okashana 1. It could be important to find out what causes differences in food preparation qualities. One explanation is the possible differences in their starch swelling temperature. As the porridge swells and thickens, it becomes difficult for more flour to dissolve; as a result lumps form and a smooth porridge cannot be obtained.

These studies showed that the farmers' LLV is very good for grinding and dehulling. It has a pleasing color and tastes good. This probably accounts for some of the reasons that the farmers have kept this variety for centuries. Some of the improved varieties such as SDMV 92040, SDMV 90016, and Okashana 1 have the same qualities as the farmers' local control above, and in addition they mature about 3 weeks to 1 month earlier. This ensures food security for the farmer and his family in good years and in seasons of terminal drought. These varieties can also be sown up to 1 month later than the locals and still ensure some harvest for the family.

Conclusion

Identifying potential varieties such as the ones discussed above early in the breeding and selection process, and concentrating efforts and resources on further improving them will be more cost-effective, and bear better results. Farmer participation with breeders in evaluating, selecting, and advancing promising genetic materials early in the breeding program is a sure way of achieving this.

Pearl Millet Production System(s) in the Communal Areas of Northern Namibia: Priority Research Foci Arising from a Diagnostic Study

C M Matanyaire[1]

Abstract

Pearl millet is the major crop in northern Namibia where 60% of the population live. Although agricultural research was conducted in these areas during the pre-independence period, the first study to obtain baseline information was conducted in 1993.

The study confirmed the predominance of pearl millet in northern Namibia, with an average sown area per household of 3.5 ha. The farmers identify short duration as the most preferred varietal trait above grain yield, and research needs to be targeted in line with the farmers' preferences. Drought was identified as the major constraint on pearl millet production followed by lack of draft power. Farmers do recognize the importance of a good crop stand, early thinning, and weeding. The use of manure is widespread while the use of chemical fertilizer is very limited.

Research priorities identified in the study include the development of drought-alleviating technologies, development of pearl millet cultivars that meet the farmers' preference, and improvement of soil fertility and crop management strategies.

A large pearl millet grain yield gap was identified with on-farm yields of 0.15 to 0.20 t ha^{1} *compared with on-station yields of 3.63 to 3.87 t ha*^{1} *during the 1992/93 season. The yield gap analysis shows the comparative grain yield gains of improved management to be between 134 and 725% (for the levels of management identified) compared with varietal change yield gains of 6 to 44% at the specified management levels. Based on these findings the Ministry of Agriculture, Water and Rural Development (MAWRD) is requested to put more effort into resource management research as opposed to genetic improvement, with more emphasis on on-farm research.*

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Background

The farmers in the northern communal areas of Namibia, namely, Caprivi, Kavango, and the four regions covering the former Owamboland—Oshikoto, Oshana, Ohangwena, and Omusati—practice a mixed farming system. The system is based on crop and livestock production systems that are interdependent.

Pearl millet is the dominant crop. With no formal pearl millet grain markets, household food security is the target for most farmers.

There are very few baseline data on the farming system and little understanding of its component production systems (UNICEF 1989). During the pre-independence period, research on pearl millet and associated production systems was not given attention. The farmers living in these areas know what is good for them; their survival is adequate testimony to their authority. This baseline survey is the first recorded comprehensive attempt to obtain quantitative data on pearl millet-based production system(s) of northern Namibia. The study seeks to identify research priorities and foci based on the knowledge and perceptions of farmers.

Method of Data Collection

A survey, using a structured questionnaire, was conducted between May and April 1993. Agricultural extension officers did the enumeration in their respective areas. A random sample of at least 20 farmers was interviewed around each Agricultural Development Centre (ADC). The ADC is the location of agriculture extension offices within the region and subregions. There was no preselection of respondents and presence at home during time of visit was an important deciding factor in the 'choice' of respondents. Considering the fact that the population densities in these areas are relatively low, the sample size at each ADC makes the respondents representative of the farming communities in northern Namibia. The actual sample sizes were as follows: Caprivi 18; Kavango 107; Omusati 38; Ondangwa 28; and Oshikoto 18.

In an accompanying exercise the areas of pearl millet and sorghum grown by farmers in the 1992/93 season were measured. This was done by extension officers using measuring wheels, with a target of measuring 20 arable holdings per ADC. Two hundred and six family holdings in the Kavango and Owambo regions were measured.

Results

Average size of holding

No national figures are available. The results of the area measurements conducted during the 1992/93 season are presented in Table 1 excluding the extreme values which had fewer than five observations in each class. On the lower end of the data set only four observations were discounted. The average size of area sown to pearl millet

Table 1. Area of pearl millet grown by individual farmers surveyed in 1993.

Class limit (ha)	Class value (ha)	Observed frequency
0.5-1.4	1	20
1.5-2.4	2	37
2.5-3.4	3	42
3.5-4.4	4	38
4.5-5.4	5	17
5.5-6.4	6	10
6.5-7.4	7	9
7.5-8.4	8	6
Mean	3.5	
SD	±1.76	

per household from this data set is 3.5 ha. If classes with 10 or fewer observations are dropped, the mean is reduced to 2.96 ha.

Constraints on pearl millet production

A primary objective was to identify the major constraints limiting pearl millet production. The rank order of the constraints was established using a score calculated as the sum of the product of:

(Number of ranking respondents x rank order value)

where first is valued 3, second is valued 2, and third is valued 1.

Drought is the most important constraint recognized by farmers. Next is lack of draft power, with lack of improved seed coming third (Table 2). Viewing the produc-

Table 2. Constraints on pearl millet production in northern Namibia identified by a diagnostic survey: May-Jun 1993.

		Regional rank by score			
Constraint	Score[1]	National	Caprivi	Kavango	Owambo
Drought	409	1	3	1	1
Lack of draft power	321	2	4	2	2
Lack of improved seed	269	3	1	3	3
Lack of grain market	176	4	2	6	-
Lack of fertilizer	173	5	5	5	-
Lack of extension	170	6	-	4	5
Low soil fertility	144	7	-	6	-
Lack of manure	76	8	-	4	-

1. Score = (Number of ranking respondents x rank order value).

tion constraints by region, the major shift from the national pattern is noted in Caprivi where lack of improved seeds and lack of a grain market are classified as the major constraints. This may be due to the wetter environment associated with annual purchase of maize hybrid seed, and the remoteness of the Caprivi region from all urban centers and rail-heads.

Desired traits in pearl millet varieties

It was important to establish reasons for pearl millet cultivar preferences, in order to provide guidelines to the national pearl millet breeding program during its formative phase. The scoring system used for constraint ranking was also applied to rank trait desirability. The results are given in Table 3. Short duration is the most desirable trait followed by grain yield. Drought tolerance and grain size are also top on the list, way above grain storability and insect and disease resistance.

Table 3. Desired traits in improved pearl millet varieties: survey results May-Jun 1993.

Trait	Score[1]	Rank	Respondents ranking first (%)
Short duration	89	1	21.0
Grain yield	72	2	14.6
Drought tolerance	59	3	9.5
Grain size	55	4	12.5
Plant height	44	5	5.7
Head size	41	6	8.8
Insect resistance	39	7	4.8
Grain color	38	8	7.3
Grain storability	34	9	5.3
Disease resistance	27	10	3.0
Bird tolerance	25	11	3.0
Stem thickness	24	12	2.3
Stover yield	22	13	1.5
Milling quality	3	14	0.5

1. Score = (Number of ranking respondents x rank order value).

Crop management

Seedbed preparation. The majority of the farmers use animal power and sow their crop on the flat. However, there are striking regional differences. Ninety-five percent of the farmers in Caprivi, 92% in Kavango, and 67% Oshikoto sow on the flat. On the other hand 81%, 65%, and 33% of the Oshana, Omusati, and Oshikoto farmers sow on the ridge and broadbed.

Mulching is not a common practice. In Kavango 37% of the respondents collect the crop residues and burn them during the process of seedbed preparation. In Owambo, the crop residues are generally grazed down before the onset of the rains.

Sowing and thinning the crop. Fifty percent of the farmers sow their pearl millet crop on hills, in a row pattern, and 34% sow on scattered hills.

Dibbling along rows and broadcasting are not popular, each practice being used by fewer than 10% of the respondents.

The majority of the Caprivi respondents (72%) sow fewer than five seeds per hill (Table 4). A large percentage of the Caprivians (38%) also do not thin their crop (Table 5). The most common reason given for not thinning is shortage of labor. Nationally, 48% of the respondents sow between 5 and 10 seeds per hill.

Table 4. Proportion of farmers (%) sowing the indicated number of seeds per hill: 1993 survey results.

	Number of seeds sown per hill				
	<5	5-10	10-15	15-20	>20
National	27.8	47.8	10.0	5.3	7.7
Caprivi	72.2	16.7	5.6	0	5.6
Kavango	26.2	48.6	9.3	6.5	8.4
Omusati	7.9	78.9	13.9	0	0
Ondangwa	35.7	21.4	17.9	10.7	14.3
Oshikoto	22.2	50.0	0	5.6	11.1

Table 5. Proportion of farmers (%) thinning their pearl millet crop to the levels indicated: 1993 survey results.

Region	Don't thin	Thin to 1	Thin to 2	Thin to 3	Thin to 4	Thin to 5
National	6.2	2.9	17.7	44.5	23.5	5.3
Caprivi	38.9	0	11.1	27.8	11.1	5.6
Kavango	5.6	1.9	12.1	53.3	21.5	5.6
Omusati	0	2.6	21.1	42.1	31.6	2.6
Ondangwa	0	10.7	28.6	32.1	28.1	0
Oshikoto	0	0	33.3	33.3	16.7	16.7

Twenty-eight percent of the respondents sow fewer than 5 seeds per hill. It is interesting to note that close on 8% of the farmers sow over 20 seeds per hill.

Forty-five percent of the farmers thin to three seedlings per hill and 85% thin to between two and four seedlings per hill (Table 5).

A plant population count at two ADCs in Kavango also came up with a mean of three to four plants per hill.

Thinning and weeding time. Timeliness of thinning and weeding was equally of concern to the baseline data collection exercise. Tables 6, 7, and 8 contain the information on thinning time, weeding time, and the number of weedings per crop cycle respectively. Farmers generally forget to thin and weed on time. Seventy-five percent of the farmers planned to thin and 72% to weed their pearl millet crop within 3 weeks of emergence. Only 8% of the respondents thin, and 6% Weed their crops later than 4 weeks after emergence. These figures are consistent, considering the fact that most farmers thin and weed in one operation.

Table 6. Proportion of farmers (%) thinning their crop at the indicated times: 1993 survey results.

		Timing of thinning after emergence (days)			
Region	Thinning	<14	14-20	21-28	>28
National	3.3	30.5	42.1	14.8	7.7
Caprivi	33.3	16.7	27.8	5.6	16.7
Kavango	0.9	22.4	41.0	21.5	10.3
Omusati	0	42.1	55.3	0	2.6
Ondangwa	0	53.6	35.7	10.7	0
Oshikoto	0	27.8	44.4	22.2	5.6

Table 7. Proportion of farmers (%) weeding their pearl millet crop during the indicated period: 1993 survey results.

	Timing of weeding after emergence (weeks)			
Region	<2	2-3	3-4	>4
National	36.7	39.0	18.1	6.2
Caprivi	10.5	31.6	42.1	15.8
Kavango	28.0	42.1	21.5	8.45
Omusati	45.0	55.0	0	0
Ondangwa	71.4	14.3	14.3	0
Oshikoto	43.8	31.3	18.8	6.3

Table 8. Proportion of farmers (%) weeding their pearl millet crop 1-4 times during the season: 1993 survey results.

	Number of weedings per season			
	1	2	3	4
National	32.4	59.5	6.7	1.0
Caprivi	68.4	31.6	0	0
Kavango	30.8	69.2	0	0
Omusati	20.0	47.5	27.5	2.5
Ondangwa	17.9	75.0	7.1	0
Oshikoto	56.3	31.3	6.3	6.3

It may be noted from Table 8 that 60% of the farmers weed their pearl millet crop twice. Over 27% of the Omusati respondents weed their crop thrice, clearly demonstrating that farmers are fully aware of the importance of weeding. However, 68% of respondents in Caprivi and 56% of respondents in Oshikoto weed their pearl millet crop only once.

The majority of the farmers (84%) use the hand-hoe for weed control. The use of animal-drawn cultivators is not common, with 24% of the Kavango, 16% of the Caprivi, and 6% of the Oshikoto farmers making use of animal-drawn implements for weed control.

Fertility management

Another specific purpose of the survey was to establish the regularity of use of kraal manure, fertilizer, rotations, and intercropping. Nationally, 2.8% of the farmers regularly use chemical fertilizers, 21.6% use them sometimes, and 75.5% have never used chemical fertilizer. All respondents in Caprivi sometimes use fertilizer. Seventy-six percent of the respondents in Oshikoto sometimes use fertilizer. In Kavango (21%), Omusati (14%), and Oshana (13%) the farmers sometimes use fertilizer. N-P-K compound fertilizers are the most commonly used chemical fertilizers by the few fertilizer users, followed by straight P fertilizers. The quantities of chemical fertilizers used per farmer are small, being less than 50 kg per farmer (average for all users) during the 1992/93 season.

None of the respondents in Caprivi uses manure. Eighty-four percent of the Kavango respondents never use manure and only 8% use it sometimes. By contrast 40% of the respondents in the former Owamboland regions regularly use manure, and 48% use it sometimes. The quantities used during 1992/93 per farmer (averaged for users only) ranged from 2.5 t in Kavango to 3 t in the former Owamboland regions. The usage of organic and inorganic manure per unit area was not easy to establish because of farmers' difficulties in area estimation.

Fallowing as a fertility management strategy is not common; only 1.6% of the farmers regularly do it. Eighteen percent of the farmers sometimes leave their lands fallow to restore fertility while 79% never do it.

Intercropping is a common practice with 45% of the respondents' cereal crop lands being regularly intercropped while 34% are sometimes intercropped (Table 9).

Table 9. Proportion of farmers (%) using legumes for intercropping: 1993 survey results.

Region	Never intercrop	Sometimes intercrop	Regularly intercrop
National	17.1	34.2	45.2
Caprivi	33.3	48.6	15.2
Kavango	12.9	33.6	51.1
Omusati	20.9	36.3	43.4
Ondangwa	14.3	28.6	47.6
Oshikoto	5.6	11.8	70.6

Cowpea is the dominant legume used for intercropping with 98% of the farmers using it. It is the sole legume used in the intercropping system of the Oshikoto and Oshana regions. The cowpea densities used are generally low and the pearl millet to cowpea ratio was not easy to quantify. Crop rotation is not common, with 74% of the lands being under continuous pearl millet. Only 5% of the lands are regularly rotated and 17% of the lands are sometimes rotated.

Discussion: Implications for Research

The pearl millet area in Namibia

The area sown to sorghum and pearl millet nationally during the 1992/93 season is given by the Namibian Early Warning and Food Information System as 171 200 ha. This is made up of 143 000 ha in Owambo, 17 000 in Kavango and 11 200 in Caprivi. These figures are not based on any known measurements.

The 1991 population census by the Ministry of Home Affairs established that the population of the pearl millet growing areas of the north is 829 000, which is 60% of the national population. The regional figures were as follows:

Owambo 601 000, Kavango 157 000, and Caprivi 71 000.

The average family sizes were established to be 4.6 (Caprivi), 6.0 (Owambo), and 6.2 (Kavango). The census figures also indicate that 80% of the population in Owambo is rural. Of the 140 000 households in the pearl millet growing areas of northern Namibia, 112 000 are estimated to be rural cultivators.

A MAWRD/ICRISAT Millet subsector study (Keyler 1993) estimated the average household hectarages during the 1993 harvest to be 3.5 ha for Owambo and 2.9 ha for Kavango. This is in agreement with the area measurements we conducted during the 1992/93 season (Table 1). Our survey results also indicated that the sorghum area per cultivator was less than 0.1 ha and the maize area was negligible. The Namibian Early Warning and Food Information System reports a maize area of 14 800 ha in Caprivi during the 1992/93 season, and no maize in Kavango and Owambo.

From the above information the national area sown to pearl millet has been re-estimated. Using the lower mean pearl millet hectarage per cultivar of 2.96 ha, it is estimated that the area under pearl millet during the 1992/93 season in northern Namibia was 331 500 ha. It is unlikely that this area varies greatly from year to year. Thus any Namibian research effort targeted to the small-scale crop growers has to be on pearl millet and its associated production systems.

Drought: the major constraint

The pearl millet-growing communal areas of northern Namibia are characterized by low, erratic rainfall ranging from 300 mm y^{-1} in the west to 600 mm y^{-1} in the east. Season length ranges from 80 to 100 days (Hutchinson 1993). The high potential evapotranspiration and the low water-holding capacity of the predominantly sandy soils with a low organic content further destabilizes the already precarious soil moisture balance potential for successful cropping.

The farmers' knowledge of their environment is good; and they do recognize this soil moisture limitation (drought) as the major constraint on pearl millet production. While no data are available the yields are known to be very variable from year to year and to be totally dependent on season quality. The production estimates from the Namibian Early Warning and Information System between 1990/91 and 1992/93 clearly indicate this trend. Research priorities are the development and adaptation of technologies that minimize the detrimental effects of drought on rainfed pearl millet production. The technology must raise yields and increase yield stability.

Draft power constraint

The human population and livestock numbers in the northern communal areas do not reflect an obvious scarcity of animal draft power. However, the results of the survey come up with lack of draft power as the number two constraint.

Rapid rural appraisals conducted in Kavango during 1993 also identified lack of draft power as one of the major constraints on crop production (Morrow 1993). There is a need to establish the livestock ownership patterns in these communal areas, which the study did not do. The data on manure use, however, suggest a more widespread cattle ownership pattern in former Owamboland and may be a sharper skew in Kavango.

In the former Owamboland regions there is extreme grazing pressure around the villages. Cattle are moved away from home during the dry season only to return when the grazing has recovered following the onset of the rains. There is no supplementary feeding for the livestock, though farmers attach little importance to crop residues.

Thus, at the start of the season there are no animals in the village to provide the needed draft power. The few that may be present are usually too weak to plow. Livestock management strategies thus aggravate the draft power scarcity constraint on crop production. Technologies that would extend the areas worked by the few draft animals available and/or make the available animal draft power more productive from the onset of the rains should be developed and adapted.

Lack of improved seed

The lack of improved pearl millet seed is a result of pre-independence neglect of research on the crop (UNICEF 1989). The post-independence release of Okashana 1 and provision of seed for the variety by Government has generated a large interest in the use of improved pearl millet seed. The Caprivi farmers have had pre-independence exposure to improved maize and sorghum seed due to the comparatively higher agricultural potential of their region; hence their greater appreciation of improved seed. This demand for improved seed needs to be addressed within the framework of the desirable cultivar traits as identified by farmers. The fact that farmers put more emphasis on variety earliness over grain yield may indicate their concern for grain yield stability and/or the need for an early harvest.

Farmers associate varietal earliness with grain yield stability. There is, however, no scientific research data to back the assumption that varietal earliness improves grain yield stability.

Furthermore, farmers still consider drought tolerance as an important trait requirement in improved cultivars, clearly showing their concern about the aridity of their environment. Grain and head size are also placed high on the farmers' priority list of desirable cultivar traits. The fact that disease and pest tolerance are not ranked high may indicate their low incidence in the existing pearl millet production systems.

The farmers indicate that Okashana 1 meets their expectations for desirable traits in improved pearl millet varieties. To avoid putting all their eggs in one 'unknown' basket the farmers do wisely continue to grow their landrace cultivars.

The cultivars to be developed in the short-term would thus have to take into consideration these clearly defined farmers' varietal trait preferences. Thus, development and adaptation of improved pearl millet cultivars that do satisfy the farmers' desirable traits, i.e., earliness, grain yield, and drought tolerance, are the research priorities.

Use of fertilizer

The recognition of constraints such as lack of fertilizer and manure indicates the farmers' sensitivity to the problems of poor soil fertility. The high risks of failure that go with cropping in the semi-arid zones result in very limited use of externally purchased inputs. The lack of a guaranteed formal grain market also discourages the use of costly purchased inputs. Consequently less than 3% of the farmers regularly use fertilizer and over 75% never use it. However, the fact that some fertilizer is used on pearl millet indicates that the crop is of great importance in the Namibian farming system, unlike the situation in other SADC countries. For example, no farmer in Zimbabwe is known to apply fertilizer on pearl millet.

The majority of farmers in the former Owamboland regions also apply manure on pearl millet. The limited use of manure in Kavango and Caprivi may be related to the low human population pressure allowing for some shifting cultivation.

There are, however, no fertilizer or manure use recommendations for the farmers in the northern communal areas of Namibia. Research priorities should, therefore, be the development and adaptation of low-cost soil fertility maintenance strategies based on a combination of organic and inorganic fertilizers.

Intercropping and crop rotations

Pearl millet/cowpea intercropping is a very common practice, with 98% of the pearl millet farmers using the system. However, the pearl millet/cowpea ratio in the cropped lands varies from farmer to farmer. There is no optimum spatial arrangement known for Namibian conditions which extension staff can recommend to farmers. The use of intercropping as drought insurance is widely used in similar regions, and research elsewhere has demonstrated increased and more stable yields from intercrops compared with sole crops (Willey 1979). The economic returns in Niger under traditional farming conditions have been reported to be substantially higher for intercropped pearl millet than sole-cropped millet (Spencer and Sivakumar 1986). Therefore, the research priorities are to develop and adapt pearl millet/cowpea intercropping technologies that enhance the production systems' grain yield and yield stability, and use cultivars of both pearl millet and cowpeas that are acceptable to the farmers.

Seedbed configuration. The use of flat seedbeds is associated with sandy soils of high infiltration and good drainage. On the other hand, the use of ridges and broadbeds is associated with soils of poor drainage situated on very flat terrain. Ridging is reported to improve seedling establishment (Fussel et al. 1986), especially during over-wet periods. There is, however, no follow-up to link these drainage measures with moisture conservation technologies later in the season when the crop water demands are higher and the potential benefits of minimizing runoff greater. The research priorities are thus the development and adaptation of technologies that minimize runoff during the latter half of the crop cycle by transforming or manipulating the surface water drainage technologies currently in use.

Use of crop residues. Farmers who use the hand-hoe for primary land preparation burn crop residues at the time of land preparation. The farmers say this reduces weeds and pests.

However, the practice of burning crop residues in an environment where soils are devoid of organic matter and have a very low nitrogen status needs reviewing.

There is merit, therefore, in developing technologies that will enable the farming system to benefit from the crop residues irrespective of the method of primary cultivation. Experiments in India have shown that use of organic mulches, for example, can increase pearl millet yield by 25%, especially in years of poorly distributed rainfall (Spencer and Sivakumar 1986).

The practicalities and economics of mulching in the situation of the small farmer remains questionable. Where crop residues are available, there is merit in using them to possible advantage. Thus, the development and adaptation of technologies that exploit the soil improvement capabilities of crop residues, whilst addressing the farmers' requirement to minimize carryover of weeds and pests, are the research priorities.

Crop thinning and weeding. Farmers know the importance of good seedling establishment, early thinning and weeding, including the potential benefits of keeping the crop clean throughout its growth cycle. Early thinning and weeding are known to contribute to good yields (Gautam and Kaushik 1980a), and yield reductions of between 25 and 50% due to weed completion have been estimated (Spencer and

Sivakumar 1986). In the former Owamboland regions and in Kavango, where pearl millet is the dominant cereal, weeding is done 2 to 3 times during the season.

The finding that the majority of Caprivi respondents only weed once may be explained by the fact that in this comparatively high agricultural potential area, pearl millet becomes a cereal of tertiary importance to maize and sorghum. The reason why the majority of Oshikoto farmers weed only once is not clear. It may be related to low weed pressures. This needs verification.

The limited use of animal-drawn, interrow weeders may be due to the farmers' and extension officers' limited exposure to the technology due to pre-independence human movement restrictions. Since farmers are aware of the importance of timely weeding, any failure to control weeds is associated with labor shortages. Consequently, the use of technologies that would make weed control easier would be beneficial to crop production. The research priorities are therefore to develop, introduce, and adapt animal-based weed-control technologies that fit into the pearl millet production systems used in northern Namibia.

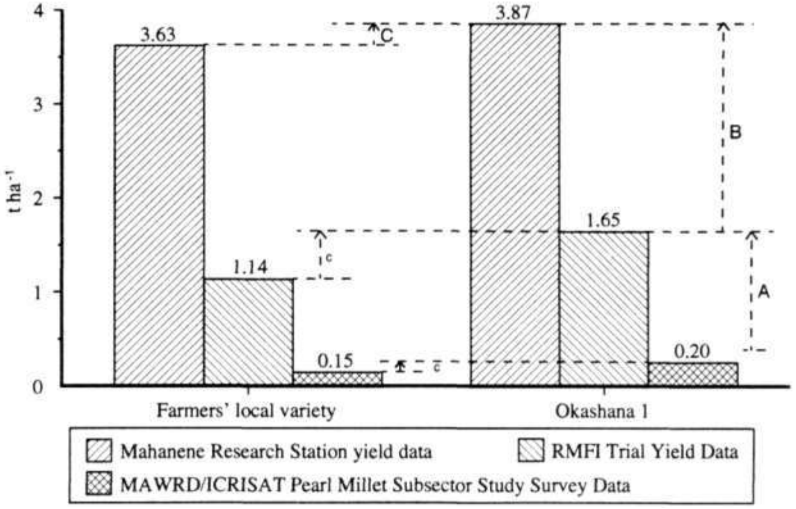
The pearl millet yield gap

The Namibian Early Warning and Food Information System, the only source of national statistics, estimated the 1992/93 pearl millet and sorghum grain yields to be between 0.24 t ha^{-1} and 0.26 t ha^{-1}. During the 1991/92 drought season, yields were estimated to be 0.1 t ha^{-1} for the main pearl millet growing areas of Owambo and Kavango.

The on-station and on-farm research data collected during the 1992/93 and 1993/94 seasons are used separately in Figures 1 and 2 to illustrate the pearl millet yield gap with respect to both the farmers' local landrace varieties (LLVs)and the improved released cultivar Okashana 1. The MAWRD/ICRISAT pearl millet subsector study yield figures used in the 1992/93 yield gap illustration are of similar magnitude to the estimates used by the Namibian Early Warning and Food Information System. By contrast, the on-station yields are about 20 times higher than the farmers' estimated pearl millet grain yields.

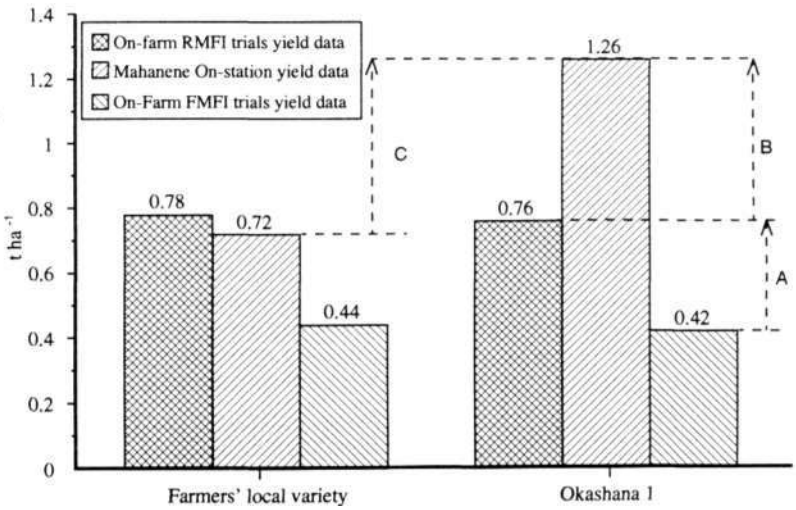
Both Figures 1 and 2 also show the yield gains due to cultivar change and management change. Using the 1992/93 data, it is interesting to note that the change in cultivar results in grain yield gains of between 6 and 44% at the three identified levels of management, while the grain yield gains by moving from one management level to the other are 134% and 725% for Okashana 1, and 218% and 660% for the farmers' LLV.

The 1993/94 pearl millet grain yield gains are less spectacular but the relative magnitude of management versus cultivar change gains is maintained.



A and B = management change yield gain C = variety change yield gain

Figure 1. The 1992/93 yield gap of Okashana 1 and the farmers' LLVs in Namibia.



A and B - management change yield gain C - variety change yield gain

Figure 2. The 1993/94 yield gap of Okashana 1 and the farmers' LLVs.

Short-term options for the Namibian NARS

The human resource capacity of the Namibian NARS for crop research is very limited. Consequently, not all the priorities enumerated above can be addressed in the short term. This calls for some stringent, hard choices and reprioritization.

The yield gain indications in Figures 1 and 2 suggest that the largest potential returns to investment in research would come from crop/soil/moisture management research as compared with crop genetic improvement. The MAWRD is, therefore, requested to seriously consider the strengthening of the national capacity for the development of management technologies in line with the priorities identified above using the available resources in order to maximize potential short-term research benefits.

Considering the limited NARS research capacity and the Division of Agricultural Extension's adoption of on-farm trials and demonstrations as an extension strategy, the returns on research may be further increased by emphasizing on-farm research in collaboration with extension. Research should therefore consider scaling down on-station research. Moreover, management-related technologies tend to be location-specific and on-farm research provides a cost-effective and time-efficient strategy to address location-specific technology adaptation and development requirements. Preliminary indications from the on-farm trials results seem to indicate that blanket, national cultivar and/or management recommendations would not be appropriate. Extension recommendations may have to be stratified on the basis of rainfall zones, with within-zone modifications for soil type. Broadly, technology development at this stage may be targeted at five zones: Owambo West, Owambo East, Kavango West, Kavango East, and Caprivi.

Prospects for technology adoption

The well-known aversion to risk and the limited resources of small-scale farmers make it necessary to review prospects for technology adoption. The Namibian pearl millet farmers have already demonstrated their dynamism and ability to adopt appropriate and affordable technology through their quick uptake of Okashana 1. In 2 years, 38% of the farmers in Owambo had adopted the new variety; and by the 3rd year it is estimated that 50% of the farmers were growing Okashana 1. This is certainly one of the success stories of technology adoption in the SADC semi-arid regions. The main advantage of genetic technology is that it is cheap. Management technologies are generally comparatively more expensive, especially the use of inorganic fertilizers.

The fact that some Namibian farmers are already using manure (large numbers) and inorganic fertilizers (few farmers) on pearl millet is an encouraging sign. The prospects of Namibian farmers adopting new management technologies will, therefore, largely depend on the appropriateness, affordability, relevance, and economics of the technology. The availability of a grain market for farmers to dispose of surplus production would be a good stimulus for the use of purchased inputs such as fertilizers. Increased yields may also promote adoption of cash crops since household annual food requirements are satisfied from a reduced pearl millet crop area. So it is important in the medium term for NARS to identify potential cash crops that fit into the agroecological zones where pearl millet is currently the major and/or sole crop.

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On-Farm Evaluation of Improved Pearl Millet Varieties in Namibia

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Abstract

Pearl millet varieties for on-farm testing in Namibia were selected from on-station testing during the 1990/91 and 1991/92 seasons. The on-farm trials were conducted at up to 14 locations in Owambolands and Kavango during the 1992/93 and 1993/94 seasons. During both seasons research-managed farmer-implemented (RMFI) trials were conducted. Farmer-managed farmer-implemented (FMFI) trials were also conducted at five locations during the 1993/94 season. Under RMFI trials, Okashana 1 gave significantly higher grain yields over the farmers' local landrace variety (LLV) in Owambolands. In Kavango the performance of Okashana 1 and the farmers' LLV control was the same over the last 2 years of testing.

Under farmer management all the varieties produced similar yields to the farmers' LLV. However, in the RMFI trial, varieties responded to fertilizer, and Okashana 1 was significantly superior to the farmers' LLV in respect of grain yield. Without any improvement in crop management practices, there seemed to be a little yield gain from cultivar change. None of the improved varieties under test produced higher grain yield than Okashana 1. The development of pearl millet cultivars needs to be targeted to zones currently broadly defined as Owambo and Kavango.

Introduction

Pearl millet is the most important crop in northern Namibia where 60% of the nation's population lives. Low rainfall (300 mm y^{-1} in the west increasing to 700 mm y^{-1} in the east), and the predominantly sandy soils in the area limit the farmers' crop choices in the west to pearl millet only. During the pre-independence era no research on pearl millet was conducted. The introduction of a pearl millet nursery by

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Matanyaire, C.M. and Gupta, S.C. 1996. On-farm evaluation of improved pearl millet varieties in Namibia. Pages 59-63 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

SADC/ICRISAT SMIP in 1987 through the Rossing Foundation led to the subsequent release of Okashana 1 following the farmers' identification of the variety as a preferred type. The post-independence government, however, is very supportive of pearl millet research. The NARS' collaboration with both SADC/ICRISAT SMIP and other regional NARS has provided a ready source of pearl millet cultivars for testing.

Following on-station testing during the 1990/91 and 1991/92 seasons, varieties for on-farm testing were identified. The on-farm trials were conducted in the Owambolands and Kavango regions during 1992/93 (11 locations) and 1993/94 (14 locations) seasons with two objectives: (a) to study the yield potential of improved varieties in farmers' fields with and without the use of improved cultivation practices, and (b) to study the traits preferred and not-preferred by farmers in new varieties. In this paper, the grain yield potential of new varieties is discussed.

Materials and Methods

During the 1992/93 season, eight varieties of pearl millet were evaluated in farmers' fields at 11 locations. The varieties included in the trial were ICMV-F 86415, ICMV 82132, Kaufela (a Zambian released variety), SDMV 89004, Okashana 1 (the improved control), Kantana 1, Kantana 2, and the host farmers' own local landrace variety (LLV). Kantana 1 and Kantana 2 are local landraces that were identified during the 1990/91 season. These RMFI trials were given a randomized complete block design (RCBD), with two replications per site. Plot size was 10 rows, 5 m long, and 0.75 m apart. Hill-to-hill spacing was 0.50 m. Eight central rows were harvested. The crop was thinned to three plants per hill 3-4 weeks after sowing. All plots were fertilized at the rate of 40 kg P ha^{-1} and 60 kg N ha^{-1}. The N was applied in two split applications: one-third at sowing and two-thirds just before the boot stage.

In the 1993/94 season, the RMFI trial was conducted in a RCBD with two factors-eight varieties, and two levels of fertilizers (with and without)—and replicated twice per location. Included in the trial were three new varieties (SDMV 90016, SDMV 91018, and SDMV 90004), three selected varieties from the 1992/93 on-farm trial (ICMV-F 86415, SDMV 89004, and Okashana 1), and two controls (Kantana and the host farmer's LLV). The fertilizer applied was 15 kg P ha^{-1} and 40 kg N ha^{-1}, based on the results of the 1992/93 fertilizer response in on-farm trials. The N was also applied in two split applications as for the previous experiment. The crop was sown and managed in the same manner as the 1992/93 RMFI trials crop. Plot size was reduced to five rows with a net plot size of three rows. Fourteen locations (eight in Kavango and six in Owambolands) were included in this study. RMFI trials were managed by extension with the assistance of researchers.

Five entries, namely SDMV 89004, ICMV-F 86415, Okashana 1, Kantana, and the host farmer's LLV were also evaluated during the 1993/94 season under the farmer's management. Each farmer provided a replicate, and the trial was sown at five locations with four farmers (replicates) at each location. The plot size was 5 x 5 m, with a net plot size of 3 x 3 m. The farmers sowed and managed the crop in the same manner as they usually do for their pearl millet crop fields. No extension/research influence was imposed on managing these trials.

The analysis of variance was carried out using ANOVA (SAS Institute, 1985). Pooled analysis was done by zone (region). The zones were based on agroecological potential as dictated by rainfall, and to a lesser extent by soils. Two major zones identified were as follows:

a) Owambo, which has an annual rainfall of 300-400 mm. This can be further divided into Owambo West (poor drainage due to terrain and soil chemical composition), and Owambo East (no drainage problems).
b) Kavango, which receives between 400 and 600 mm of rainfall per year. This can be further divided into Kavango West and Kavango East which receive 400-500 mm and 500-600 mm annual rainfall respectively.

Results and Discussion

The grain yield data for 1992/93 season in four zones are presented in Table 1. Four varieties in Owambo West and three in Owambo East were significantly superior to the farmers' LLV control in respect of grain yield production. However, none of the improved varieties was superior to the farmers' LLV in the Kavango East and Kavango West zones, although they performed equally well as the farmers' LLV Two varieties—Okashana 1 and SDMV 89004 (released in Zimbabwe as PMV 2)—produced significantly higher grain yields in comparison with the farmers' LLV in both Owambo West and Owambo East zones. These Jesuits suggest to some extent that the improved varieties are more adapted to the zones of Owambo than to the zones of Kavango.

Table 1. Mean grain yield (t ha^{-1}) trial data of on-farm pearl millet varieties averaged over one to four locations in different regions of Namibia, 1992/93 season.

Variety	Owambo West	Owambo East	Kavango West	Kavango East
Okashana 1	1.71**	1.83*	1.93	1.25
ICMV-F 86415	1.48**	1.42	2.14	1.34
SDMV 89004	1.39*	2.19**	2.03	1.17
ICMV 82132	1.44**	1.44	1.78	1.03
Kaufela	1.11	1.75*	2.13	1.18
Kantana 1	1.01	0.97	1.57	1.13
Kantana 2	1.02	1.22	2.07	1.20
Farmers' LLV control	1.05	1.33	2.00	1.33
SE	±0.096	±0.118	±0.142	±0.066
Mean	1.27	1.52	1.95	1.20
CV(%)		11.0	-	-
Number of locations	3	1	3	4

*, ** Significantly different from farmers' control variety at 5% and 1% levels of probability respectively.

Table 2. Mean squares (M.S.) for grain yield (t ha^{-1}) trial data of on-farm pearl millet research-managed farmer-implemented varieties in two regions of Namibia: Kavango and Owambolands, and across two regions, 1993/94 season.

	Owambolands		Kavango		Namibia	
Sources	d.f.	M.S	d.f.	M.S	d.f.	M.S
Varieties (V)	7	0.336**	7	0.128	7	0.261
Fertilizers (F)	1	2.265**	1	3.679**	1	5.941**
Locations (L)	5	14.708**	7	32.048**	13	22.941**
V * F	7	0.052	7	0.125	7	0.106
L * V	35	0.271**	49	0.089	91	0.168
L * F	5	0.313**	7	0.296	13	0.280*
L * V * F	35	0.148*	49	0.148	91	0.142
Pooled error	90	0.088	120	0.171	210	0.136

*, **, Significant at 5% and 1% levels of probability respectively.

During the 1993/94 season, RMFI trials were conducted with and without fertilizer at 14 sites. Combined data analysis suggests that the differences among varieties were significant only in Owambolands and not in Kavango (Table 2). These results are in agreement with the findings of the 1992/93 season.

The mean squares due to fertilizers and locations were significant in Owambolands and Kavango as well as on a combined-location basis (Table 2). With the application of fertilizers, on an overall basis, grain yields increased significantly from 0.73 to 0.95 t ha^{-1} in Owambolands, and from 0.67 to 0.91 t ha^{-1} in Kavango. It is interesting to note that there were no interactions between varieties and fertilizers (Table 2), and therefore the variety means over fertilizer levels are discussed.

Table 3. Mean grain yield (t ha^{-1}) trial data of on-farm pearl millet research-managed farmer-implemented varieties averaged over two fertility levels and eight locations in Kavango, six locations in Owambolands, and across 14 locations, Namibia, 1993/94 season.

Variety	Owambolands	Kavango	Namibia
Okashana 1	1.00**	0.73	0.85
SDMV 90016	0.93*	0.74	0.82
SDMV 91018	0.92	0.92	0.92
SDMV 90004	0.90	0.81	0.85
SDMV 89004	0.87	0.80	0.83
ICMV-F 86415	0.79	0.82	0.81
Farmers' LLV	0.76	0.80	0.78
Kantana	0.63	0.72	0.68
SE	±0.061	±0.073	±0.049
Mean	0.85	0.79	0.82

* ** Significantly different from farmers' control variety at 5% and 1% levels of probability respectively.

Table 4. Mean grain yield (t ha^{-1}) trial data of on-farm peart millet farmer-managed farmer-implemented varieties averaged over three locations in Kavango, two locations in Owambolands, and across five locations, Namibia, 1993/1994 season.

Variety	Owambolands	Kavango	Namibia
Okashana 1	0.72	0.32	0.49
SDMV 89004	0.76	0.35	0.51
ICMV-F 86415	0.77	0.32	0.50
Farmers' LLV	0.67	0.36	0.49
Kantana	0.44	0.31	0.36
SE	±0.087	±0.035	±0.040
Mean	0.68	0.33	0.47

Two varieties in the RMFI trial—Okashana 1 and SDMV 90016—produced significantly higher grain yields as compared with the farmers' LLV in Owambolands (Table 3). The results for two seasons suggest that Okashana 1 has yielded significantly higher than the farmers' LLV in Owambolands.

The evaluation of the improved varieties under farmers' own management during the 1993/94 season showed that none of the improved varieties had grain yield superiority to the farmers' LLV in both Kavango and Owambo regions (Table 4).

The results of 2 years of testing indicate the following findings:

1. Under research management, Okashana 1 gave significantly higher grain yield over the farmers' LLV in Owambolands . In Kavango the performance of Okashana 1 and the farmers' LLV was the same over the last 2 years of testing.
2. Under farmer management, all the varieties produced similar yields to the farmers' LLV. However, in the RMFI trial, varieties responded to fertilizer, and Okashana 1 was significantly superior to the farmers' LLV in respect of grain yield. Without any improvement in crop management practices, there seemed to be a little yield gain from cultivar change.
3. None of the improved varieties under test produced higher grain yield than Okashana 1.
4. The development of pearl millet cultivars needs to be targeted to zones currently broadly defined as Owambo and Kavango.

Evaluation of Crop Performance and Farmer Preference for Pearl Millet Varieties in Tanzania

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Abstract

This study was carried out to select an improved pearl millet variety acceptable to the farming community of Tanzania, after comparison with farmers' local land-race varieties (LLVs). Twenty-one farmers from three districts participated. Improved varieties TSPM 91018 and TSPM 91001, which had been used in national on-station trials for more than three seasons and were found to be promising, were established in the farmers' fields in three districts in the 1993/94 season. The farmers' LLV and Serere 17, an improved released variety, were included in the Singida district trial for additional comparison.

The variety TSPM 91018 was selected by farmers because of its earliness in maturity, long heads, large grain size and high yield. This variety was superior overall to the farmers' LLV and the improved released variety Serere 17. Across villages in the three districts TSPM 91018 produced 2.31 t ha^{-1} of grain, 43% more than the farmers' LLV (1.62 t ha^{-1}). In Dodoma district, where both the farmers' LLV and Serere 17 were included, the new variety yielded 28% and 48% more respectively. This variety matures about 2 weeks earlier than the farmers' LLV, which gives it an advantage of escaping drought in seasons characterized by the early termination of rains—a normal occurrence in the central plateau of Tanzania.

Introduction

The Tanzania national agricultural research program and SADC/ICRISAT/SMIP have participated in a joint project to improve pearl millet varieties for Tanzania since

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1989. Through this project several high-yielding varieties have been developed and tested in several research stations throughout the country.

Pearl millet is a major crop, particularly in the central part of Tanzania, comprising Dodoma, Singida, and Shinyanga regions. The crop covers about half of the land under cereal cultivation in the three regions and, apart from sorghum, it is a crop on which farmers depend for their food. The average annual rainfall in these areas is about 600 mm. The farmers have been growing this crop for a long time and the most common varieties are still their local landraces. It is a crop of high value in the community and it is used for food, particularly in the preparation of both thin and stiff porridge, as well as a source of cash.

The local landrace varieties (LLVs) take a long time to mature and, as a result of the small amount of rainfall in this part of the country, in most years the plants are unable to fill the grain due to early termination of the rains. So it is desirable to obtain a variety that matures earlier than farmers' LLVs. Earlier, Serere 17 was bred to serve this purpose. But it was observed to mature too early, i.e., its maturity coincided with the annual migration of quelea birds in the pearl millet zone. As a result this variety suffered considerable damage from bird attack, and is no longer popular in the farming community.

Essentially, an improved variety is needed that is earlier than the farmers' LLVs, to escape terminal drought which is often experienced by these cultivars, but with slightly later maturity than Serere 17, in order to avoid maturing when quelea birds migrate.

Since superiority of a new variety over that of the farmers' LLVs must be established in on-farm conditions, the Tanzania national sorghum and millets program began on-farm research in Dodoma and Singida regions, which are the extension target areas for the crop. On-farm research gave farmers a chance to grow new pearl millet varieties in their own environments and an opportunity to select the variety of their choice.

Materials and Methods

Farmers were selected from five different villages in three districts to represent the farmers in the target area, so that new varieties could subsequently be recommended for adoption with the assistance of extension personnel. The villages involved in the trials were Ilolo and Chanhumba in Dodoma rural district, Ntondo and Unyianga in Singida rural district, and Tulya in Iramba district.

In general most of the villages had sandy loam and sandy clay loam soils. Dry seeding is normally done in Dodoma in November while, in Singida, seed is normally sown in January after the land has been tilled with an oxen-drawn plow. These trials were sown in Dec 1993 in Dodoma district and the rains came early in Jan 1994. In Singida and Iramba districts sowing was done from early January to early February.

In all villages seeds were sown at a spacing of 80 x 30 cm (41 667 plants ha^{-1}). Most farmers in Dodoma did not use any fertilizers or manure, whereas most farmers in Singida and Iramba applied farmyard manure just before sowing at a rate of 10 t ha^{-1}

(250 g hole^{-1}). The number of weedings was variable; while most farmers in Dodoma weeded twice, those in Singida did up to three weedings before the crop flowered, and in Iramba weeding was done twice.

In all three districts no disease or pest control program was undertaken because field pests and diseases were not a major problem in the 1993/94 season. As during the previous grain harvest, the major problem encountered was storage pests, and follow-up studies are planned.

Field data were collected by the extension personnel and, because data on the number of days to flowering and the number of days to maturity were not recorded at all locations, this information is not presented in the tables. The data collected were from a sample area of 45 m^2 and included the following parameters:

1. Number of hills: determined by counting the number of hills from the sample areas.
2. Head count: the number of heads harvested from a sample area.
3. Head weight: determined by weighing the dried heads from the sample area.
4. Grain yield: after threshing the grain was collected and weighed in grams per plot.
5. Farmer preference: i.e., which variety was most preferred, followed by the second choice.

Results and Discussion

In Dodoma district TSPM 91018 produced the highest grain yield (1.44 t ha-^{1}) and was significantly superior to all other varieties in respect of grain production (Table 1). This variety had a yield advantage of about 29% over the farmers' LLV. This variety also had significantly higher threshing percentage as compared with the farmers' LLV and Serere 17. TSPM 91001 had the highest plant population, whereas Serere 17 produced the highest number of heads per plot.

Table 1. Performance data of pearl millet on-farm verification trial entries averaged over a total of eight unreplicated sites in two villages, Dodoma rural district Tanzania, 1993/94 season.

Variety	Plant count (ha^{-1})	Head count (ha^{-1})	Threshing (%)	Grain yield (t ha^{-1})
TSPM 91018	25703	76094	67.9	1.44
TSMP 91001	29609	76796	61.6	1.13
Farmers' LLV	27656	50625	58.8	1.12
Serere 17	27344	92813	60.0	0.97
Mean	27578	74082	62.1	1.17
SE	±985	±5291	±2.8	±0.10
CV(%)	10.1	20.2	12.9	24.2

Table 2. Performance data of pearl millet on-farm verification trial entries averaged over a total of nine unreplicated sites in two villages, Singida rural district, Tanzania, 1993/94 season.

Variety	Plant count (ha^{-1})	Head count (ha^{-1})	Threshing (%)	Grain yield ($t\ ha^{-1}$)
TSPM 91018	37500	100089	59.6	2.90
TSPM 91001	36736	97917	60.5	2.40
Farmers' LLV	31000	84125	47.5	1.98
Mean	35625	95357	57.1	2.46
SE	±3336	±4002	±4.2	±0.14
CV(%)	28.1	12.6	6.2	16.9

In Singida district, TSPM 91018 gave significantly higher grain yield as compared with TSPM 91001 and the farmers' LLV (Table 2). It had yield advantage of about 46% over the farmers' LLV, and 16% over TSPM 91001 (Table 2). Serere 17 was not included in this trial. Both TSPM 91018 and TSPM 91001 were superior to the farmers' LLV in respect of head count per hectare and threshing percentage.

In Iramba district TSPM 91018 also produced significantly higher grain yield as compared with other varieties (Table 3). There were no significant differences among varieties for other traits.

Table 3. Performance data of pearl millet on-farm verification trial entries averaged over a total of four unreplicated sites in one village, Iramba district, Tanzania, 1993/94 season.

Variety	Plant count (ha^{-1})	Head count (ha^{-1})	Threshing (%)	Grain yield ($t\ ha^{-1}$)
TSPM 91018	25469	48281	73.0	3.01
Farmers' LLV	32188	58125	76.7	2.18
TSMP 91001	25313	47656	71.0	2.05
Mean	27656	51354	73.5	2.41
SE	±2724	±6229	±4.2	±0.28
CV(%)	19.7	24.3	11.3	23.3

Based on the mean over all the sites across three districts, TSPM 91018 produced the highest grain yield (2.31 $t\ ha^{-1}$) followed by TSPM 91001 (1.85 $t\ ha^{-1}$) (Table 4). TSPM 91018 had 43% yield advantage over the farmers' LLV and 25% over TSPM 91001. TSPM 91018 had a higher threshing percentage, and a greater number of heads per plot as compared with the farmers' LLV.

Although data on days to flowering were not collected in all villages, in those villages where they were taken Serere 17 was the earliest to flower (42 days after sowing), followed by TSPM 91018 (47 days) and TSPM 91001 (55 days), while the

Table 4. Performance data of pearl millet on-farm verification trial entries averaged over 21 unreplicated sites across five villages of three districts: Dodoma rural, Singida rural, and Iramba, Tanzania, 1993/94 season.

Variety	Plant count (ha^{-1})	Head count (ha^{-1})	Threshing (%)	Grain yield ($t\ ha^{-1}$)
TSPM 91018	30000	79079	65.9	2.31
TSPM 91001	31845	80297	62.9	1.85
Serere 17	27344	92812	60.0	1.62
Farmers' LLV	29705	62242	59.7	1.62
Mean	30192	76759	62.5	1.82
SE	±1290	±3017	±1.6	±0.08
CV (%)	19.6	18.0	11.5	21.2

farmers' LLV took 64 days. Because it matures 30-35 days earlier than the farmers' LLV, Serere 17 is seriously attacked by birds. It was also observed that the farmers' LLV suffers from terminal drought.

Farmers' Preference

Throughout the growing season, farmers observed the performance of varieties in on-farm trials.

Just after emergence, 70% of the farmers selected TSPM 91018 as their first choice, particularly on the basis of seedling vigor, while the remaining farmers selected their LLV as the first choice.

On the basis of plant vigor (before heading), the first choice was TSPM 91018, followed by the farmers' LLV, TSPM 91001, and Serere 17.

After noting the days to flowering, all farmers selected TSPM 91018 as their first choice, followed by TSPM 91001, their LLV, and Serere 17. The reasons given for choosing TSPM 91018 are that it flowered earlier than their LLV and the heads were very long.

The fourth evaluation was done when all varieties had matured. The farmers' first choice was still TSPM 91018. Reasons for this choice were that it was earlier in flowering and matured in 79 days, while their LLV took more than 100 days to mature. They also cited long heads and larger grain size as added advantages over the LLVs.

Since Serere 17 is no longer popular in this area for the reasons already noted, it is desirable to obtain a variety that matures later than Serere 17 but earlier than the farmers' LLV. TSPM 91018 matures 15 days after Serere 17 but earlier than the farmers' LLVs. This variety was also superior in yield to all the varieties that were evaluated on farmers' fields, including the farmers' LLVs used in all the locations.

Conclusion

TSPM 91018 was observed to possess the desirable characters of earliness and high grain yield. In addition, it was the farmers' first choice in all the villages where the trials were conducted. This variety also fits well into the short rainy season of the central Tanzania zone. Due to its proven superiority in both yield and acceptability by farmers, this variety will be recommended to the variety release committee for prerelease in Nov 1994, for possible release in Oct 1995. During the 1994/95 season information will be collected from more villages in more districts throughout Tanzania to make a stronger case for release.

Farmers' Priorities for New Sorghum and Pearl Millet Varieties based on On-Farm Trials in Semi-Arid Tanzania

G Holtland[1]

Abstract

In the 1993/94 cropping season the Mvumi Rural Training Centre (MRTC) conducted on-farm trials with new sorghum and pearl millet varieties in cooperation with the Ilonga research station and the SADC/ICRISAT Sorghum and Millet Improvement Program (SMIP). Postharvest aspects were tested on-station. Taste preferences and farmers' priorities for further breeding were identified through discussions in selected villages.

All new sorghum varieties have poor postharvest qualities. Based on field observations, farmers liked SDS 2293-6 most. SV 1 was found to be too similar to the introduced variety Tegemeo to be of interest. Pearl millet variety TSPM 91018 was successful: it outyielded others by more than one-third and has good postharvest characters. TSPM 91001 is too similar to the local variety to be of interest.

In general improved pearl millet varieties merit high research priority because this is the most important food crop and it has no postharvest or marketing problems. New and available pearl millet varieties would be an incentive for farmers to further improve the management of their crops. The pure seeds needed could be produced by the MRTC in cooperation with research staff.

Introduction

The MRTC is a church-based NGO, but its extension work is done by village extension workers (VEWs) from the Ministries of Agriculture and Livestock and of Natural Resources. As a result of this cooperation, the MRTC was asked by the Regional Extension Officer of Dodoma to conduct on-farm trials in cooperation with the Tanzanian SMIP program in Ilonga. As one of the aims of the MRTC is to develop new technologies in a participatory way, it agreed to do so.

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Background Information

The Mvumi division is part of Ugogo, the dry heart of semi-arid Tanzania. Its problems are characteristic of semi-arid Africa: unreliable and low rainfall (550 mm y^{-1}), poor (sandy loam) soils, overpopulation (75 inhabitants km^{-1}), outmigration of men (38%), and overgrazing.

The accelerated soil erosion resulting from the overexploitation of the natural resources could be stopped only by enforced destocking in 1986 by the Dodoma soil conservation project (HADO). Since 1991, the MRTC has been successfully introducing zero-grazing in the area: it is economically viable and ecologically sound (Holtland 1994a).

The cropping system is based on hoe cultivation. Fallow periods are reduced to nearly nil and crop residues are burnt. Two major types of fields can be distinguished:

1. *Migunda* (84% of the area): dry-planted cereals, intercropped with minor crops such as Cucurbitaceae, lablab, cowpea, and pigeonpea. Pearl millet occupies roughly 75% of the area, while maize and sorghum occupy each half of the remaining 25%. Dry-planting is essential because the rainy season can start or stop at any time.
2. *Vigundu* (12%): groundnuts and bambara nuts in pure stands, sown after a proper land preparation after the onset of the rainy season.

Over the years many improved cropping practices have been tried. All have failed, including oxen-drawn tillage and the use of chemical fertilizer. Despite this, and despite the reduced fallow, the average yield is still the same as 50 years ago (±500 kg ha^{-1}) due to an improved management of the crops (through increased labor input ha^{-1}). Because of the deteriorating exchange rate between external inputs and local products (due to the liberalization policy of the Tanzanian Government) for the near future only innovations that build on this slow process of intensification can be successful. So new varieties that respond better to improved management must be an important component of any extension message, together with planting on lines and higher plant densities (Holtland 1994b).

Methodology

The trials involved sorghum and pearl millet. Four varieties were used of each crop: a local landrace variety (LLV), the locally used improved variety, and two not yet released varieties from the Tanzanian Sorghum and Millet Improvement Program (SMIP).

To make the trials realistic, a quarter of an acre (0.101 ha) was sown with each variety. As only small amounts of seeds were available, the number of farmers had to be limited to 12 per crop. These 12 were divided over two villages selected by the MRTC.

The farmers were selected by the VEWs in cooperation with the MRTC committee of the village. The VEWs and the MRTC assisted the farmers in selecting the fields for the trial. As the seeds were obtained rather-late, most farmers had already planted most of their (best) fields. So many fields were not uniform.

The seeds were given to the farmers with only one precondition: they should plant on lines 75 x 30 cm. The farmers decided on the management (weeding and thinning) themselves, so no organic or inorganic fertilizer was used. (On a future occasion the spacing might also be left to the farmers to decide, because different varieties have a different optimum plant density.)

In order to assess the harvest, subsamples were taken from all plots. Due to the high variability of the fields and the modest number of farmers, complete random sampling was not done because it would probably not have provided any statistically significant data. So data from obviously deviating trial areas were omitted from the sampling: mostly after lengthy discussions with the farmer on the history of the field and other causes of the observed variation (old kraals, old river beds, etc.). As most of the deviating areas in the plots were bad, the measured yields are higher than the real yields. It is more the potential yield under good farmer management which is measured than the actual yield under average farmer management conditions. This is in line with the need to obtain new varieties that respond better to improved management.

The yield of the subsamples were taken to the MRTC where the threshing, dehulling, and milling was done (and the time taken was recorded). The flour was taken back to the villages and a blind taste test was conducted. On the same occasion the farmers were asked to evaluate the varieties and to give their priorities for new varieties. This was done in three steps: first the farmers were asked to mention the differences between pairs of varieties. The most important differences were then taken as criteria to evaluate all varieties systematically. The last step was to ask farmers to indicate the most important characters of possible new varieties. In describing these, the farmers were obliged to prioritize them by allocating more or less of the 20 points available (visualized by maize cobs) to the different characters. In this last step men and women recorded their findings separately.

The rainy season of 1993/94 was reasonable. It started very late (05 Jan) but continued without dry spells until mid-March. So drought-escaping crops did relatively well compared with drought-tolerant crops.

Results

Sorghum

Introduction. Locally, many landrace varieties of sorghum are grown. All are long-straw, open-headed, white-seeded, and late-maturing. Most are grouped under the name Lugugu, a Guinea type of sorghum (Rao et al. 1989). Earlier adapted varieties from outside the area are Sandala and Bangala which are shorter and earlier-maturing. The local landrace variety (LLV) chosen for this trial was Mhoputa, which matures slightly earlier than the others in the Lugugu group.

Up to now the only successfully introduced variety is Tegemeo: a short, early-maturing variety, released in 1983. It is appreciated for its earliness and high yields, but has a number of disadvantages: problems with pests (in the field and during storage), dehulling is difficult (and gives high losses), and it has a poor taste. So it is difficult to sell locally. And because the expected industrial market did not materialize, marketing is problematic. The price is 20% lower than for other sorghums. This is one of the major reasons (next to loan repayment problems) for the failure of the Global 2000 program to transform the farming system in Dodoma. This failure also made farmers shy away from capital-intensive, market-oriented messages from the extension service.

In addition to Mhoputa and Tegemeo, two new varieties were selected for inclusion in the trial by the Tanzanian SMIP: SV 1 and SDS 2293-6.

The seeds were dry-planted by 11 of the 12 farmers. After the onset of the rains the improved seeds germinated very poorly. In the farmers' fields only 5-20% emerged, while in an on-station germination test only 51-62% of the improved seeds proved viable. The cause of the problem was poor storage of the seeds in Ilonga. The LLV had no germination problems. So the seeds were reallocated to the best fields and soaked before sowing. Thus, in the second round, a few farmers managed to get enough plants to assess the basic characters of the varieties.

Grain yields. Only two fields had a fair stand of all varieties and they were used to assess the yield. Table 1 gives the results. It shows that all new varieties outyielded the LLV. The two new varieties produced about one-third more, while Tegemeo produced over 50% more. As the LSD (5%) is 1040 kg ha^{-1} only in the case of Tegemeo, the difference is statistically significant.

Table 1. Average grain yield (kg ha^{-1}) of four sorghum varieties, Mvumi, 1993/94.

Variety	Mean
Mhoputa (LLV)	1929
Tegemeo	3026
SV 1	2648
SDS 2293-6	2607
SE	±327
CV(%)	13

Postharvest aspects. Table 2 gives an overview of the postharvest characters of the four varieties.

The new varieties have bigger seeds and higher threshing rates but lower flour/grain ratios. The losses during dehulling depend on how clean the end-product should be. Some people want the flour to be as white as possible (i.e., leading to losses of 45% for SDS 2293-6), while others do not dehull at all. Poor people, using milling stones, have to do a proper dehulling, otherwise milling is impossible. Bigger losses during the dehulling are accompanied by longer dehulling times. The extra time

Table 2. Some postharvest characters of the four sorghum varieties.

	Mass (g/100 seeds)	Threshing rate (%)	Minutes to dehull 4 kg (1 mortar)	Flour/grain ratio (%)	Flour yield (kg ha^{-1})
Mhoputa	1.8	68	15	75	1447
Tegemeo	2.3	78	20	60	1816
SV 1	2.1	74	20	63	1668
SDS 2293-6	2.6	78	21	61	1590

needed is about one-third. In the overall process from grains to flour (including winnowing, second pounding, second winnowing, and soaking) the extra time needed is about 20% for Tegemeo and SV 1 and 25% for SDS 2293-6.

Compared with Mhoputa, the yield in terms of kg flour ha^{-1} is only 10-15% higher for SV 1 and SDS 2293-6 and 25% for Tegemeo.

The three taste tests (including 39 respondents) did not give clear results. Too many factors contribute to the final taste, among them the cleanliness of the flour (depending on the extent to which the dehulling was 'completed'), the process of cooking (i.e., water content and whether it was well cooked), and customs (some people are not used to dehulled sorghum and others not to fermented flour). In general the LLV scored best. If it is well prepared (meaning big losses during dehulling), SDS 2293-6 also has a good taste. Tegemeo and SV 1 have a similar taste, which is not considered good but is acceptable.

Farmers' evaluation. Due to the germination problems, only a few farmers have a clear impression of the new varieties. In general, they were impressed by SDS 2293-6 because it is vigorous, has big semicompacted heads with big white seeds, matures early, and is not too tall. Its vigor is associated with high yields and drought-tolerance. So many farmers who saw the trial fields are keen to obtain SDS 2293-6 seeds. As threshing the new varieties had not been started at the time of writing, the farmers have no opinion about the postharvest aspects of the trial.

Farmers' priorities for new varieties. Table 3 gives the criteria farmers would like to be used in selecting new varieties.

Most priorities are in line with those of the Tanzanian sorghum breeding program, as given by Rao et al. (1989), except for the taste. Surprisingly, farmers give taste a lower priority than researchers. Farmers aim to improve household food security and are prepared to eat everything that is available. That a bad taste makes marketing difficult seems to be less important.

The priority for high yields is clear to everyone, but the importance of losses during dehulling is not explicitly mentioned by Rao et al. (1989). Saadan and Mndolwa (1993), on the other hand, suggest that this has been an important criterion in selecting new varieties. It seems that the result is not yet good enough, so women want dehulling problems to be addressed.

Table 3. Farmers, priorities for the new varieties (each group could allocate 20 points).

	Male farmers		Female farmers		
	Mvumi makulu	Idifu	Mvumi makulu	Idifu	Total
Yield	5	4	5	4	18
	6	4	3	4	17
Earliness	4	3	2	3	12
Taste[1]	2	3	3	2	10
Storage	1	2	1	2	6
Easy pounding[2]			3	2	5
Plant length[3]	1	2		2	5
Beer quality		1	2	1	4
Covered kernel smut	1	1	1		3

1. Good taste is associated with white seeds.
2. Easy pounding is associated with small dehuiling losses.
3. Not too tall plants make bird scaring easier and there is less lodging.

Regarding diseases, covered kernel smut is the biggest problem. For farmers in Mvumi it merits a higher priority than it does in the present breeding policy (Rao et al. 1989).

Conclusions. Farmers are most impressed by the vigor of SDS 2293-6, but Tegemeo had the highest yield. SV 1 does not differ much from Tegemeo, so it should be replaced by a variety that is selected for its drought tolerance and easy dehuiling.

As industrial marketing has failed, more attention should be paid to solving sorghum postharvesting handling problems in rural households.

Pearl millet

Introduction. Due to its property of cross-pollination, only one (very heterogeneous) pearl millet local landrace variety (LLV) is available in Mvumi: Uwele. After the second world war Buluma was introduced from Burma. People liked its earliness and big heads. But, because of its cross-pollination, the variety disappeared. In the 1970s Serere was introduced: a composite variety that ripens very early. It has a short straw and small heads, but the seeds are big. It has not been widely adopted in Mvumi because it is often eaten by birds or stolen, and farmers do not like the small heads.

In the trial, additionally to Uwele and Serere, two varieties not yet released from SMIP were used: TSPM 91001 and TSPM 91018.

Nine of the 12 fields were dry-planted. Only 7 fields were finally included in the analysis: one farmer planted too late, one failed to plant on lines properly, two failed to do the weeding of the different varieties within a reasonable time span, and one field showed a clear gradient in soil fertility.

Grain yields. Table 4 shows the yields of the four pearl millet varieties. The yields are smaller than those of sorghum, but still had considerably more than the average of normal farmers' fields. Only TSPM 91018 produced more (38%) than the LLV. As the LSD (5%) is 382 kg ha^{-1} the difference is statistically significant.

Table 4. Average grain yield (kg ha^{-1}) of four millet varieties, Mvumi, 1993/94.

Variety	Mean
Uwele	1239
Serere	1076
TSPM 91001	1217
TSPM 91018	1696
SE	±382
CV(%)	14

Postharvest aspects. Table 5 shows the most important postharvest characters of the four pearl millet varieties selected.

Table 5. Some postharvest characters of the four millet varieties.

	Mass (g/100 seeds)	Threshing rate (%)	Minutes to dehull 4 kg (1 mortar)	Flour/grain ratio (%)	Flour yield (kg ha^{-1})
Uwele (LLV)	0.7	68	16	75	922
Serere	1.1	65	17	74	796
TSPM 91001	0.7	60	14	70	852
TSPM 91018	0.9	71	16	74	1255

Serere and TSPM 91018 have bigger seeds and a higher threshing rate (specially TSPM 91018) than the LLV. The time for dehulling and the flour/grain ratio do not differ much.

The two taste tests gave consistent results. Many people could not identify the LLV and TSPM 91001 and TSPM 91018 scored better than the others in both cases.

Farmers' evaluation. The farmers appreciate TSPM 91018 greatly. They like its time of maturity (early, but not so early that it is eaten by birds), its long heads and big seeds (both associated with high yield), its appropriate length and, of course, its high yield. They have doubts about its drought tolerance: although no long dry spells occurred in 1993/94, some farmers claimed it was the worst variety in this respect.

Serere is considered useful as a hunger-relief crop, but its earliness attracts too many birds and thieves. Several solutions are advocated for this: sowing around the house or interplanting between taller varieties, breaking of the first heads (and harvesting the regrowth), and late sowing. Only in the first case is the advantage of an early harvest achieved. Its abundant tillering was appreciated, but it was not considered very drought-tolerant.

TSPM 91001 was considered to be the same as the LLV in nearly all respects.

Farmers' priorities for new pearl millet varieties (Table 6). More than in the case of sorghum, the main interest expressed seems to be food security. The only other priorities are the prevention of diseases in the field and tillering.

The farmers' priorities are closely similar to those of the Tanzanian millet breeding program, as described by Saadan and Mndolwa (1993).

Table 6. Farmers' priorities for new pearl millet varieties (with up to 20 points allocated for each group).

	Male farmers		Female farmers		
	Chanhumba	Ilolo	Chanhumba	Ilolo	Total
Yield[1]	6	5	5	8	24
Drought resistance	10	5	5	4	24
Earliness[2]	4	5	5	3	17
Field diseases		2	2	1	5
Tillering		2	1		3
Easy dehulling[3]			2	1	2
Taste		1		1	2
Beer quality				1	1
Plant length				1	1
Storage					1

1. Associated with long heads.
2. Associated with short straw.
3. Associated with easy milling.

Conclusion. TSPM 91018 performed very well, both in the field and during postharvest handling. Farmers like it very much. The characters of TSPM 91001 are too similar to the LLV to be of interest.

The Tanzanian breeding program for pearl millet seems to be on the right track from the point of view of farmers in Mvumi.

Discussion

The reported on-farm trials and on-station tests with sorghum and pearl millet yielded many useful data and insights. An interesting question is whether all the work required to collect the data was worth the effort. In other words: do the data provide insights that could not be gained by discussions with farmers? In general the answer should be negative. The data on yields and postharvest processing only endorse the farmers' own ideas and hardly add to them. Nevertheless, an important gain from data collection is that the researcher, when doing this work, has to acquaint himself or herself thoroughly with the farming system. This is where the learning process starts, because it enables the researcher to start a really effective dialogue with the farming community. In other words, such data collection greatly improves the quality of interaction with the farmers.

The ultimate dialogue, of course, is not about data nor their statistical significance. It is about seeds. Specifically, for the cross-pollinating pearl millet crop a permanent source of pure seeds (grown in isolation) is needed. In this respect the new seed production policy of the Tanzanian government is a major step forwards (Lujuo 1994). Under this new legislation the MRTC could produce the seeds needed in Mvumi in cooperation with SMIP.

Conclusions and Recommendations

For sorghum it seems difficult to offer new varieties to farmers as long as postharvest processing—particularly dehulling and marketing—remains problematic. Farmers will engage in market-oriented production again only if they have confidence in a well established market.

The development of better pearl millet varieties for home consumption should receive the highest priority because of the severe shortages of food in the overpopulated Mvumi division, and the high percentage of farming land occupied by the crop. New varieties that respond well to improved management can increase cropping-system productivity.

TSPM 91018 performed very well in the 1993/94 season. If it also proves to be drought-tolerant, it should be released as a variety for widespread use. In that event, SMIP should supply the MRTC and other rural projects in Dodoma with foundation seed, so that they can produce the amount of pure seeds needed.

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Sorghum and Pearl Millet On-Farm Research Work in Zimbabwe

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Abstract

The Department of Research and Specialist Services, jointly with the Department of Technical and Extension Services and four NGOs, conducted research- and farmer-managed trials of sorghum and pearl millet in Natural Regions IV and V of Zimbabwe in 1992/93. The objectives were to verify the performance of elite lines, and to promote released varieties in the communal areas where farmers still plant traditional landrace varieties. In the research-managed farmer-implemented trials farmers were supplied with inputs and agronomic packages, whereas in the farmer-managed farmer-implemented trials, farmers used their own cultivation practices.

Sorghum hybrids were superior to open-pollinated varieties in both trials. Newly developed open pollinated varieties performed better than released varieties under research rather than farmer management. Both SDMV 89007, a pearl millet variety, and SDSH 148, a sorghum hybrid, gave the best yields in both trials. The most preferred varieties by farmers were not necessarily the highest-yielding, but had other desirable aspects such as color, grain size, earliness, and drought tolerance. Open-pollinated varieties were preferred to hybrids because farmers can retain their seed for sowing in subsequent seasons.

Introduction

Sorghum and pearl millet are the most important cereals grown by Communal farmers in Natural Regions IV and V of Zimbabwe (Vincent and Thomas 1961). The regions are characterized by a low, erratic and poorly distributed rainfall (<650 mm yr^{-1}). In these regions, sorghum and pearl millet play an important role in stabilizing household food security.

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National average yields of sorghum (401 kg ha^{-1}) and pearl millet (462 kg ha^{-1}) are low largely because communal farmers still plant their low-yielding local landrace varieties (LLVs) (Central Statistical Office 1990). Drought, pests, diseases, and poor soil fertility also contribute to these low yields.

Sorghum and pearl millet varieties are developed at research stations under improved management, which is not representative of communal-area environments. Farmers are rarely involved in the identification and evaluation of technologies of which they are the future beneficiaries. Interaction between farmers, researchers, and extension staff helps to identify needs and constraints in the generation of new technologies by the parties involved, and can also promote the adoption of new technologies. Thus the objectives of the on-farm research were as follows:

- To evaluate improved varieties under farmers' conditions.
- To involve farmers in the identification and generation of new technologies.
- To identify needs and constraints in generating new technologies.
- To promote developed technology through formal and informal contacts with, and between, farmers.

Organizations participating in these activities were: the Ministry of Lands Agriculture and Water Development (the Department of Research and Specialist Services [DR&SS]; the Department of Agricultural Technical and Extension Services [AGRITEX]; SADC/ICRISAT; and the following NGOs: COOPIBO; Environmental Development Activities (ENDA-Zimbabwe); and Coordinated Agriculture Rural Development (CARD).

Methods and Materials

Two sets of sorghum and pearl millet trials—research-managed farmer-implemented (RMFI), and farmer-managed farmer-implemented (FMFI)—were planted across 13 districts in a randomized complete blocks design (Table 1).

In the RMFI trials there were 10 entries of sorghum or pearl millet including the farmers' LLVs (Table 2). The plot size for all the trials was 75 m^2 (10 rows x 10 m long). The plant population for pearl millet trials was thinned to 44 444 plants ha^{-1} (0.75 m between rows and 0.30 m between plants), and for sorghum it was thinned to 88 889 plants ha^{-1} (0.75 m between rows and 0.15 m between plants). All plots received 200 kg ha^{-1} Compound D fertilizer at sowing (24 kg ha^{-1} N, 42 kg ha^{-1} P_2O_5, and 21 kg ha^{-1} K_2O) and 100 kg ha^{-1} ammonium nitrate in a topdressing (60 kg ha^{-1} N). The trials were replicated twice at each location.

Six entries, including the farmers' LLV were tested in the sorghum FMFI trial, and there were five entries including the farmers' LLV in the pearl millet trial (Table 2). The farmer used his/her own cultivation practices in all FMFI trials. Individual farmers were used as replications. Eight central rows were harvested excluding 0.5 m length at both ends. The heads were threshed, and grain weight and moisture content were recorded.

Table 1. List of locations, Zimbabwe.

Abbreviation	Full name (Province)	Natural Region
Tsho	Tsholotsho (Matebeleland North)	IV
Bing	Binga (Matebeleland North)	V
Hwan	Hwange (Matebeleland North)	V
Lupa	Lupane (Matebeleland North)	IV
Plum	Plumtree (Matebeleland South)	IV
Beit	Beitbridge (Matebeleland South)	V
Gwan	Gwanda (Matebeleland South)	IV
Muto	Mutoko (Mashonaland East)	IV
Mudz	Mudzi (Mashonaland East)	IV
Maro	Marondera (Mashonaland East)	III
Gutu	Gutu (Masvingo)	IV
Chiv	Chivi (Masvingo)	IV
Muza	Muzarabani (Mashonaland Central)	IV
Buhe	Buhera (Manicaland)	IV
Mara	Marange (Manicaland)	IV

Table 2. Entries used in research-managed farmer-implemented (RMFI) and farmer-managed farmer-implemented (FMFI) trials, Zimbabwe, 1992/93.

Sorghum	Pearl Millet
RMFI trials	
SDSH 148 (hybrid)	SDMV 89007
SDSH 378 (hybrid)	SDMV 89008
SDSH 48 (hybrid)	PMV 2
ZWSH 1 (hybrid)	SDMV 89005
8739H (hybrid)	SDMV 87001
8725H (hybrid)	SDMV 89002
NL 829	SDMV 89001
SV 2	ZWPMV 46
LARSVYT 46	Composite D
Farmers' LLV	Farmers' LLV
FMFI trials	
SV 2	SDMV 89007
NL 829	PMV 2
LARSVYT 46	SDMV 89005
NL 609	Composite D
Farmers' LLV	Farmers' LLV
SDSH 148 (hybrid)	

Stability analysis (Finlay and Wilkinson 1963) was used to determine the relative adaptation of varieties across districts.

Field visits were conducted with the host farmer and staff of AGRITEX, DR&SS, and SADC/ICRISAT to evaluate each entry in the trials. We asked the host farmer to tell us his/her best entries, and why he/she selected them. Those entries selected most frequently were considered to be generally preferred in that area. Observations recorded were:

date of planting; dates of fertilizer application;
grain yield; farmer's first two preferred varieties.

Number of trials:

sorghum: RMFI (10); FMFI (13);
pearl millet: RMFI (10); FMFI (11).

Results

Sorghum

RMFI trials. Hybrids were superior to open-pollinated varieties across locations (Table 3). At Tsholotsho and Muzarabani, the open-pollinated variety, NL 829, was the best- yielding variety. The yield gain of the top-yielding hybrid over the farmers' LLV exceeded 40%. Open-pollinated varieties, despite having lower yields than hybrids, were relatively more stable in yield across locations. Farmers' LLVs, although the lowest-yielders, were the most consistent across locations. The trials at Tsholotsho, Binga, Marondera, and Mutoko had high coefficients of variation.

FMFI trials. Hybrid SDSH 148 outyielded all varieties included in the trials (Table 4). The released open-pollinated variety, SV 2, was superior to all other open-pollinated varieties. The farmers' LLV and NL 609 were the lowest-yielders across locations. SV 2 and Larsvyt 46 performed consistently in their yield across locations compared with SDSH 148 and NL 829. The CVs were particularly high in Binga and Marondera districts.

Pearl millet

RMFI trials. Two varieties of pearl millet (SDMV 89007 and SDMV 89008) outyielded other varieties, including the local check (PMV 2), across locations (Table 5). At Plumtree (Plum), the farmers' LLV was the highest-yielding entry. ZWPMV 46, with the lowest β-value was the earliest entry to mature.

FMFI trials. There were no new varieties that performed significantly better than the released variety, PMV 2, across locations (Table 6). However, SDMV 89007 was

Table 3. Grain yield (t ha^{-1}) of sorghum in the research-managed farmer-implemented trials at different locations, Zimbabwe, 1992/93.

Entry	Tsho	Bing	Hwan	Plum	Muto	Gutu	Chiv	Muza 1	Muza 2	Maro	Mean	β-value
SDSH 148	1.30	2.60	4.46	1.53	1.82	2.09	3.60	3.22	2.98	0.84	2.40	1.20
SDSH 378	0.44	2.74	4.23	1.63	1.12	1.82	3.12	5.09	2.49	0.66	2.33	1.31
SDSH 48	1.83	2.21	4.13	1.21	1.03	1.56	4.32	3.52	2.94	0.45	2.32	1.31
ZWSH 1	1.36	2.03	4.52	1.32	1.76	2.10	3.86	2.56	1.91	0.93	2.23	1.08
8739H	1.37	2.25	3.78	2.25	2.24	1.81	3.28	2.59	2.06	0.40	2.20	0.89
NL 829	1.92	2.45	4.02	1.65	2.11	1.02	3.11	1.90	3.17	0.41	2.17	0.93
SV 2	1.22	1.32	3.03	1.57	1.77	1.47	2.83	3.00	3.15	-	2.15	0.76
8725H	1.50	2.51	3.29	1.74	1.95	1.13	3.39	2.42	1.74	0.41	2.01	0.88
LARSVYT 46	0.95	2.64	3.35	1.24	0.61	1.39	2.91	2.64	1.01	-	1.86	1.03
Fs' LLV	1.08	2.11	2.14	1.00	1.01	1.53	3.44	0.80	2.01	0.45	1.56	0.67
Mean	1.30	2.29	3.69	1.51	1.54	1.59	3.39	2.77	2.35	0.52	2.10	
SE	±0.56	±0.79	±0.47	±0.24	±0.45	±0.30	±0.36	±0.61	±0.42	±0.18	±0.15	
EI[1]	-0.8	0.19	1.59	-0.59	-0.56	-0.51	1.29	0.67	0.25	-1.58		
CV (%)	61	49	18	23	41	27	15	31	25	47	32	

1. EI = Environmental index: site mean minus grand mean.

Table 4. Grain yield (t ha^{-1}) of sorghum in the farmer-managed farmer-implemented trials at different locations, Zimbabwe, 1992/93.

Entry	Bing	Hwan	Lupa	Tsho	Plum	Gwan	Beit	Muto	Maro	Gutu	Chiv	Muza 1	Muza 2	Mean	β-value
SDSH 148	2.19	4.12	1.97	1.54	1.80	0.86	1.97	2.44	1.94	1.65	3.47	3.65	2.41	2.31	1.32
SV 2	2.08	3.30	1.86	1.52	1.44	0.97	2.30	2.38	1.73	1.33	2.85	2.79	1.78	2.05	1.09
NL 829	2.18	3.98	2.27	1.35	1.59	0.80	1.52	2.01	1.29	1.10	2.77	3.09	1.95	1.99	1.28
Larsvyt 46	1.19	3.05	1.63	0.98	1.23	1.64	2.67	3.11	1.13	3.21	1.83	1.50	1.69	1.91	0.67
Fs' LLV	2.13	2.22	1.69	1.06	1.26	0.92	-	2.45	1.14	1.46	3.11	1.98	1.75	1.76	0.86
NL 609	2.21	2.42	1.51	0.91	1.20	1.11	2.30	2.73	0.91	0.90	1.26	1.16	1.05	1.51	0.75
Mean	2.03	3.18	1.82	1.40	1.42	1.05	2.15	2.55	1.30	1.46	2.55	2.36	1.77	1.92	
SE	±0.43	±0.34	±0.31	±0.29	±0.16	-	-	±0.48	±0.34	±0.17	±0.37	±0.29	±0.23		
EI[1]	0.11	1.26	-0.10	-0.52	-0.50	-0.87	0.23	0.63	-0.62	-0.46	-0.63	0.44	-0.15		
CV (%)	43	19	29	36	19	-	-	33	53	16	29	24	26		
Farmers	4	3	3	3	3	1	1	3	4	2	4	4	4		

1. EI = Environmental Index: site mean minus grand mean.

Table 5. Grain yield (t ha⁻¹) of pearl millet in the research-managed farmer-implemented trials at different locations, Zimbabwe, 1992/93.

Entry	Mara	Buhe	Muto	Gutu	Chiv	Bing	Gwan	Plum	Tsho	Lupa	Mean	β-value
SDMV 89007	1.40	2.00	1.21	0.97	4.17	3.96	1.73	1.36	2.39	0.82	2.00	1.03
SDMV 89008	1.46	1.08	0.98	1.46	4.29	2.89	1.65	1.11	2.67	0.67	1.83	1.00
PMV 2	0.90	1.11	1.12	1.39	4.50	2.96	1.62	1.29	2.11	0.72	1.77	1.04
SDMV 89005	0.81	1.33	0.76	2.00	3.82	2.51	1.30	1.18	2.83	0.95	1.75	0.85
SDMV 87001	0.92	1.50	1.47	0.86	3.88	3.39	0.53	1.36	1.84	1.61	1.74	0.90
SDMV 89002	1.24	1.29	0.70	1.13	4.40	3.11	1.02	1.37	2.28	0.77	1.73	1.08
Fs' LLV	1.25	0.78	1.32	0.78	4.16	3.93	0.90	1.40	2.29	0.40	1.72	1.16
SDMV 89001	1.06	1.40	1.19	1.00	4.89	2.92	1.42	1.10	1.59	0.56	1.71	1.13
ZWPMV 46	1.25	1.31	0.78	1.67	4.25	2.70	1.43	1.31	1.86	0.53	1.71	0.35
Composite D	0.95	0.84	0.92	0.87	3.56	2.46	0.99	0.85	2.11	0.67	1.42	0.87
Mean	1.12	1.26	1.05	1.21	4.19	3.08	1.26	1.23	2.19	0.78	1.74	-
SE	±0.24	±0.34	±0.22	±0.23	±0.41	±0.32	±0.16	±0.12	±0.14	±0.28	±0.08	
CV (%)	31	38	30	27	14	15	17	14	9	50	21	
EI[1]	-0.62	-0.48	-0.69	-0.53	2.45	1.34	-0.48	-0.51	0.45	-0.96		

1. EI = Environmental index: site mean minus grand mean.

Table 6. Grain yield (t ha^{-1}) of pearl millet in the farmer-managed farmer-implemented trials at different locations, Zimbabwe, 1992/93.

Entry	Mara	Buhe	Gutu	Chiv	Muto	Hwan	Beit	Plum	Tsho	Bing	Lupa	Mean	β-value
SDMV 89007	1.49	1.49	1.89	4.38	2.52	0.74	1.35	1.15	1.36	0.73	0.86	1.63	1.37
PM 2	1.21	1.38	1.88	3.71	2.47	0.81	1.25	1.22	1.13	1.98	0.74	1.62	1.14
SDMV 89005	0.99	0.92	1.53	3.35	2.53	0.97	1.26	1.11	1.34	1.50	0.83	1.48	1.05
Fs' LLV	0.64	0.58	1.47	2.21	2.49	1.17	0.90	1.06	1.41	1.13	0.77	1.26	0.71
Composite D	0.90	1.27	1.20	2.59	1.84	0.84	1.21	0.87	0.97	1.14	0.57	1.22	0.74
Mean	1.04	1.19	1.59	3.25	2.37	0.91	1.19	1.08	1.24	1.30	0.75	1.44	
SE	±0.27	±0.30	±0.26	±0.32	±0.36	±0.15	±0.11	±0.09	±0.20	±0.38	±0.11		
EI[1]	-0.4	-0.25	0.15	1.81	0.93	-0.53	-0.25	-0.36	-0.20	-0.14	-0.69		
CV (%)	52	35	33	20	30	29	13	14	32	41	29		
Farmers	4	2	4	2	4	3	2	3	3	2	4		

1. EI = Environmental index: site mean minus grand mean.

the best-yielding variety at seven out of the eleven sites. At Tsholotsho, the farmer's local variety was superior to all the new varieties. The highest grain yields were observed at Chivi.

Farmers' selection

Farmers generally selected SV 2, NL 829, and Larsvyt 46 as their best sorghum entries in both FMFI and RMFI trials. For pearl millet, farmers generally selected PMV 2 and SDMV 89007 as their best entries.

Discussion

RMFI grain yields of both sorghum and pearl millet trials were similar to those of FMFI trials at some sites. This was because farmers received free inputs from the government for drought recovery that they used on trials. In addition, there was extra management effort by farmers to impress research and extension staff.

The yield gap between traditional and elite varieties was greater in RMFI trials than in FMFI trials across locations. Farmers' LLVs were adapted to low levels of inputs and did not respond much to improved management.

Sorghum. Hybrids were generally superior to all open-pollinated varieties across locations. However, farmers preferred white, open-pollinated varieties to higher-yielding hybrids because the seed of open-pollinated varieties can be recycled for sowing, unlike hybrid seed. As a result, farmers' preference varieties were not necessarily related to ranked yield. Other factors, such as earliness, grain size and color, grain quality, recycling of seed, and end-use of the variety were important.

Chivi had the highest grain yields because it is located on the boundary of Natural Regions III and IV which has a good rainfall. In addition, the management practices of farmers in this area are excellent because they have been exposed to research trials.

Farmers selected SDMV 148, NL 829, and SV 2 as their best sorghum entries. Farmers selected these entries because they matured early, had white bold grain and large panicles, were drought-tolerant and offered the option of seed recycling. Early-maturing entries provided food early during times of critical food shortages, as happened in 1992/93 after a drought. White-grained sorghum varieties were preferred to red sorghums because they were easy to thresh and could be used in the preparation of food as well as for brewing beer, whereas red sorghums could be used only for beer. Similar observations were made by Gono et al. (1994). Farmers generally preferred open-pollinated varieties in comparison with hybrids because they could retain seed for sowing in the next season and thus reduce input costs.

Pearl millet. Farmers selected PMV 2 and SDMV 89007 frequently because they matured early, formed many productive tillers, were easy to thresh and had little chaff, and were drought-tolerant. All fanners did not select their LLVs because these were tall and late-maturing and failed to provide food when food supply was critical.

Field visits conducted at physiological maturity of the crops indicated that most of the trial sites were highly variable due to nonuniformity in soil fertility, uneven application of manure, presence of anthills in trials, and waterlogged areas. The results also indicated that sorghum had the highest grain yield per unit area across locations. However, the land area allocated to pearl millet was far more than that for sorghum, possibly indicating that farmers preferred pearl millet.

Farmers rarely used the plant spacing that was recommended by research and extension personnel. From general observations, extension recommendations on plant spacing and on crop-management were not appropriate for the dry regions. New recommendations need to be developed under farmers' conditions.

Conclusions

Hybrids of sorghum were generally superior to open-pollinated varieties. New varieties of pearl millet and sorghum seem to be appropriate under good management practices. Thus, there is need to verify our technology over seasons under farmers' conditions. Farmers are interested not merely in yield when selecting varieties; other factors also play an important role.

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Crop Management: Nutrients, Weeds, and Rain

M D Clegg[1]

Abstract

Data derived from experiments with sorghum and pearl millet in the USA, relative to the amounts of several nutrients that are taken up by different crops, show the effect of added nitrogen and the removal of weeds on yield and water-use efficiency (WUE). For a sorghum yield of 2 t ha^{-1} the crop's annual requirements in t ha^{-1} are 60 N, 20 P, and 60 K. Rotation with soybean increased the yields of sorghum and pearl millet, and additional nitrogen benefits yields. But the cultivation practices of removing competitive weeds and increasing WUE are shown to increase the yields of both crops, whether they are grown continuously or in rotation with soybean. WUE gains of between 2.9 and 7.5 kg ha^{-1} mm^{-1} are reported, and complete weed control was found to increase WUE on average by 10 kg ha^{-1} mm^{-1}. It is concluded that, mainly through the more efficient use of rain, a single application of nonrenewable nutrients and effective weed control can double or triple crop yields.

Introduction

The most common limiting factors in crop production are the availability of nutrients and water. Population growth in many countries has reduced the availability of good land for farming. Thus, the same land is continuously being farmed with nutrients being removed with the harvested crop. This becomes critical as many soils do not have large quantities of nutrients, particularly of such a nonrenewable nutrient as phosphorus. Without water, even the best insect- and disease-resistant crops, grown with proper cultivation practices, will not yield well.

Effort and resources have been directed towards the improvement of open-pollinated varieties or hybrids so that crops grown from improved seed have better yield potential than the yields being obtained from local landrace varieties. However, there are cultivation practices that can improve the crop productivity of soils with poor fertility, and also improve moisture use.

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Clegg, M.D. 1996. Crop management: nutrients, weeds, and rain. Pages 91-97 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Nutrients

The amount of nutrients that are taken up in relation to yields typically obtained with sample crops are shown in Table 1. All five nutrients shown are taken up in relatively large amounts, but nitrogen and potassium uptake is the greatest. Unless the soil has a large capacity for these nutrients, any one can become limiting and reduce yield. Only N is a renewable nutrient with its reduction to usable forms in biological systems, including legume nodules.

Table 1. Nutrient uptake by different crops.[1]

Crop	Yield ($t\ ha^1$)	N	P_2O_5	K_2O	Mg	S
		($kg\ ha^{-1}$)				
Maize	12.54	298	128	298	73	37
Groundnut	4.48	269[2]	44	207	28	24
Sorghum	8.96	266	94	269	45	43
Sunflower	3.36	169	67	123	40	16
Napier grass	26.43	335	121	482	75	52
Banana	26883	448	448	1680	175	-

1. Source: Potash and Phosphate Institute, Atlanta, GA, USA.
2. Nitrogen-fixing crop.
3. Plants ha^{-1}.

Table 2. Nutrient uptake ($kg\ ha^{-1}$) by grain sorghum for different yield levels.[1]

Yield level	Total nutrient uptake N	Total nutrient uptake P_2O_5	Total nutrient uptake K_2O	Grain nutrient uptake N	Grain nutrient uptake P_2O_5	Grain nutrient uptake K_2O
500	15.0	5.0	15.0	7.5	3.7	2.0
1000	30.0	11.0	30.0	15.0	7.5	3.9
1500	45.0	16.0	45.0	22.5	11.2	5.9
2000	60.0	21.0	60.0	30.0	15.0	7.8

1. Source: Potash and Phosphate Institute, Atlanta, GA, USA.

The total and grain uptake by sorghum at various yield levels are compared in Table 2. To obtain a yield of 2 $t\ ha^{-1}$, the crop will require 60, 20, and 60 $kg\ ha^{-1}$ of N, P, and K respectively. This has to be available each year. Removing all the biomass removes about 100% more N, 40% more P, and 650% more K in comparison with removal in the grain. In traditional methods of farming, in which all the crop is normally removed for use, soil fertility is quickly reduced. This is especially true ifthe soil has low organic matter.

Sorghum and pearl millet responses to applied N and in rotation with soybean are shown in Tables 3 and 4. Applying N results in the greatest yield increase with the first increment. Grain yield is further increased with added N. Nitrogen applied to

Table 3. The effect of nitrogen and soybean-sorghum rotation on sorghum grain yield.

Cropping system	Nitrogen treatment (kg ha^{-1})	Grain yield (t ha^{-1})
Continuous	0	3.5
	57	6.5
	114	7.9
	171	8.8
Rotation	0	7.1
	57	8.0
	114	8.7
	171	8.6

Table 4. The effect of nitrogen and soybean-pearl millet rotation on pearl millet grain yield.[1]

		Grain yield	
Cropping system	Nitrogen treatment (kg ha^{-1})	1986	1987
		..........(kg ha^{-1})	....
Continuous	0	5.69	4.22
	45	6.42	5.88
	90	7.13	6.85
Rotation	0	6.54	5.73
	45	7.04	7.28

1. Mohamed and Clegg, 1993, Agronomy Journal 85:1009-1013.

these crops following soybean in rotation also results in greater yields. Comparing the continuous and rotation systems with no applied N showed that the crops, after soybean, yielded at a level equal to about 57 kg N ha-^{1}. This benefit of greater yields of sorghum and also maize seems to be consistent over a range of environments (Clegg 1992).

Weeds

The effect of weeds on crops depends on many factors. These include the types of weeds, the crops, and their responses to the environment. A field will support the production of a finite amount of biomass depending on its resources. This biomass is partitioned into either weeds or crops because weeds directly compete for nutrients and water.

Increased weed biomass reduced sorghum grain yield almost kilogram for kilogram in a study in Nebraska (Fig. 1). Similarly, in Kansas, weeds reduced sorghum grain yield (Fig. 2). The impact of the weeds was not as severe in the Kansas study.

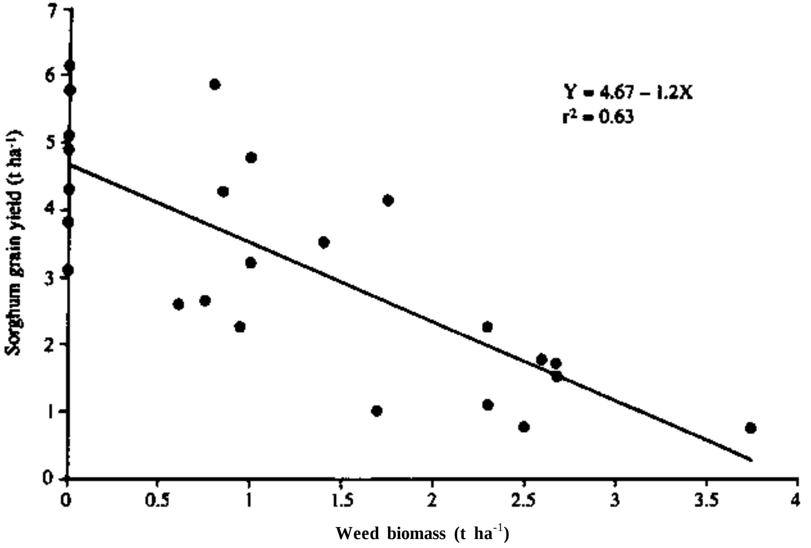

Figure 1. Effect of weed biomass on sorghum grain yield (Maliro 1993).

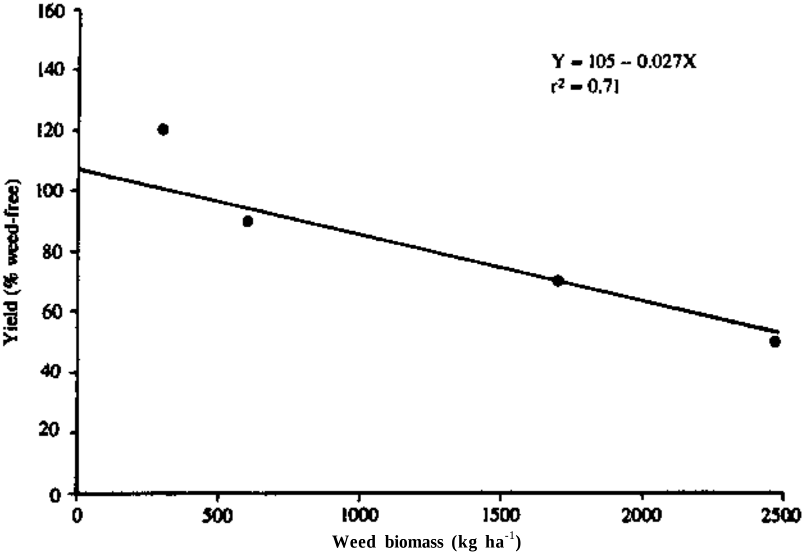

Figure 2. Effect of weed biomass on grain yield as a percentage of yield obtained from the weed-free treatment (Lele 1993).

However, in both cases, considerable grain yield was lost. The effect of weeds might become even more critical when resources are limited.

Rain

Rain is the source of water for crops, unless irrigation is available. Where water supply is limited, its efficient use is necessary to maximize productivity. Two important ways to increase this efficiency are by adding nutrients that are limiting and by removing competitive plants (weeds).

Water-use efficiency (WUE) is defined as grain yield (kg ha^{-1}) divided by the amount of rain (mm^{-1}) for that cropping year (Table 5). WUE was increased by 7.5 kg ha^{-1} mm^{-1} with the highest N treatment as compared with no N in sorghum grown continuously. The increase was only 2.9 kg ha^{-1} mm^{-1} for the same comparisons with sorghum grown after soybean. Comparing treatments with no N in both systems showed WUE was increased by 5.1 kg ha^{-1} mm^{-1} when sorghum was grown in rotation. Similar results were obtained with pearl millet grown continuously and in rotation with soybean (Table 6). Bationo et al. (1991) reported that, with pearl millet, water-use efficiencies increased 2.2 to 4.4 times with addition of fertilizer.

The affect of weed management on WUE is shown in Table 7. Complete weed control increased WUE on the average 10 kg ha^{-1} mm^{-1} and all the genotypes responded in the same way. Even delayed weeding in this study increased WUE very significantly (5.88 kg ha^{-1} mm^{-1}). The hybrids were more efficient than the variety Segaolane in using the rain.

WUEs for sorghum, whether from improvement with N or weed control, varied according to the year. This variation was because different amounts of rain were credited to the growing seasons. Low amounts of rain did not necessarily result in lower WUEs. This is because rain at the main growth stages throughout the season is extremely important.

Table 5. The effect of nitrogen and soybean-sorghum rotation on water-use efficiency (WUE)[1].

Cropping system	Nitrogen treatment (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})
Continuous	0	4.8
	57	9.0
	114	11.0
	171	12.3
Rotation	0	9.9
	57	11.2
	114	12.2
	171	11.9

1. WUE is defined as grain yield (kg ha^{-1}) divided by rain mm^{-1} (total rain = 720 mm).

Table 6. The effect of nitrogen and soybean-pearl millet rotation on millet water-use efficiency (WUE)[1].

Cropping system	Nitrogen treatment (kg ha^{1})	WUE (kg ha^{-1} mm^{-1}) 1986	1987
Continuous	0	7.75	10.55
	45	8.74	14.70
	90	9.71	17.12
Rotation	0	8.91	14.32
	45	9.59	18.20

1. WUE is defined as grain yield (kg ha') divided by rain mm^{-1} (total rain in 1986 = 734 mm; in 1987 = 400 mm). Source: Mohamed and Clegg, 1993, Agronomy Journal 85:1009-1013.

Table 7. The effect of weed management and genotype on water-use efficiency (WUE) of grain sorghum, Mead, NE, USA, 1990[1].

Weed management	Genotype DK 48	DK 39Y	Segaolane	Mean
	WUE (kg ha^{-1} mm^{-1})			
No weeding	5.09	3.79	4.44	4.44
Cultivation	12.09	10.12	8.75	10.32
Clean	14.89	17.60	10.81	14.44
Mean	10.69	10.50	8.00	

1. WUE is defined as grain yield (kg ha^{-1}) divided by rain mm^{-1} (total rain = 321 mm). Source: Maliro (1993).

Conclusion

Yields of crops grown continuously on fields without added inputs will become less each year. If any nutrient is limiting, neither genetic improvement of varieties or hybrids nor adequate water will be sufficient to increase yields. The desired yield level and soil type will dictate the nutrients needed and the amount that will have to be applied. Adding nutrients to correct deficiencies will be required. However, a single application of nonrenewable nutrients can be effective for several years (Solberg et al. 1993). Legumes can be used to increase N availability. Weed control increases productivity through reduction of the use of nutrients and water. The adoption of only the latter two cultivation practices can double or even triple yield, mainly through more efficient use of rain.

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Response of Sorghum Genotypes to Drought in Zimbabwe

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Abstract

This study determined the yield response of 20 sorghum genotypes to late-season drought at Chiredzi and Lucydale, over two seasons, 1992/93 and 1993/94. Chiredzi is on a clay loam soil in Natural Region V, whereas Lucydale is on a sandy loam soil in Region IV. The 1992/93 season had higher and more evenly distributed rainfall compared with the 1993/94 season, which experienced a late-season drought. Genotypes were evaluated for grain yield, days to 50% flowering, plant height, exsertion of panicle, and 1000-seed mass.

At both Chiredzi and Lucydale, sorghum genotypes-varied in yield depending on season. Under good rainfall at Chiredzi in 1992/93, NL 803, SV 1, NL 836-2, and NL 265 gave the highest yields. However, under late-season drought conditions in 1993/94, SV 1, NL 535, NL 699, and NL 692 gave the highest yields. At Lucydale, Chibonda, NL 265, NL 836-2, and SV 1 had the highest yields under adequate rainfall in 1992/93, but under late-season drought in 1993/94 season, SV 1, SV 2, NL 267, and NL 653 had the highest grain yields.

Grain yield was positively correlated with plant height, exsertion of panicle, and 1000-seed mass, but not days to 50% flowering. Our breeding effort, therefore, should aim to develop cultivars that mature early for those areas in which late-season drought is common.

Introduction

Sorghum is grown mainly by communal farmers (90%) and a few large-scale commercial farmers (10%) under rainfed conditions in Natural Regions III, IV, and V of Zimbabwe. These regions are generally characterized by low, erratic, and poorly distributed rainfall (<650 mm yr^{-1})(Vincent and Thomas 1961). Sorghum grown in

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Regions III, IV, and V is subject to unpredictable drought, either at the beginning, in the middle, or towards the end of the growing season, resulting in low grain yields (about 401 kg ha^{-1}) (Zimbabwe CSO 1993). Because drought constitutes a major yield constraint in these regions, there is a need to identify genotypes that give high yields under drought conditions.

Selection among traditional local landrace varieties (LLVs) or their progenies, under drought-prone conditions, is the most common and efficient approach to breeding for drought stress (Sneep et al. 1979). Under drought conditions, Garrity et al. (1979) reported differences in grain yields among genotypes. Rapid stand establishment, early maturity, photoperiod sensitivity, control of evapotranspiration losses, desiccation tolerance, a dense root system, and rapid recovery after drought stress were important drought-resistance mechanisms (Sneep et al. 1979).

The objective of this study was to identify sorghum genotypes suitable for production under drought conditions in Regions IV and V of Zimbabwe. The yield response of these genotypes to late-season drought was of particular interest, because late-season drought commonly occurs in these regions.

Materials and Methods

Twenty sorghum varieties (Table 1) selected for their high yield and other agronomic characters in drought-screening nurseries between 1986 and 1991 were planted at Chiredzi (altitude 429 m), and Lucydale (altitude 1338 m). All the varieties were developed by the Department of Research and Specialist Services with the exception of Chibonda, a farmer's LLV and SV 1 and SV 2 that originated from SADC/ICRISAT. The experiment was sown in 1992/93 and 1993/94 using a randomized complete block design with three replications. Lucydale is located in Region IV and is on sandy loam soils, whereas Chiredzi is in Region V on clay soils. In 1992/93, Chiredzi received 526 mm and Lucydale 638 mm rainfall between sowing and physiological maturity. However, in 1993/94, Chiredzi received 350 mm and Lucydale received 292 mm rainfall. The mean daily

Table 1. List of sorghum genotypes used in the study.

Genotype	Days to 50% flowering
NL 632	67
SV 1	75
NL 265	74
NL 836-2	73
NL 267	71
NL 692	74
NL 699	74
NL 753	76
NL 335	73
NL 535	70
SV 2	68
NL 653	69
NL 634	75
NL 852	73
NL 471	75
NL 775	74
NL 768	77
NL 803	94
NL 205	78
Chibonda	92

temperature at Chiredzi during the growing season was 31.5°C, and at Lucydale, 27.4°C

At Chiredzi, trials were sown on 24 Nov 1992, and 13 Nov 1993. At Lucydale, trials were sown on 17 Dec 1992, and 16 Dec 1993. Seed was dibbled by hand into rows 75 cm apart. Seedlings were thinned to a plant population of 88 889 plants ha^{-1} 3 weeks after emergence. Fertilizer was applied at the rate of 24 kg N ha^{-1}, 42 kg P_2O_5 ha^{-1}, and 21 kg K_2O ha^{-1} at sowing. At 6 weeks after sowing, 60 kg N ha^{-1} was applied as a topdressing. Each plot had four rows 5 m long. The center two rows were harvested in order to determine grain weight. We also recorded days to 50% flowering, plant height, exsertion of panicle, and 1000-seed mass. Grain yield per hectare was calculated at 12.5% seed moisture content.

The analysis of variance was conducted using MSTATC. Differences among seasons at each location were tested using the replication x year mean square as the error term. Correlations among the traits measured were determined using raw data collected across locations.

Results

At both Chiredzi and Lucydale, grain yield among genotypes varied with season. Days to 50% flowering, plant height, exsertion of panicle, and 1000-seed mass also generally varied with season at both locations. Grain yield was significantly correlated with plant height (r= 0.35***), panicle exsertion (r= 0.16**), and 1000-seed mass (r= 0.29***), but not days to 50% flowering (r= 0.10) (Table 2).

Table 2. Correlation coefficients (r) of grain yield with four characters.

Character	Grain yield (r value)[1]
Days to 50% flowering	0.10
Plant height	0.35***
Exsertion of panicle	0.16**
Seed mass	0.29***

1. *, **, *** = significant at P <0.05, P <0.01, P <0.001, respectively.

Yields were generally larger in 1992/93 than in 1993/94 at both Chiredzi and Lucydale (Table 3).

At Chiredzi, in 1992/93 the four highest-yielding genotypes were NL 803, SV 1, NL 836-2, and NL 265. However, in 1993/94, SV 1, NL 535, NL 699, and NL 692 were among the highest-yielding genotypes. Chibonda, a local landrace variety, and NL 803 did not flower at Chiredzi in 1992/93.

Table 3. Grain yields (t ha^{-1}) of 20 sorghum genotypes, Chiredzi and Lucydale, Zimbabwe, 1992/93 and 1993/94.

	Chiredzi			Lucydale			Across sites means
	1992/93	1993/94	Mean	1992/93	1993/94	Mean	
SV 1	5.26	2.76	4.01	4.09	2.76	3.16	3.72
NL 265	4.99	1.95	3.47	4.61	2.07	3.34	3.41
NL 632	4.90	1.90	3.40	4.06	2.25	3.16	3.28
NL 836-2	5.06	1.98	3.52	4.30	1.76	3.03	3.27
NL 267	4.84	1.99	3.42	3.80	2.43	3.11	3.27
NL 692	4.81	2.45	3.63	3.77	1.82	2.79	3.21
NL 699	4.02	2.45	3.23	3.70	2.25	2.97	3.10
NL 753	4.90	1.34	3.12	3.52	1.87	2.70	2.91
NL 335	3.97	1.91	2.94	3.47	2.25	2.86	2.90
NL 471	3.94	1.92	2.93	3.52	2.11	2.81	2.87
NL 535	4.08	2.73	3.41	3.07	1.54	2.31	2.86
SV 2	3.89	1.24	2.56	4.09	2.73	2.42	2.86
NL 653	4.27	2.11	3.19	2.58	2.38	2.48	2.84
NL 775	4.10	1.28	2.69	4.03	1.82	2.92	2.81
NL 634	3.84	1.57	2.71	3.91	1.81	2.86	2.78
NL 768	3.92	2.23	3.07	3.44	1.50	2.47	2.77
NL 852	4.24	1.15	2.69	2.99	2.36	2.67	2.68
NL 803	5.70	0.00	2.85	2.88	0.69	1.78	2.32
NL 205	3.12	0.84	1.98	2.86	2.35	2.60	2.29
Chibonda	2.07	0.00	1.03	4.63	0.59	2.61	1.82
Mean	4.30	1.69	2.99	3.66	1.92	2.80	2.90
SE	±0.39	±0.21	±0.22	±0.50	±0.22	±0.27	±0.18
CV(%)	16	21	18	24	19	24	21

At Lucydale, Chibonda, NL 836-2, NL 265, and SV 1 were among the best-yielding genotypes in 1992/93. However, in 1993/94, SV 1, SV 2, NL 267, and NL 653 were the highest-yielding genotypes. Chibonda and NL 803, the later-maturing genotypes had the lowest grain yields in 1993/94.

Discussion

Yields were related to the amount of rainfall received. In 1992/93, Chiredzi received 526 mm, and Lucydale, 638 mm of rainfall between planting and 50% physiological maturity. However, in 1993/94, Chiredzi received 350 mm and Lucydale, 292 mm rainfall. In 1992/93, rainfall was well-distributed throughout the growing season. However, in 1993/94, rains stopped during the 1st week of Feb 1994 when the crop was still booting. Hence, crops sown in 1993/94 suffered from a late-season drought which may have adversely affected grain-filling, resulting in poor grain yields.

At Chiredzi, NL 803, SV 1, NL 836-2, and NL 265 had high yields under high rainfall in 1992/93. In 1993/94, SV 1, NL 535, NL 692, and NL 699 were the better-yielding genotypes because they flowered and matured before the drought set in. Chibonda and NL 803, which took long to flower and mature were adversely affected by the late-season drought. Differences among genotypes in yield response to drought were also reported by Garrity et al. (1979). Across seasons, SV 1 gave the highest grain yields, suggesting that this genotype may be suitable in those areas likely to experience a late-season drought.

At Lucydale, Chibonda, NL 265, NL 836-2 and SV 1 were among the four highest-yielding genotypes under adequate rainfall in 1992/93. However, under late-season drought in 1993/94, SV 1, SV 2, NL 267, and NL 653 were the better-yielding genotypes. The highest-yielding genotype across seasons was NL 265. SV 1 was among the top genotypes in both seasons, again suggesting that this genotype may be suitable in areas prone to late-season drought. Chibonda and NL 803 had high yields in a good season (1992/93), but yielded poorly under late-season drought in 1993/94. The latter genotypes took long to flower and mature and, hence, were unsuitable under late-season drought conditions.

Correlations between grain yield and plant height ($r = 0.35^{***}$), exsertion of panicle ($r = 0.16^{***}$), and 1000-seed mass ($r = 0.29^{**}$) suggested that these traits may be important in determining yield under drought conditions. A genotype with good panicle exsertion may ensure that its panicle comes out of the flag leaf and sets seed even if a drought period occurs at booting. In the event of a late-season drought, the capacity of a plant to remobilize and translocate dry matter to the grain for grain-filling may be an important drought-resistance mechanism. Under such conditions, the size of the plant may determine how much can be transferred to the grain. Our data strongly suggested that genotypes that took long to flower and mature were unsuitable in areas prone to late-season drought. This was in agreement with observations made by Gono et al. (1994) when they evaluated different sorghum genotypes on farmers' fields in Zimbabwe. We therefore need to breed for earliness to ensure that the crop matures within the available short season typical of most sorghum-growing areas in Regions III, IV, and V.

Conclusions

Sorghum genotypes at Chiredzi and Lucydale differed in grain yields depending on the season. SV 1 was among the highest-yielding genotypes regardless of location or season. Genotypes that took long to flower and mature generally gave poor grain yields under late-season drought conditions. The ability of a genotype to get its panicle out of the flag leaf sheath, and fill its grains were also important traits under late-season drought conditions.

areas of Natural Regions III, IV, and V (450-650 mm yr^{-1}) (Vincent and Thomas 1961). Commercial farmers produce the remainder of the crop (10%) which is used mainly for brewing or feeding livestock.

Grain yields of sorghum in the communal areas are still very low (about 401 kg ha^{-1}) in spite of the large area devoted to the crop (Zimbabwe CSO 1993). This is probably caused by inadequate soil fertility because communal farmers rarely apply manure or fertilizers to their crop although their soils are generally deficient in nitrogen and phosphorus (Mashiringwani 1983). Farmers therefore need sound recommendations on how much nitrogen and phosphorus to put on their sorghum crop to improve yields and maximize profits. Fertilizer studies in sorghum showed significant yield responses to nitrogen (Zharare and Whingwiri 1986; Gono 1990). However, the yield-input relationships in these studies were not continuous, and could not be used to derive fertilizer recommendations for sorghum.

In this study, we tested the hypothesis that poor sorghum grain yields were caused by low soil nitrogen and low soil phosphorus. We fitted a quadratic function to the data and derived nitrogen and phosphorus recommendations for different locations in Zimbabwe.

Materials and Methods

Ten locations were selected for the study (Table 1). Six of these locations (Gwebi, Panmure, Kadoma, Mlezu, Makoholi, and Matopos) were at experimental stations, whereas the other four locations (Chiwundura, Marange North, Jerera, and Rushinga) were on farmers' fields. Gwebi, Panmure, and Kadoma were on heavy, clay soils whereas the other locations were generally on light, sandy soils. The study was conducted over three seasons (1987/88, 1988/89, and 1989/90). Where we did not have three seasons' data, the trial was either discontinued (Gwebi, Panmure, Kadoma, Marange North and Jerera) or written off because of poor stand establishment (Chiwundura). Table 1 shows the sowing dates, rainfall received from sowing to 50% physiological maturity, soil texture, and soil nitrogen and soil phosphorus status before planting.

Three levels of nitrogen (0, 50, and 100 kg N ha^{-1}), and three levels of phosphorus (0, 30, and 60 kg P_2O_5 ha^{-1}) were tested in randomized complete block designs with three replications. We used ammonium nitrate (34.5% N) and single superphosphate (18.5% P_2O_5) as sources of nitrogen and phosphorus, respectively. Potassium was applied at a uniform rate of 30 kg K_2O ha^{-1} using muriate of potash (60% K_2O). Half the nitrogen, and all the potash and phosphate were banded at planting. We used a two-pronged hoe to mark out separate furrows for seed and fertilizer. The remaining nitrogen was topdressed at 4 weeks after planting.

Sorghum variety SV 2 was planted using a seed rate of 16 kg ha^{-1}. Sowing was generally scheduled to begin during the 1st week of December. Seed was dibbled by hand into rows 0.75 m apart and 30 mm deep. The gross plot area was 22.5 m^2 (6 rows at 0.75 m x 5 m) whereas the net plot area was 12.0 m^2 (4 rows at 0.75 m x 4 m). The net plot was obtained after discarding one row on either side of the gross

Table 1. Description of experimental sites.

Location	Natural Region	Year	Rainfall (mm yr^{-1})	Sowing date	Soil texture[1]	Incubated N (ppm)	Resin P_2O_5 (ppm)
Gwebi	IIa	1988	726	2-12-87	MgSaCL	33	21
		1989	616	5-12-88	n.s.	n.s.	n.s.
Panmure	IIb	1988	682	1-12-87	MgSaCL	23	42
		1989	581	6-12-88	n.s.	n.s.	n.s.
Kadoma	IIb	1988	780	14-12-87	MgSaCL	38	46
		1989	423	11-12-88	MgSCL	30	42
Mlezu	III	1988	636	2-12-87	n.s.	n.s.	n.s.
		1989	284	3-12-88	MgS	18	16
		1990	380	2-12-89	MgSL	12	21
Makoholi	IV	1988	526	8-12-87	MgS	8	51
		1989	213	1-12-88	MgS	24	14
		1990	410	1-12-89	MgS	15	48
Matopos	IV	1988	500	22-12-87	n.s.	n.s.	n.s.
		1989	343	19-12-88	n.s.	n.s.	n.s.
		1990	362	6-12-89	n.s.	n.s.	n.s.
Chiwundura	III	1988	551	1-12-87	MgS	18	8
		1990	693	11-12-89	MgS	19	9
Marange North	III	1988	402	4-12-87	MgS	8	14
		1989	509	3-12-88	MgS	18	12
Jerera	IV	1988	450	10-12-87	MgS	15	16
		1989	261	2-12-88	MgS	13	2
Rushinga	IV	1988	638	4-12-87	MgSL	15	13
		1989	830	8-12-88	MgSL	15	24
		1990	452	28-12-89	MgSL	19	33

1. MgSaCL = medium-grained sandy clay loam
MgS = medium-grained sand
MgSCL = medium-grained sand clay loam
MgSL = medium-grained sand loam
MgSaC = medium-grained sandy clay
n.s. = not sampled

plot and 0.5 m on either end. Thinning was done at 3 weeks after planting to achieve a uniform plant population of 100 000 plants ha^{-1}.

The trial was conducted under rainfed conditions. All pests and diseases were controlled as and when necessary. We harvested the net plot after 50% physiological maturity to determine grain yield. The analysis of variance (ANOVA) was conducted on grain yield using SAS (SAS 1985). We used regression procedures to fit quadratic functions to the response data. On the assumption that the farmers' objective was to maximize profit, partial derivatives from the profit function (#) were calculated in order to derive nitrogen (N*) and phosphorus (P*) recommendations, as described by Debertin (1986).

Quadratic function:

$$Y = f(Y) = a + bN + cP + dNP + eN^2 + fP^2$$

where Y = grain yield (kg ha^{-1})
N = nitrogen (kg ha^{-1})
P = phosphorus (kg P_2O_5 ha^{-1})
a, b, c, d, e, and f = regression coefficients

Profit function:

$$\# = p[f(Y)] - r_N - r_P$$
$$= p(a + bN + cP + dNP + eN2 + fp2) - r_N - r_P$$

where # = profit (\$ ha^{-1})
r_N = price of nitrogen = \$ 1.23 kg^{-1} N
r_P = price of phosphorus = \$ 0.96 kg^{-1} P_2O_5
p = price of grain sorghum = \$ 0.52 kg^{-1}.

Results and Discussion

Nitrogen increased grain yields at two on-station (Mlezu and Makoholi) and at all on-farm locations (Chiwundura, Marange North, Jerera, and Rushinga) (Table 2). On-farm locations were generally deficient in nitrogen (<20 ppm) (Table 1). Hence, application of nitrogen improved grain yields.

Table 2. Analysis of variance on grain yield (kg ha^1).[1]

Location	Year	N	P	N x P	Year x N	Year x P	Year x N x P
Gwebi	**						
Panmure	**						
Kadoma[2]							
Mlezu		***				*	
Makoholi	*	***	**		***		
Matopos	***						
Chiwundura		***				**	*
Marange North	***	*		*			
Jerera	**	***					
Rushinga		***	**		**	*	

1. *, **,*** Significant at $P<0.05$, $P<0.01$, and $P<0.001$, respectively. 2. No data available.

Table 3. Regression equations and optimal levels of nitrogen (N*) and phosphorus (P*) for each location and season.

Location	Year	Equation	R^{2}[1]	N* (kg ha^{-1})	P* (kg P_2O_5 ha^{-1})
Gwebi	1988	$Y = 4177.674 + 5.954N + 5.557P - 0.149NP - 0.050N^2 + 0.057P^2$	0.09	28.718	4.849
	1989	$Y = 3208.574 - 5.266N + 11.294P - 0.011NP + 0.040N^2 - 0.384P^2$	0.28	96.013	11.317
	Mean			62.366	8.083
Panmure	1988	$Y = 4011.907 + 10.359N - 11.872P - 0.012NP - 0.041N^2 + 0.179P^2$	0.31	102.699	0
	1989	$Y = 3018.194 + 0.105N + 8.138P + 0.011NP - 0.010N^2 - 0.364P^2$	0.26	0	6.686
	Mean			51.350	3.343
Kadoma	1988	$Y = 4246.157 - 14.719N + 0.562P - 0.171NP + 0.228N^2 + 0.095P^2$	0.15	60.286	60.722
	1989	$Y = 4854.444 + 12.284N - 36.535P + 0.060NP - 0.089N^2 + 0.427P^2$	0.47*	68.844	40.145
	Mean			64.565	50.434
Mlezu	1988	$Y = 2936.648 + 25.506N + 27.156P + 0.223NP - 0.209N^2 - 0.795P^2$	0.15	69.143	25.612
	1989	$Y = 1840.185 + 34.541N + 17.389P + 0.016NP - 0.218N^2 - 0.149P^2$	0.43*	75.801	57.204
	1990	$Y = 1815.898 + 51.672N - 44.642P + 0.061NP - 0.373N^2 + 1.016P^2$	0.54**	67.797	20.818
	Mean			70.914	34.545
Makoholi	1988	$Y = 196.472 - 0.319N + 7.371P + 0.058NP + 0.020N^2 - 0.118P^2$	0.43*	77.379	42.168
	1989	$Y = 114.269 + 1.807N + 1.632 - 0.051NP - 0.023N^2 + 0.074P^2$	0.28	0	0
	1990	$Y = 476.093 + 34.310N + 27.609P + 0.024NP - 0.218N^2 - 0.410P^2$	0.50**	74.946	33.503
	Mean			50.775	25.224
Matopos	1988	$Y = 4221.602 + 10.106N - 44.394P + 0.154NP - 0.050N^2 + 0.634P^2$	0.31	112.600	22.878
	1989	$Y = 8583.194 - 10.694N + 23.506P - 0.045NP + 0.057N^2 - 0.588P^2$	0.15	0	23.022
	1990	$Y = 1049.037 - 5.269N + 41.157P - 0.247NP + 0.212N^2 - 0.332P^2$	0.34	43.194	43.234
	Mean			51.931	29.711
Chiwundura	1988	$Y = 413.046 + 26.941N - 8.805P - 0.155NP - 0.161N^2 + 0.254P^2$	0.34	57.778	38.627
	1990	$Y = 376.148 + 16.924N + 43.856P + 0.088NP - 0.128N^2 - 0.681P^2$	0.72***	69.075	35.338
	Mean			63.426	36.982
Marange North	1988	$Y = 3333.444 + 10.864N - 14.433P + 0.506NP - 0.271N^2 - 0.342P^2$	0.49**	22.398	16.376
	1989	$Y = 402.870 + 10.916N + 24.180P + 0.077NP - 0.056N^2 - 0.401P^2$	0.46*	102.591	37.607
	Mean			62.494	26.992
Jerera	1988	$Y = 3269.287 + 4.639N - 0.758P - 0.089NP + 0.042N^2 + 0.066P^2$	0.23	0	5.647
	1989	$Y = 495.722 + 23.838N - 8.394P - 0.024NP - 0.111N^2 + 0.390P^2$	0.47**	98.765	0
	Mean			49.382	2.824
Rushinga	1988	$Y = 1905.111 + 17.926N + 0.117P + 0.062NP - 0.069N^2 + 0.323P^2$	0.68***	108.966	0
	1989	$Y = 1787.537 - 6.084N - 3.711P - 0.121NP + 0.089N^2 + 0.157P^2$	0.03	80.107	48.492
	1990	$Y = 1012.574 + 20.347N + 16.944P + 0.116NP - 0.104N^2 - 0.290P^2$	0.70***	113.455	48.386
	Mean			100.843	32.293

1. *, **, *** Significant at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively.

Phosphorus had a small effect on grain yield and this depended on the season at Mlezu, Chiwundura, and Rushinga (Table 2). Interactions between nitrogen and phosphorus were significant only at Marange North.

Because of significant differences in grain yield among seasons at most locations (Table 2), we fitted regressions for individual seasons and locations (Table 3). We derived economic levels of nitrogen (N*) and phosphorus (P*) using these regressions.

The quadratic function provided a reasonably good fit to the data with R^2 values ranging from 0.03 at Rushinga in 1988/89 to 0.72*** at Chiwundura in 1989/90. On average, about 60 kg N ha^{-1} and 21 kg P_2O_5 ha^{-1} were optimal on heavy, clay soils in regions Ila and lIb, whereas on infertile, sandy soils in regions III and IV, about 65 kg N ha^{-1} and 27 kg P_2O_5 ha^{-1} were adequate. The optimal levels of nitrogen (N*) and phosphorus (P*) derived from this function are generally within the ranges recommended for sorghum (50-60 kg N ha^{-1}, and 35-45 kg P_2O_5 ha^{-1}) by our Chemistry and Soil Research Institute. These levels thus provide a general guide to farmers on how much nitrogen or phosphorus to put on sorghum in order to increase yields and maximize profits.

Conclusions

Nitrogen increased sorghum grain yields at Mlezu and Makoholi (on-station), and at all on-farm sites (Chiwundura, Marange North, Jerera, and Rushinga). Phosphorus generally had a small effect on grain yield, which varied with season.

A quadratic function provided a reasonably good fit to the yield response data (R^2 = 0.03-0.72***), and enabled us to derive both agronomically and economically sound nitrogen and phosphorus recommendations for grain sorghum.

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Classification of Sorghum Races in the Southern Africa Sorghum Germplasm

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Abstract

As a component of the characterization of indigenous sorghum germplasm collected in Zimbabwe from the 10 countries of the SADC region, a total of 1217 accessions, from 8 of the 10 countries, were classified for basic and hybrid races. The race classification exercise identified 5 basic races containing 600 accessions, and 10 intermediate hybrid races containing 611 accessions, and a wild group (Drummondii) of 6 accessions only. Both basic and hybrid races were found to be almost equally present in the SADC region's sorghum germplasm.

Introduction

Characterization of germplasm is an important first step, after collection, in the identification and evaluation of indigenous accessions. A significant component of characterization is the classification of the different types of accessions contained in the collection. Within the different types of sorghum accessions in the world, several forms have been identified. These were originally classified into cultivated (31 species) and related wild species (17 species) (Snowden 1936; 1955).

The various groups of sorghum and their distribution were further described by de Wet et al. (1970). It was not until later that a method of classification of the cultivated sorghums was developed by Harlan and de Wet (1972). They divided the cultivated sorghums (subspecies *bicolor),* into five basic races: Bicolor (B), Guinea (G), Caudatum (C), Kafir (K), and Durra (D); and 10 hybrid races which are com-

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binations, and really stable intermediate hybrids, of the basic races. These include Guinea-Bicolor (GB), Guinea-Caudatum (GC), Guinea-Kafir (GK), Guinea-Durra (GD), Caudatum-Bicolor (CB), Kafir-Bicolor (KB), Kafir-Caudatum (KC), Kafir-Durra (KD), Durra-Bicolor (DB), and Durra-Caudatum (DC). Harlan and de Wet (1972) used mature spikelet types for their classification.

Several reasons can be adduced for classifying cultivated sorghums into races. The most important of these are based on the uses to which the information derived is put. These include:

- identification of sources of such desirable traits as disease, pest, and drought resistance;
- identification of adaptation zones;
- forms of productivity and stability among diverse genotypes;
- local knowledge and farmer paradigms in sorghum cultivation; and
- better understanding and use of relationships among species, and genotypes within species, to improve the crop.

To achieve the above, and for purposes of conservation, ICRISAT, NARS of the 10 countries of SADC, and IPGRI, have collected and assembled 3010 sorghum germplasm accessions from the region (Mengesha and Appa Rao 1990). Out of these, 2234 are kept at SADC/ICRISAT SMIP at Matopos, Bulawayo, as a working collection. Some of these have been categorized with passport data (Appa Rao and Mushonga 1987), but not characterized and evaluated in detail.

Materials and Methods

A set of 1217 sorghum accessions, out of the 2234 that constitute sorghum germplasm from the SADC region, were sown, as a germplasm characterization exercise, at Aisleby and Muzarabani in the 1988/89 and 1992/93 crop seasons (the latter for Namibian germplasm only). Two replications were used in each location. These accessions were part of the total working collection of 12 343 cultivated sorghum germplasm accessions from all over the world that are being conserved at Matopos. They also represent germplasm from eight SADC countries: Angola, Botswana, Lesotho, Malawi, Namibia, Swaziland, Tanzania, and Zimbabwe.

Observations were recorded from two-row plots for 13 descriptors as described in 'Revised Sorghum Descriptors' (IBPGR and ICRISAT 1984). However, for the purposes of this study, only three of the descriptors, namely head shape, grain covering, and grain shape, were used in classifying the accessions into race groups.

At harvest, two head samples per accession were closely observed before threshing for their shape, the covering of the grain by glumes, and the shape of the grains. Observations were recorded for each accession in each replication at Aisleby and Muzarabani. The data were processed with simple analysis of variance, and for primary statistical parameters.

Results and Discussion

Total numbers and percentages for the different basic and intermediate hybrid races of sorghum for each of the eight SADC countries are shown in Table 1. There were no observed variations in head shape, glume covering, and grain shape of the 1217 germplasm accessions—an indication of the stability of these three descriptors with no environmental effect on their expression.

In the germplasm accessions classified (Table 1), all the five basic races—Bicolor (B), Guinea (G), Caudatum (C), Kafir (K) and Durra (D)—and the 10 hybrid races—DC, GB, CB, KB, DB, GC, GK, GD, KC, and KD—described earlier by Harlan and de Wet (1972), were identified, based on their classification method, using mature spikelets, and combined with classes of head and grain shapes.

Among the basic races Guinea was most abundant (276), followed by Kafir (132), Caudatum (118), and Durra (61). Bicolor was least-abundant with only 11 out of the 1217 accessions classified. Interestingly, among the intermediate hybrid races, this least-abundant basic race combined in nature with one of the abundant races to form a stable natural hybrid, CB (Caudatum-Bicolor). This race, with 149 accessions, was next to the most abundant intermediate race GC, which had 187 accessions. The third most abundant of the hybrids was DC with 124 accessions. These results are of significance for the relative importance of the races, and their combining abilities in crop improvement. Caudatum, with a frequency of only about 10.0%, was recorded as the best natural combiner. It produces, in nature, stable hybrids with three other races, G, B, and D, and forms the most abundant hybrid races in the region. These Caudatum hybrid races occur with 15.4% (GC), 12.3% (CB), and 10.2% (DC) frequencies, relative to the remaining seven races that range from 0.6% (KB) to 3.7% (KD). The Kafir race has the least ability to combine with other races in nature, as indicated from the relative frequencies (percentages) of occurrence of the intermediate hybrid races.

A wild and weedy sorghum group, Drummondii (DR), appeared in the germplasm only from Angola and Namibia, both with only six accessions (0.5% of the total). It tends to be important in Angola due to its relative frequency of 20.0% in the country's very small germplasm collection. The weedy form might have resulted from a crossing of cultivated and wild sorghum as suggested by de Wet et al. (1970).

Table 1 presents the significant differences in the relative frequencies and distribution of sorghum germplasm in southern Africa. Interestingly, Kafir, which is absent from western Africa and restricted more to eastern and southern Africa (de Wet 1972), was found in only five of the eight countries studied. Except for Namibia, where it is only 2.3% of the accessions, it is fairly abundant in Botswana (17.0%), Lesotho (13.8%), Swaziland (28.0%), and Zimbabwe (16.2%).

Another interesting observation in this study is the appearance of Durra in significant proportions in Botswana (20.0%) and Namibia (14.7%). This is a new, important finding. In the description by de Wet et al. (1970), the Durra sorghums were restricted to western Africa and eastern Africa above latitude 5°S. The finding of Caudatum (21.7%) and Durra-Caudatum (20.9%) in Namibian sorghum germplasm is also new to the distribution presented by de Wet et al. (1970), and possibly not

Table 1. Classification of sorghum germplasm from southern Africa into basic and intermediate hybrid races for eight SADC countries.

	Basic races					Intermediate hybrid races[1]										
Country	Bicolor B	Guinea G	Caudatum C	Kafir K	Durra D	DC	GB	CB	KB	DB	GC	GK	GD	KC	KD	DR
Angola	6	1	1	-	1	-	-	3	-	-	2	-	-	-	-	4
	(30)[2]	(5.0)	(5.0)	-	(5.0)	-	-	(15.0)	-	-	(10.0)	-	-	-	-	(20.0)
Botswana	-	11	4	17	20	14	2	8	-	3	5	1	-	3	12	-
	-	(11.0)	(4.0)	(17.0)	(20.0)	(14.0)	(2.0)	(8.0)	-	(3.0)	(5.0)	(1.0)	-	(3.0)	(12.0)	-
Lesotho	-	1	2	15	1	20	1	29	5	2	28	1	-	4	-	-
	-	(0.9)	(1.8)	(13.8)	(0.9)	(18.3)	(0.9)	(26.6)	(4.6)	(1.8)	(25.7)	(0.9)	-	(3.7)	-	-
Malawi	3	153	10	-	1	4	11	5	-	1	32	-	9	-	-	-
	(1.3)	(66.8)	(4.4)	-	(0.4)	(1.7)	(4.8)	(2.2)	-	(0.4)	(14.0)	-	(3.9)	-	-	-
Namibia	-	7	28	3	19	27	-	-	-	-	22	5	2	5	3	2
	-	(5.4)	(21.7)	(2.3)	(14.7)	(20.9)	-	-	-	-	(17.1)	(3.9)	(1.6)	(3.9)	(2.3)	(1.6)
Swaziland	-	1	3	12	-	1	8	11	-	1	4	-	-	1	1	-
	-	(2.3)	(7.0)	(28.0)	-	(2.3)	(18.6)	(25.6)	-	(2.3)	(9.3)	-	-	(2.3)	(2.3)	-
Tanzania	-	17	12	-	4	3	3	2	1	2	21	-	2	-	-	-
	-	(25.0)	(17.6)	-	(5.9)	(4.4)	(4.4)	(2.9)	(1.5)	(2.9)	(30.9)	-	(2.9)	-	-	-
Zimbabwe	2	85	58	85	15	55	3	91	1	11	73	5	5	8	29	-
	(0.4)	(16.2)	(11.0)	(16.2)	(2.9)	(10.5)	(0.6)	(17.3)	(0.2)	(2.1)	(13.9)	(0.9)	(1.0)	(1.5)	(5.4)	-
Total	11	276	118	132	61	124	28	149	7	20	187	12	18	21	45	6
	(0.9)	(22.7)	(9.7)	(10.9)	(5.0)	(10.2)	(2.3)	(12.3)	(0.6)	(1.6)	(15.4)	(1.0)	(1.5)	(1.7)	(3.7)	(0.5)

1. Hybrid races are combinations of the basic races.
2. Numbers in parentheses are percentages.

hitherto recorded by any other study. With the abundance in Namibia of the two hybrid races, GC and DC, it can be hypothesized that the country could be an area of natural hybridization of Caudatum and Durra followed by their diversification into intermediate hybrid races. This phenomenon could be useful when parents are chosen for crop improvement in the SADC region, generally, and Namibia, specifically.

Bicolor is almost absent from southern Africa, except for Angola where 30.0% of the accessions are Bicolor types. This is in line with the distribution of cultivated sorghums given by de Wet et al. (1970).

Malawi is predominantly a Guinea-sorghum country (67% G, 14% GC). Tanzania (25.0%), Zimbabwe (16.2%), and Botswana (11.0%) follow in the importance of Guinea in their sorghum germplasm. Frequencies to those in Malawi were recorded in Nigeria for Guinea sorghums (Prasada Rao et al. 1985).

Figure 1 shows the distribution of sorghum races with average rainfall for the eight SADC countries studied. From the frequencies of sorghum-race distribution, it is observed that in Tanzania, Malawi, and Angola (countries between latitudes 2 and 17°S, and with high average annual rainfall between 809 and 1320 mm), basic sorghum races were equally or more frequently observed than hybrid races. In contrast, in Namibia, Zimbabwe, Botswana, Swaziland, and Lesotho (countries further away

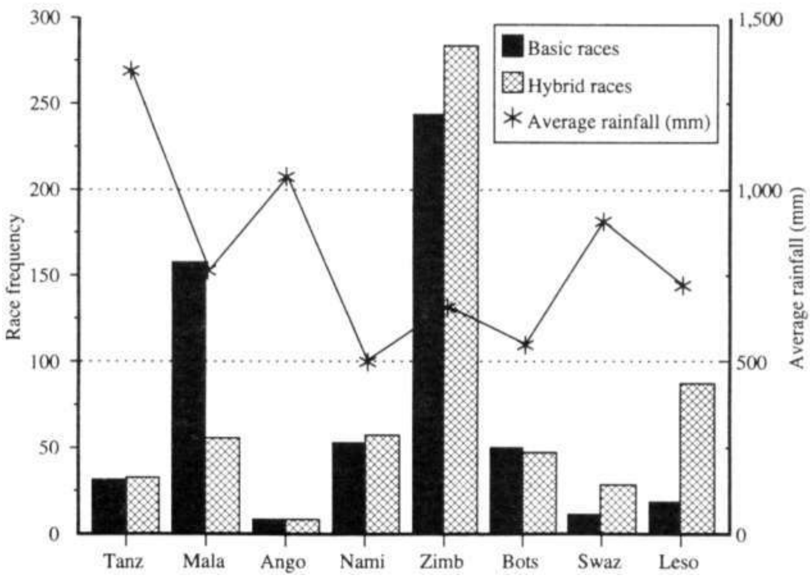

Figure 1. Distribution of sorghum races with average annual rainfall for eight SADC countries.

from the equator, between latitudes 17 and 32°S, and with lower average annual rainfall of 500-900 mm), hybrid sorghum races were more, or as frequently, observed as the basic races.

Using the analysis of patterns of allozyme variation in wild and cultivated sorghum, Aldrich et al. (1992) characterized the geographic distribution of genetic diversity in both sorghum types. Their analysis showed that levels of genetic diversity are greater in wild sorghum than in cultivated sorghum, although variability within the cultivated sorghums was more than in wild sorghums, according to de Wet et al. (1970). In using allozyme analysis for crop improvement, it would be necessary to study the correspondence between Guinea and Caudatum of southern Africa and those of western Africa. The expected results would facilitate sorghum breeders to capitalize on genetic diversity and variability across the two regions.

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Influence of Soil Fertility and Soil Salinity on the Performance of some Sorghum Genotypes

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Abstract

Sorghum is one of the three most important crops in Mozambique. It is grown throughout the country, but mainly in northern and central regions. It is sown in diverse soil types, mostly by smallholder farmers.

The performance of some sorghum genotypes under increased conditions of acid and saline soil is reported. Several groups of the genotypes were evaluated on acid soil in the central part of the country (Chimoio), and on saline soil in the south (Umbeluzi). There was a large variation in tolerance of both soil acidity (aluminum toxicity) and soil salinity. Many genotypes exhibiting tolerance of soil acidity/aluminum toxicity also demonstrated tolerance of soil salinity. Work on the evaluation and selection of the most suitable genotypes continues.

Introduction

Because of increased demands for food production, acid and saline soils are being brought into cultivation. According to Foy (1983a), liming and fertilization to optimum levels were profitable on moderately acidic soils when lime, fertilizers, and fuel were not expensive. Soil salinity is a similar problem. In many developing countries, using such inputs has never been practical. Also, for marginal soils in some parts of the tropics and subtropics, scientists are developing new technologies based on crop production with minimum inputs rather than for maximum output. So, breeding plants for tolerance of stress conditions is receiving increasing attention, particularly in developing countries. The most important benefits of a plant breeding approach to solving soil infertility are that it is ecologically clean, energy conserving, and cheaper than amending the soil (Foy 1983b).

Sorghum is one of the three most important crops in Mozambique. It is grown throughout the country (461 540 ha), with 42.6% of total sorghum area in the north, and 50.3% in central regions. It is produced mainly by smallholder farmers in diverse soil types.

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Research reported in this paper was undertaken to study the performance of some groups of sorghum genotypes under increased soil acidity and/or salinity.

Materials and Methods

The sorghum genotypes studied have different origins. They comprised promising open-pollinated varieties (OPVs) and hybrids from different seed companies from South Africa (Pannar, Ag-Seed, Sensako), Zimbabwe (Seed Coop), and Zambia (Zam-Seed), together with Mozambican material. Later additional material comprised advanced promising white sorghum lines from SADC/ICRISAT, Zimbabwe, which made possible the creation of the initial SEMOC Collection. Additionally, a set of 11 red grain lines, and a set of 39 lines tolerant of acid soils, were obtained from SADC/ICRISAT. In 1992 a set of 27 genotypes was received from the same source.

After evaluation of these materials, the most promising genotypes were selected and, in 1993/94, they were amalgamated as SEMOC Collections 1 and 2. In 1993 some new materials were received from Zambia (Mount Makulu Research Station). These were evaluated in acid soil in Chimoio (central Mozambique) and/or in 'normal' and saline soil in the south (Umbeluzi).

Chemical analyses were done at INIA (National Institute for Research in Agronomy, Maputo) following the methods recommended by Juo.

Results and Discussion

Principal chemical soil characteristics related to soil acidity and salinity

During maize and sorghum seed production it was observed that, in many places in the field, plants after emergence showed symptoms of mineral nutrient deficiency, with subsequent decrease in yield. In order to study the possible influence of soil in this situation, soil samples were analyzed for the principal chemical characteristics related to soil acidity and salinity. Data are presented in Table 1, showing different types of soils found in four locations.

Umbeluzi. Saline soil, with normal pH values, measured in water (6.1) and KC1 (5.7) but without H ions and soluble Al (no saturation with H+Al). However, the sum of exchangeable bases (Ca, Mg, K, Na) was high (52.2 me 100 g^{-1} of soil), with 100% saturation of exchangeable bases and high electrical conductivity (EC): 7.8 mS cm^{-1} for soil extract and 28.1 for paste.

Lionde. Alkaline and saline soil, with higher pH values in water (7.8) and KCl (7.5) without H ions and soluble Al (no saturation with H+Al), and a very high sum of exchangeable bases (93.7 me 100 g^{-1} of soil), with 100% saturation of exchangeable

Table 1. Principal chemical soil characteristics related to soil acidity, in four loctions, Mozambique.

Location	pH		H + Al (me 100 g^{-1} soil)	% of H + Al saturation	Exchangeable bases (me 100 g^{-1} soil)						EC (mS cm^{-1})	
	H_2O	KCl			Ca	Mg	K	Na	Sum of bases	% of saturation	Soil extract (1:2,5)	Past saturation
Umbeluzi	6.1	5.7	0.0	0.0	20.6	10.7	1.3	19.6	52.2	100.0	7.8	28.1
Lionde (435)	7.8	7.5	0.0	0.0	26.9	18.9	0.5	47.4	93.7	100.0	22.5	81.4
Chimoio	4.6	4.0	4.4	78.6	0.8	0.1	0.2	0.1	1.2	21.4	0.01	-
Namialo (3)	6.7	5.5	1.3	8.4	11.3	1.96	0.88	0.06	14.2	91.2	0.08	-

bases and very high electrical conductivity for soil extract (22.5 mS cm^{-1}) and for paste (81.4 mS cm^{-1}). This soil was completely infertile for sorghum production. However, other soils less affected with salinity were used for producing sorghum seeds.

Chimoio. Acid soil, with low pH values both in water (4.6) and KCl (4.0), an increased amount of H ions and soluble Al (4.4 me 100 g^{-1} of soil), a high level of saturation (78.6%) with H ions and Al, a very low sum of exchangeable bases (1.2 me 100 g^{-1} of soil), low saturation with exchangeable bases (21.4%) and very low electrical conductivity of soil extract (0.01 mS cm^{-1}).

Namialo. 'Normal' soil, with good pH values in water (6.7) and KCl (5.5), low concentration and saturation with H ions and soluble Al (1.3 me 100 g^{-1} of soil and 8.4% of Al saturation, respectively), exchangeable bases at 14.2 me 100 g^{-1} of soil and 91.6% saturation. Electrical conductivity of soil extract is low (0.08 mS cm^{-1}), indicating that the salt concentration is also very low.

Influence of soil acidity/Al toxicity on the performance of some sorghum genotypes

Data presented in Table 2 show the yield of 14 sorghum genotypes under high and low inputs at the SEMOC farm in Chimoio. Before the sowing of the trial, 2 t ha^{-1} of lime were applied to reduce the soil acidity/Al toxicity. During the vegetative period the trials were irrigated whenever a shortage of rainfall occurred. The average yield under high inputs was 6.41 t ha^{-1}. Two varieties, ZSV 1 and SV 2, yielded over 8 t ha^{-1}. Other high-yielders were Ana, WSV 387, and Macia with yields of about 7 t ha^{-1}.

Relatively high yields were obtained also under' low inputs (without fertilizers and insecticides). The average yield was 4.19 t ha^{-1}, which is 35% less

Table 2. Sorghum genotype trial, Chimoio, 1990/91.

Genotype	High inputs			Low inputs			Ratio low:high inputs
	% of mean	t ha^{-1}	CV(%)	% of mean	t ha^{-1}	CV(%)	
PNR 8544	96.1	6.16	13.6	97.4	4.08	6.2	0.66
Framida	103.7	6.65	9.4	90.9	3.81	19.8	0.57
Segoalane SC	78.3	5.02	9.3	73.5	3.08	21.5	0.61
WSV 387	109.2	7.00	13.7	112.4	4.71	14.2	0.67
Segoalane AS	92.0	5.90	7.3	89.7	3.76	17.8	0.64
SASK. 52	92.9	6.02	12.8	143.2	6.00	17.4	0.99
ZSV1	127.8	8.19	11.8	128.9	5.40	2.3	0.66
Mamonhe	89.9	5.76	5.3	85.0	3.56	7.0	0.62
PNR 8564	101.6	6.51	2.8	122.0	5.11	13.2	0.78
G 766 W	71.5	4.58	6.8	51.1	2.14	20.4	0.47
PN3	93.1	5.97	5.0	91.2	3.82	15.3	0.63
SV2	126.2	8.09	7.8	127.0	5.32	14.8	0.66
Ana	110.1	7.06	9.9	88.3	3.70	20.4	0.52
Macia	108.6	6.96	13.4	100.5	4.21	11.6	0.60
Mean	100.0	6.41	15.9	100.0	4.19	24.5	0.65

than the average yield under high inputs. Maximum yields were obtained with SASK 52 (6.0 t ha^{-1}, ZSV 1 (5.40 t ha^{-1}), SV 2 (5.32 t ha^{-1}), and the PNR 8564 hybrid (5.11 t ha^{-1}). As expected, average variation due to environment was lower under high inputs (CV = 15.9%) than under low inputs (CV = 24.5%).

Data from red sorghum at Chimoio, with high inputs but without liming, are shown in Table 3. The average yield was 2.86 t ha^{-1}. The highest yield was obtained with SDSL 88298 (3.98 t ha^{-1}), followed by ZSV 3 (3.32 t ha^{-1}), SDSL 89473 (3.26 t ha^{-1}), and SDS 1710-1 (3.07 t ha^{-1}).

The performance of SDS lines tolerant of acid soils at Chimoio, with 1 t ha^{-1} of lime and high inputs, is shown in Table 4a. These data show a very high average yield of 4.97 t ha^{-1}. The maximum yield of 8.96 t ha^{-1} was achieved with line 43-1 (SDS 6021), followed by the line M-90812 (SDS 6014). Another 10 lines exhibited yields between 6 and 8 t ha^{-1}. Al-tolerant line IS 8577 (Hill et al. 1989) also showed high yield at 7.46 t ha^{-1} (50% higher yield than the average of all lines in the trial).

The yields of the SEMOC collection from multiplication plots (nonreplicated, 100 m^2) from three locations are shown in Table 4b. The average yield over locations was 2.41 t ha^{-1}, being the highest in Chimoio (2.53 t ha^{-1}), followed by Namialo (2.41 t ha^{-1}), with the lowest in Lionde (1.71 t ha^{-1}). The highest-yielders over locations were Macia (3.47 t ha^{-1}), WSV 387-S1 (3.21 t ha^{-1}), Kuyuma (2.98 t ha^{-1}), and SV 2 (2.93 t ha^{-1}).

It should be noted that these three locations represent three different types of soils: saline/alkaline soil (Lionde), acid soil (Chimoio), and 'normal' soil (Namialo). The difference in yields between the locations might thus be at least partly ascribed to soil conditions.

Table 3. Trial with red sorghums from SADC/ICRISAT, Chimoio, 1991/92.

Genotype	Yield (t ha^{-1}) Mean	SD	CV (%)	Plant stand ('000 ha^{-1})	Days to heading	Plant height (cm)	Crop aspect (1-5)[1]	Bird damage (%)[2]	Maturity
ZSV 3	3.32	0.39	11.6	127	93.3	214	2.0	0.5	Late
SDS 1948-3	3.00	0.26	8.8	125	52.3	164	1.3	13.5	Early
SDS 1710-1	3.07	0.84	27.5	125	56.0	146	1.8	6.3	Early
SDS 3472	2.11	0.39	18.4	126	83.3	181	2.3	3.0	Late
SDSL 88298	3.96	0.61	15.5	125	55.0	144	1.0	8.8	Early
SDSL 89502	2.72	0.68	24.8	125	54.3	195	1.5	9.0	Early
SDSL 89473	3.26	0.77	23.7	125	58.8	129	1.5	6.0	Intermediate
LARSVYT 19	2.12	0.69	32.4	114	60.5	102	1.5	1.0	Intermediate
Marupantse	2.25	0.42	18.5	124	60.8	131	2.0	1.5	Intermediate
Town-Check	2.93	0.56	19.0	125	51.3	199	1.3	19.8	Early
Serena-Check	2.79	0.36	13.0	125	82.0	200	1.5	18.0	Late
Mean	2.86	0.56	19.6	124	64.3	164	1.6	6.4	-

1. 1 = excellent; 5 = poor.
2. 1 = no damage; 5 = heavy damage.

Table 4a. Trial with acid-tolerant SDS lines, Chimoio (acid soil), 1991/92.

SDS no.	Origin	Yield (t ha^{-1})	% of mean	Plant stand ('000 ha^{-1})	Days to harvest	Crop aspect (1-5)
600	IS-2765	3.18	64.0	92	145	3
6002	IS-3071	6.66	134.1	80	128	2
6003	IS-6944	1.22	24.6	58	114	5
6004	IS-8577	7.46	150.2	58	114	3
6005	IS-8931	6.06	122.0	85	145	3
6007-1	IS-8959	3.67	73.9	94	142	3
6007-2	IS-8959	3.79	76.3	90	142	3
6008	IS-8996	3.53	71.1	96	128	3
6009	IS-9084	4.32+	87.0	60	142	3
6010	MN-4508	6.17	124.2	86	114	3
6012	IS-7173C	1.80	36.2	50	114	4
6013	M-3 5585	7.24	145.8	56	145	2
6014	M-9 0812	8.16+	164.3	80	114	1
6015	M-9 0975	6.73	129.5	58	114	3
6016	M-9 019	5.06*	101.9	54	114	3
6017	M-9 1057	2.97	59.8	61	114	2
6018	D-7 1020	5.89	118.6	57	114	3
6019	SPV 475	3.88	78.1	63	114	3
6020	IS-12664-3	3.57	71.9	79	128	2
6021	43-1	8.96**	180.4	50	114	3
6022	Tortillero	6.57*	132.3	53	114	2
6023	PPQ-2	5.88	118.3	85	128	3
6024	PPQ-4	3.70	74.5	87	145	3
6025	IS-1054XEN (3332-2) DER	4.06	81.7	63	145	3
6026	2KX17 white	2.99+	60.2	85	145	3
6027	(MSFGI)-68-311	1.94+	39.1	62	114	3
6028	(MSFG-I)-68-312	4.07	81.9	66	145	3
6029	(MSFG-I)-68-321	5.03	101.3	75	128	3
6030	(MSFG-I)-68-322	5.91	119.0	63	128	3
6031	(MSFG-1)-102-531	6.59+	132.3	54	114	2
6032	(MSFG-1)-107-212	5.90**	118.8	56	114	2
6033-1	(MSFG-1)-139-212	7.44	149.8	90	114	2
6033-2	(MSFG-1)-139-212	7.34	147.8	91	145	3
6034	(MSFG-1)-139-221	4.16	83.8	57	114	3
6036	(MSFG-2-157-211)	2.57	51.7	57	114	3
6037	(MSFG-2-195-411	5.1	103.3	51	114	3
6038	(MSFG-4-157-211)	4.69*	94.4	52	114	2
6039	(MSFG-4-165-411)	3.77	75.9	65	114	2
6040	(MSFG-4-165-421)	5.95	119.8	58	114	2
	Mean	4.97	100.0	68.7	-	2.7

Bird damage: + = 5-7%;* = 15-17%;** = 20%.

Table 4b. Yield data (t ha^{-1}) from sorhgum multiplication plots in three locations, Mozambique, 1991/92.

Genotype	Lionde	Chimoio	Namialo	Mean
Mamonhe	2.00	1.50	4.68	2.73
Macia	1.72	3.84	4.84	3.47
SV 2	1.7	3.08	4.00	2.93
ZSV 1	1.41	3.34	2.58	2.44
WSV 387-S1	-	3.52	2.89	3.21
ZSV 5	1.96	3.26	1.64	2.29
ZSV 6	2.13	2.52	1.03	1.89
ZSV 8	1.41	3.5	2.36	2.42
Sima	1.93	3.62	1.91	2.48
Kuyuma	-	3.05	2.91	2.98
SDSL 2690	0.62	1.58	1.28	1.16
SDSL 89420	1.01	2.46	2.89	2.12
SDSL 87019	1.91	3.54	0.89	2.11
SDSL 89566	2.67	3.09	1.49	2.42
Mean	1.71	2.99	2.53	2.41

Several groups of genotypes have therefore also been evaluated on saline and nonsaline soils.

Influence of soil salinity on the performance of some sorghum genotypes

Red sorghum on saline soil. Data obtained with red sorghum grown on saline soil (at Umbeluzi) are shown in Table 5. The average yield of 2.79 t ha^{-1}, with the same genotypes, was similar to that obtained on acid soil in Chimoio (2.86 t ha^{-1}). The only variety that exhibited higher yield than the average, on both acid and saline soil, was ZSV 3.

The SEMOC Collection on nonsaline soil. Results from the trial with the SEMOC Collection of genotypes grown on nonsaline soil at Umbeluzi, under medium inputs (50% of those for maize), are presented in Table 6. The average yield of 4.41 t ha^{-1} was obtained with a relatively low plant density (61 500 plants ha^{-1}). The highest yield (6.21 t ha^{-1}) was obtained with SDSL 89566, followed by ZSV 6 at 6.01 t ha^{-1}. These

Table 5. Trial with red sorghums from the SEMOC collection and SADC/ICRISAT, Umbeluzi (saline soil), 1992/93.

Genotype/Population	Yield (t ha^{-1})		Plant stand ('000 ha^{-1})		Crop aspect (1-5)	Grain quality (1-5)	Aphid attack (1-5)	Days to flower
	Mean	CV (%)	Mean	CV (%)				
ZSV 3	2.96	25.4	92.9	7.9	4.0	2.7	3.7	74.7
SDS 1048-3	2.48	28.6	104.6	15.1	2.7	3.0	2.0	61.7
SDS 1710-1	2.63	22.0	99.2	19.1	2.3	3.0	2.0	63.0
SDS 3472	3.21	30.4	115.4	4.4	3.7	3.3	3.0	73.3
SDSL 88298	2.50	12.5	93.8	15.4	3.3	3.7	3.0	76.0
SDSL 89502	2.13	4.8	119.6	11.6	3.7	3.7	1.0	62.0
SDSL 89473	2.49	12.8	100.4	7.5	2.3	3.7	1.0	69.0
LARSVYT 19	2.97	7.0	154.2	19.5	2.7	3.7	2.3	65.3
Marupantse	3.11	26.1	139.6	0.7	2.7	2.0	1.0	67.7
Town check	2.49	10.0	140.4	13.9	3.0	1.3	2.3	62.0
Serena check	3.68	19.0	143.8	11.1	4.3	4.0	2.7	76.7
Mean	2.79	18.6	118.5	11.5	3.2	3.1	2.2	68.3

Table 6. SEMOC Collection, Umbeluzi 1992/93, Mongolime

Genotype/ population	Yield ($t\ ha^{-1}$)		Plant stand ('000 ha^{-1})		Grain per head (g)	Days to heading	
	Mean	CV(%)	Mean	CV(%)		Mean	CV(%)
SDSL 87019	4.26	20.1	62.1	20.4	56.8	72.0	4.5
SDS 2690	4.23	24.4	55.7	10.2	56.4	80.3	1.9
SDSL 89566	6.26	(4.21)	36.9	17.2	83.5	78.5	1.3
Kuyuma	3.90	12.5	72.7	13.3	52.0	71.0	2.8
Sima	5.79	11.3	32.4	15.3	77.2	79.0	2.1
ZS V-8	3.77	6.5	72.0	4.5	50.3	73.8	2.8
ZS V-6	6.01	21.7	49.4	4.3	80.2	79.5	1.3
ZS V-5	5.78	6.2	51.1	19.4	77.1	77.3	2.7
Mamonhe	1.73	28.4	73.0	12.9	23.0	74.0	3.2
Macia	3.81	21.2	67.4	6.9	50.7	71.0	2.8
ZSV 1	3.90	9.2	78.4	1.3	52.0	72.0	0.0
WSV 387 S1	4.75	28.7	61.0	25.1	63.3	72.0	3.9
SV 2	3.98	24.5	72.7	1.4	53.1	72.5	1.4
SDSL 89420	3.52	24.5	76.5	3.0	46.9	68.3	0.7
Mean	4.41	20.2	61.5	11.1	58.8	74.4	2.2

two genotypes exhibited also the highest grain mass per head (83.5 g and 80.2 g, respectively). A high yield of 5.8 t ha^{-1} was also obtained with Sima and ZSV 5.

White sorghum on nonsaline soil. Data from the group of SADC white sorghum genotypes grown on nonsaline soil at Umbeluzi are shown in Table 7. This trial was sown with a medium application of fertilizer (kg ha^{-1}: $N:P_2O_5:K_2O$ = 64:36:18) and gave an average yield of 3.87 t ha^{-1}. The best yielder was SDSL 88160 (5.14 t ha^{-1}), observed to be resistant to disease, followed by SDSL 88219 (4.78 t ha^{-1}) and SDS 2690 (4.72 t ha^{-1})—all displaying a good aspect during growth.

Acid-tolerant sorghums on 'normal' and saline soil. The performance of 40 genotypes tolerant of acid soil was studied in Umbeluzi on 'normal' (non-acidic/nonsaline) soil and saline soil. The results are presented in Table 8. The average yield of the trial grown on normal soil was 2.23 t ha^{-1}, and 2.78 t ha^{-1} on saline soil, i.e., somewhat higher at 19.8%. The crop aspect was better on saline than on nonsaline soil. Time to heading on nonsaline soil averaged 74.2 days, and on saline soil 76.3 days. The average score for pest damage (mainly aphids) on nonsaline soil was 3.6, and on saline 2.0.

The best yielders on nonsaline soil were SPV 475 (4.68 t ha^{-1}), D-71020 (3.8 t ha^{-1}), and (MSFG)165-4-1-1 (3.06 t ha^{-1}). Another three genotypes gave yields close

Table 7. Trial with white sorghums from SEMOC collection and SADC/ICRISAT, Umbeluzi (nonsaline soil), 1992/93.

Genotype	Grain yield			Plant stand ('000 ha^{-1})	Days to heading	Crop aspect (1-5)	Disease damage (1-5)
	% of mean	t ha^{-1}	CV (%)				
Macia	94.3	3.65	()	61.3	74.3	3.0	2.3
LARSVYT 4685	76.5	2.96	8.9	80.9	68.0	2.5	3.0
SDSL 87019	94.6	3.66	18.4	66.9	70.0	3.0	2.0
Kuyuma	119.1	4.61	11.4	93.1	71.0	2.3	1.8
Sima	109.3	4.23	4.4	57.5	77.5	4.0	2.5
ZSV 5	102.8	3.98	17.7	69.6	75.3	3.0	3.8
ZSV 6	114.7	4.44	8.7	55.0	79.0	1.3	1.0
Kanyesto	49.9	1.93	5.5	66.3	68.0	5.0	2.3
Segoalane B	109.6	4.24	19.6	83.1	77.7	3.8	2.5
SPV 351	112.1	4.34	30.2	72.5	66.8	3.5	1.8
SPV 475	108.8	4.21	12.9	82.5	72.0	2.5	3.0
SDSL 87018	77.3	2.99	6.3	58.3	74.5	3.5	2.5
SDS 2690	122.0	4.72	24.2	67.5	78.5	1.8	2.0
SDS 2293-6	119.1	4.61	4.3	65.0	80.5	3.5	1.7
SDSL 87013	56.6	2.19	()	66.3	78.5	3.3	2.3
SDSL 87015	113.2	4.38	10.1	82.5	74.3	2.8	2.5
SDSL 81021	82.4	3.19	28.5	53.4	70.0	3.5	2.5
SDSL 87029	93.3	3.61	29.6	75.4	78.8	2.5	2.8
SDSL 87040	90.4	3.50	22.6	60.0	74.8	2.8	1.8
SDSL 87046	86.0	3.33	18.5	75.4	76.7	4.5	3.5
SDSL 87046	96.6	3.74	23.0	65.9	77.3	2.0	2.0
SDSL 88059	104.1	4.03	12.7	55.0	78.8	3.5	2.8
SDSL 88219	123.5	4.78	14.1	102.5	73.5	3.8	2.3
SDSL 89420	104.1	4.03	17.6	73.1	69.0	3.5	2.0
SDSL 49426	101.6	3.93	23.5	87.5	73.5	2.8	3.0
SV 2	108.3	4.19	16.6	75.0	76.0	3.3	2.3
Mean	100.0	3.87	16.3	71.2	74.5	3.4	-
SD	-	0.76	-	12.2	4.0	-	-
CV (%)	-	19.5	-	17.1	5.3	-	-

Table 8. Trial with acid-tolerant SDS lines in 'normal' and saline soils, Umbeluzi.

		Yield data						Crop aspect (1-5)[1]		Days to heading		Aphid damage (1-5)[2]	
		'Normal' soil			Saline soil								
SDS no.	Origin	% of mean	t ha^{-1}	CV (%)	% of mean	t ha^{-1}	CV (%)	'Normal'	Saline	'Normal'	Saline	'Normal'	Saline
SDS 6001	IS-2765	112.9	2.69	20.7	120.5	3.35	-	5.0	5.0	83.0	80.0	4.0	3.2
SDS 6002	IS-3071	61.9	1.43	17.4	80.6	2.24	(34.8)	5.0	4.0	80.0	77.7	4.3	2.3
SDS 6003	IS-6944	114.7	2.66	(62.1)	36.3	1.01	17.5	3.3	2.3	67.3	75.3	4.7	1.3
SDS 6004	IS-8577	40.9	0.95	4.7	59.4	1.65	30.6	5.0	5.0	82.7	77.0	5.0	2.7
SDS 6005	IS-8931	109.9	2.55	11.8	103.6	2.88	28.3	4.7	4.7	81.3	80.3	3.7	1.7
-	SV 2	115.5	2.68	(42.1)	60.8	1.69	-	2.7	2.7	73.0	79.3	4.7	2.0
SDS 6007-1	IS-8959	41.4	0.96	0.0	73.7	2.05	25.2	5.0	4.0	81.3	80.3	5.0	3.2
IS-8959	IS-8959	104.7	2.43	20.2	90.3	2.51	11.5	4.7	4.73	83.0	79.0	4.7	2.0
SDS 6008	IS-8996	113.8	2.64	(37.9)	73.7	2.05	29.8	5.0	4.7	82.3	82.0	4.7	2.7
SDS 6009	IS-9084	63.8	1.48	-	139.6	3.88	20.5	5.0	5.0	84.0	80.7	3.7	1.7
SDS 6010	MN-4508	87.9	2.04	15.2	111.5	3.17	21.7	5.0	4.37	82.7	79.0	3.3	1.7
SDFS 6012	IS-7173C	23.7	0.55	19.3	49.6	1.38	-	5.0	3.7	62.0	67.3	5.0	2.3
SDS 6013	M-35585	126.7	2.94	23.1	55.4	1.54	5.7	2.7	2.0	73.3	80.0	2.7	1.0
SDS 6014	M-90812	87.5	2.03	26.2	121.9	3.39	14.6	1.0	1.3	78.7	78.7	1.0	1.0
SDS 6015	M-90975	135	3.14	4.1	68.3	1.90	32.1	3.0	3.0	72.0	74.5	1.7	2.0
SDS 6016	M-91019	112.9	2.62	23.7	122.7	3.41	(38.5)	3.3	3.0	71.0	76.3	3.3	1.3
SDS 6017	M-91057	113.8	2.64	19.1	117.7	3.30	32.4	4.7	3.3	73.3	75.0	5.0	1.7
SDS 6018	D-71020	163.8	3.8	(35.10)	102.2	2.84	5.0	2.0	1.7	70.7	71.0	2.0	2.0
SDS 6019	SPV 475	201.7	4.68	(40.4)	132.7	3.69	15.8	1.0	1.3	72.0	73.0	2.7	2.0
SDS 6020	IS-12644-3	90.9	2.11	27.2	86.7	2.41	(40.9)	4.7	3.7	81.7	78.7	4.0	3.0
SDS 60021	43-1	128.4	2.98	10.1	146.0	4.06	23.9	2.7	2.7	67.3	71.0	3.3	1.3
SDS 60022	Tortillero	115.9	2.69	6.1	145.3	4.04	(6.18)	4.0	3.0	69.3	72.7	4.0	1.0
SDS 60023	PPQ-2	122.0	2.83	13.1	69.4	1.93	25.3	3.0	3.3	78.0	77.0	3.7	2.7
SDS 60024	PPQ-4	121.1	2.81	13.8	96.4	2.68	26.3	2.7	2.0	78.7	79.3	3.0	1.7
SDS 60025	15-1054XEN3332-2	97.09	2.25	10.7	84.9	2.36	(45.3)	4.3	4.7	73.7	73.0	4.3	4.0
SDS 6026	2KX1768-3-1-1	111.6	2.59	6.8.1	110.1	3.06	9.8	2.7	1.7	78.0	77.3	3.7	1.7

Continued

Table 8. *Continued*

SDS no.	Origin	Yield data: 'Normal' soil % of mean	'Normal' soil t ha⁻¹	'Normal' soil CV (%)	Saline soil % of mean	Saline soil t ha⁻¹	Saline soil CV (%)	Crop aspect (1-5)[1] 'Normal'	Crop aspect Saline	Days to heading 'Normal'	Days to heading Saline	Aphid damage (1-5)[2] 'Normal'	Aphid damage Saline
SDS 6027	(MSFG)104-21W1R	51.7	1.20	4.4	49.6	1.38	12.2	4.0	4.0	71.0	74.3	1.0	1.3
SDS 6028	(MSFG)683-1-2	37.97	0.88	(-)2	45.0	1.25	(-)5	4.3	4.03	77.7	81.7	3.7	1.0
SDS 6029	(MSFG)68-3-2-1	107.8	2.50	(51.9)	87.4	2.43	9.98	4.7	3.3	74.0	77.7	3.0	1.0
SDS 6030	(MSFG)008-3-2-2	66.8	1.55	12.5	91.0	2.53	(-)	3.7	2.7	71.7	72.7	2.3	2.7
SDS 6031	(MSFG)102-5-3-1	75.0	1.74	9.4	63.3	1.76	23.6	3.7	3.7	68.7	71.0	4.3	3.0
SDS 6032	(MSFG)107-2-1-2	91.8	2.13	8.7	59.0	1.64	8.1	3.7	2.7	71.0	75.7	3.7	1.0
SDS 6033-1	(MSFG)139-2-1-2	94.8	2.20	14.5	77.0	2.14	26.1	5.0	4.7	80.0	80.0	4.3	2.7
SDS 6034	(MSFG)139-2-1-2	84.1	1.95	14.1	86.49	2.41	-4.6	3.3	3.0	65.0	72.0	4.3	2.0
SDS 6035	(MSFG)139-2-2-1	90.5	2.10	-.1	86.4	2.41	19.0	5.0	5.0	79.3	82.0	4.3	1.3
SDS 6036	(MSFG)157-2-1-1	128.4	2.98	28.3	104.0	2.91	(18.95)	3.7	3.7	62.0	70.7	4.3	2.0
SDS 6037	(MSFG)195-4-1-1	105.6	2.45	24.8	87.17	2.43	0.44	3.7	4.0	66.3	68.7	4.0	2.7
SDS 6038	(MSFG)157-2-1-1	92.7	2.15	32.5	112.2	3.13	22.3	3.0	3.00	66.0	76.3	2.0	1.3
SDS 6039	(MSFG)165-4-1-1	131.3	3.06	23.74)	88.9	2.48	-	3.3	2.7	72.0	76.7	2.0	2.0
SDS 6040	(MSFG)165-4-2-1	114.2	2.66	16.9	97.9	2.73	(20.49)	3.0	3.3	63.0	68.3	3.3	2.0
Mean		100.0	2.32	20.3	100.0	2.78	21.3	3.7	3.4	74.2	76.3	3.6	2.0
SD				-			-	1.2	1.1	6.4	3.8	1.1	0.7
CV (%)				-			-	32.8	32.0	8.6	5.0	30.0	36.6

1. Crop aspect from 1 to 5; 1 excellent and 5 poor. 2. Pest damage 1 to 5; 1 no attack and 5 heavy attack.

Table 9. Trial with sorghum genotypes from SEMOL Collection 1, Umbeluzi (saline soil), 1993/94.

Genotype	% of mean	Yield ($t\ ha^{-1}$)	Plant stand ('000 ha^{-1})	Plant height (m)	Days to flower	Vigor (1-5)	Crop aspect (1-5)	Grain aspect (1-5)	Pest damage (1-5)
SDS 2690	143.6	4.35	74.4	1.70	73.5	2.25	1.25	1.75	2.50
SDS 6014-S1	133.0	4.03	74.1	1.37	74.0	2.00	1.25	1.75	3.50
ZSV 6-S4	126.7	3.84	72.5	1.64	72.0	2.75	1.50	2.27	3.00
ZSV 5-S4	118.2	3.58	75.9	1.75	69.0	2.50	2.25	1.50	2.00
SDSL 87019-S3	117.2	3.55	89.7	1.63	61.3	2.00	2.50	1.50	2.50
WSV-387-S1S4	114.2	3.46	76.6	1.33	65.8	1.25	2.00	1.50	2.00
SPV 475-S3	108.9	3.30	77.2	1.52	63.0	2.50	2.50	4.50	1.75
Kuyuma-S4	106.6	3.32	81.9	1.43	63.5	2.00	2.75	1.75	3.25
ZSV 1-S3	103.0	3.12	85.6	2.00	65.8	2.25	2.75	.275	1.75
SDSL 89566-S3	100.3	3.04	64.1	1.36	71.0	2.25	2.50	1.00	3.75
SDS 6021-S1	98.3	2.98	93.8	1.30	59.3	2.00	4.00	3.00	2.75
SDS 6013-S1	89.8	2.72	82.2	1.36	68.5	2.25	4.25	2.75	4.25
SDS 6015-S1	89.4	2.71	73.1	1.53	61.8	2.00	3.75	2.25	4.75
SDSL 89420-S3	88.8	2.69	92.5	2.00	62.0	1.75	3.50	3.50	2.50
Mamonhe	85.5	2.59	118.1	2.84	71.0	3.25	4.25	4.50	1.25
SV 2	84.2	2.55	78.1	1.95	68.3	2.25	2.50	2.50	1.75
ZSV-8-S4	83.5	2.53	66.9	1.25	67.8	2.25	3.50	2.00	4.25
Macia	81.8	2.48	70.9	1.31	64.0	1.75	2.75	2.50	2.00
SPV 351 S3	75.2	2.28	85.0	1.41	60.3	2.50	4.25	3.75	3.00
Sima-S4	54.8	1.66	58.4	1.93	73.5	2.25	4.75	4.75	3.75
Mean	100.0	3.03	79.5	1.63	66.8	2.20	2.94	2.59	2.81
CV (%)	-	20.0	16.5	13.2	3.8	35.2	19.4	29.2	40.1
LSD (5%)	-	0.86	22.2	0.304	-	-	-	-	-

Table 10. Trial with sorghum genotypes from SEMOC Collection 2, Umbeluzi (saline soil), 1993/94.

Genotype	% of mean	Yield t ha^{-1}	Plant stand ('000 ha^{-1})	Days to flower	Plant height (m)	Vigor (1-5)	Crop aspect (1-5)	Grain aspect (1-5)	Pest damage (1-5)
SDSL 88160	156.4	3.52	77.2	76.8	2.14	1.75	1.00	2.75	3.00
SDSL 6018-S1	139.1	3.13	77.5	66.8	1.46	1.75	1.75	2.00	2.25
Serena	129.8	2.92	101.3	72.8	1.96	4.00	5.00	2.25	4.25
SDSL 87049	117.8	2.65	6.66	71.3	1.25	2.25	1.50	2.75	3.00
SDS 6010-S1S3	116.9	2.63	97.5	77.5	1.81	4.50	5.00	2.50	3.75
SDS 6002-S1	113.8	2.56	75.0	75.3	2.04	4.00	5.00	2.25	3.25
SDS 6033	113.8	2.56	83.4	71.3	1.75	4.25	5.00	2.25	4.75
SDS 6026	109.8	2.47	65.6	75.0	0.99	.750	1.75	1.25	3.00
Etosha	109.9	2.47	84.7	68.5	1.50	2.25	1.25	2.50	3.75
SDSL 87015	101.8	2.29	56.9	70.5	1.44	2.50	1.25	2.25	3.25
SDS 6031	96.0	2.16	83.1	63.3	1.33	2.75	1.00	2.00	3.25
SDS 6003-S1	94.2	2.12	91.3	61.5	1.36	4.50	1.00	1.75	2.00
SDS 87029S1	89.3	2.01	65.0	74.3	1.59	2.00	1.75	1.25	3.25
SDSL 6032	88.9	2.00	7.00	70.0	1.84	3.25	2.50	2.25	3.50
SDS 6030	88.9	2.00	64.41	71.0	1.68	3.25	2.75	1.50	4.25
SDS 6023	77.8	1.75	70.0	72.0	1.38	3.00	5.00	2.25	3.25
SDSL 88059	70.7	1.59	57.2	74.8	1.81	3.75	2.75	2.25	3.50
SDS 6022	67.1	1.51	72.5	69.3	1.15	3.75	2.00	1.75	3.50
Chokwe	60.0	1.35	33.1	71.8	1.35	1.75	2.50	1.00	3.50
Segaolane B	58.0	1.31	81.9	55.5	1.39	4.75	3.50	1.75	3.50
Mean	100.0	2.25	73.7	70.5	1.56	3.09	2.66	2.03	3.34
CV (%)	-	25.8	21.3	7.6	12.4	25.3	26.7	38.5	33.9
LSD (5%)		0.87	20.5					N.S.	N.S.

to 3 t ha^{-1}. On saline soil the best yielders were genotypes 43-1 (4.06 t ha^{-1}), Tortillero (4.04 t ha^{-1}), IS 9084 (3.88 t ha^{-1}), and SPV 475 (3.69 t ha^{-1}). There were another six genotypes with yields over 3 t ha^{-1}. Ten genotypes gave higher yields than average on both nonsaline and saline soil. Most of the genotypes that had a good aspect on saline soil also exhibited a good aspect on nonsaline soil, and vice versa. But with pest damage the situation was different. Many genotypes tolerant of pest damage on saline soil were less tolerant on nonsaline soil.

SEMOC Sorghum Collections 1 and 2 on saline soil. The original SEMOC Collection of 14 genotypes was augmented by 24 genotypes selected from acid-tolerant lines (see Tables 4a and 8) and SADC white sorghum (Table 7), including two new genotypes: Etosha and Chokwe. These materials now constitute Collection 1 (Table 9) and Collection 2 (Table 10).

Both Collections were sown at Umbeluzi on saline soil. The average yield from Collection 1 was 3.03 t ha^{-1} (Table 9). The best yields were obtained with SDS 2690-S3 (4.35 t ha^{-1}) and SDS 6014-S1 (M-90812) (4.03 t ha^{-1}), followed by ZSV 6-S4 (3.84 t ha^{-1}), ZSV 5-S4 (3.58 t ha^{-1}), and SDSL 87019-S3 (3.50 t ha^{-1}). Another five genotypes exhibited yields over 3 t ha^{-1}. In the case of Collection 2 (Table 10), the average yield was 2.25 t ha^{-1}. The best yielders were SDSL 88160 (3.52 t ha^{-1}) and SDS 6018-SI (3.13 t ha^{-1}). Another five genotypes gave yields over 2.5 t ha^{-1}.

The average number of panicles was 79 500 ha^{-1} for Collection 1 and 73 700 for Collection 2. There were also positive differences between average values of other agronomic characters (plant height, days to flowering, vigor, crop and grain aspect, and pest damage) in favor of genotypes from Collection 1.

Sorghums from Mount Makulu on saline soil. A group of genotypes from Mount Makulu (Zambia) was grown at Umbeluzi on saline soil (Table 11). The average yield was 2.94 t ha^{-1}. The best yields were obtained with ZSV 5 (4.21 t ha^{-1}) and SV 15 (3.95 t ha^{-1}), followed by ZSV 14 (3.77 t ha^{-1}) and ZSV 7 (3.71 t ha^{-1}).

In a separate trial with three open-pollinated varieties (OPVs) and five hybrids from Zambia (Table 12), the average yield was 3.39 t ha^{-1}. Hybrids performed better (average yield 3.68 t ha^{-1}) than the OPVs (average yield 2.91 t ha^{-1}). The best genotype among the hybrids was MMSH 413 (4.68 t ha^{-1}) and, among the OPVs, ZSV 12 (3.30 t ha^{-1}).

Adaptability of Different Sorghum Genotypes under Diverse Soil Conditions

To obtain an indication of the performance of different sorghum groups, and the genotypes within each group, in different soil conditions, average relative yields were calculated (see Table 13). Absolute yields of trials under different types of soils are presented.

Table 11. Trial with advanced sorghum cultivars from Mount Makulu, Umbeluzi (saline soil), 1993/94.

Cultivar	% of mean	Yield (t ha[1])	SD
ZSV 13	95.2	2.80	1.02
ZSV 14	128.2	3.77	0.79
9017-5-1-1	91.1	2.68	0.45
ZSV 6	101.4	2.97	0.17
ZSV 7	126.2	3.71	1.09
WSV 387-10-1	76.5	2.25	0.57
ZSV 3	94.2	2.77	0.33
ZSV 5	143.2	4.21	(1.38)
SDS 4282-1	117.3	3.45	0.50
ZSV 15	134.4	3.95	0.98
ZSV 16	104.4	3.07	0.42
SDS 3291-2	80.3	2.36	0.37
43-1	72.1	2.12	1.06
ZSV 17	84.0	2.47	0.46
ZSV 18	101.0	2.97	0.99
SDS 4345-2	77.2	2.27	0.52
ZSV 19	90.8	2.67	0.40
Framida	90.1	2.65	0.56
Sima	100.3	2.95	0.30
Kuyuma	89.10	2.62	0.39
Mean	100.0	2.94	0.64
SD		0.59	

Table 12. Trial with sorghum hybrids and open-pollinated varieties from Mount Makulu, Umbeluzi, 1993/94.

Hybrid/OPV	% of mean	Yield (t ha^{-1})	SD
Sima	81.1	2.75	0.67
Kuyuma	79.1	2.68	0.73
ZSV 12	97.3	(3.30)	(1.89)
MMSH 375	110.4	3.74	0.91
MMSH 413	138.1	4.68	1.14
MMSH 928	105.3	3.57	0.98
WSH 287	111.5	3.78	0.47
WSH 1256	77.9	2.64	0.73
Mean	100.0	3.39	0.79
SD		0.70	

Table 14 shows the relative yields under different soil conditions. In this group the genotypes giving the highest mean relative yield were: SDS 6021 (143.7%), SDS 6019

Table 13. Relative yields (%) of Sorghum genotypes from the SEMOC Collection in different types of soils.

	Chimoio	Umbeluzi		
Genotype	Acid soil	Saline soil	'Normal' soil	Mean
Mamonhe	50.2	143.4	39.2	77.6
Macia S 2	128.4	81.8	86.4	98.9
SV 2	103.0	84.2	90.2	92.5
ZSV 1	111.7	103.0	88.4	101.0
WSV 387 - S4	117.7	114.2	107.7	113.2
ZSV 5	109.0	118.2	131.1	119.4
ZSV 6	84.3	126.7	136.3	115.8
ZSV 8	117.1	83.5	85.5	95.4
SIMA	121.1	54.8	131.3	102.4
Kuyuma	102.0	106.6	88.4	99.0
SDSL 2690	52.8	143.6	95.9	97.4
SDSL 89420	82.3	88.8	79.8	83.6
SDSL 87019	118.4	117.2	96.6	110.7
SDSL 89566	103.3	100.3	142.0	115.2
Mean (t ha^{-1})	2.99	3.03'	4.41	3.48

1. Mean of 20 genotypes from Collection 2.

Table 14. Relative yields (%) of acid-tolerant SDS lines in different soils.

SDS no.	Acid soil	Saline soil	Normal soil	Mean
6001	64.0	120.5	112.0	98.8
6002	134.1	97.3[1]	61.9	97.8
6003	24.6	65.3[1]	115.0	68.3
6004	150.2	59.4	40.9	83.5
6005	122.0	103.6	109.9	111.8
SV 2	-	60.8	116.0	88.4
6007 - 1	73.9	73.7	41.4	63.0
6007 - 2	76.3	90.3	104.7	90.4
6008	71.1	73.7	113.8	86.2
6009	87.0	139.6	63.8	96.8
6010	124.2	114.3[1]	87.9	108.8
6012	36.2	49.6	23.7	36.5
6013	145.8	47.6[1]	126.7	106.7
6014	164.3	127.5[1]	87.5	126.4
6015	129.5	78.9[1]	135.3	114.6
6016	101.9	122.7[1]	112.9	112.5
6017	59.8	118.7	113.8	97.4
6018	118.6	120.6[1]	163.8	134.3

Continued

Table 14. *Continued*

SDS no.	Acid soil	Saline soil	'Normal' soil	Mean
6019	78.1	132.7	201.7	137.5
6020	71.9	86.7	90.9	83.2
6021	180.4	122.2[1]	128.4	143.7
Tortillero	132.3	106.2[1]	116.0	118.7
PPQ 2	118.3	73.6[1]	122.0	104.7
PPQ 4	74.5	96.4	121.0	97.3
IS-1054Xender	81.7	84.9	97.0	87.9
2KX17white	60.2	110.1	111.6	94.0
(MSFG 1)68-311	39.1	49.6	51.7	46.8
68-312	81.9	45.0	37.9	54.9
68-321	101.3	87.4	107.8	98.8
68-322	119.0	90.0[1]	66.8	91.9
102-531	132.3	79.7[1]	75.0	95.7
107-212	118.8	74.0[1]	91.8	94.9
139-212	149.8	95.0[1]	94.8	113.2
139-212	147.8	99.7[1]	81.4	109.6
139-221	83.8	86.4	90.5	86.9
(MSFG 2)157-211	51.7	104.5	128.4	94.9
195-411	103.8	87.1	105.6	98.8
(MSFG 4)157-211	94.4	112.2	92.7	99.8
165-411	75.9	88.9	131.3	98.9
165-421	119.8	97.9	114.0	110.6
Mean ($t\ ha^{-1}$)	4.97	2.52	2.32	3.27

1. Mean of two experiments.

(137.5%), SDS 6018 (134.3%), and SDS 6014 (126.4%). Four other genotypes exhibited a mean relative yield over 110% on both acid and saline soil, and the highest values were achieved by SDS 6021 (151.3%) and SDS 6014 (145.9%).

In a group of 11 red sorghum genotypes only ZSV 3 exhibited high relative yield on both acid and saline soil (Table 15).

Soil analysis (Table 1) indicated that a low pH value is followed by low concentrations of Ca and Mg and high concentrations of Al and Mn. Consequently, this reduces the soil to a low percentage of exchangeable base saturation and a high percentage of Al saturation. In the case of saline and saline/alkaline soils, there is a contrary situation: high exchangeable base saturation and low Al saturation. According to Jackson (1967), infertility of acid soils is due to one or more of the following factors: Al toxicity, Ca or Mg deficiency, Mn toxicity. This finding is in agreement with our results obtained with different maize genotypes from the tropical zone (Denic and Vidakovic 1984) and the temperate zone (Denic and Lazic-Jancic 1992). Similar reactions were found in the case of sorghum (Gourley and Salinas 1987). Al-tolerant line IS 8577 (Hill et al. 1989) exhibited a high yield on acid soil at Chimoio.

Table 15. Relative yields (%) of red sorghums in acid and saline soils.

	Chimoio	Umbeluzi	
Genotype	Acid soil	Saline soil	Mean
ZSV 3	116.1	106.1	111.1
SDS 1948-3	104.9	88.9	96.9
SDS 1710-1	107.3	94.3	100.8
SDS 342	73.8	115.1	94.5
SDSL 88928	138.5	89.6	114.1
SDSL 89502	95.1	76.3	85.7
SDSL 89473	114.0	89.2	101.6
LARSVYT 19	74.1	106.5	90.3
Marupantse	87.7	115.5	99.6
Town-Check	102.4	89.2	95.8
Serena-Check	97.6	131.9	114.8
Mean (t ha^{-1})	2.86	2.79	2.83

Similar to soil acidity/Al toxicity variation there is also wide variation between and within genotypes' tolerance of soil salinity. In the case of sorghum, the results of Igartua et al. (1993) showed wide variation in EC 50 values between different sorghum genotypes (range from 6.85 to 11.50 dSm cm^{-1}).

It has been reported that synthesis of specific proteins responds dramatically to such abiotic factors as drought, salt, heat, and cadmium stress. Our results (Lazic-Jancic et al. 1991) demonstrate that the 54 kDa and 65 kDa, synthesized from mRNAs isolated from Al-stressed roots, were also present among in-vitro translation products from heat-shocked plants. These products accumulated to a higher extent in the roots of the tolerant genotype than in the sensitive one. This might also suggest that a common mechanism is involved in tolerance of soil salinity. Our results show that the group of acid-tolerant genotypes included seven (17.9% of the total) that also exhibited tolerance of saline soil. And the group of sorghums comprising the original SEMOC Collection, and the group of red sorghums—21.4% and 9.1% of genotypes respectively—exhibited good tolerance of both acid and saline soil.

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Pearl Millet Research in Botswana

M Mogorosi[1]

Abstract

A variety trial was conducted at three locations in Botswana in the 1993/94 season in which 15 varieties of pearl millet were compared with Serere 6A and the farmers' local landrace variety (LLV) as controls. The sowing of a demonstration plot at Etsha 8 confirmed that improved varieties SDMV 89004, at a yield of 1267 kg ha^{-1}, and ICMV 88908 at 798 kg ha^{-1}, should be considered as pre-release varieties because of their superiority to other test varieties.

Introduction

Pearl millet ranks third in production after sorghum and maize. On average, 60% of the land is sown to sorghum alone, while maize occupies 23% and millet 6%. However, such national production figures do not reveal pearl millet's importance. This is because, in the areas where it is sown, it reverses the national trend, sometimes occupying as much as 90% of the cropped land, as in the refugee settlement villages of Etsha in the northwest.

Methods

Pearl millet research in Botswana evaluates varieties from SADC/ICRISAT SMIP for adaptation and yield stability. The adapted material is then tested in the farmers' fields for verification. In the 1993/94 season a national pearl millet variety yield trial was conducted at three locations in the country: Sebele, Matsaudi, and Etsha 8. The trial consisted of 15 varieties with Serere 6A and the farmers' LLV as controls. A randomized block design with four replications was used. At sowing 300 kg ha^{-1} of compound fertilizer containing NPK in a ratio of 2:3:2 was used. Two varieties, SDMV 89004 and ICMV 88908 (popularly known as Okashana 1), outyielded Serere 6A and the farmers' LLV at all three locations. These two varieties are already being tested in the farmers' fields.

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Results and Discussion

The highest grain yields were obtained from Sebele (Table 1). This is mainly due to the more fertile soil in the eastern part of the country which has a high water-holding capacity compared with the other two sites. SDMV 89004 and ICMV 88908 out-yielded Serere 6A and the farmers' LLV. The high yields at Sebele are also again due to the fairly well distributed rainfall from sowing which occurred around Nov/Dec to the end of March (Fig. 1).

Table 1. Means of three traits of promising pearl millet varieties grown at Sebele, Botswana, 1993/94.

Variety	Days to flowering	Plant height (cm)	Grain yield (kg ha^{-1})
SDMV 89004	59	165	3797
SDMV 89005	59	182	3793
ICMV 88908	59	147	3406
Serere 6A	58	140	2903
Farmers' LLV	67	205	1483
CV (%)	5.82	7.23	16.57
Mean	63	247	3317
SE	±1.84	±8.95	±275

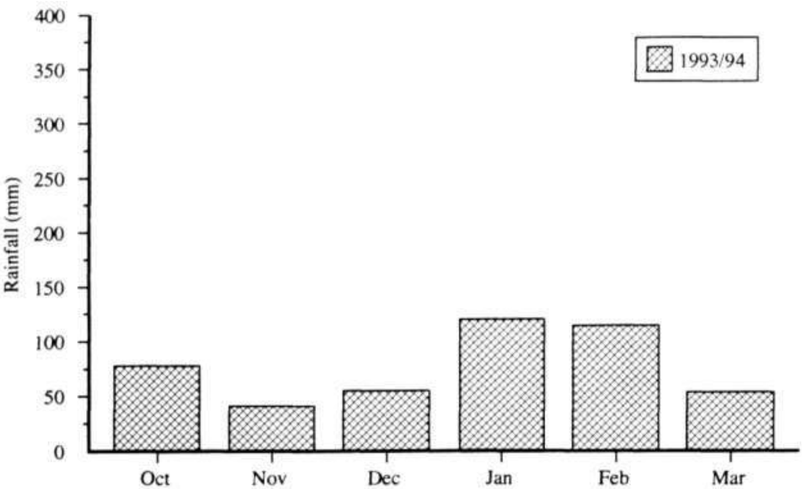

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Figure 1. Rainfall distribution at Sebele Research Station, Botswana, 1993/94.

At Matsaudi in the northwest, the grain yields were lower than those at Sebele and Etsha 8, caused by sandy soils with low fertility and a low water-holding capacity. The highest-yielder was ICMV 88908 at 688 kg ha^{-1} and Serere 6A was the lowest at 345 kg ha^{-1} (Table 2).

Table 2. Means of three traits of promising pearl millet varieties grown at Matsaudi, Botswana, 1993/94.

Variety	Days to flowering	Plant height (cm)	Grain yield (kg ha^{-1})
ICMV 88908	59	135	688
SDMV 89004	76	120	550
SDMV 89005	70	148	503
Farmers' LLV	76	143	503
Serere 6A	64	118	345
CV (%)	12.67	21.92	45.51
Mean	69	127	455
SE	±4.38	±13.92	±104

While the total rainfall at Matsaudi was also reasonable, it was not well-distributed; about half the total rainfall fell in January (Fig. 2). The long-term average rainfall was well-distributed in comparison with that in the 1993/94 season.

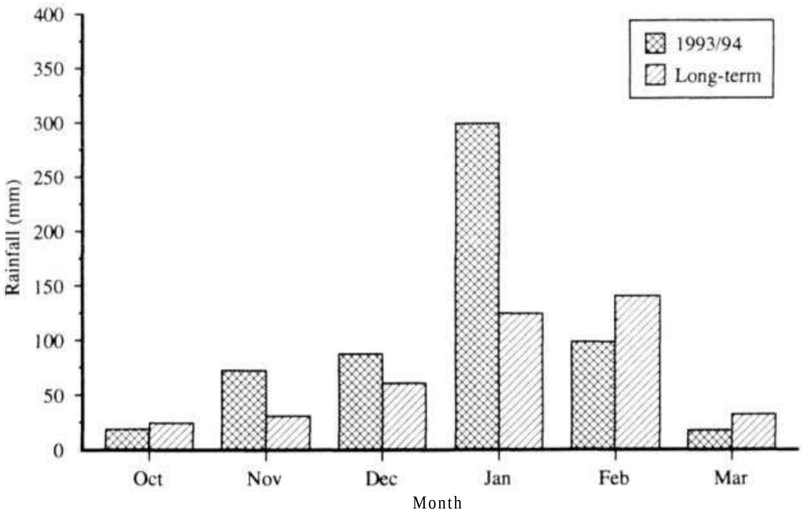

Figure 2. Rainfall distribution at the Matsaudi trial location, Botswana: comparison between 1993/94 seasonal data and long-term averages.

The grain yields at Etsha 8 were higher than those at Matsaudi; as expected, SDMV 89004 and ICMV 88908 outyielded Serere 6A and the farmers' LLV (Table 3). Hence these varieties are being tested in the farmers' fields. The rainfall pattern for Etsha 8 is similar to that of Matsaudi (Fig. 3). More than half the total rainfall fell in January (380 mm) and there was no rainfall in March.

Table 3. Means of three traits of promising pearl millet varieties grown at Etsha 8, Botswana, 1993/94.

Variety	Days to flowering	Plant height (cm)	Grain yield (kg ha')
SDMV 89005	59	182	1016
SDMV 89004	59	165	893
ICMV 88908	59	147	776
Serere 6A	58	140	600
Farmers' LLV	67	205	430
CV (%)	9.38	16.32	55.34
Mean	58	162	758
SE	±2.77	±13.25	±204

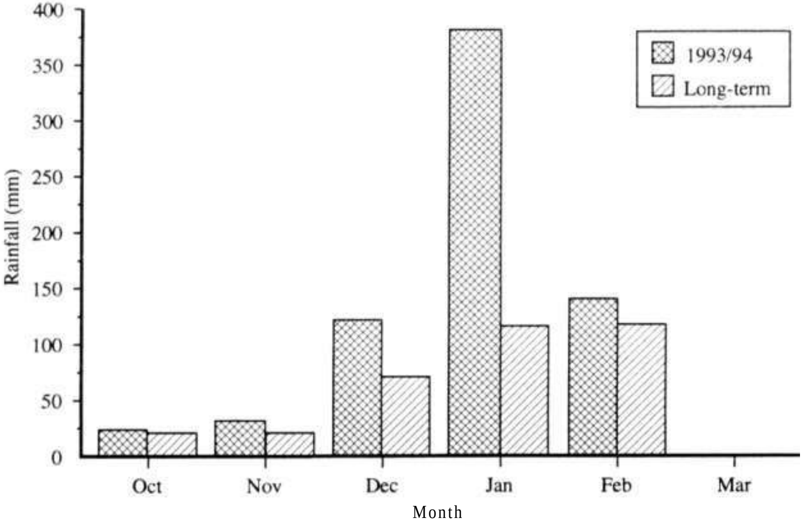

Figure 3. Rainfall distribution at the Etsha 8 trial location, Botswana: comparison between 1993/94 seasonal data and long-term averages.

For the first time we had a demonstration plot at Etsha 8 for these prerelease varieties. The plot size was 7.5 m wide by 40 m long for each variety. No fertilizer was added to the plot. The results are presented in Table 4. These varieties outyielded our standard variety, and the farmers' LLV. On 23 Mar 1994 we had a Field Day at Etsha 8, and most farmers present were impressed by the performance of these varieties.

Table 4. Yield data from the demonstration plot at Etsha 8, Botswana, 1993/94.

Variety	Grain yield (kg ha^{-1})
SDMV 89004	1267
ICMV 88908	798
Serere 6A	515
Farmers' LLV	313

Selection Gains in Pearl Millet Composites in Zambia

F P Muuka[1] and Pheru Singh[2]

Abstract

Half-sib and mass selection procedures are employed to improve grain yield and other characters of composites in the Zambian Pearl Millet Improvement Programme. Currently six composites are in different cycles of improvement, four of which formed the basis of the present study. The method used to improve the composites and derive varieties from them under limited physical facilities, resources, and skilled technical personnel is described. The test of cycle bulks over 2 years indicated increased grain yield and corresponding plant height without any change in head length and flowering dates over initial bulks. Fourth-cycle bulks of early and medium composites outperformed their original counterparts, giving 4.0% and 2.6% gains per cycle respectively.

Similarly, third-cycle dwarf and late composites gave 4.7 and 3.3% gains per cycle. Medium and late composites showed higher yield potential and are therefore the source of high-yielding varieties. Lubasi, a variety mass-selected from medium composite has been released. And ZPMV 90521, which was developed by mass selection from the CO cycle of late composite, is the most promising among the new varieties.

Introduction

The choice of breeding method is determined by the objective of the program, character under selection, its gene action and available physical facilities, resources and personnel. The main goal of the Zambian Pearl Millet Breeding Programme is to develop broadly adapted, high-yielding, disease- and pest-resistant varieties through mass and half-sib selection schemes. The program is currently improving six genetically diverse and morphologically dissimilar composites.

According to Andrews et al. (1985), it is possible to change gene frequencies for some important characters in pearl millet populations using recurrent selection.

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Recurrent selection can mobilize large genetic variation and increase the frequency of desirable genes and gene combinations by providing recombination among selected lines. Singh et al. (1988) compared a range of breeding methods to improve pearl millet composites and concluded that none of the methods proved superior to the other, although strict scientific comparison could not be made as population size, selection intensity, etc., were not constant across methods and composites.

Mass selection uses phenotypic performance of individual plants as a selection criterion on the assumption that phenotypic value of the selected individual is correlated with its genotypic value. Characters with high heritability can be easily improved by this method, with the rate of gain being proportional to the magnitude of heritable values (Rattunde et al. 1989). The main practical advantages of mass selection are its simplicity, which permits the handling of large populations with little effort, and rapid turn-around (one generation per cycle). But mass selection is theoretically less efficient due to lack of control on the male parentage of the offspring and the inaccurate assessment of the performance of the individuals.

Preference of family selection over mass selection arose because of the difficulty in determining the genetic worth of an individual and low heritabilities of most traits of economic importance. Family selection is generally effective in improving traits with complex inheritance and low heritabilities because it makes use of the information on the breeding value. Half-sib selection, like other family selection procedures, involves three phases, i.e., development of progenies, their evaluation over environments, and intermating the selected progenies. These steps are repeated until the objectives of the selection program are attained. An adequate number of plants are necessary to sample the genetic variability in the population, whereas adequate testing is necessary to identify the genetic differences among the sampled families.

Materials and Methods

Three main steps involved in population improvement are: formation of a base population; improvement through an appropriate selection scheme; and utilization of the improved population. The base population is formed by intermating suitable parents in an isolation plot for at least three generations. During the initial intermatings, mild selection is applied to eliminate weak and undesirable plants. At the end of the final random-mating 300-500 superior half-sib plants are selected, based on their phenotypic performance.

The progenies of the selected plants are evaluated in replicated nurseries at one or more locations for grain yield, disease resistance, and other characters. Superior half-sib progenies are identified on the basis of their overall performance. In the beginning, for three cycles in each composite, individual plant selections were made from the additional set of half-sib nursery plants grown for random-mating in isolation. Performance of progenies was the main criterion for selection. Mostly better plants from superior progenies were selected. However, in some cases, the outstanding plants from other progenies were also chosen. Selection intensities were kept relatively low with 30-35% progenies identified for selection of single plants. The main aim in the initial cycles was to allow sufficient random-mating and eliminate the undesirable variability without risking the useful variability in the composites. In this way one cycle in one crop season was completed.

From the third cycle onward, the half-sib selection method was followed. The remnant seed of the selected progenies was bulked and grown in isolation for random-mating and selection of individual plants. The half-sib progenies were evaluated and selected in the next season. In this way, three crop seasons were required to complete a cycle. During selection, in addition to grain yield and quality, emphasis was placed on identifying the most common diseases: downy mildew (*Sclerospora graminicola* [Sacc] Schroet.), smut (*Tolyposporium penicillariae* Bref.), and ergot (*Claviceps fusiformis* Lov.)

Formation of Varieties

In each selection cycle new varieties are formed by using the remnant seed of superior progenies. Sometimes superior plants from outstanding progenies in isolation plots are harvested and their seed is bulked and planted in isolation to form the variety. Such varieties are further mass-selected at a low selection intensity at one or more locations to eliminate the undesired variability and to improve their adaptation. It may be noted that intensive subsequent selection in the absence of appropriate population size within a variety may lead to a loss of genetic variability, resulting in inbreeding and excessive uniformity. This may limit the buffering capacity and adaptation of the variety to perform well over a range of environmental conditions and management regimes existing among pearl millet farmers.

Sowing and Evaluation

The different cycle bulks of early (PMEC), dwarf (PMDC), medium-maturing (PMMC), and late-maturing (PMLC) composites were evaluated along with some varieties derived from them in a randomized complete block design with four replications in two trials at four and three locations during the 1992/93 and 1993/94 crop seasons respectively.

Sowings coincided with the onset of regular rains, usually between mid-November and mid-December. The recommended hill planting with an interrow and intrarow spacing of 0.60 m with five to eight seeds per hill was followed. Plot size consisted of four rows of 4.2 m long. Two-week old seedlings were thinned to three or fewer plants per hill. The recommended rate of fertilizers (40 kg ha^{-1} nitrogen with 20 kg ha^{-1} phosphorus) were applied.

Data collected included: grain yield in kg after sun-drying and threshing; days to flowering (number of days from sowing to 50% flowering); plant height in cm measured from ground level to the tips of the panicles; head length in cm (average length of five randomly selected panicles); number of heads nr^2; and agronomic score on a scale from 1 (very good) to 5 (very poor).

Table 1a. Gain due to selection and other characters of pearl millet composites (PMCBT-2), Zambia, 1992/93 and 1993/94.

Population cycle	Grain yield (kg ha^{-1}) 1992/93	Grain yield (kg ha^{-1}) 1993/94	Grain yield (kg ha^{-1}) Mean	Plant height (cm) 1992/93	Plant height (cm) 1993/94	Plant height (cm) Mean	Days to 50% flowering 1992/93	Days to 50% flowering 1993/94	Days to 50% flowering Mean	Head length (cm) 1992/93	Head length (cm) 1993/94	Head length (cm) Mean	Head count (m^{-2})	Agronomic score (1–5)
PMEC C0	1.71	2.70	2.20	198	204	201	55	56	56	27	27	27	23.8	2.7
C1	1.74	2.85	2.29	200	209	205	56	55	56	28	26	27	26.8	2.4
C2	1.94	2.73	2.33	206	206	206	55	55	55	28	25	27	27.6	2.2
C3	2.03	3.06	2.55	215	212	214	55	55	55	28	28	28	26.2	2.4
C4	-	3.13	-	-	211	-	-	57	-	-	28	-	26.2	1.9
Gain cycle^{-1} (%)	6.4	4.0												
PMDC C0	1.52	2.28	1.90	174	161	168	56	57	57	32	34	33	23.2	2.5
C1	1.68	2.50	2.09	178	168	173	56	58	57	32	30	31	24.2	2.2
C2	1.77	2.81	2.29	179	170	175	57	58	58	31	32	32	26.0	2.2
C3	-	2.61	-	-	171	-	-	57	-	-	30	-	24.0	2.1
Gain cycle^{-1} (%)	8.5	4.7												
LSD (kg ha^{-1}) range	423–822	372–939												
CV (%) range	23.3–26.9	13.1–20.1												

Table 1b. Gain due to selection and other characters of pearl millet composites (PMCBT-1), Zambia, 1992/93 and 1993/94.

	Grain yield (kg ha^{-1})			Plant height (cm)			Days to 50% flowering			Head length (cm)				Agro-
													Head	nomic
Population cycle	1992/ 93	1993/ 94	Mean	1992/ 93	1993/ 94	Mean	1992/ 93	1993/ 94	Mean	1992/ 93	1993/ 94	Mean	count (m^{-2})	score (1–5)
PMMC C0	1.95	2.76	2.35	232	242	237	58	58	58	28	30	29	25.0	2.5
C1	1.81	2.28	2.05	239	237	238	58	61	60	30	31	31	17.5	2.6
C2	2.09	2.84	2.47	236	246	241	57	58	58	28	30	29	23.2	2.3
C3	2.47	2.86	2.67	255	246	251	59	58	59	31	30	31	23.2	2.3
C4	-	3.05	-	-	251	-	-	59	-	-	31	-	22.0	2.0
Gain cycle^{-1} (%)	8.9	2.6												
PMLC C0	1.86	2.73	2.29	255	270	263	62	62	62	37	38	38	19.0	2.2
C1	2.49	2.74	2.62	263	262	263	62	61	61	34	40	37	20.2	1.9
C2	2.28	2.85	2.56	268	265	267	62	61	61	36	40	38	21.4	2.1
C3	-	3.00	-	-	275	-	-	62	-	-	42	-	21.0	1.9
Gain cycle^{-1} (%)	11.4	3.3												
LSD (kg ha^{-1}) range	574–905	457–865												
CV (%) range	21.1–28.7	15.3–21.4												

Results and Discussion

Comparison of cycle bulks of four composites in two trials conducted over 2 years indicated that selection has been effective in increasing the grain yield levels of the composites. The magnitude of the gain per cycle over the years differed substantially (Tables 1a, 1b). In 1992/93, the gains per cycle for grain yield ranged from 6.4% in early composite to 11.4% in late composite. Such rates of gain are obviously high, which could be mainly due to the fewer cycles involved. The rate of gains per cycles for grain yield in 1993/94 with an extra cycle ranged from 2.6% in PMMC to 4.7% per cycle in PMDC (much lower than 1992/93). Andrews et. al. (1985) observed genetic gains for grain yield of from 1.8 to 5.0% per cycle in Super Serere and D2 composites respectively. In maize, gains from 2.0 to 4.6%, obtained by different workers using various methods, were reported by Sprague and Eberhart (1977). The pooled data for grain yield for the bulk, common over both years, showed gains from 4.4% (in PMMC) to 10.3% (in PMDC) per cycle.

Interestingly, the increase in grain yield was found to be associated with the increase in plant height in all composites over both years. However, the flowering date and head length remained unchanged. An increase in head number per plot was observed in all composites except PMMC where selection emphasis has been on larger heads. All the composites improved in their agronomic score over cycles. This is possible due to the gradual elimination of the undesirable proportion of the variability.

Performance of Varieties

The comparative mean grain yield of the varieties and their parental composite bulks are reported in Table 2. In 1992/93 the varieties outperformed their parental bulks from 4.6 to 31.8%. In 1993/94 such performance ranged only from 8.4 to 21.4%. In fact, the variety ZPMV 90521, which was derived by mass selection from the CO cycle of late composite, has performed well in several trials conducted over seasons and locations as well as in farmers' demonstration plots. The large and long panicles of this variety are an additional attraction for farmers. However, Singh et al. (1988) reported evidence to the effect that varieties may not markedly outperform the composite bulks from which they were derived.

Another variety, Lubasi, released in Zambia in 1993, was developed from the medium-maturing composite by mass selection. In 140 replicated tests conducted over 6 years, Lubasi has given 49.8% more grain yield than the local landrace variety (LLV) (Table 3). Because of its excellent performance in farmers' fields in the drought-prone areas of Western province, it is popularly known as Malubasi (mother of family).

Table 2. Comparative mean grain yield performance (kg ha^{-1}) of varieties with their parental composite bulks, Zambia, 1992/93 and 1993/94.

Bulk/variety	1992/93 (5 locations)	1993/94 (3 locations)	Variety as % of cycle bulk 1992/93	Variety as % of cycle bulk 1993/94
PMLC CO	1856	2728	100	100
ZPMV 90521	2447	2957	131.8	108.4
PMMC CO	1948	2762	100	100
ZPMV 88402	2373		121.8	
PMMC C1	1793	2283	100	100
ZPMV 90411	1875	2773	104.5	121.4
LSD (kg ha^{-1})	574-905	457-865		
CV (%) range	21.1-28.7	15.3-21.4		

Table 3. Comparative performance of Lubasi with Kaufela and the local landrace variety (LLV), Zambia, 1987/88 to 1992/93.

Year	Trials	Locations	Grain yield (kg ha^{1}) Lubasi	Grain yield (kg ha^{1}) Kaufeia	Grain yield (kg ha^{1}) LLV
1987/88	1	1	3050	2590	1590
1988/89	3	13	3559	3238	2571
1989/90	6	33	2363	2069	1554
1990/91	8	39	3205	2932	2243
1991/92	5	17	2619	2308	1861
1992/93	7	37	2069	1895	1440
Total	30	140	-	-	-
Mean	-	-	2811	2505	1877
% of Kaufela			112.2	100	74.9
% of LLV			149.8	133.5	100

Conclusion

Preliminary results have shown that it is possible to improve the yielding ability of pearl millet composites using a combination of the relatively cheap mass selection and half-sib recurrent selection procedures. Additionally, superior varieties can be derived from the composites.

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The Potential of Local Landrace Varieties in Pearl Millet Improvement

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Abstract

SADC/ICRISAT SMIP jointly evaluated with NARS the pearl millet germplasm from Tanzania and Zimbabwe in 1988/89, and from Namibia in 1991/92. The objectives were to identify some superior accessions that could be rapidly improved through grid mass selection or limited backcrossing and then release these back to the farming community for cultivation; and to select accessions that could be incorporated into the breeding program by crossing to create a diversified segregating population from which new improved varieties could be developed.

Much heterosis vigor was observed in crosses between local landrace variety (LLV) accessions with improved released varieties. Yield superiority of 6.8-46.6% over the released variety in Zimbabwe (PMV 2) was observed among intervarietal hybrids with LLVs from Zimbabwe. Heterosis values as high as 98.9% over superior parents and a yield superiority of up to 89.8% over the released variety in Tanzania (Serere 17) were observed within crosses involving Tanzanian LLVs. In backcross studies to improve Okashana 1, progenies similar to Okashana in grain size and time to maturity, but with up to 24% superiority in yield and other trait advantages, were identified in the third backcross generation.

This study suggests that considerable potential exists for improving yield and other traits preferred by farmers through greater utilization of LLVs in breeding programs.

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Introduction

Pearl millet is the third most important cereal after maize and sorghum in terms of area under production in the SADC region. Tanzania, Zimbabwe, and Namibia are the largest producers and consumers of this crop, where it occupies roughly 12.1, 9.1, and 42.3% respectively of the total area under cereal production (FAO 1989).

The crop is grown on marginal lands with poor soils, which are often too infertile for other crops to survive. Annual rainfall in these localities is low (<600 mm) and very erratically distributed. To compound these problems, the farmers in these areas still grow their LLVs, which are locally adapted but have poor yield potential.

In collaboration with SADC/ICRISAT, NARS have released improved pearl millet varieties in Zambia, Zimbabwe, and Namibia. More varieties are at the on-farm verification stage and may soon be released in Malawi and Tanzania. The greatest advantage these new released varieties have over LLVs is early maturity, which assures family food security, especially in years of severe drought.

The yield potential of these varieties, though only slightly better than LLVs, can be significantly improved. LLVs from Tanzania, Zimbabwe, and Namibia in this study were used to diversify the genetic base of the breeding materials from which new varieties are to be developed. The main objective of the study was to exploit the heterotic vigor inherent in local germplasm, much of which has remained under-utilized. Essentially, the equatorial photosensitive germplasm from Tanzania has remained isolated from the rest of the SADC region because of its daylength specificity (i.e., it requires short days to flower).

Materials and Methods

Germplasm collection missions were carried out by SADC/ICRISAT and the concerned NARS for Malawi (Appa Rao et al. 1986), Tanzania (Prasada Rao and Mengesha 1980), Zimbabwe (Appa Rao and Mengesha 1982; IBPGR 1987), and Namibia (Appa Rao et al. 1992). A total of 361 accessions were collected from Tanzania, 277 from Malawi, 961 from Zimbabwe, and 1000 from Namibia. Each of the germplasm collections was evaluated in its country of origin and at SADC/ICRISAT locations in Zimbabwe (except for the Tanzanian germplasm which was evaluated in Tanzania because of its particular daylength requirement).

Sowing and evaluation of the Tanzania germplasm

The 361 entries were arranged in a simple lattice design (19 x 19), replicated twice. The trial was sown at two locations in Tanzania: Ukiriguru Research Station (2°S 33°E) on 1 Feb 1989 (delayed from Dec 1988), and at Ilonga Research Station (7°S, 37°E) on 27 Feb 1989 (normal month). At both locations, seeds were sown 75 cm between rows and plants were thinned to 40 cm apart within the row, retaining only one plant per hill. Plot size was one row 5 m long. Thinning was done during the third week after emergence. The crop at Ukiriguru was harvested from the entire row on 20 Jun 1989. The Ilonga trial was harvested on 14 Jul 1989.

The germplasm was evaluated for maturity, yield, and agronomic desirability. Selection of materials for promotion into the breeding program was based mainly on a visual score because bird damage and ergot attack were very severe on some entries.

Sowing and evaluation of the Zimbabwe germplasm

The 961 entries were similarly arranged in a 31 x 31 simple lattice design replicated twice. Plot size was one row 4 m long. Sowing was done in a similar manner at two locations in Zimbabwe: Aisleby near Bulawayo (20°S, 26.5°E) and Makoholi near Masvingo (20°S, 31°E). The trials were sown on 29 Nov 1988 and 2 Dec 1988 respectively. Harvesting at Aisleby was done on 17 Apr 1989 and at Makoholi on 24 Apr 1989. The data were analyzed as a randomized complete block design because the MSTAT ANOVA lattice cannot handle a 31 x 31 lattice. As in Tanzania above, reliance was placed on visual scores in selecting breeding materials.

Collection and evaluation of the Namibian germplasm

During collection efforts were made to identify genotypes that could be used directly in breeding work to produce varieties in three or four seasons only. Forty-nine such accessions were identified. This special collection of 49 out of the total of 1000 was sown in our off-season nursery in Muzarabani during the winter of 1991, along with the others for multiplication, in order to obtain sufficient seed for evaluation of the entire germplasm. About 3000 individual plants were selected from the special collection, and crosses were made with 12 outstanding varieties from SADC/ICRISAT, resulting in 1208 individual crosses. The objective of the crosses was to create segregating populations that combined good characters from both sources. Adequate seed quantities of the entire germplasm were produced by hand-sibbing for evaluation at three locations: two in Namibia and one in Zimbabwe. The germplasm was split into three sets of 256 entries each, and all these sets were sown at each of the two locations in Namibia (Omahenene and Mashare) and one location in Zimbabwe (Muzarabani). Omahenene is located at 17°S 14°E, Mashare at 17.5°S 19°E, and Muzarabani at 16.5°S 31.5°E.

Sowing was done at the end of Dec 1990 at all three locations. There was adequate rainfall for germination and crop establishment was good at all locations. The rainy season ended in late January and the Muzarabani evaluation failed totally. Data collection and further selection were therefore possible only from the Namibia trials, which did not suffer as much drought as Zimbabwe.

Selection of LLVs for use in breeding

Several accessions from each LLV evaluated were selected according to plant type, time to maturity, and grain type and quality. Preference was given to plants that had strong stalks, resistance to lodging, and good tillering and yield abilities. Varieties with bold or large grains are known to be preferred and were therefore targeted for selection. White- and cream-colored accessions were similarly selected for their known good grain quality, including a hard corneous endosperm. Seventeen entries were selected from the Tanzanian germplasm, 18 from Zimbabwe, and 49 from Namibia. Each of these has been crossed with selected SADC/ICRISAT varieties, with two objectives:

1. To improve the designated LLV for particular traits using the improved variety as donor parent.
2. To create a range of diversified segregating populations from which new improved varieties can be developed.

Results and Discussion

Performance of intervarietal hybrids

In improving the LLV accessions from Zimbabwe and Tanzania we also examined their potential for creating intervarietal hybrids. Pearl millet has a great potential for intervarietal hybridization because of its protogynous nature. By carefully selecting the 'male' and 'female' parents that differ in time to flowering—such that there is always plenty of pollen when the female is at stigma stage—hybrids can be produced.

From the Zimbabwe germplasm some intervarietal hybrids were obtained which had yield superiority ranging from 6.8 to 46.6% over the improved released control variety PMV 2 (Table 1). The 1989/90 season was a normal season, and performance of varieties was indicative of their normal potential. PMV 2 gave a yield of 2.94 t ha^{-1}, whereas the highest-yielding intervarietal hybrid (a cross between IBMV 8502 and SDMV 87006) produced 4.31 t ha^{-1} grain. This clearly demonstrated the advantages and potential of intervarietal hybrids.

The highest-yielding intervarietal hybrid constituted from a cross between an improved variety (SDMV 89003) and a LLV (SDPM 626) produced 3.93 t ha^{-1} grain. This yield was 33.7% higher than the released variety PMV 2. There is some heterotic vigor inherent in crosses of such diverse backgrounds as LLVs and improved varieties introduced from outside the region. As can be seen in the last-mentioned cross, the heterosis value over the superior parent (SDPM 626) was 57.2%. Heterosis values ranging from 18 to 72% were observed between LLVs and improved varieties, and grain yield superiority over that of the PMV 2 control ranged from 6.8 to 33.7%. The highest heterosis value over the best parent recorded was 87.4%, with a yield superiority over PMV 2 of 46.6% (Table 1).

An almost similar situation was observed with regard to crosses between improved varieties and 17 of the best LLVs out of the germplasm from Tanzania. Heterosis values as high as 98.9% were recorded and yield superiority of 89.8% over the improved released variety Serere 17 was realized (Table 2). As stated above, one of the objectives in making these crosses was to improve the good LLV, as already identified, with a few desirable traits. The improved varieties used were therefore

Table 1. Performance data for pearl millet intervarietal hybrids utilizing local landrace varieties and improved varieties at Lucydale, Zimbabwe, 1989/90.

Entry	Time to 50% flowering (d)	Plant height (cm)	Panicle count (6 m^{-2})	Panicle length (cm)	Threshing percentage	Heterosis over best (%)	Grain yield (t ha^{-1})	Superiority over control (%)
Intervarietal hybrids								
IBMV 8502 × SDMV 87006	60	278	40	34	70	87.4	4.31	46.6
IBMV 8502 × ICMV 87901	53	245	44	30	76	60.4	4.25	44.5
IBMV 8501 × SDMV 89003	55	268	44	32	71	78.8	4.06	38.1
SDPM 626 × SDMV 89003	55	290	47	33	68	57.2	3.93	33.7
SDGP 1514 × WGC	56	284	75	37	70	47.4	3.73	26.9
SDPM 625 × WGC	58	279	44	36	66	58.8	3.70	25.8
SDPM 630 × SDMV 89003	56	263	54	30	60	72.5	3.57	21.4
SDMV 89005 × SDMV 87006	55	266	43	39	66	28.2	3.50	19.0
SDMV 89005 × SDMV 87018	53	242	52	29	70	26.0	3.44	17.0
SDGP 1514 × ICMV 87901	56	282	42	37	65	23.0	3.26	10.9
SDGP 1489 × ICMV 87901	54	230	41	33	72	18.5	3.14	6.8
Improved variety parents								
PMV 2 (control)	56	241	48	30	66	-	2.94	-
SDMV 89005	57	243	44	27	74	-	2.73	-
ICMV 87901	51	216	43	24	73	-	2.65	-
SDMV 87006	65	291	37	36	65	-	2.30	-
SDMV 89003	60	160	40	36	66	-	2.28	-
IBMV 8501	56	257	34	32	65	-	2.27	-
WGC	53	243	41	26	72	-	2.24	-
IBMV 8502	61	222	28	32	68	-	1.94	-
SDMV 87018	55	241	36	27	63	-	1.87	-
Local landrace variety parents								
SDGP 1514	69	240	28	29	64	-	2.53	-
SDPM 626	55	237	36	30	69	-	2.50	-
SDPM 625	58	279	35	36	66	-	2.33	-
SDPM 630	56	247	36	28	71	-	2.07	-
SDGP 1489	59	253	26	34	64	-	1.48	-
Mean (90)	55.74	259.80	41.20	33.16	67.84		3.00	
SE	±1.40	±12.84	±6.42	±2.92	±4.19		±0.42	
CV (%)	4.39	8.56	27.03	15.45	10.71		24.40	

mainly selected on the basis of desired traits for this transfer. It is expected that not more than three backcrosses will be required to transfer these selected traits to the LLV (SADC/ICRISAT 1993; 1994).

In this manner we obtain most of the genes of the elite variety while retaining some of the qualities of local adaptation. However, if more of the traits of the LLV are required, then, after the required trait from the donor parent has been obtained, the LLV should be used as the pollen donor in the subsequent backcrossing, each time with selection for the required trait until it is fixed. The traits most sought for inclusion into LLVs are early maturity, tillering ability, grain size, and, sometimes, yield potential.

As can be seen from Table 2, the LLVs were very late, all requiring at least 70 days to reach 50% flowering, and some requiring as many as 102 days. This means that the LLVs require a growing season of between 110 and 130 days to reach maturity. As a result, when the rainy season ends early there is normally a massive crop failure. There is thus a need to reduce the time they take to mature.

Performance of LLV backcross progenies

By 1992/93 the first backcrosses made had already reached the third backcross generation and were evaluated across locations in Zimbabwe and compared with their parents and released variety controls Okashana 1, Kaufela, and PMV 2.

The obvious superiority of these backcross progenies over the improved variety parents was now obvious (Table 3). Yield improvements in comparison with the LLV in these locations ranged from 37.8 to 71.3%. Similarly, improvements over the released variety PMV 2 ranged from 4.4 to 24.3%. At the same time yields of particular improved varieties and the LLVs used in the study were very significantly improved.

From the example of the cross SDPM 626 (LLV) x SDMV 87006 (improved variety), which gave a yield of 5.07 t ha^{-1} averaged over locations, it is seen that this yield is 37.8% superior to that of SDPM 626 (3.68 t ha^{-1}), and 57.4% superior to that of SDMV 87006 (3.22 t ha^{-1}). Another example of a desired improvement is shown in the backcross involving SDGP 1514 and ICMV 88908 (Okashana 1). The resulting BC_3F_1 progenies look closely similar to Okashana 1, as intended. This backcross progeny retained the earliness of Okashana 1, flowering in 58 days vs 56 days for Okashana 1, and it has the same large bold grain in a slightly taller plant (169 vs 159 cm), better tillering ability (assessed by counting the number of harvestable panicles per 6 m^2), and a yield improvement over Okashana of 24%.

In the evaluation of F_4 progenies resulting from advancing some of the segregating backcross progenies at Lucydale during 1993/94, many of the progenies had yield superiority that more than doubled that of the farmers' LLV (Table 4).

Out of the top 20 entries from a nursery of 144, there was only one variety, SDMV 90016 (which ranked 14th and yielded 1.30 t ha^{-1} vs 1.99 t ha^{-1} from the progeny of the top-ranking backcross) that had a 24% grain yield superiority over control entry PMV 2. The only nonbackcross-derived entries in the top 20 were hybrids (Table 4). Yield superiority of the top 20 entries in this trial over PMV 2 ranged from 7.6 to 89.5%.

Table 2. Performance data for pearl millet intervarietal hybrids at Ukiriguru, Tanzania, 1989/90.

Entry	Time to 50% flowering (d)	Plant height (cm)	Panicle count (6 m^{-2})	Panicle length (cm)	Threshing percentage	Heterosis over best (%)	Grain yield (t ha^{-1})	Superiority over control (%)
Intervarietal hybrids								
SDGP 23 × SDMV 89003	70	190	27	16	52	28.1	2.05	89.8
SDGP 156 × SDMV 89005	73	199	26	15	50	17.8	1.92	77.8
SDGP 61 × SDMV 89003	70	178	20	20	56	76.6	1.89	75.0
SDGP 135 × ICMPES 28	77	182	25	21	51	48.4	1.87	73.1
SDGP 704 × SDMV 89005	81	185	25	25	52	13.9	1.80	66.7
SDGP 192 × SE 360	84	187	29	30	51	39.4	1.77	63.9
SDGP 13 × SDMV 89005	77	192	24	10	56	98.9	1.67	54.6
SDGP 199 × SE 360	77	194	31	31	44	13.3	1.53	41.7
SDGP 639 × ICMPES 28	71	185	23	20	54	34.6	1.44	33.3
SDGP 626 × SDMV 89005	74	192	24	24	50	49.1	1.61	49.1
SDGP 103 × SDMV 89003	82	188	32	10	56	15.9	1.60	48.1
Local landrace variety parents								
SDGP 156	76	201	32	30	54	-	1.63	50.9
SDGP 23	83	199	28	30	50	-	1.60	48.1
SDGP 704	83	187	25	25	58	-	1.58	46.3
SDGP 103	77	189	35	30	51	-	1.38	27.8
SDGP 199	71	217	24	25	53	-	1.35	25.0
SDGP 192	102	196	30	35	45	-	1.27	17.6
SDGP 135	102	221	23	25	38	-	1.26	16.7
Serere 17 (control)	63	141	18	28	45	-	1.08	-
SDGP 626	97	197	25	39	47	-	1.08	0.0
SDGP 639	83	198	27	35	43	-	1.07	−0.9
SDGP 61	71	183	23	30	47	-	1.07	−0.9
SDGP 13	79	202	26	35	36	-	0.84	−22.2
Mean (90)	78.29	191.32	26.02	22.53	47.08		1.32	
SE	±6.09	±11.95	±3.10	±4.72	±4.89		±0.25	
CV (%)	10.99	8.83	11.66	29.65	14.67		26.42	

Table 3. Performance data of pearl millet local landrace varieties (LLVs) improved by limited backcrossing vs their parents across two locations in Zimbabwe, 1992/93.

Entry	Time to 50% flowering (d)	Plant height (cm)	Panicle count (6 m^{-2})	Grain yield (t ha^{-1})			Improvement (%)	
				Makoholi	Lucydale	Mean	LLV	PMV 2
Improved LLVs (BC_3F_1 selections)								
(SDPM 626 × SDMV 87006)-13	71	218	103	7.39	2.74	5.07	71.3	24.3
(SDGP 1704 × SDMV 89003)-6	67	208	130	7.15	2.82	4.98	68.2	22.1
(SDGP 1514 × SDMV 87006)-14	71	244	146	6.63	2.43	4.53	53.0	11.0
(SDGP 1514 × SDMV 89003)-5	68	193	116	6.39	2.63	4.51	52.4	10.5
(SDPM 626 × SDMV 89003)-1	74	220	108	5.84	3.07	4.45	50.3	9.1
(SDPM 625 × WGC)-3	66	202	109	5.83	3.04	4.44	50.0	8.8
(SDGP 1514 × ICMV 88908)-7	58	169	120	5.11	3.62	4.37	47.6	7.1
(SDPM 626 × WGC)-9	60	175	118	5.49	3.03	4.26	43.9	4.4
(SDPM 626 × ICMV 88908)-8	58	165	111	4.40	3.21	3.81	28.7	-
(SDGP 1489 × SDMV 89003)-10	66	207	112	5.23	2.34	3.78	27.7	-
(SDPM 630 × SDMV 89003)-4	65	179	138	4.68	2.58	3.63	22.6	-
(SDPM 625 × SDMV 89003)-15	71	201	89	4.35	2.85	3.60	21.6	-
LLV parents								
SDGP 1514	80	218	93	5.44	2.36	3.90	-	-
SDPM 626	66	210	120	4.82	2.55	3.68	-	-
SDGP 1704	70	193	80	4.23	2.88	3.56	-	-
SDPM 625	76	215	86	4.50	2.26	3.38	-	-
SDGP 1489	68	200	97	4.44	2.25	3.34	-	-
SDPM 630	65	197	134	3.87	2.73	3.30	-	-
Farmers' LLV (control)	69	175	94	4.10	1.82	2.96	-	-
Improved nonrecurrent parents								
PMV 2 (control)	59	182	96	4.92	3.24	4.08	37.8	-
ICMV 88908 (Okashana 1)	56	159	92	4.39	2.65	3.52	-	-
SDMV 89003	64	148	94	4.42	2.20	3.31	-	-
SDMV 87006	78	234	71	4.23	2.20	3.22	-	-
Mean (36)	66.30	193.89	108.91	5.13	2.75	3.94		
SE				±0.586	±0.296			
CV (%)				19.78	18.65			

Table 4. Performance data of the top 20 backcross F_4 progenies derived from local landrace variety (LLV) germplasm, hybrids, and improved varieties at Lucydale, Zimbabwe, 1993/94.

Entry	Time to 50% flowering (d)	Plant height (cm)	Panicle count ($6m^{-2}$)	Threshing percentage	Grain yield ($t\ ha^{-1}$)	Improvement (%)	
						LLV	PMV 2
Backcross derivatives							
(IBMV 8502 × ICMV 87901)-BC_4F_1-1	52	156	83	63	1.99	298	89.5
(SDMV 89005 × SDGP 1207)-1-2-BC_1F_4-22	63	196	63	59	1.70	240	61.9
(SDGP 1514 × SDMV 89003)-1-2-BC_2F_4-46	63	150	66	71	1.55	210	47.6
(SDGP 1311 × ICMV 87901)-5-4-BC_1F_4-34	58	150	73	53	1.47	194	40.0
(ICMV 88908 × SDGP 1560)-1-2-BC_1F_4-9	64	184	66	52	1.47	194	40.0
(SDMV 89004 × SDGP 1298)-8-4-BC_1F_4-25	65	160	59	57	1.33	166	26.7
(SDPM 2264 × SDGP 1751)-2-1-BC_1F_4-7	68	153	78	57	1.31	162	24.8
(SDGP 1514 × WGC-C1)-1-1-BC_2F_4-35	64	170	67	55	1.31	162	24.8
(SDMV 89005 × SDGP 1289)-4-1-BC_1F_4-13	74	143	46	55	1.30	160	23.8
(SDGP 1514 × SDMV 87006)-2-2-BC_2F_4-2	71	152	59	49	1.24	148	18.1
(SDGP 1514 × SDMV 87018)-2-1-BC_2F_4-28	66	180	67	48	1.19	138	13.3
(IBMV 8502 × WGC-C1)-1-1-BC_2F_4-61	64	192	62	51	1.16	132	10.5
(SDMV 89003 × SDGP 1688)-1-3-BC_1F_4-5	65	146	73	51	1.15	130	9.5
(SDGP 1311 × ICMV 87901)-5-1-BC_2F_4-32	59	147	75	47	1.14	128	8.6
(SDGP 1311 × SDMV 87006)-1-1-BC_2F_4-40	64	154	46	69	1.13	126	7.6
Hybrids, improved varieties and LLV control							
SDMH 92018 (hybrid)	56	153	80	65	1.86	272	77.1
SDMH 92020 (hybrid)	49	167	73	67	1.79	258	70.5
SDMH 92012 (hybrid)	59	154	63	58	1.50	200	42.9
ICMH 88088 (hybrid)	60	144	81	57	1.44	188	37.1
SDMV 90016 (improved variety)	60	158	67	56	1.30	160	23.8
Okashana 1 (released variety)	57	158	59	56	1.13	-	-
PMV 2 (released variety)	57	170	60	41	1.05	-	-
Kaufela (released variety)	62	165	69	44	1.04	-	-
LLV (control)	76	181	35	42	0.50	-	-
Mean (144)	66.9	161.2	57.7	47.7	0.91		
SE	±1.55	±7.61	±9.19	±6.23	±0.19		
CV (%)	4.02	8.18	27.57	22.61	36.37		

Conclusion

This study suggests that considerable potential exists for improving yields through using LLVs available in the region. Some of the gains reported probably arise from the fact that most improved and available varieties are derived from crosses between introduced materials. There is noticeable unrelatedness between these improved varieties and the LLVs which is manifested in the heterosis observed. This is to be expected, because much of the germplasm within the SADC region was collected less than 10 years ago and has therefore not been fully utilized in regional breeding programs. These materials thus represent a valuable source of variability for the future improvement of varieties for use by farmers in the region.

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First Results of Research on the Armored Bush Cricket (*Acanthopolus discoidalis*) on Pearl Millet in Namibia: Population Dynamics, Biology, and Control[1]

B Wohlleber[2]

Abstract

Annual attacks by the bush cricket (Acanthopolus discoidalis/. Iris 1992) cause severe losses in pearl millet production in Owamboland, Namibia, of approximately 10 000 t yr^{-1}, e.g., 30% of the total harvest in 1993. Research in this study is geared to the development of an integrated pest management (IPM) system based on the biology and ecology of the cricket relevant to the socioeconomic environment of communal farmers in Namibia. Understanding of the biology and population dynamics of the cricket should provide adequate knowledge for the development of integrated pest management components with special emphasis on (a) the development of a population forecasting method; (b) the development of yield loss evaluation methods in farmers' fields, involving the quantification of damage caused by the insect at different stages in its growth cycle; and (c) the development of cultural, biological, and chemical control methods.

The data reported comprise selected results from second-season trials and are therefore subject to later reassessment.

Introduction

Studies on the biology and control of the armored bush cricket associated with pearl millet production were started in Nov 1992. The research project was initiated by K Leuschner (SADC/ICRISAT) and the Department of Research in the Ministry of

1. This paper presents preliminary data, subject to further PhD studies, in a cooperative research project organized by the Department of Research, Ministry of Agriculture, Water and Rural Development, Namibia, the Institute of Applied Zoology, Justus-Liebig University, Giessen, Germany, and SADC/ICRISAT, Bulawayo, Zimbabwe. The data are not for citation and all rights are reserved by the author.

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Wohlleber, B. 1996. First results of research on the armored bush cricket *(Acanthopolus discoidalis)* on pearl millet in Namibia: population dynamics, biology, and control. Pages 163-172 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Agriculture, Water, and Rural Development. The project was located at the Omahenene Research Station in northern Owamboland. The station is in the center of a large area infested by the pest.

An objective of the project is to determine the most important factors influencing the population dynamics of the cricket. Studies on the reproductive cycle, as well as an analysis of interactions between the plant, the pest, and their environment will therefore be necessary, after which it is intended to develop an appropriate control strategy. In order to ensure that research findings are relevant to specific situations within the production system in communal areas of Owamboland, field trials are carried out on-farm in close interaction with the farmers. An IPM approach to pest control measures is favored over those based on the sole use of chemicals.

Methods

The life cycle of the cricket was studied with singly-caged nymphal stages in a screenhouse and in pearl millet head cages in farmers' fields. Feeding and food preference studies were carried out in screenhouse cages.

Yield loss analysis in the field

To determine yield losses a modification of the loss-assessment method proposed by Pantenius and Krall (1993) was chosen as relevant to the problems and agricultural conditions of the area.

The modifications were the following:

a) Measurements were carried out on marked plants in the trial plots (16 plants $plot^{-1}$).
b) Panicles were classified according to their degree of compactness into three classes: (1) compact; (2) less compact; (3) loose. For every class a multiplication factor ($g\ cm^{-2}$) was determined by means of a linear regression model:
   Class 1: 0.15 $g\ cm^{-2}$ (r^2=0.76**;n=276)
   Class 2: 0.10 $g\ cm^{-2}$ (r^2=0.81*;n=130)
   Class 3: 0.07 $g\ cm^{-2}$ (r^2=0.68*;n=130)

Subsequently the weight of each panicle was calculated by measuring the surface of the head and by multiplying it with the respective class factor. Damage suffered by the plant at different stages was estimated following Pantenius and Krall's (1993) loss assessment method.

In order to ensure precision in the calculation of severe degrees of damage, the damage level was determined by estimating feeding damage on both sides of the panicle. The average damage was then multiplied by the number of damaged plants in the plot or field. The combination of these methods thus provided an accurate assessment of yield and loss for pearl millet expressed in kg ha^{-1}.

Loss evaluation of different cricket stages

Crickets of different stages (4-7) were weighed and put into panicle cages (35 x 15 cm: one cage-[1]) placed on pearl millet heads at the plant's development stages 5-9 in a farmer's field, based on development stages proposed by Mati and Bidinger (1981). These range from 0 to 9: 5 = boot stage, 6 = 50% flowering, and 7-9 = cover grain development.

After 10 days the content of the cages, including the pearl millet head, was measured and weighed in the laboratory. The feeding damage was estimated and the weight of the crickets and the faeces was determined.

For each cricket and pearl millet development stage three replicates were carried out. The trial was repeated three times. A total of 60 cages were used for every trial.

For each cricket development stage the amount of grain consumed at different grain development stages was calculated in g day^{-1} $plant^{-1}$ (Pantenius and Krall 1993). For total yield loss per hectare, data from 10 000 planting hills were recorded, because 10 000 plants ha^{-1} represents an average pearl millet plant density on farmers' fields in Owamboland.

Integrated pest management

Choice of sowing date and millet variety. To establish the effect of sowing date and varieties' time (days) to maturity on cricket damage, the following varieties and sowing dates were tested in farmers' fields (LLV = local landrace variety):

1: LLV: 120 days	sowing date 20 Nov 1993
2: LLV: 120 days	sowing date 31 Jan 1994
3: Okashana 90 days	sowing date 31 Jan 1994.

Each plot (20 x 20 m) was hand-sown by the farmer.

The randomized block layout consisted of three replicates for each treatment. LLVs consist of a genetic mix of awned and nonawned plants, and it is claimed that awned plants are less frequently attacked by the cricket. To verify this, therefore, at the dough stage 48 awned plants were selected out of varieties 1 and 2 and were assigned to three groups (three replicates).

During the growing period farmers were asked to fill in forms at 3-day intervals concerning: plant stage, cricket stage, number of crickets, and 20% damage per plant (Jago 1993). Observations by farmers were controlled and verified at 7-day intervals.

The date of harvest was determined by the farmers (19 May 1994). Yields were estimated and damage was calculated. Collection of crickets within the trial plots was avoided.

Change of harvesting procedure. Crickets, especially during migration and aggregation, are attracted to field edges of taller crops and landmarks within a harvested field. This behavior is especially expressed during mating and oviposition. It was assumed that cricket adults would aggregate at specifically created landmarks (stooks of harvested plants) and could be controlled either by hand collection or chemicals. Any egg pods laid at this spot could be easily destroyed by digging them up, thus enabling the farmer to reduce the next year's population.

To exploit this method of cricket control, before oviposition 18 plots, each covering an area of 400 m^2, were harvested early (shortly after physiological maturity) by removing the whole plants which were then stacked to lean against both sides of trestles. These consist of a wooden beam supported on two poles. In this way tent-like landmarks were created in the bare field. These triangular stooks also provided the shade underneath required for egg-laying. The number of crickets concentrated on a single stook could be recorded weekly. Three similar-sized plots, which were not harvested, served as controls.

After the natural decline of the population at the beginning of May, the density of egg pods was determined under each stook (15 m^2) and in the remaining area (385 m^2), and compared with the egg pod density in the unharvested plots (number of egg pods m^{-2}). In this area, also, a plot of 15 m^2 was selected to simulate the area under a stook.

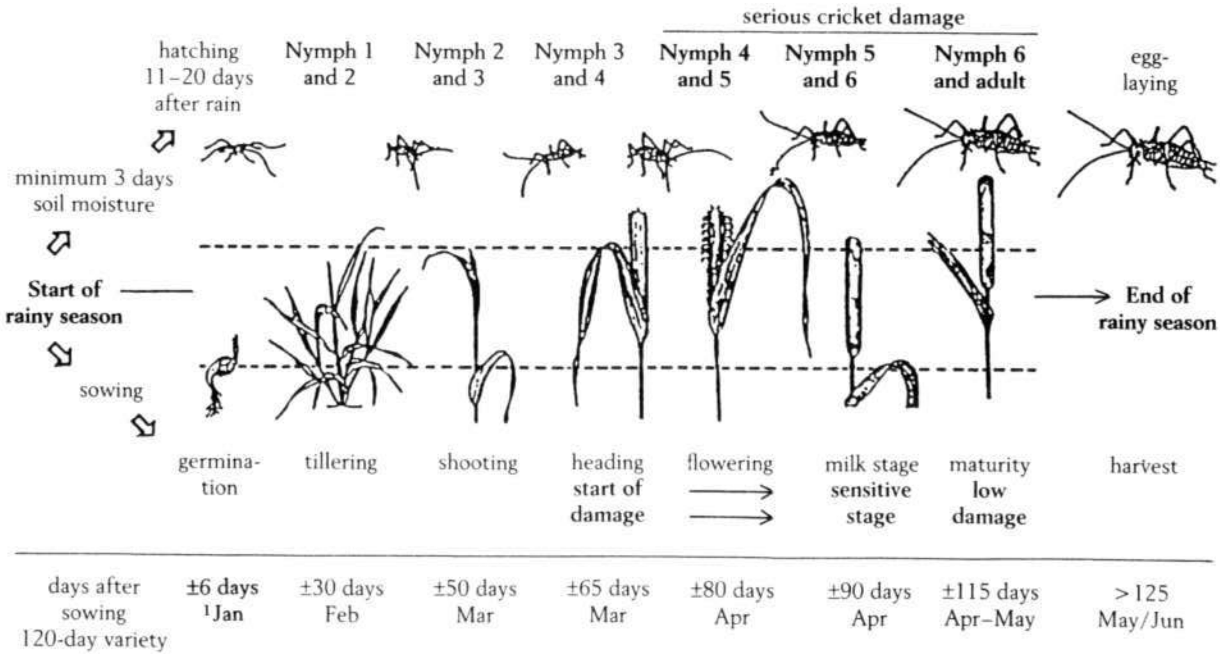
Results and Discussion

Cricket life cycle and pearl millet development

At the beginning of the rainy season in January, first-instar nymphs start to hatch from the egg pods. The rate of hatching is dependent on soil moisture. The topsoil layer (15 cm deep) has to be moist for at least 3 days before hatching starts at 11-20 days afterwards. This finding has to be verified, and could be used as an indicator for forecasting the hatching of cricket nymphs.

Hatching coincides with the germination of pearl millet. After hatching the cricket develops over six nymphal stages before the adult stage after about 70 days. Crickets can develop only on generative plant parts (flowers and grain), although they are able to maintain themselves for some time on leaves without further development. As long as pearl millet is in the vegetative growth stage cricket nymphs depend for food on the generative plant parts of grasses and broadleafed weeds.

The first damage on pearl millet appears only at flowering (Fig. 1). The most serious damage will be caused by the nymph stages 4-6 and by adult crickets. During the milk stage pearl millet is most sensitive to cricket damage. Most serious damage can be expected when the milk stage coincides with the cricket stages 5-7. Later, at grain maturity, pearl millet grain will be too hard for the mouth-parts of the cricket and therefore less attractive during all cricket stages. At the end of the season the cricket lays its egg pods in the shaded soil of perennial trees and shrubs that do not shed leaves and at the base of pearl millet plants in the field. The eggs remain in diapause in the soil until embryonic development starts in October. Fully developed embryos remain in eggs until moisture conditions are right for hatching, as mentioned above.



1 = initial date depends on first intensive rainfalls

Figure 1. Cricket life cycle and development of pearl millet from January to May. The different cricket (1–7) and pearl millet stages (0–9) are listed according to the time of occurrence. Cricket stages that cause the most damage, and plant stages in which most of the damage occurs, are shown in bold.

Yield loss caused by different cricket development stages

Figure 2 shows that, with increasing pearl millet development (grain maturity), feeding with all tested cricket development stages approaches 0. This relation between damage and grain maturity can be seen clearly by comparing the bars of pearl millet and cricket stages. All cricket stages cause most severe loss at the milk stage of the plant. However, the adult stages cause the highest yield loss.

Daily losses of 5 kg potential harvest can be expected if an arbitrary population of 10 000 crickets ha^{-1} is taken into consideration. Comparatively, cricket stage 4 does not contribute much to the yield loss except at the milk stage. Modest yield losses from physiological maturity onwards could be explained by difficulties experienced by crickets in cracking the grain.

The results indicate that major grain damage could be avoided if the milk and soft dough grain development stages of pearl millet do not coincide with the most voracious feeding stages of the cricket.

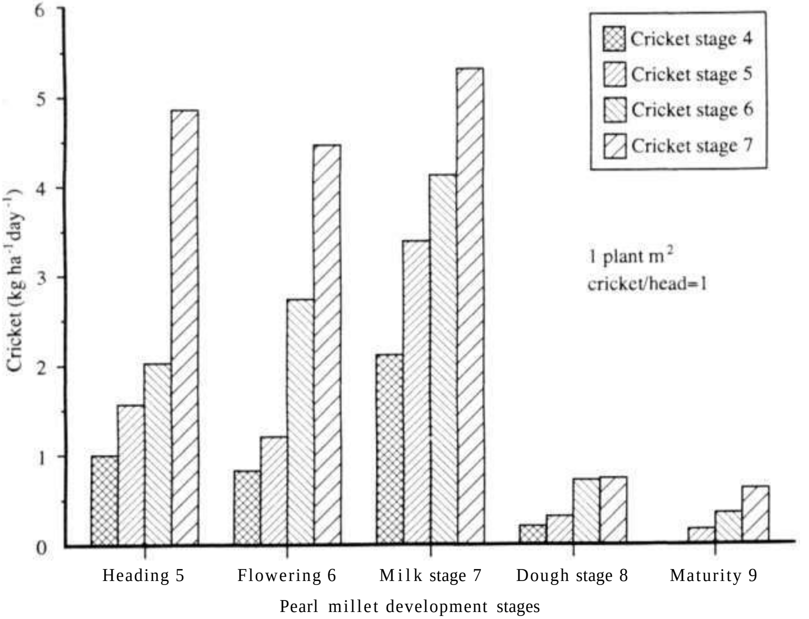


Figure 2. Cricket damage, i.e., food intake by stages 4-7 (kg ha^1) day^1 at pearl millet development stages 5-9 (Mati and Bidinger 1981).

Integrated pest management

Choice of sowing date and millet variety. Yield and damage was estimated and respectively calculated according to the sigmoid curve for quantification of grain loss (Fig. 2). In Figure 3 the damage ratings (classes) can be converted into % yield loss.

Severe grain damage caused by crickets is highly correlated with late sowing date (LLV: 42%) (Fig. 4), while a low level of damage on the same variety is associated with early sowing date (11%). Late-sown Okashana suffered 22% damage, but it partially escaped severe cricket feeding because of its early maturity (90 days).

To understand how yield losses are caused by crickets, the pest's life cycle and the damage potential of its different stages must be considered. If a 120-day variety is sown late, the sensitive pearl millet stages 5, 6, and 7 will coincide with the older cricket stages that cause the most damage. If the same variety is sown at an earlier date, severe damage can be prevented through earlier maturing of the grain. The Okashana 90-day variety takes an intermediate position, because the time required for grain development to maturity is shorter.

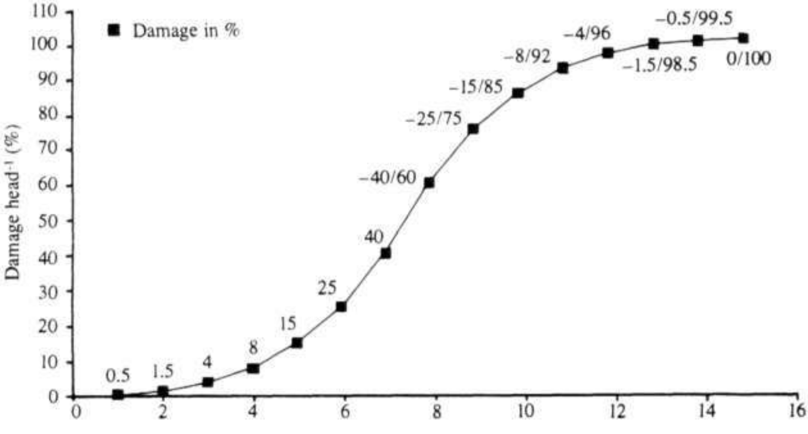


Figure 3. Sigmoid curve for quantification of grain losses caused by crickets. Different damage ratings are shown for each loss quantity as classes from 1 to 15 (x axis). The damage level in % is shown by the y axis. From class 1 to 7 the damaged part of the panicle surface is estimated. From class 8 to 15 the non-damaged part of the panicle surface is estimated (negative damage estimation method).

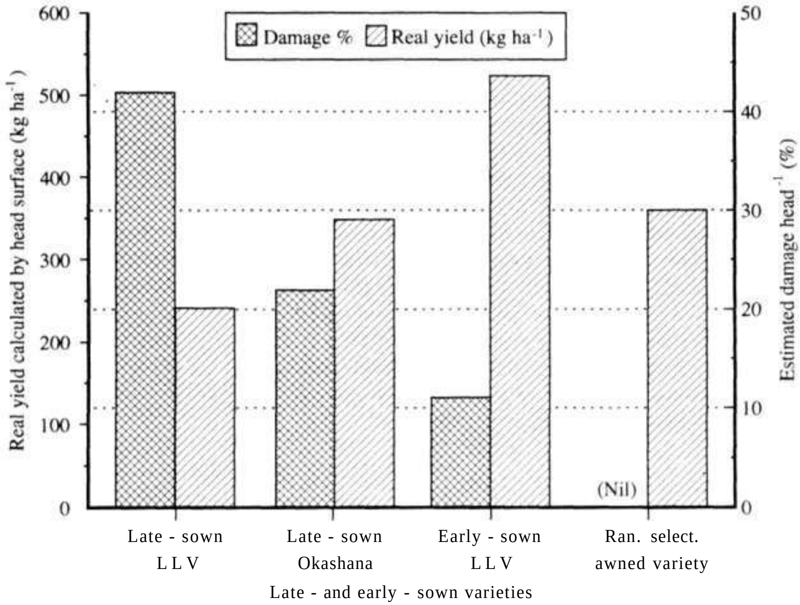


Figure 4. Yield loss caused by crickets for different sowing dates and varieties expressed in % and kg ha^{1}.

The results indicate that, if sowing dates are well managed and varieties are selected for their time to maturity, cricket damage can be avoided or reduced. And initial data suggest there is some effect by awns, in the awned variety, which reduces cricket damage. This needs to be further investigated.

Change in harvest procedure

By harvesting early (Fig. 5) and by erecting stooks before egg-laying starts, the concentration of egg pods under the stooks can be observed. Under stooks (15 m^2) an average of 71 egg pods were found in comparison to 21 egg pods found in the remaining harvested area (385 m^2) surrounding the stooks. On average 0.23 egg pods m^{-2} were recovered within the harvested and stooked areas (400 m^2). In the traditionally late-harvested area (400 m^2: panicles only) an average of 5 egg pods were found in randomly selected 15-m^2 plots (simulating the area under stooks). In the remaining area of 385 m^2 an average of 101 egg pods were found. In the randomly selected area egg pod density was 0.33 nv^2, compared with 0.26 egg pods nr^2 in the remaining area, which shows that egg pods are randomly laid when pearl millet plants

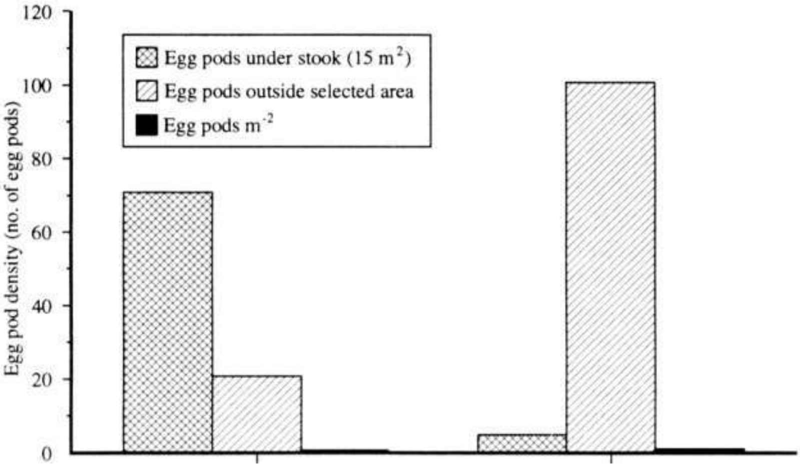


Figure 5. Number of egg pods found under stooks (15 m^2) and the surrounding area (385 m^2) compared with egg pods found in a traditionally harvested area (15 m^2, selected) and the surrounding area (385 m^2).

are in the field. The results show clearly that stooking concentrates egg-laying in the stooked areas in the field.

The reason why farmers leave their pearl millet crop in the field after grain maturity is to let the grain dry to a low moisture content suitable for storage. Such drying is also possible with early harvesting and the stooking of whole plants. So, as the stooks attract adult crickets for mating and oviposition, aggregated adults could be hand-collected from the stooks, and egg pods could be destroyed later in the season by digging them up.

Conclusion

The two methods of control described—early planting in combination with early maturity, and stooking after harvesting—are promising components of a possible integrated pest management system. Other components, such as clean-weeding and control with bait, are under investigation and, after careful testing in farmers' fields, are additional candidates for inclusion in an integrated pest management system for the sustainable control of armored cricket in Namibia.

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Methodology for Screening Sorghum Resistance to Storage Pests

K Leuschner[1]

Abstract

*To assist plant breeders in obtaining suitable material for screening sorghum resistance to storage insect attack, test grain from a susceptible variety (Red Swazi) was used to determine the best combination of minimal trial material with optimal infestation. Three masses of 10, 15, and 20 g were infested with 10, 15, 20, 25, 30, 35, and 40 10-day-old adult weevils (*Sitophilus oryzae*) and with the same quantities of eggs of the grain moth (*Sitotroga cerealella*). Results are discussed according to progeny output in relation to infestation levels and grain mass. Combinations of 30 weevils and 20 g of grain, and 40 grain moth eggs and 15 g of grain are recommended for use in further resistance screening.*

Introduction

Adequate storage of sorghum grain by small-scale farmers is vital for food security in rural areas of the SADC region. Farmers usually store 50% of their harvested grain for various lengths of time depending on the amount harvested (Giga 1986). One of the main constraints to storage is attack by insects which, according to Giga and Katerere (1986), can destroy 6-15% of the stored harvest in one storage season in Zimbabwe. The main storage insects in the region are *Sitophilus zeamais* (Motschulsky), S. *oryzae* (L.) (Curculionidae: Coleoptera), and *Sitotroga cerealella* (Olivier) (Gelechiidae: Lepidoptera). Sorghum is mainly infested by *Sitophilus oryzae* (95%) and *Sitotroga cerealella.*

Insecticides such as malathion and pirimiphos methyl (actellic) are commonly used to control these insects because they are effective. But both can be harmful to humans if not properly used, and they are expensive.

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ICRISAT Conference Paper no. CP. 1060

Leuschner, K. 1996. Methodology for screening sorghum resistance to storage pests. Pages 173-179 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Fortunately, however, farmers are fully aware of the alternative advantages that can be gained through sowing varieties with host-plant resistance. This character is often present in local landrace varieties of sorghum, and breeding for the selection of this character is an inexpensive and durable control method, that is harmful neither to the environment nor to humans.

Because farmers place great emphasis on insect resistance when they evaluate new varieties in their fields, it is necessary that any new variety proposed for release to farmers should be carefully screened for its level of resistance to storage insects.

Sources of resistance are available (SADC/ICRISAT 1993), and breeders are encouraged to use them to improve resistance levels in newly bred varieties. To assist in this process, it became necessary to develop a reliable and efficient resistance- screening method that reduced to a minimum the amount of seed required for breeding trials and ensured an optimum number of infesting insects. The objective of this study was to identify the optimum ratio of insects to the grain offered for testing in further screening.

Materials and Methods

Adult weevils (*Sitophilus oryzae*) and grain moth (*Sitotroga cerealella*) eggs were obtained by laboratory culture. (In earlier tests with S. *cerealella* egglaying was found to be highly variable when adults were used. Consequently, in this study grain moth infestation was done with eggs rather than adult females.)

The insects were reared on the susceptible sorghum variety Red Swazi at 27°C and 70% RH. Three different masses of Red Swazi grain (10, 15, and 20 g) were infested with 10, 15, 20, 25, 30, 35, and 40, 10-day-old adult weevils; and the same masses of grain were infested with the same number of eggs of the grain moth. Eggs were collected according to a method described by Mills (1965). Before infestation the grain was deep-frozen for 48 hours (-24°C) to eliminate any natural infestation. Grain moisture was 13.5%, measured with a Dole Grain Moisture Meter.

Weevils for infestation were not sexed, since separation of sexes can be done only by examining their genitalia, which is a time-consuming process. It was assumed that a 1:1 female to male ratio exists, which is supported by Widstrom et al.(1978). Each insect/grain mass combination was replicated 20 times, and kept in pill boxes measuring 35 mm in diameter and 60 mm in height for weevil tests, and 60 mm diameter and 75 mm height for grain moth tests. The trial was organized as a randomized block design and the material was kept at 27°C and 70% RH in a temperature- and humidity-controlled room. Adult weevils were left for 7 days in the test jars and then removed to ensure oviposition for a given period only.

The progenies—adult weevils and moths—were collected from 28 days after infestation onwards at 1-day intervals for a total of 14 days. Data from both tests were subjected to analysis of variance.

Results and Discussion

Grain weevil

Results showed significant differences in progeny output from the different grain masses (P = 0.01) (Table 1).

Table 1. Number of *Sitophilus oryzae* progenies developing from different adult infestation levels and three grain masses, SADC/ICRISAT, Zimbabwe, 1994.

No. of adults	10 g of grain	15 g of grain	20 g of grain
10	41.1	42.4	56.5
15	50.9	57.8	64.2
20	50.8	68.9	65.3
25	55.2	78.9	78.2
30	69.6	91.6	137.2[1]
35	85.4	127.7	165.2
40	78.6	109.9	187.5
SE	±2.05	±3.35	±5.31
Mean	61.63	82.46	107.69
CV (%)	31.39	35.19	35.39

1. Selected and recommended combination.

Progenies derived from the infestation of 10 g of grain with 10-40 weevils indicate that the gain in progenies with increasing infestation is small up to 25 weevils. Progeny output peaks at 35 weevils, and declines in real terms with 40 (Fig. 1) when progeny differences between 35 and 40 are taken into account.

Comparison of these results with progeny outputs from grain masses of 15 and 20 g (Table 1) shows that a 10-g mass is too low, and limits the number of eggs laid and, consequently, the output of adult progeny.

A similar trend is observed from 15 g of grain infested. A fairly steady linear increase in progenies can be observed from 10 to 30 weevils. But at 35 weevils a significant progeny peak (127.7) appears, followed by a decline in real terms at 40 weevils (Fig. 2). Limited availability of grain for oviposition seems to be the dominating factor when 40 weevils are used for infestation.

When a grain mass of 20 g was infested, there was a low increase in progenies up to 25 weevils and a significant peak (137.2) at 30 weevils (Table 1). Higher infestation levels of 35 and 40 weevils showed a further increase but, in real terms, a decline compared with 30 weevils (Fig. 3).

The results of all three grain masses indicate that a critical number of weevils is required for maximum progeny output. This critical infestation level can only show its full reproduction potential if enough oviposition sites (grains) are available. This is illustrated (Table 1) by the increasing progenies produced by the combinations of

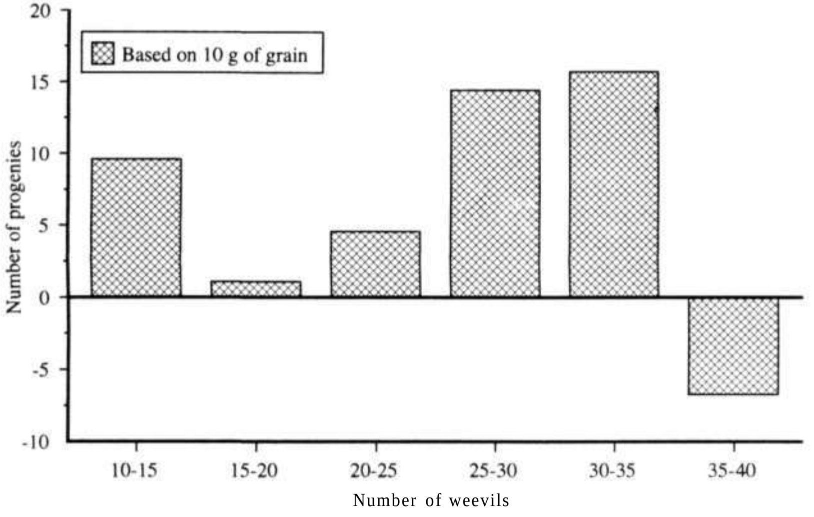

Figure 1. Increase/decrease in weevil progeny output with 10 g of grain between different infestation levels.

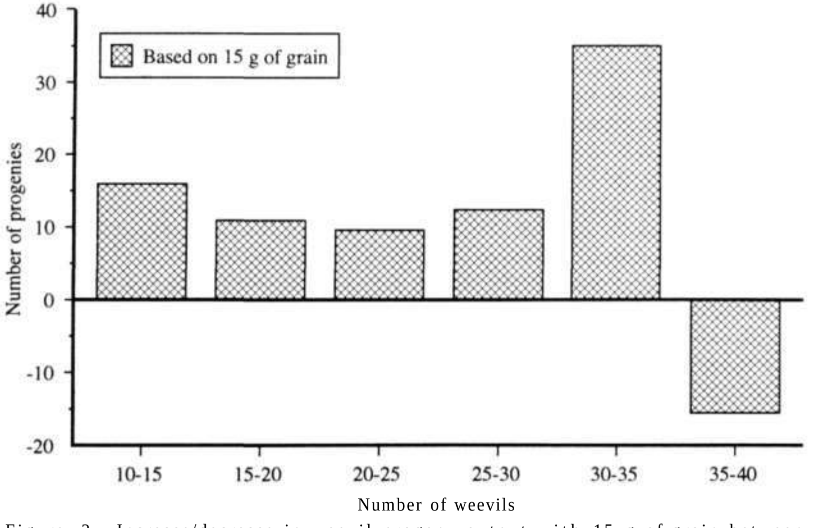

Figure 2. Increase/decrease in weevil progeny output with 15 g of grain between different infestation levels.

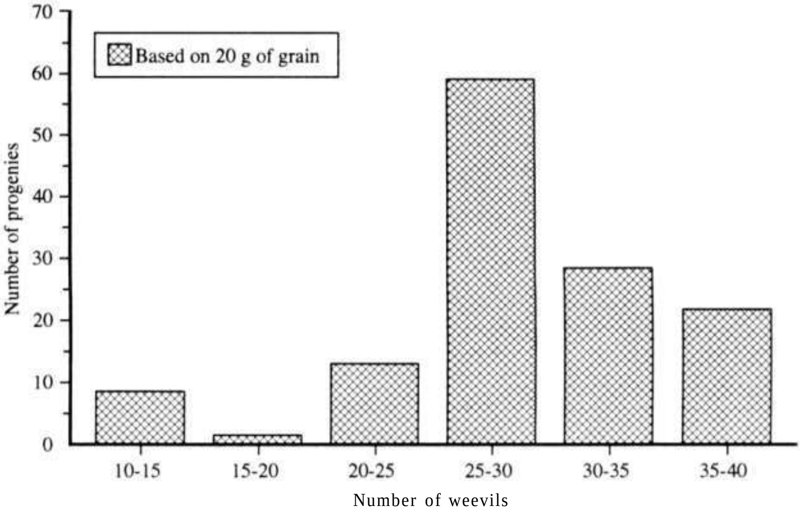

Figure 3. Increase/decrease in weevil progeny output with 20 g of grain between different infestation levels.

35 weevils 10 g^{-1}, 35 weevils 15 g^{-1}, and 30 weevils 20 g^{-1} (Table 1). With each 5-g increase of grain mass, progeny numbers approximately doubled.

Since in the case of 40 weevils and 10 and 15 g of grain progeny numbers decreased in real and relative terms, it is assumed that 35 weevils are the optimum number for these masses of test grain.

In the case of 20 g of grain 30 weevils produced the optimum number of progenies, followed by a relative decline when weevil numbers were increased to 35 and 40 (Fig. 3).

A comparison between progeny output based on 30 weevils across the three different grain masses showed that the largest increase took place with 20 g (Fig. 3). When increased progeny output from 30 to 35 weevils was compared in the same way, 15 g yielded an increase over 10 g but showed a relative decline at 20 g (Figs 1, 2, 3).

This can be interpreted to mean that 15- and 20-g grain masses are still too low to realize the full reproduction potential of this infestation level. Therefore 30 weevils and 20 g of seed mass are considered optimal for future resistance screening tests.

Grain moth

The results of the trial (Table 2) showed no significant progeny output differences between grain masses. This is also illustrated in Figure 4, which shows the clear linear relation between infestation levels and progeny output.

Table 2. Number of *Sitotroga cerealella* progenies developing from different egg infestation levels and three grain masses, SADC/ICRISAT, Zimbabwe, 1994.			
No. of eggs	10 g of grain	15 g of grain	20 g of grain
10	6.5	8.2	7.4
15	9.2	7.7	12.0
20	17.0	16.9	15.2
25	22.8	22.9	19.0
30	19.1	28.2	27.4
35	24.1	26.9	27.5
40	37.6	38.6[1]	36.6
SE	±0.98	±1.02	±0.97
Mean	19.44	21.34	20.69
CV(%)	33.69	29.45	31.86

1. Selected and recommended combination.

This can be interpreted in two ways. The most obvious explanation is that, in this test, only relatively small numbers of eggs have been used for infestation. The larvae:grain ratio was therefore largely in favor of the grain, and enough grain kernels for feeding were available. Based on the 1000-grain mass of 16 g of Red Swazi sorghum, 625, 925, and 1250 grains will have been available for feeding the 10-40 larvae developing from the egg infestation.

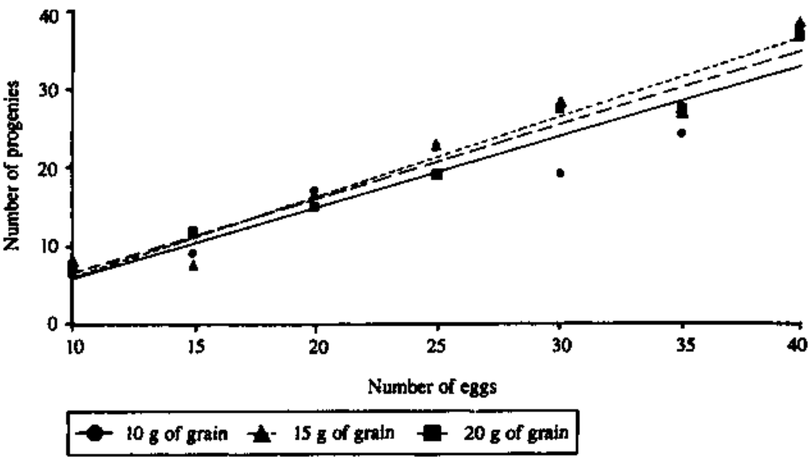

Figure 4. Differences between three grain masses infested with different numbers of grain moth eggs.

In addition, because of their fragile nature, *S. cerealella* adults can infest only the top layer of a grain mass (Mills 1985). This means that only the grains on the surface of the grain mass, and not the total number of grains, determines the number of eggs laid. The resulting larvae also may not have penetrated deeply into the grain mass, feeding only on the top 5 cm of the heap (in the absence of manual disturbance). Larger test jars were therefore used in this test to increase the grain surface.

Based on these results, any of the egg/grain mass combinations could theoretically have been used. But it was decided to select the combination 40 eggs and 15 g of grain. This reduces the demand for breeders' seed and gives a fairly high infestation level for better determining the differences between progenies possibly related to levels of sorghum variety resistance.

Acknowledgment. I thank Elliot Tembo for his help in collecting and analyzing the data.

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Incidence of Sorghum Downy Mildew in Relation to Date of Sowing in Botswana

P Ditshipi[1]

Abstract

The disease incidence due to downy mildew of sorghum induced by Peronosclerospora sorghi *in relation to time of sowing for 1993/94 was assessed in the epidemic area of Pandamatenga in Botswana. Fields of sorghum with different downy mildew incidences were obtained by evaluating crops sown at three different dates: Dec, Jan, and Feb. The percentage disease incidence was inversely proportional to the sowing date. There was a highly significant negative correlation between percentage of downy mildew incidence and date of sowing. Late-sown crops had a high percentage incidence of sorghum downy mildew disease.*

Introduction

Sorghum downy mildew, induced by *Peronosclerospora sorghi* (Weston and Uppal) Shaw is a serious disease in Pandamatenga farms in Botswana. Although no systematic and well planned studies on estimation of loss in yield have been conducted in Botswana, there have been reports of yield loss up to 86-90% in maize caused by downy mildew (Botswana 1980). Pandamatenga provides an ideal environment for the spore-germination, growth, and development of sorghum downy mildew because of its annual rainfall, and soils with high water-retention capacity. This paper reports the results of a study aimed at assessing the percentage incidence of sorghum downy mildew in relation to date of sowing in the Pandamatenga area.

Materials and Methods

The percentage disease incidence was monitored and evaluated through a survey of farmers' fields and research stations where sorghum varieties Segaolane, NK-222, and Macia were being grown. The incidence (percentage calculated on the basis of the

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Ditshipi, P. 1996. Incidence of sorghum downy mildew in relation to date of sowing in Botswana. Pages 181-183 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICR1SAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

number of diseased plants over the total plants) of the downy mildew was assessed 60 days after sowing.

The monitoring of sorghum downy mildew percentage incidence in research stations and farmers' fields was evaluated on the basis of three dates of sowing: early, mid-season, and late. All the commercial farms were visited twice, and the early-sown crop was compared with the mid-season and late-sown crop, to assess the percentages of disease incidence.

Results

The relation between the incidence of downy mildew and date of sowing is shown in Figure 1. For the three dates the percentage incidence ranged from approximately 5.0 to 81.8%. There was a highly significant negative correlation between the incidence of sorghum downy mildew and date of sowing.

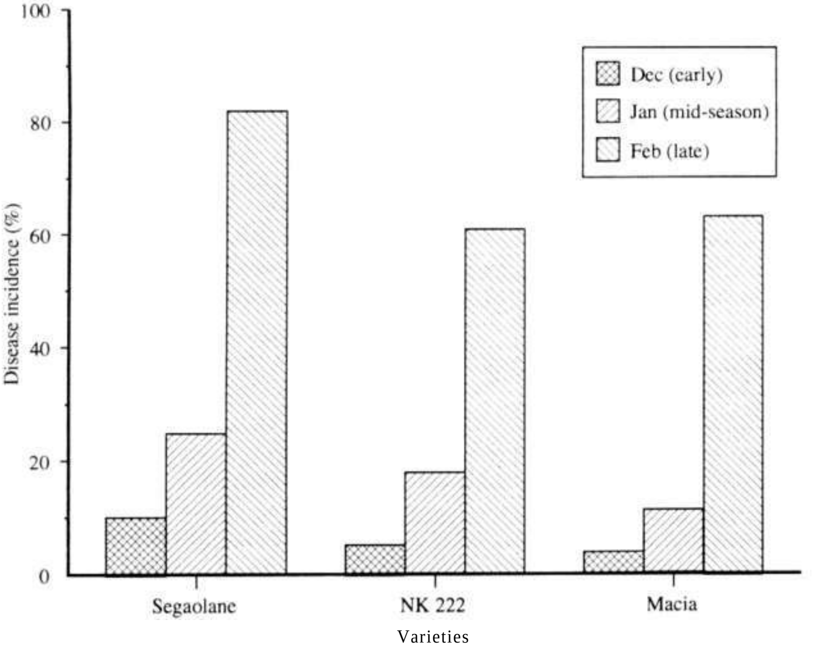

Figure 1. The relation between the incidence of downy mildew and sowing date for three sorghum varieties, Pandamatenga area, Botswana, 1993/94.

Low percentage incidence of sorghum downy mildew was recorded in the early-sown crop and high percentage in the late-sown crop. An estimated yield reduction of 45.7-73.2% was expected for the local variety, Segaolane, in the late-sown crop compared with the early-sown crop. The percentage incidence of downy mildew was high for Segaolane at all dates.

Frederikson et al. (1993) reported the presence of sorghum downy mildew in 83% of the fields in which the incidences were 4-55% local lesion downy mildew and 11% for the systemic form, in a survey conducted in mid-Feb 1992 in Pandamatenga.

Discussion

This investigation has shown the high percentage incidence of sorghum downy mildew which can cause enormous losses in yield in the epidemic-prone region (Pandamatenga) of Botswana in late-sown crops. Early-sown crops escape the infection in most cases. Released sorghum varieties could therefore be usefully evaluated regarding the parameter of sowing date. This would permit the elimination of the most susceptible varieties at an earlier stage.

The results indicate that while Macia, NK-222, and Segaolane were not resistant, they were tolerant of sorghum downy mildew, thereby indicating that the three varieties could be protected by using fungicides and judicious management of the time of sowing.

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Evaluation of Systemic Seed Dressings for the Control of Covered Kernel Smut on Sorghum in Zimbabwe

E Mtisi[1]

Abstract

*Covered kernel smut disease (*Sporisorium sorghi *[Ehrenberg] Link: syn* Spacelotheca sorghi *[Link] Clinton) is widespread on sorghum in some areas of Zimbabwe. In the search for control measures, two systemic seed-dressing fungicides, Apron Plus® 50 DS and Vitavax® 75% WP, were evaluated in the field and greenhouse in the 1993/94 season. In both experiments the two fungicides were effective in controlling the disease.*

Introduction

Covered kernel smut is a seedborne pathogen of sorghum. A national pest survey conducted in 1985 indicated that covered kernel smut was widespread in the communal areas of Zimbabwe (Page et al. 1985). Inspection of records of the samples arriving at the Plant Protection Advisory Clinic in the 1992/93 season revealed that covered kernel smut is widespread in the Marange and Chiredzi areas. Our recent on-farm trial visits during the 1993/94 season also confirmed these reports, with Sabi and Gwanda now added to the list of areas affected by the disease (Gono et al. 1994). In summary, these reports confirm that covered kernel smut is increasingly gaining importance in the communal areas where farmers continuously use unimproved and uncertified seed.

The importance of this disease cannot be overemphasized. It causes direct yield loss of grains by replacing them with smut sori. Seedborne inocula facilitate the rapid spread of the disease to areas where it was previously absent.

It has already been established that seed treatments are effective in controlling covered kernel smut (Frederiksen 1986). In Zimbabwe there is no fungicide specifically registered for the control of covered kernel smut. It was therefore decided to set

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Mtisi, E. 1996. Evaluation of systemic seed dressings for the control of covered kernel smut on sorghum in Zimbabwe. Pages 185-188 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

up an experiment to screen fungicides which could then be registered for the control of this disease.

Vitavax® 75% WP (carboxin), a well-known fungicide that has been effective in controlling loose smut (*Ustilago tritici*) on wheat, was chosen as a candidate. Apron Plus® 50 DS (metalaxyl + carboxin + furathiocarb), a seed dressing now extensively used in Nigeria, Burkina, and Mali (pers. comm. Mtetwa 1993) was similarly selected as a candidate.

Materials and Methods

Seed was obtained from a farmer in the communal area Marange whose field was heavily infested with covered kernel smut (about 100% disease incidence). After threshing, the seed was densely covered with smut spores. The seed was divided into three 1-kg portions and treated just before sowing, as follows:

1. Control: no seed dressing.
2. Vitavax® 75% WP (carboxin): at the rate of 150 g 100 kg^{-1} seed (1.5 g product 1 kg^{-1} seed).
3. Apron Plus® 50 DS: at the rate of 10 g product 1 kg^{-1} seed.

Field experiment

The trial was sown in Marange area in Natural Region IV, near Bazeley Bridge, in a randomized block design with five replications. Each plot consisted of five rows, spaced at 4 x 0.75 x 0.2 m. Basal fertilizer, compound D, was applied at the rate of 50 kg $ha*^{1}$. Topdressing with ammonium nitrate was not done because the rains stopped early in the growing season. Weeding was done 3 weeks after emergence, and stand populations were counted 6 weeks after sowing. The number of infected plants were counted at the soft dough stage and expressed as a percentage of the total population per plot (% disease incidence). We analyzed percentage disease incidence and plant population per plot. No yields were recorded at harvesting because we observed some off-types in the plots.

Pot experiment

Seed that was left after sowing the field experiments was brought to Harare station and planted in pots, using the same layout and design as in the field. The plants were thinned to five plants per pot 2 weeks after emergence. Disease incidence was recorded at the soft dough stage.

Results and Discussion

Results of both experiments followed the same trend. All plots and pots with seed-dressing treatment showed complete control of the disease, and all the control plots of the field experiment had diseased plants, though not up to 100% incidence. In the pot experiment, two replications of the control treatments had no disease. This is probably due to 'escape' because the plants were few per pot. As a result, the pot experiment results were not analyzed. Therefore, the results discussed below relate to the field experiment only.

The two seed-dressing treatments were effective in suppressing the disease and the level of efficacy seems to be the same (Table 1). The explanation for this might be that both fungicides have carboxin as one of the active ingredients. Carboxin is known to be effective against smuts of small grains and is already registered in Zimbabwe for control of loose smut in wheat (Muchenje and McClaymont 1990).

Table 1. Effect of seed-dressing treatment on covered kernel smut, Zimbabwe, 1993/94.

Treatment	Disease incidence (%)	Plants ha^{-1} ('000)
Control	16.5	141 547
Vitavax®	0.0	142 187
Apron Plus®	0.0	144 427
SE	±3.7	±4 050
LSD (5%)	12.2	13 206
P(5%)	0.021	0.872

During the on-farm trial visits in the 1994 season, it was of interest to note that only the farmers' local landrace varieties were attacked by covered kernel smut, but not the improved varieties. It has not yet been established whether the improved varieties are resistant to the disease, whether seed was disease-free, or whether this is due to seed treatment.

Conclusions

Since these are preliminary results, further investigations are required on the following:

1. Using different seed dressing rates to find the most economic rate.
2. Testing in different locations in order to obtain conclusive results.
3. Yield-loss studies.
4. Checking whether improved varieties are resistant.

Acknowledgments. I wish to express my gratitude to A Nyakabau and E Tande for managing the experiments in Marange and Harare Research Station respectively. Many thanks are also due to L T Gono for his critical review of this paper.

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Field Evaluation of Seed-Dressing Fungicides for the Control of Sorghum Downy Mildew in Zambia

G M Kaula[1]

Abstract

Chemical control of downy mildew (Peronosclerospora sorghi) *through the use of seed-dressing fungicides was tested with Apron Plus®, Ridomil®, and thiram, applied to seeds of susceptible and resistant sorghums (three hybrids and two varieties) sown in a disease hot-spot in Zambia. Data from the one-season trial were insufficient to be conclusive, and it is therefore being continued. But initial results show that Apron Plus® controlled systemic downy mildew 84% better than the untreated control, with comparative data for Ridomil® at 74% and thiram at 13%. A similar trend was observed in the control of local lesions.*

Introduction

Research on sorghum downy mildew has progressed smoothly and successfully in Zambia. The main emphasis has been on determining the sources of resistance using the spreader-row technique to screen all breeding materials. By using this method, a number of resistant lines have been identified. The present investigation of a method of chemical control was carried out at a sorghum downy mildew hot-spot, and supplements host-plant resistance breeding research.

The trial to evaluate seed-dressing fungicides was started in the main rainy season of 1993/94. Two metalaxyl-based fungicides (Apron Plus® and Ridomil®) were evaluated together with the commonly-used fungicide thiram. The weather during the season was not conducive to the development of downy mildew because there were several dry spells.

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Kaula, G.M. 1996. Field evaluation of seed-dressing fungicides for the control of sorghum downy mildew in Zambia. Pages 189-193 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Materials and Methods

The sorghum downy mildew hot-spot selected for the trial was in Golden Valley, Zambia. Five sorghum entries of different levels of susceptibility to downy mildew were used. These included three commercially grown hybrids: MMSH 375 and MMSH 413 (of moderate susceptibility) and MMSH 928 (as a resistant control); and two varieties: Kuyuma (resistant control) and SDS 3845 (susceptible control). The fungicides tested were Apron Plus® at 10 g kg^{-1} of seed, Ridomil®, also at 10 g kg^{-1} of seed (metalaxyl-based fungicides) and thiram (Thirasan M®) at 2 g kg^{-1} of seed. Thiram was used as a control because it is commercially marketed in the country as a seed dressing.

The healthy seeds of various sorghum entries were thoroughly mixed with fungicides in the plastic containers. The seed-lots of all fungicides were treated dry.

These seed-lots were then sown in a split-plot design with fungicides as main plots and sorghum entries as subplots. The plot size was 3 x 4 m with 0.3 m between plants. Each treatment was replicated four times.

The experiment was located at one site comprising virgin land surrounded with wild sorghum, assumed to be *Sorghum halepense,* which is highly susceptible to downy mildew. No artificial inoculum was applied on the treated seed-lots.

Results and Discussion

The three fungicides varied in their performance. Data from the trial, over 1 year, show that Apron Plus® controlled the systemic downy mildew 84% better than the untreated control, followed by Ridomil® at 74%, while thiram was only 13% better than the untreated control. The untreated plots had the highest incidence of systemic downy mildew, and lowest were the plots treated with Apron Plus® (Fig. 1). The results were statistically significant at 1%.

Regarding the control of local lesions by the same chemicals (Fig. 2), the trend is the same. Apron Plus® was 57% better than the untreated control, Ridomil® by 36%, and thiram by only 9%.

However, after the performance or the efficacy of the fungicides was compared with the two infection types—oospore infection (soilborne and primary) and conidia (a secondary infection), it was observed that the fungicides controlled soilborne (systemic) infection better than the secondary infection (local lesions) (Fig. 2). Basically, the metalaxyl-based fungicides, when used as seed dressings, protect the plants from infection by soilborne pathogens.

Data for the sorghum entries treated with these seed-dressing fungicides were significant at 1%. However, the entries reacted differently (Fig. 3). As expected, Kuyuma and MMSH 928 were resistant to systemic downy mildew, MMSH 413 showed moderate resistance, whereas MMSH 375 and SDS 3845 were susceptible.

Local lesions reaction from systemic downy mildew (Fig. 4) was different: Kuyuma and MMSH 928 remained free from the infection. Among the susceptible

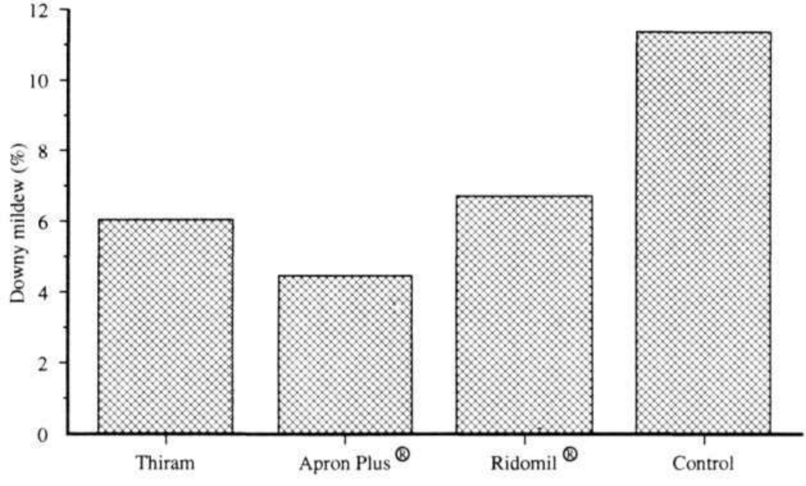

Figure 1. The comparative efficacy of three seed-dressing fungicides used in the control of sorghum downy mildew.

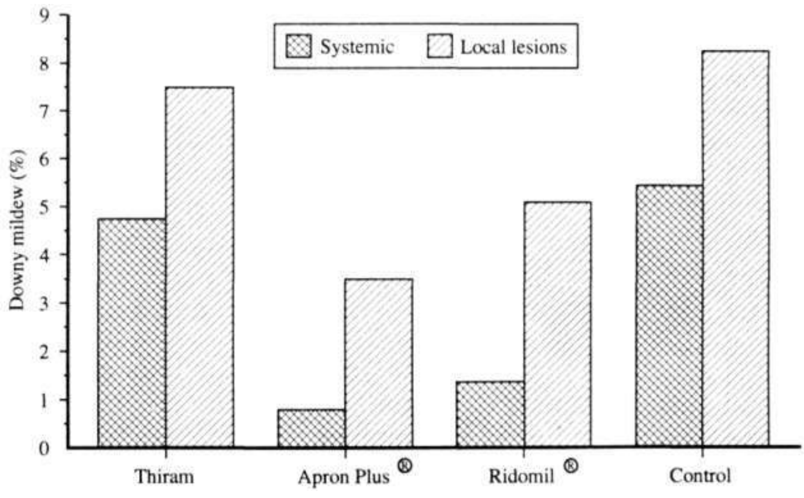

Figure 2. The relative performance of three seed-dressing fungicides in controlling systemic sorghum downy mildew and local lesions.

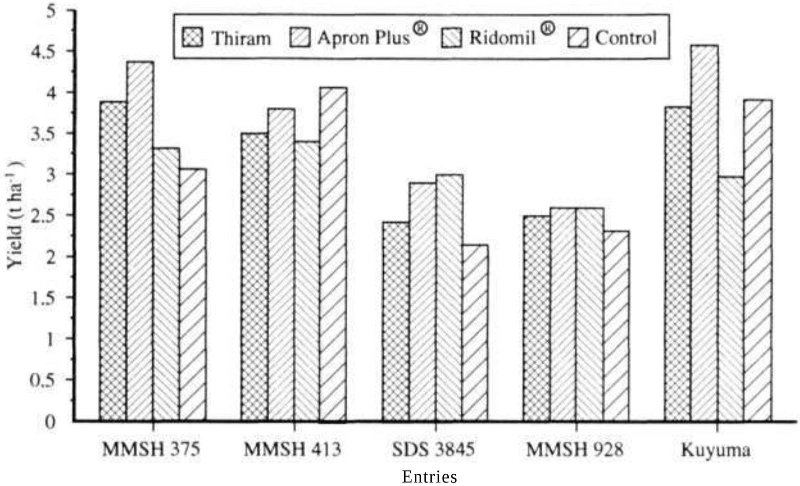

Figure 3. Yield performance of sorghum entries (hybrids and varieties) in the fungicide trial.

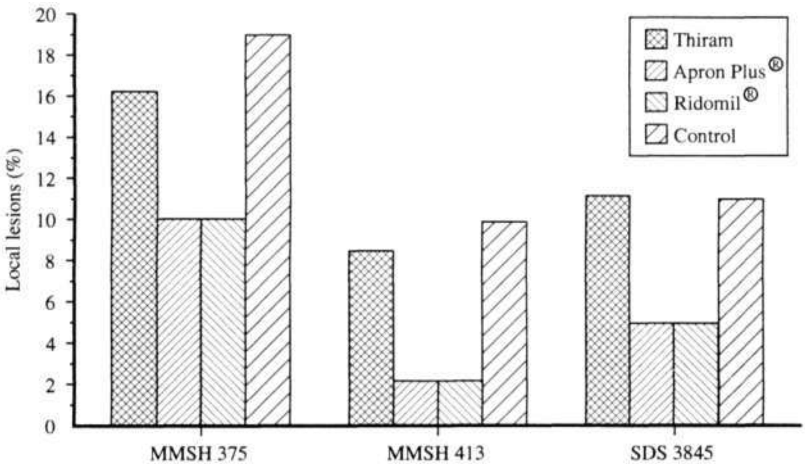

Figure 4. Comparative efficacy of three fungicides in controlling sorghum downy mildew local lesions.

sorghums, MMSH 375 had a higher rating than SDS 3845, and MMSH 413 was moderately susceptible.

Data on yield show that, even though Apron Plus® performed better than other fungicides in suppressing the disease, the differences were not significant (Fig. 5).

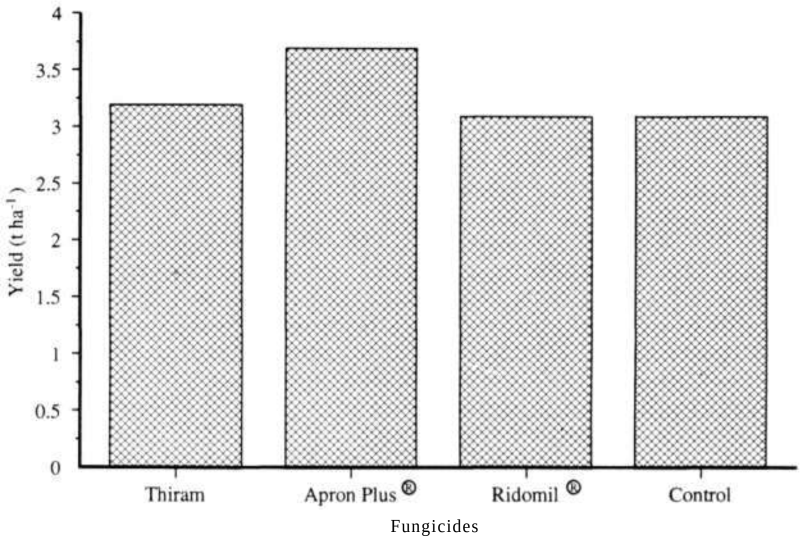

Figure 5. Comparative efficacy of three fungicides in controlling sorghum downy mildew by yield performance.

Conclusion

From these preliminary results no conclusive inferences can be drawn. The trial is expected to continue for another 2 years.

Status of *Striga* Species in Tanzania: Occurrence, Distribution, and On-Farm Control Packages

A M Mbwaga[1]

Abstract

Striga *species are important as endemic pests of cereals, including sorghum, maize, millets, and upland rice, grown in the semi-arid tropical and equatorial regions of Tanzania. The distribution of* Striga *species of economic importance in the country has been extensively surveyed. The most frequently observed species included* S. asiatica, S. hermonthica, *and* S. forbesii. *Each has been found to have a different geographic range, some of which overlap.*

Farmers interviewed recognized Striga *as a major constraint in cereal* produc-*tion, and they requested an immediate solution to the problem. Preliminary results from on-farm trials have shown that early-sown cereal crops yielded more than late-sown ones, despite higher* Striga *infestation in early-sown crops.* Sor-*ghum or maize intercropped with cowpea (the spreading type) in the same row had the least* Striga *emergence, and the highest cereal yield was obtained from this treatment.*

Sorghum varieties SAR 29, Weijita, and Serena showed very low incidence of S. asiatica *and* S. forbesii *compared with the susceptible varieties Tegemeo and Sandala. Serena was also observed to have the least infestation by* S. hermonthica *at Ukiriguru.*

A postemergence herbicide, 2,4-D, applied twice at a rate of 2 kg a.i. ha^{-1} at 8 and 10 weeks after emergence of sorghum, had the least Striga *infestation. The highest sorghum grain yield was also obtained from this treatment.*

Introduction

Striga species (Scrophulariaceae family) are obligate hemiroot parasites of sorghum, maize, upland rice, millets, sugar cane, and cowpea, especially in the Sahelian and savanna zones of Africa (M'boob 1986). In Tanzania, pearl millet has been observed to be free of *Striga* attack (Mbwaga and Obilana 1993). The parasite is particularly

1. Senior Agricultural Research Officer, Agricultural Research and Training Institute, Ilonga, Kilosa, Tanzania.

Mbwaga, A.M. 1996. Status of *Striga* species in Tanzania: occurrence, distribution, and on-farm control packages. Pages 195-200 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

important as an endemic pest of cereal crops grown in the semi-arid tropical and equatorial regions of Tanzania.

Striga species reported in Tanzania include S. *asiatica* (L.) Kuntze, *S. aspera* (Wild) Benth., *S. elegans* Benth., *S. euphrasiodes* Benth., S. *forbesii* Benth., S. *fulgens* Hepper, S. *gesnerioides* (Wild) Vatke, and *S. hermonthica* (Del.) Benth. (Obilana and Ramaiah 1988). *Striga asiatica, S. hermonthica,* and S. *forbesii* are of economic importance because they parasitize staple food crops. Hence Tanzania lies in a unique belt of the tropics where the three most damaging and economically important *Striga* species in Africa exist in overlapping association.

Distribution of *Striga* Species

S. *asiatica* (red-flowered) is the most extensive and common species covering the largest area of the country (Fig. 1), from Lake Victoria in the north to Ruvuma region in the south, and also along the coastal regions from Tanga to Mtwara region in the south, infesting sorghum, maize, upland rice, and finger millet.

The predominant *Striga* species in north and northwestern Tanzania around Lake Victoria is S. *hermonthica,* which overlaps with S. *asiatica* in Shinyanga and Mwanza regions. It extends further north into Nyanza province of Kenya. The weed has been observed infesting sorghum, maize, and finger millet.

S. *forbesii* has been found in only a few areas, especially in Morogoro region where it infests sorghum, maize, upland rice, and sugar cane. It overlaps with S. *asiatica* in this region. The two *Striga* species have been observed to appear on the same fields and they have even been found infesting the same host plant. In many cases S. *forbesii* was observed to emerge earlier than S. *asiatica.* It has also been observed that S. *forbesii* is more aggressive than S. *asiatica,* but this needs to be confirmed.

Farmers' Awareness of the *Striga* Problem

During an extensive parasitic weed survey carried out in the 1992 and 1994 cropping seasons, it was found that farmers recognized *Striga* as one of the major constraints in cereal production in the country. They have reported yield losses up to 90% and above caused by *Striga* damage.

The major reasons given for *Striga* increase in the last 10-15 years are: the continuous growing of susceptible cereals in monoculture; mechanization in land preparation (which encourages the spread of the weed); loss of soil fertility (because many farmers cannot afford to buy fertilizer); and limited crop rotation caused by a shortage of arable land. It was also observed that farmers use their own seeds harvested from Striga-infested fields, which may be the major source of its spread to Striga-free fields.

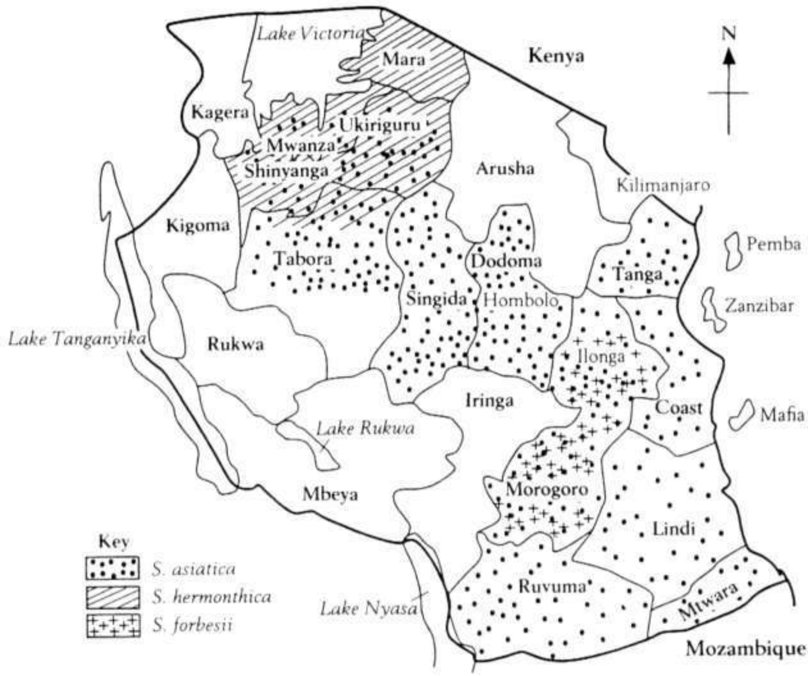

Figure 1. Distribution of *Striga* species in Tanzania.

Farmers' *Striga* Control Practices

Farmers were observed to carry out some *Striga* control measures. These included: hand-pulling or hoe-weeding and leaving the *Striga* plants to dry on the surface of the field; crop rotation with such noncereal crops as cassava, groundnut, and sesame for 1-2 years; leaving the land fallow for 2-3 years; the mixed cropping of such combinations as maize/sorghum/cassava, sorghum/maize/pigeonpea, sorghum with groundnut, or maize with upland rice. Few farmers were observed to transplant upland rice or sorghum and thus enable the crop to escape severe *Striga* damage.

From farmers' experience none of these control practices offers significant *Striga* control. This may be due to lack of knowledge about the biology of *Striga,* about the optimal time to carry out control measures, and about practical means for its control in the field.

On-Farm *Striga* Control Packages

Effect of sowing date on infestation of cereals by *S. hermonthica*

Cereals (sorghum and maize) sown in January (early) were compared with those sown a month later for *S. hermonthica* infestation. Early-sown crops had higher grain yields than late-sown crops, despite a high *Striga* count per host plant from early-sown crops (Table 1). Early sowing gives a cereal crop the chance to establish itself before *Striga* has had time to damage the crop (Burtt-Davy 1904). From a late-sown crop not all *Striga* weeds emerge above the ground because of soil crusting; it is then possible to count only the *Striga* plants that have managed to emerge.

Table 1. Effect of sowing date on cereal infestation with *Striga* at Ukiriguru, Mwanza, Tanzania.

	Crop infested			
	Maize		Sorghum	
Sowing date	*Striga* count plant^{-1}	Yield (kg ha^{-1})	*Striga* count plant^{-1}	Yield (kg ha^{-1})
Early sowing	7	333.4	9	1508.0
Late sowing	3	35.6	7	757.0
Mean	5.0	184.5	8.0	1132.5
SD	2.0	148.9	1.0	375.5

Effect of intercropping cereal with cowpea to control *Striga*

Low *Striga* infestation was observed in plots with intercropping, especially where cereal was intercropped with cowpea in the same row (Tables 2 and 3). The relatively low *Striga* emergence in the intercropped plots could be due to the shading effect of the cowpea, which on the other hand will have created unfavorable conditions for *Striga* germination. It is also known that cowpea stimulates *Striga* germination but it does not support its development (Doggett 1953).

Table 2. Sorghum and cowpea intercropping for the control of *Striga* at Ukiriguru, Mwanza, Tanzania.

Treatment	*Striga* count plant^{-1}	Grain yield (kg ha^{-1})
Sorghum pure stand	9	1351
Sorghum in alternate rows with cowpea	8	1431
Sorghum in the same row with cowpea	5	1742
Mean	7.3	1508.0
SD	1.7	168.7

Table 3. Maize and cowpea intercropping for the control of *Striga* at Ukiriguru, Mwanza, Tanzania.

	Striga count plant^{-1}	Grain yield (kg ha^{-1})
Maize pure stand	5	107.6
Maize in alternate rows with cowpea	6	214.4
Maize in the same row with cowpea	2	672.0
Mean	4.3	331.4
SD		244.8

Evaluation of Sorghum Varieties for *Striga* Resistance

Six sorghum varieties, two with partial resistance to *Striga* (SAR 29 and Serena), one tolerant (Weijita), and three susceptible were evaluated for their performance on farmers' fields infested with *Striga.* One set was planted at Mangae (Morogoro rural), an area infested with S. *asiatica* and S. *forbesii,* while the second set was sown at Ukiriguru, in a field that is a hot-spot for S. *asiatica* and *S. hermonthica.*

At Mangae, SAR29 and Weijita were observed to be free of *Striga* infestation, while Serena showed a very low level of *Striga* infestation at both locations. Tegemeo had the highest levels of *Striga* count at both locations, i.e., Ukiriguru and Mangae (Table 4).

Table 4. *Striga* infestation levels of sorghum varieties under farmers' crop management.

	Location[1]		
	Mangae[2]	Ukiriguru[3]	
Sorghum variety	% *Striga* infestation plant^{-1}	% *Striga* infestation plant^{-1}	Grain yield (kg ha^{-1})
SAR 29	0	-	
Weijita	0	-	
Serena	30	50	1231.7
Tegemeo	80	1110	270.2
Sandala	110	9700	234.7
Nchengaviduha	-	9200	275.0

1. *Striga* infestation (inf. plant*[1]) was calculated by dividing the total *Striga* count plot'[1] by the plant stand count at harvest.
2. Mangae = *S. asiatica* and *S. forbesii.*
3. Ukiriguru = *S. asiatica* and *S. hermonthica.*

Control of *Striga* Using Herbicide 2,4-D Amine

The herbicide 2,4-D amine was applied on sorghum variety Tegemeo (susceptible) at Ukiriguru to control both *S. asiatica* and *S. hermonthica* at a rate of 2 kg a.i. ha^{-1}. The nozzle was directed to the area between rows so that the spray liquid touched only the lower stalks of the crop, 8-10 weeks after emergence.

Postemergence application of 2,4-D gave the best control of *Striga,* especially when it was applied three times (Table 5). Although sorghum yield was generally affected by drought, relatively high yield was obtained from the treatment where 2,4-D was applied twice. Similar results have been reported elsewhere (Edgerton 1955).

Table 5. Chemical control of *Striga* using 2,4-D amine at Ukiriguru, Mwanza, Tanzania.

Treatment	Mean *Striga* count $plant^{-1}$	Grain yield (kg ha^{-1})
Hoe-weeding (no pre-emergence herbicide)	2.5	26.7
Hoe-weeding (with pre-emergence herbicide)	5.0	155.6
2,4-D amine applied once	0.7	222.2
2,4-D amine applied twice	0.2	800.0

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Mbwaga A.M. and Obilana, A.B. 1993. Distribution and host specificity of *Striga asiatica* and *Striga hermonthica* on cereals in Tanzania. International Journal of Pest Management 39(4):449.

Screening Sorghum Cultivars for Resistance to Witchweed (*Striga asiatica*) in Zimbabwe

S Mabasa[1]

Abstract

Pot and field experiments were conducted at Henderson Research Station and Chiwundura Communal Area, respectively, in the 1991/92, 1992/93, and 1993/94 seasons to evaluate the resistance of 17 sorghum cultivars to the parasitic weed Striga asiatica *(L.) Kuntze.* S. asiatica *emerged and flowered within 64.8-71.6 and 88-105.6 days from sorghum sowing, respectively. The sorghum cultivars SAR 29, SAR 33, SAR 35, SAR 37, and SAR 16 significantly supported low* S. asiatica *infestation counts, compared with the recommended cultivars DC 75, SV 1, and SV 2. Although the SAR cultivars showed considerable resistance to* S. asiatica, *their grain yields were very low. The cultivars DC 75, SV 1, SV 2, and MMSH 413, which were highly infested with* S. asiatica, *outyielded these resistant cultivars and can probably be described as tolerant of* S. asiatica. *There is therefore a need to improve the grain yield potential of the SAR cultivars through breeding.*

Introduction

In Zimbabwe, sorghum is mainly grown by smallholder farmers in Natural Regions III, IV, and V with annual rainfalls of 650-800 mm, 450-650 mm, and 450 mm or less, respectively. The parasitic weeds *Striga asiatica* (L.) Kuntze and *S. forbesii* Benth. are a major constraint to sorghum production in smallholder farming areas. S. *asiatica* is the most common parasitic weed in the country (Zimbabwe Agronomy Institute 1993). Sorghum grown in farmers' fields in *Striga* hot-spots can fail to produce grain. Maize and sorghum yield losses of 5-40% have been attributed to this weed (Knepper 1989).

Witchweeds are difficult to control using currently available control methods, probably because of the life cycle of *Striga.* One *Striga* plant can produce up to 500 000 seeds that may survive for 20 years in farmers' fields (Holm et al. 1977). Thomas (1970) reported that *Striga* was no longer a problem on large-scale commer-

1. Team Leader, Weed Research, Henderson Research Station, PO Bag 2004, Mazowe, Zimbabwe.

Mabasa, S. 1996. Screening sorghum cultivars for resistance to witchweed (*Striga asiatica*) in Zimbabwe. Pages 201-209 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

cial farms. He suggested that effective methods of controlling witch weed were: treatment with such postemergence herbicides as 2,4-D and MCPA, use of trap or catch crops, and preventing the witchweed from setting seed. However, these control methods are too expensive for smallholder farmers. So the use of resistant sorghum cultivars by farmers is the most feasible control method.

Sorghum cultivars that are resistant to *S. asiatica* have been identified in India (Obilana et al. 1991). The objective of the study was therefore to screen sorghum cultivars for this resistance character.

Materials and Methods

Pot screening

Ten sorghum cultivars—SAR 29, SAR 33, SAR 19, SAR 35, SAR 37, MMSH 413, DC 75, SV 2, SV 1, and MMSH 375—were screened in pot experiments at Henderson Research Station in the 1991/92 season. No pot experiments were carried out in the following year and, in the 1993/94 season, cultivars SAR 29, SAR 19, and MMSH 375 were not tested because of a shortage of seed. They were replaced by SAR 16, SDSH 148, SDSH 378, Muchayeni, and Chibonda. In Zimbabwe, SV 1, SV 2, and DC 75 are the recommended cultivars and Muchayeni and Chibonda are local landrace varieties. DC 75 was used as the susceptible control. The sorghum seeds were supplied by SADC/ICRISAT at Matopos Research Station.

Five seeds of sorghum were sown on 17 Dec in 1991/92 and on 21 Dec in 1993/94, in pots filled with sandy soil. Each pot measured 22.2 cm in diameter and 22.3 cm in depth. About 0.02 g of *S. asiatica* seed were mixed in the top 5 cm of soil before sowing. Sorghum was thinned to one plant per pot at 2 weeks after crop emergence. Sorghum was supplied with the following nutrients: 170 kg ha^{-1} of N, 56 kg ha^{-1} of P_2O_5, and 28 kg ha^{-1} of K_2O. In all pots all the K and P and one-third of N were applied at sowing and the balance of N was applied as a topdressing at 6 and 8 weeks after crop emergence. The pots were watered daily. Other weeds were hand-pulled. A randomized block design with four replicates was used.

Although the number of emerged *S. asiatica* was noted in each pot every 2 days, the number at peak emergence (110 days from sowing) was used for statistical analysis. The number of days to first *S. asiatica* emergence and flowering was recorded for each pot. The sorghum measurements were as follows: days to flowering, days to maturity, root dry weight, plant height, and grain yield. Analysis of variance was done on these measurements and treatment means were compared using the least significant difference (LSD, $P < 0.05$). *S. asiatica* counts were analyzed after logarithmic transformation of data (log [counts + 1]) (Mead and Curnow 1983). The days to flowering, days to maturity, plant height, and grain yield data for sorghum were correlated with the count pot^{-1} for *S. asiatica.*

Field screening

The field screening was done at Henderson Research Station (Natural Region II, 800 mm average annual rainfall and clay loam soil) and Chiwundura Communal Area (Natural Region III, 650-800 mm annual rainfall and sandy soils). Ten sorghum cultivars—SAR 29, SAR 33, SAR 19, SAR 35, SAR 37, AG 9, SV 1, SV 2, MMSH 413, and MMSH 375 were evaluated for grain yield production in a *Striga-free* environment at Henderson Research Station in 1992/93. At Chiwundura the same cultivars were grown in fields naturally infested with *Striga,* and Marupanzi was used as the susceptible control in 1992/93 and AG 9 in 1993/94.

Land preparation at Henderson in 1992 involved plowing in July and disking in October. At Chiwundura, plowing was done in November in both seasons. In 1992/93 sorghum cultivars were sown on 28 Dec at Henderson and on 8 and 3 Dec at Chiwundura in 1992/93 and 1993/94, respectively. A seed rate of 18 kg ha^{-1} was used. The sorghum rows were 75 cm apart. Thinning of the crop to one plant at every 15 cm within the row was done at 2 weeks after emergence. At Chiwundura and Henderson the gross plots measured 2.0 x 3.0 m and 5.0 x 3.75 m, respectively. There were three plots per cultivar at Chiwundura and four at Henderson. The cultivars were arranged in a randomized complete block design. At Chiwundura the sorghum cultivars Marupanzi (1992/93) and AG 9 (1993/94) were sown in four (susceptible) plots surrounding the test plot, forming a checkerboard layout (Vasudeva Rao 1987).

At all sites, 56 kg ha^{-1} P_2O_5, 28 kg ha^{-1} K_2O, and 32 kg ha^{-1} N were applied at sowing and then 62 kg ha^{-1} N as a topdressing at 3 weeks after crop emergence. Weeding was done twice during the season. To determine grain yield at the end of the season, the sorghum was harvested in an area of 2.0 x 1.5 m at Chiwundura and 4.0 x 2.25 m at Henderson. At Chiwundura, crop height was measured at harvest and *S. asiatica* counts were taken in two crop rows of 2 m, at 115 days after sorghum sowing. It was not possible to collect data on days to first *S. asiatica* emergence and flowering in 1993/94 at Chiwundura.

Sorghum grain yield data were analyzed for variance. Initially the analysis of covariance was done on *S. asiatica* counts in the test plots using the mean count from four adjacent plots as a covariate. However, a better picture was obtained by doing analysis on logarithmically transformed *S. asiatica* counts (log [counts + 1]). So data interpretation was based on the latter. Treatment comparisons and correlation analysis were as described in pot screening.

Results

Striga asiatica emergence

The days to *S. asiatica* emergence were not significantly different ($P < 0.05$) in 1991/92 at Henderson (Table 1), and ranged from 56.3 and 76.5. In 1993/94 the days to *S. asiatica* emergence were significantly different ($P < 0.001$, Table 1). *S. asiatica*

Table 1. Mean days to first *Striga asiatica* emergence in sorghum cultivars at Henderson, Zimbabwe (pot screening), 1991/92 and 1993/94.[1]

Cultivars	1991/92	1993/94
SAR 29	693	-
SAR 33	70.0	85.8
SAR 19	49.0	-
SAR 35	76.5	90.0
SAR 37	67.8	80.0
SAR 16	-	84.5
DC 75	68.5	73.0
SV 2	63.0	54.3
SV 1	63.8	87.8
MMSH 413	56.3	60.3
MMSH 375	63.3	-
SDSH 148	-	63.0
SDSH 378	-	60.8
Muchayeni	-	64.5
Chibonda	-	54.8
SE	±12.0	±6.0
Mean	64.8	71.6
LSD (P <0.05)	-	12.2
CV(%)	31.8	16.9

1. - = not tested.

emerged early in SV 2 and Chibonda, and late in SAR 35. The mean days to first emergence, across the two seasons, ranged from 64.8 to 71.6.

Striga asiatica flowering

The days to first *S. asiatica* flowering, which were not significantly different (P >0.05) across sorghum cultivars, ranged from 78.0 to 101.5, 90.0 to 116.5, and 71.3 to 97.3 in 1991/92, 1993/94, and 1992/93, respectively. In 1991/92 S. *asiatica* in SAR 35 and SAR 37 failed to flower. The mean days to first flowering ranged from 88.2 to 105.6 across the three seasons.

Striga asiatica counts

The *S. asiatica* counts in sorghum cultivars were not significantly different (P >0.05) at Henderson in 1991/92 (Table 2). However, it seemed the SAR cultivars SAR 29, SAR 33, SAR 19, SAR 35, and SAR 37 supported low *S. asiatica* counts compared to other sorghum cultivars, including DC 75, the control. The cultivar DC 75 produced the highest *S. asiatica* count and SAR 19 the lowest. The sorghum cultivars influ-

Table 2. Mean *Striga asiatica* counts in sorghum cultivars at Henderson (counts pot^{-1}) and Chiwundura (counts 3 m^{-2}), Zimbabwe, 1991/92 to 1993/94.[1]

	Henderson		Chiwundura	
Cultivars	1991/92	1993/94	1992/93	1993/94
SAR 29	10.3(1.01)	-	25.3(1.39)	5.0 (0.70)
SAR 33	3.8 (0.58)	5.3 (0.71)	34.7(1.54)	6.0 (0.78)
SAR 19	0.3 (0.08)	-	28.0(1.43)	6.0 (0.78)
SAR 35	1.5(0.18)	1.8(0.25)	48.7(1.68)	5.7 (0.76)
SAR 37	13.0(1.11)	3.5 (0.54)	23.0(1.36)	3.7 (0.57)
SAR 16	-	4.0 (0.60)	-	-
DC 75	35.0(1.54)	18.8(1.27)	-	-
Marupanzi	-	-	34.3(1.53)	-
AG 9	-	-	-	19.7(1.29)
SV 2	21.8(1.34)	20.3(1.30)	41.7(1.62)	1.7(0.23)
SV 1	22.0(1.34)	9.3 (0.97)	38.7(1.58)	16.0(1.18)
MMSH 413	26.0(1.42)	12.5(1.11)	29.7(1.47)	57.7(1.76)
MMSH 375	16.5(1.22)	-	42.7(1.63)	41.3(1.62)
SDSH 148	-	28.0(1.45)	-	-
SDSH 378	-	24.3(1.38)	-	-
Muchayeni	-	14.5(1.16)	-	-
Chibonda	-	6.0 (0.78)	-	-
SE	±0.30	±0.18	±0.05	±0.29
LSD (P <0.05)		0.37	0.11	
CV(%)	61.1	32.9	6.1	56.1

1. Numbers in parenthesis = $\log_{10}(x + 1)$.
\- = not tested.

enced S. *asiatica* counts (P <0.01) in 1993/94 at Henderson. Cultivars SAR 35 and SDSH 148 produced lowest and highest counts, respectively. The SAR cultivars supported low S. *asiatica* counts compared with other cultivars, including DC 75. Chibonda, a local landrace variety grown by communal farmers, supported low counts of S. *asiatica.*

At Chiwundura *S. asiatica* infestation was higher in 1992/93 than in 1993/94. Sorghum cultivars affected the *Striga* counts in 1992/93 (P <0.01) and not in 1993/94 (P >0.05). Cultivars SAR 37 and SAR 35 produced the lowest and highest *S. asiatica* count, respectively, in 1992/93. The 1993/94 Chiwundura data closely followed that obtained from pots at Henderson (1991/92).

Grain yield

Sorghum cultivars produced grain yields that were significantly different in pot evaluations at Henderson in 1991/92 (P <0.001) and 1993/94 (P <0.01) (Table 3). In 1991/92 SV 2, DC 75, MMS 375, MMSH 413 produced high grain yield and SAR

Table 3. Sorghum mean grain yields at Henderson and Chiwundura, Zimbabwe, 1991/92 to 1993/94.[1]

	Henderson[2]			Chiwundura	
Cultivars	1991/92 (g pot^{-1})	1993/94 (g pot^{-1})	1992/93 (t ha^{-1})	1992/93 (t ha^{-1})	1993/94 (t ha^{-1})
SAR 29	6.3	-	3.2	2.0	0.8
SAR 33	2.3	5.8	1.8	2.5	0.5
SAR 19	3.4	-	2.6	2.1	0.8
SAR 35	1.4	10.8	1.8	2.4	1.0
SAR 37	2.9	7.8	2.2	2.0	0.9
SAR 16	-	5.0	-	-	-
DC 75	16.3	17.0	-	-	-
Marupanzi	-	-	-	2.9	-
AG 9	-	-	2.7	-	0.8
SV 2	17.1	8.8	1.7	3.9	1.2
SV 1	9.4	3.3	4.5	2.8	1.4
MMSH 413	10.3	14.3	6.7	4.6	1.7
MMSH 375	15.7	-	4.2	2.6	1.4
SDSH 148	-	8.8	-	-	-
SDSH 378	-	11.0	-	-	-
Muchayeni	-	5.5	-	-	-
Chibonda	-	12.0	-	-	-
SE	±3.2	±2.3	±0.2	±0.5	±0.3
LSD (F <0.05)	6.6	4.7	0.5	1.1	-
CV(%)	55.7	50.6	11.3	29.3	46.0

1. - = not tested.
2. *Striga*-free environment.

cultivars low yield. A comparable trend of results was obtained in 1993/94, but SV 1 and Muchayeni were among the low-yielding cultivars.

In field evaluations, sorghum cultivars produced grain yields that were significantly different in 1992/93 at Henderson ($P < 0.001$) and Chiwundura ($P < 0.05$). At Chiwundura grain yields were not significantly different ($P > 0.05$) in 1993/94. MMSH 413 produced the highest grain yields at Henderson and Chiwundura. Cultivars SAR 33 and SAR 37 produced low grain yields.

Association of 5. *asiatica* counts with sorghum parameters

In 1991/92 *S. asiatica* count was negatively associated with sorghum days to flowering and days to maturity (Table 4). Sorghum grain yield was positively associated with *S. asiatica* count. In 1993/94 this was negatively associated with sorghum days to maturity and positively associated with sorghum height. In the field evaluations at Chiwundura, *S. asiatica* count was not associated with sorghum parameters.

Table 4. The association of *Striga asiatica* count with sorghum parameters (r values), Henderson and Chiwundura, Zimbabwe, 1991/92 to 1993/94.

	Henderson		Chiwundura	
	1991/92	1993/94	1992/93	1993/94
Days to 50% flowering	-0.807**	-0.244 NS	0.419 NS	0.024 NS
Days to maturity	-0.786**	-0.294*	0.317 NS	
Plant height	-0.120 NS	0.292*	0.054 NS	0.126 NS
Root dry weight	-0.610 NS	0.140 NS		
Grain yield	0.383*	0.087 NS	0.205 NS	0.264 NS

Discussion

S. asiatica was found to emerge within 64.8 and 71.6 days from sorghum sowing. This period lies within the range reported for *S. hermonthica* (Olivier et al. 1991). S. *asiatica* emerges when most farmers have completed their weeding. This partly explains why farmers do not control *S. asiatica* in communal areas of Zimbabwe. For instance, the survey carried out in Mangwende and Chivi Communal Areas (Shumba 1986) showed that farmers were not controlling *Striga* even if it was present. S. *asiatica* in SAR 35 and SAR 37 failed to flower. These cultivars are important in reducing *S. asiatica* seed production.

Data from pot and field evaluations showed that cultivars SAR 29, SAR 33, SAR 19, SAR 35, SAR 37, and SAR 16 consistently supported low *S. asiatica* counts. This meant that these cultivars were resistant to *S. asiatica.* Similar results were obtained in Botswana and Tanzania (Riches 1988; Obilana et al. 1991). Knepper et al. (1991), using the modified checkerboard design, identified *S. forbesii* resistance to or tolerance of five sorghum cultivars: SAR 29, SAR 33, SAR 19, SAR 35, and SAR 37.

The combined February and March rainfall of 245.3 mm in 1991/92 and 32.0 mm in 1993/94 could have accounted for the differences in the *S. asiatica* counts obtained in the two seasons at Chiwundura. The suppressive effect on *S. asiatica* emergence caused by SAR sorghum cultivars was more pronounced in a season of low rainfall (1993/94) than a season of high rainfall (1992/93) at Chiwundura.

Differences in sorghum grain yields obtained at Chiwundura in the two seasons could be accounted for by the differences in the rainfall received. The sorghum grain yield data obtained from pot and field evaluations seemed to be related. For instance, the sorghum cultivars that were high- and low-yielding in pots were also high- and low-yielding in the field. The cultivar MMSH 413 produced high grain yields in both pot and field evaluations, whereas SAR 33 and SAR 37 invariably produced low yields.

Although sorghum cultivars DC 75, SV 1, SV 2, MMSH 413, and MMSH 375 produced high grain yields (Henderson 1991/92 pot data and Chiwundura 1993/94 field data), they supported high *S. asiatica* counts. So these sorghum cultivars should probably be described as tolerant of *S. asiatica.* On the other hand, the SAR cultivars consistently supported low *S. asiatica* counts and produced low grain yields. This could explain why *S. asiatica* was positively associated with sorghum grain yield in 1991/92, and the lack of association in the other seasons.

Conclusions

The fact that data from pots were almost related to those from the field means that the pot technique is essential in screening sorghum cultivars for *Striga* resistance. However, this technique cannot accommodate a large number of cultivars. An alternative is to use the recently developed agar gel assay techniques (Hess et al. 1991).

Since the SAR cultivars have been reported to be resistant to either *S. asiatica* or *S. forbesii* in Botswana, Tanzania, and Zimbabwe, they probably have stable resistance. In areas where farmers have failed to grow cereals because of witchweed infestation, the SAR cultivars—SAR 29, SAR 19, SAR 33, SAR 35, SAR 37, and SAR 16—may be recommended for cropping. However, there is a need to find out whether smallholder farmers will accept them. So there is also a need to improve the grain yield potential of the SAR cultivars through continued breeding work that includes on-farm trials.

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Fingerprinting of Sorghum Disease Nursery Cultivars by Random Amplified Polymorphic DNA Markers

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Abstract

Random amplified polymorphic DNA (RAPD) markers were used to characterize sorghum cultivars in the SADC/ICRISAT disease nursery. The use of single primers, 10 nucleotides in length, and of arbitrary nucleotide sequence resulted in the amplification of DNA fragments that were unique to some cultivars in the disease nursery. Fingerprint images of 10 cultivars are presented, and the application of RAPD fingerprinting for the identification of cultivars, the general evaluation of germplasm, and the possible improvement of the sorghum breeding program are discussed. It is concluded that genetic marker-based technology can be used to assist researchers in future sorghum breeding work.

Introduction

Sorghum is becoming the most important cereal crop in the African continent where drought is persistent. Not only has sorghum proved to be an ideal food crop for parts of the continent with low and marginal rainfall, but it can also be used outside the food industry. Sorghum, particularly sweet sorghum, has a huge potential as an energy source (Schaffert and Gourley 1982). Considerable genetic diversity exists in both cultivated and wild sorghums. Considerable effort has been spent on the collection, assembly, and storage of sorghum germplasm (Mengesha and Prasada Rao 1982). The importance of a broad genetic base for development of new cultivars is a recognized necessity. Traditionally, the collected material is evaluated for morpho-agronomic characters, insect and disease resistance, and drought tolerance.

The effectiveness of using these traits in other crops to estimate genetic diversity has been questioned (Brown 1979). The relatively long generation time of some

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accessions also means that some of the agronomic traits can be assessed only at maturity. The problem is compounded further by the fact that some of these traits are influenced by environmental factors. Furthermore, there are very strong possibilities that some landraces obtained from farmers' fields are reverted hybrids, because there is a tendency for some smallholder farmers to reuse their hybrid seed.

As molecular and biochemical markers are not subject to environmental influence, they provide an opportunity to examine the genetic variability within collected accessions. This technology has been used successfully with a number of crops (Bernatzky and Tanksley 1989). Isozymes are currently the method of choice for routine characterization of maize accessions (pers. comm., Nowell 1994). Nuclear restriction fragment length polymorphism (RFLP) has been and is still being used to fingerprint a whole range of plant species, but it requires the development of specific probes, and it is often time-consuming and labor-intensive. The same could be said for minisatellite DNA sequences that have been used to distinguish between genotypes of the members of the Rosaceae family (Nybom et al. 1990). Recently, the identification of DNA polymorphism in plants based on the polymerase chain reaction (PCR) has been described (Williams et al. 1990; Welsh and McClelland 1990).

The latter technique does not have many of the disadvantages of classical methods of genomic fingerprinting. And in this paper I report the application of the RAPD marker system (Williams et al. 1990) in fingerprinting sorghum genotypes from the SADC/ICRISAT disease nursery.

Materials and Methods

Plant material

Seeds from the sorghum cultivars listed in Table 1 were obtained from the SADC/ICRISAT Sorghum and Millet Improvement Program, Matopos, Bulawayo, Zimbabwe. The seeds were germinated on moist filter paper in a petri plate. Leaf material was harvested 2 days after germination. Genomic DNA was extracted from the leaf tissue according to a modified method of Coyne et al. (1994), with the following modifications. The DNA extraction was performed in a safe-lock 1.5-mL eppendorph tube and the leaf tissue was initially macerated in 0.5 mL of TE buffer (10 mM tris [hydroxymetnyl] aminomethane, 1 mM ethylenediamino tetraacitic acid [EDTA] pH 7.6). The relative concentrations of SDS (sodium dodecyl sulphate), proteinase K, NaCl and CTAB (hexadecyltrimethyl ammonium bromide) were as according to the original protocol. The extracted DNA was resuspended in a final volume of 100 µL.

Polymerase chain reaction (PCR)

PCR reactions (50 µL final volume) contained the following: 100 ng genomic DNA diluted in TE buffer, 200 µM each in final concentration of dATP, dCTP, dGTP, and

Table 1. Cultivars in the sorghum variety disease nursery used for characterization.

Cultivar	Color
N. Mex 31	Red
Hegari	White
Cargill 40	Red
SA 394	White
BTX 378 RedLan	Red
SC0175-14E	White
BTX 398-Martin	Red
QL 11	White
SV 1	White
QL 3 India	White

dTTP, and 0.5 µM primer. The reaction was run in IX *Taq* polymerase buffer containing 2 mM Mg^{2+} ion concentration, and 2.5 units of *Taq* DNA polymerase (Promega). Each reaction was overlaid with 50 µL of sterile mineral oil to prevent evaporation of the reaction mixture. The random nucleotide sequence decamers used in this study were purchased from Operon Technologies Inc., and are listed in Table 2.

Table 2. Base sequence of primers used in this study.

Primer number	Sequence 5' to 3'	%G + C
OPJ-2	CCCGTTGGGA	70
OPJ-3	TCTCCGCTTG	60
OPJ-4	CCGAACACGG	70
OPJ-5	CTCCATGGGG	70
OPJ-6	TCGTTCCGCA	60
OPJ-7	CCTCTCGACA	60

For amplification of polymorphic markers, the samples were subjected to 45 repeats of the following thermal cycle in a JDI Thermal Cycler, model 8012:1 min at 94°C followed by 1 min at 36°C and 2 min at 72°C. The first denaturation step was preceded by an initial denaturation step of 93°C for 2 min. The penultimate extension was also followed by a final extension of 72°C for 5 min. The fragments generated by random amplification were separated according to size in a 2% horizontal agarose gel slab run in IX TBE (89 mM tris-HCL [pH 8.3], 89 mM boric acid, 5 mM EDTA). The gel was stained with ethidium bromide and visualized on a UV transilluminator set at 254 nm. Twenty µL of the amplification product were loaded on each gel and at least one lane of *X* DNA cut with Pst 1 was included as a molecular weight marker.

Results and Discussion

An approximate concentration of 100 ng μL^{-1} was obtained for each DNA extraction of the 10 cultivars. To determine the suitability of the RAPD technique to fingerprint sorghum cultivars, six different decamer primers (Table 2) were used to amplify specific sequences within the genomes of the 10 cultivars of sorghum. Figures 1 to 5 show that amplification products could be obtained from all the sorghum cultivars and that these products could be easily resolved in a 2% agarose gel slab. The amplification products ranged in size from approximately 200 bp to 4 kb.

Of the six primers tested, one failed to produce amplification products, even after repeated attempts. The likelihood that its sequence is not present in the sorghum genome is minimal. The most likely explanation for the nonamplification is the presence of some inhibitory factor in the primer stock solution. As the primers were purchased from Operon Technologies in freeze-dried form and were then resuspended in the laboratory, it is possible that an inhibitory substance managed to contaminate the primer during the resuspension process.

All the other primers were able to produce amplification products, and their patterns on agarose gels could be observed with ease. Primer OPJ-7 was observed to be the best for discriminating between the different cultivars, although this primer could not differentiate between cultivars SC 0175-14E, BTX 398-Martin and QL 11.

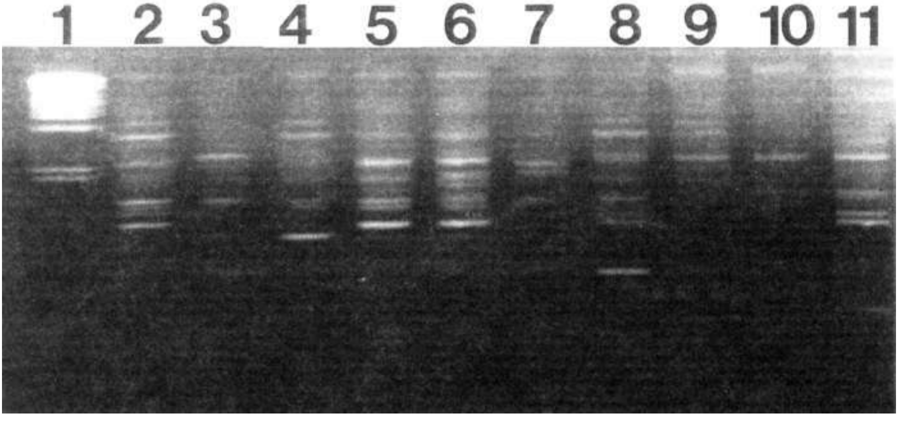

Figure 1. RAPD fingerprints of sorghum cultivars using primer OPJ-3. λ DNA cut with Pst 1 (lane 1), N. Mex 31 (lane 2), Hegari (lane 3), Cargill 40 (lane 4), SA 394 (lane 5), BTX 378 RedLan (lane 6), SC 0175-14E (lane 7), BTX 398-Martin (lane 8), QL 11 (lane 9), SV 1 (lane 10), and QL 3 India (lane 11).

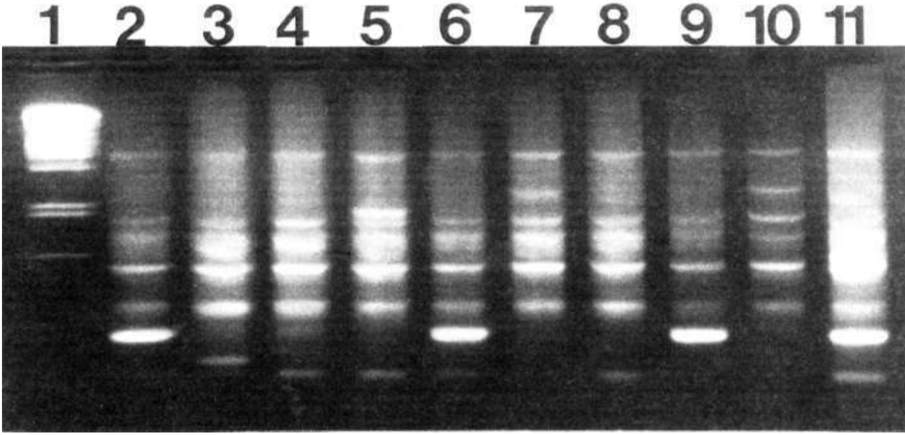

Figure 2. RAPD fingerprints of sorghum cultivars using primer OPJ-4. λ DNA cut with Pst 1 (lane 1), N. Mex 31 (lane 2), Hegari (lane 3), Cargill 40 (lane 4), SA 394 (lane 5), BTX 378 RedLan (lane 6), SC 0175-14E (lane 7), BTX 398-Martin (lane 8), QL 11 (lane 9), SV 1 (lane 10), and QL 3 India (lane 11).

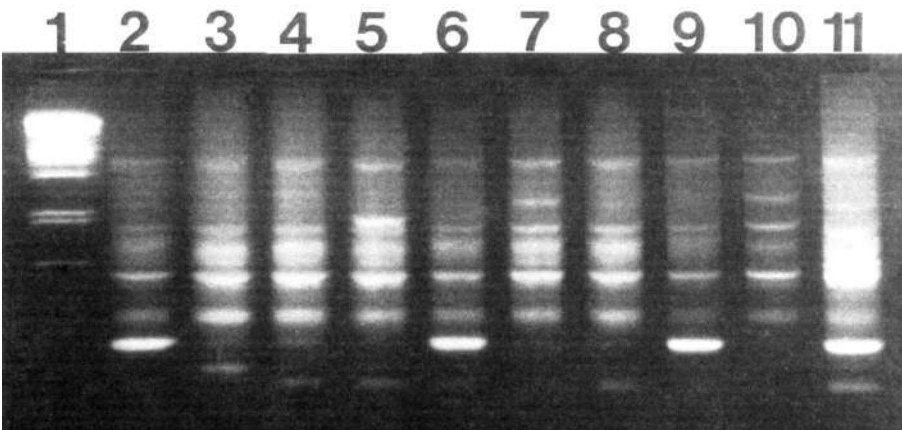

Figure. 3. RAPD fingerprints of sorghum cultivars using primer OPJ-5. λ DNA cut with Pst 1 (lane 1), N. Mex 31 (lane 2), Hegari (lane 3), Cargill 40 (lane 4), SA 394 (lane 5), BTX 378 RedLan (lane 6), SC 0175-14E (lane 7), BTX 398-Martin (lane 8), QL 11 (lane 9), SV 1 (lane 10) and QL 3 India (lane 11).

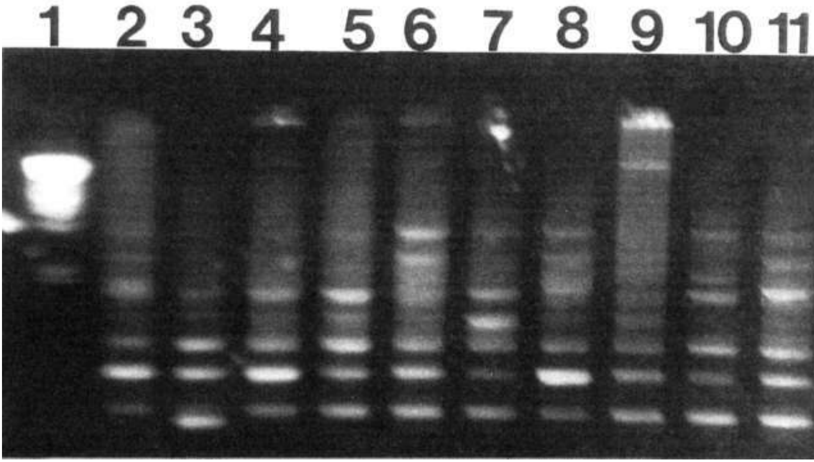

Figure 4. RAPD fingerprints of sorghum cultivars using primer OPJ-6. λ DNA cut with Pst 1 (lane 1), N. Mex 31 (lane 2), Hegari (lane 3), Cargill 40 (lane 4), SA 394 (lane 5), BTX 378 RedLan (lane 6), SC 0175-14E (lane 7), BTX 398-Martin (lane 8), QL 11 (lane 9), SV 1 (lane 10), and QL 3 India (lane 11).

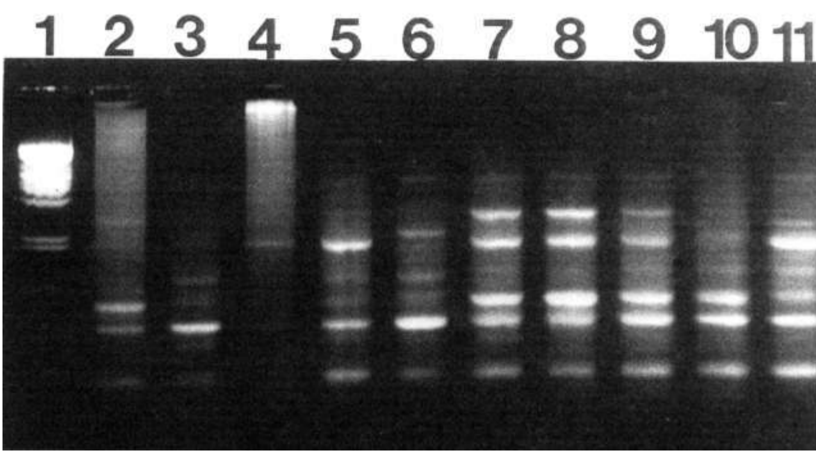

Figure 5. RAPD fingerprints of sorghum cultivars using primer OPJ-7. λ DNA cut with Pst 1 (lane 1), N. Mex 31 (lane 2), Hegari (lane 3), Cargill 40 (lane 4), SA 394 (lane 5), BTX 378 RedLan (lane 6), SC 0175-14E (lane 7), BTX 398-Martin (lane 8), QL 11 (lane 9), SV 1 (lane 10), and QL 3 India (lane 11).

This paper represents the first known attempt to use RAPD markers to fingerprint sorghum cultivars. A relatively small subset of sorghum genotypes was examined and an even smaller number of primers were examined. Nevertheless, RAPDs have proven to be an alternative method of discriminating between at least some sorghum cultivars. More importantly, the technique is simple and quick to perform and does not use radioactive isotopes, as in RFLP mapping; thus it can be used in localities where radioactive disposal is not well developed. Furthermore, the amount of DNA required to perform RFLP mapping is of several magnitudes more than that needed to perform RAPDs.

Conclusion

I have demonstrated that RAPD markers may be used to genetically fingerprint sorghum cultivars. A larger sample of genotypes and primers needs to be included in further studies. It is anticipated that the method described in this paper can have a major impact on the management of sorghum resources, and can act as a catalyst for the use of genetic marker-based technology for this very important crop.

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Socioeconomic Reflections on the Development and Performance of Improved Small Grains: Experiences from Zimbabwe

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Abstract

This paper outlines the development and diffusion of new sorghum and pearl millet varieties, and documents the setbacks encountered in the process. The paper then reviews the performance of two improved, small-grain varieties, PMV 2 (pearl millet) and SV 2 (sorghum), based on various studies that include the initial findings of the SADC/ICRISAT/DR&SS Small Grains Impact-Assessment Study under way in Zimbabwe in 1994. Both varieties were welcomed by farmers because they were high-yielding, of short duration, and easy to thresh; but farmers found PMV 2 very susceptible to bird damage. Concerning taste, both varieties were rated good but were less preferred to local landrace varieties, and both have limited storability due to their softness. Improved small grains, however, contribute to overall farm profitability.

Issues arising from small-grains research in Zimbabwe are identified as: (a) reducing the gap between yields obtained on research-managed plots and those of farmers; (b) the need to involve farmers in selecting for plant traits; (c) revitalizing agronomy programs; and (d) the need for researchers to take an interest in the technology- transfer process.

Introduction

Sorghum and pearl millet are traditional food crops in Zimbabwe, but they have been marginalized with the increased sowing of maize. The expansion of maize at the expense of small grains came about through vigorous research efforts that started in the 1930s, and the formulation of various policies favoring the production of maize (Kupfuma 1993a). In 1949, official crop production estimates for the African farmlands issued for the 1947, 1948, and 1949 harvests showed that maize accounted for about half of the grain output, followed by sorghum, finger millet, and pearl millet

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(Masters 1990). Research on small grains began in the 1940s and was mainly geared towards malting red- or brown-grain varieties that were grown mostly by commercial farmers. It was not until 1979 that objectives were remapped to include development of white-grain and hard-endosperm varieties suitable for human food consumption (Mushonga and Rao 1986). Breeding work initiated by the Department of Research and Specialist Services (DR&SS) culminated in the development of two open-pollinated sorghum varieties, SV 1 and SV 2, and two pearl millet varieties, PMV 1 and PMV 2.

This paper outlines the development of the new varieties and documents the setbacks encountered in the process. It further reviews the performance of the improved small grains among target farmers based on initial findings of the SADC/ICRISAT/DR&SS Small Grain Impact-Assessment Study, an initiative under way in Zimbabwe in 1994.

Development of the Improved Varieties

The two sorghum varieties, SV 1 and SV 2, were developed from segregating material introduced from ICRISAT in India (Mushonga and Rao 1986). They are both high-yielding, pearl white-grained and easily dehullable varieties. SV 1 was released in 1985, and SV 2 two years later. The pearl millet varieties, PMV 1 and PMV 2, were released in 1987 and 1991. The original population from which PMV 1 was selected came from the USA. PMV 1 was identified from mass selection and tested against local material. The variety was found to be high-yielding and of short duration (80-100 days). Material for PMV 2 came from SADC/ICRISAT, originally brought from populations at ICRISAT Asia Center. PMV 2 was tested at Matopos and in the DR&SS testing programs under different environments against local material, and was found to be superior in yield and duration.

Commercial seed production of improved varieties released by research services is done by the Zimbabwe Seed Co-operative under a tripartite agreement which gives the Seed Co-operative (Seed Co-op) monopoly rights to produce seed commensurate with the national demand for the major grain staples (SADC/ICRISAT 1993). Following the release of SV 1 in 1985, breeder seed was supplied to the Seed Co-op for bulking but nothing was done until 1989/90. In 1987, SV 2 and PMV 1 were released and also given to the Seed Co-op. Again, commercial seed multiplication stalled. PMV 2, released in 1991, faced the same problem. For pearl millet, the Seed Co-op encountered a special problem. Contracted commercial seed multipliers found pearl millet production less profitable than maize, and more risky because of bird damage. It was not until 1992/93 that the Seed Co-op contracted an NGO, Environmental Development Activities (ENDA), to multiply PMV 1 and PMV 2 at almost twice the Grain Marketing Board price, using communal farmers. The exercise produced enough seed to cover only 5% of the nation's projected pearl millet hectarage for the 1993/94 planting season (SADC/ICRISAT 1993).

The slow diffusion of improved small grains is largely a result of the malfunctioning of the seed multiplication mechanism. However, the seed marketing system also restricted the availability of improved sorghum and pearl millet seed. Up until the recent drought-recovery program efforts, seed was never widely distributed to communal farmers. Most farmers had little or no access to improved small grain seed (Rohrbach 1991). Though there were significant problems in the diffusion of improved small grains, some farmers managed to get access to the seed and grew it for several seasons. Feedback from these farmers on the performance of the improved small grains forms an integral part of the research process to ensure that national and regional research programs are delivering the right materials.

Farmers' Feedback

Any new technology developed should, among other things, offer a yield advantage over farmers' current practices, take cognizance of the grain and plant traits preferred by farmers within the farming system, and be compatible and profitable given the resource base of the target areas. For semi-arid areas, SV 2 and PMV 2 are the recommended varieties. An assessment of the two varieties based on yield level, profitability, and plant traits is presented below.

Yield level

Table 1 presents the results of the performance of the improved varieties in comparison with local landrace varieties (LLVs) during the 1992/93 cropping season. The data reveal that research-managed trial results are more than twice those attained by farmers growing the SV 2 and LLV sorghum. It is also interesting to note that the improved-sorghum yields are greater than those of LLVs (the expected scenario), but the opposite is true for pearl millet.

Table 1. Mean grain yields (kg ha^{-1}) of improved varieties SV 2 and PMV 2 compared with LLVs based on on-farm trials and farmers' estimates, Zimbabwe, 1992/93.

	Sorghum		Pearl millet	
	SV 2	LLV	PMV 2	LLV
On-farm trial results	2061	1764	1616	1257
Communal area harvest	1000	649	547	770

Source: SADC/ICRISAT 1993.

Profitability

Seed technology is more likely to be adopted than other agricultural technologies because it is cheaper to acquire. However, profitability is affected not merely by an addition of seed cost onto the variable costs. Other factors such as yield levels, market availability, and prices come into play. Mazhangara (1993) undertook a study to evaluate the potential impact of tied ridges, SV 2, and inorganic fertilizer usage on farm-resource allocation, enterprise mix, and farm household incomes in low-rainfall areas of Zimbabwe. Results of the study showed that uptake of SV 2 alone increased net farm income by 9%, while the adoption of tied ridges improved net farm income by 22%. A combination of the two technologies raised net farm income by 30%. SV 2 satisfies the household, annual-minimum grain-subsistence level with less hectarage compared with LLVs because it intensifies production and releases land to cash crops, which further increase farm profitability. When linked to a moisture-enhancement technology, the impact of SV 2 on income increases.

Plant traits assessment

Farmers adopt new crop varieties on the basis of acceptable plant traits apart from yield gains.

Stover yield is usually considered less important than grain yield and quality. Stover is important for granary construction and cattle feeding. In group interviews conducted in Masvingo, Midlands, and Matebeleland provinces by SADC/ICRISAT, PMV 2 stover was deemed less palatable and slow to decompose. Most pearl millet stover tends to be similar. Farmers preferred the stover from SV 2 because of its 'stay-green' quality.

The interviewed farmers stated that they saw no major differences between the LLVs and the improved varieties with regard to pest and disease tolerance or susceptibility.

Farmers found PMV 2 to be susceptible to bird damage. Farmers pointed out that, in contrast, bristled varieties would be less susceptible. The plant height of the improved small grains was favorably commented on by the farmers. Short to medium-height plants were preferred for ease of harvesting.

Farmers also strongly approved the short duration of the improved varieties.

Grain traits assessment

Small grains differ from maize in the way they are processed for consumption. They are threshed and winnowed before being pounded in a mortar for dehulling. After dehulling, the grains are roasted to dry them, and to enhance flavor. They are then ground on a stone or sent to a grinding mill to produce flour. It is possible the mortar stage will be by-passed by the use of mechanical dehullers, prototypes of which have been tested and reviewed favorably in the main sorghum and pearl millet growing areas of Zimbabwe. However, threshing still has to be done manually. Farmers stated that both PMV 2 and SV 2 were easy to thresh, a factor that strengthens the acceptance of the improved varieties.

With regard to taste, both PMV 2 and SV 2 were rated inferior to traditional LLVs.

The farmers expressed the need of a grain variety that should last up to 3 years in storage—an important trait in semi-arid areas. LLVs can last from 5 to 10 years in storage. The improved varieties tend to be soft, and hence very susceptible to weevil damage.

Emerging Issues for Small-Grains Research in Zimbabwe

The gap between the researchers' yields and the farmers' yields is becoming a cause for concern. Breeding programs target the release of high-yielding varieties. However, the farmers do not attain yields remotely approaching these. In conducting an economic analysis of any trial results, a 5-30% yield-adjustment factor is put on experimental yields to reflect what farmers actually receive as a result of differences in management, plot sizes, harvest dates, and methods of harvest (CIMMYT 1988). This is good practice for analytical purposes because it is a step towards reality.

Much of the potential to reduce the yield gap lies with crop husbandry, or management of the new varieties. Release of high-yielding varieties has shown that it is not always true that doubling the yields will lead to uptake. Breeding should take into consideration other plant and grain traits as well. While breeders do look at some of these aspects, it is the weight attached to these traits that needs to be openly demonstrated. Involvement of farmers in the selection process is one step in the right direction, especially for grains whose end-use is home consumption rather than the market.

Institutions should reallocate resources to tap the vast agronomic potential. Agronomists should work with social scientists and farmers. Most on-farm trials have been research-managed and have tended to produce yield levels that differ from the farmers'. Agronomic recommendations need to be revised. For instance, research recommendations on fertilizer application are unusable because they are targeted at high-potential, large-scale commercial farming, a totally different agro-socioeconomic environment.

Mombeshora et al (1989) reported that farmers in semi-arid areas do not use fertilizers at all. Where current fertilizer recommendations on sorghum and pearl millet may produce statistically significant yield difference, the levels of fertilizer applied tend to be uneconomic (Kupfuma 1993b). Therefore, farmers do not even apply fertilizer on small grains (Chipika 1988). Work with other forms of soil-fertility maintenance rather than chemical fertilizers, in combination with moisture-enhancement techniques, should be tried.

On-farm trials that are research-managed tend to help researchers to test the performance of technologies in soil and physical environments different from those on the station, but they do not permit the influence of farmer-management to be felt. As in the case of the PMV 2 and SV 2, some of the weaknesses of the varieties were not apparent, even using on-farm trials. As a solution, farmer-managed verification trials ought to be introduced early in the technology-generation process as a solution. In such trials, researchers should provide only seed (or the technology) and information on the new technology, then make periodic visits to observe and collect management and yield records, getting farmers' comments. Such trials should be given more weight since they enable saving of research funds through facilitating early detection of activities that need fine-tuning.

There is some current thinking in favor of promoting drought-tolerant cash-cropping in the semi-arid areas in view of grain liberalization, so that farmers can sell cash crops and, with the income, buy grain from surplus areas. While conceivable in theory, this is not really practical because the food-first strategy is firmly rooted among many smallholders. Farmers in semi-arid areas prefer to produce dual-purpose crops, i.e., crops that are meant for home consumption and are marketable whenever a surplus exists. This is one among numerous reasons why maize is produced in semi-arid areas. Improved small grains, particularly sorghum, enhance overall farm profitability by releasing land to be sown to higher-value crops while meeting the subsistence food consumption with minimum hectarage.

Technology transfer has traditionally been a concern outside agricultural research. The recent breakdown in seed multiplication for improved small grains serves as a reminder of the need to concentrate some energy and resources towards the transfer of technologies if research is to have some impact.

Conclusion

Increased availability of new small-grain varieties considerably enhanced food production in the semi-arid areas of Zimbabwe.

Farmers interviewed in groups appreciated the short duration and drought tolerance of the improved varieties. They pointed out, however, that taste and grain storage were weaknesses of the improved varieties. Yieldwise, a large gap remains between the farmers' and researchers' plots, and effort is needed to reduce it. Revitalizing agronomy programs, and early involvement of farmers in the research process should go a long way in reducing this gap.

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Promotion of Small Grains Seed Production by an NGO in Zimbabwe

D Shumba[1]

Abstract

Hybrid seed has been replacing local landrace varieties (LLVs) grown by smallholder farmers, leading to the disappearance of local germplasm. For its conservation, and to increase its availability, participants in the ENDA-Zimbabwe Indigenous Seeds Project have collected the LLV seed of 116 small grains (sorghum, pearl millet, finger millet) and of 11 open-pollinated maize varieties, and subsequently characterized, selected, and improved these LLVs. Seeds have been multiplied for distribution, and an exchange program between communal farmers is in operation. Additionally, two sorghum and two pearl millet improved LLVs are being evaluated by Zimbabwe's Research and Specialist Services.

ENDA has subcontracted smallholder farmers to multiply improved varieties of small grains. In 1994 they provided about 90% of the supply of released pearl millet seed in the formal market, but an insignificant amount of sorghum seed.

Dehulling and grinding technology has been developed and commercialized, with 71 systems in place, and meal marketing trials for small grains were started in 1994.

Introduction

ENDA-Zimbabwe (ENDA) was established in 1983 from activities connected with drought relief. Its program of work has evolved and expanded to involve rural and urban households in various projects that address issues of food security, environment-resource management, and employment.

ENDA strives to promote and develop opportunities for wealth creation for the rural and urban poor through sustainable natural resource use and development of the capacity of Zimbabwean human and institutional resources. Its mission is to empower local communities to identify their needs and participate in the formulation of sustainable development programs.

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A major ENDA thrust is to achieve household food security in the marginal rainfall areas of Zimbabwe by promoting the production of small grains, because they are more drought-tolerant and can be stored longer than the country's staple crop: maize.

Among other factors identified, key constraints in small grains production in Zimbabwe are:

- Low crop productivity.
- High labor requirements.
- Low market prices (especially in formal markets).
- Nonavailability of improved varieties. Although several varieties have been released, their diffusion to smallholder farmers has been limited.
- Aggressive marketing and extension of maize hybrid seeds by the seed industry and government agencies.
- Low taste preference for small grains.
- Low and uncertain rainfall in the areas where small grains are grown.

This paper describes three ENDA projects that promote the production, consumption, and alternative use of small grains in marginal rainfall areas of Zimbabwe.

Indigenous Seeds Project

Introduction

In May 1985 ENDA launched this action-research project designed to explore the traditional cultivation and use of maize and small grains in the marginal rainfall areas of Zimbabwe. The Zimbabwe Seeds Action Network (ZSAN) project was born as a result of the frequent droughts affecting smallholder farmers located in drought-prone areas. The research project aimed to promote the cultivation of small grains and develop an alternative to the use of hybrid seed.

ENDA found the alternative to hybrid seed to be a traditional seed network that resulted in the conservation, multiplication, and dissemination of these seeds. The goal was not to undermine hybrid seed production, but rather to complement it in an effort to ensure that communal farmers in remote drought-prone areas of Zimbabwe had a more reliable food base. A further goal was to establish a network linking farmers, government bodies, local agriculture-oriented institutions, and development aid organizations concerned with smallholder food production.

A research project was carried out to identify which cultivars are sown in marginal rainfall areas, how they are preserved and used, and farmers' attitudes towards them. The research methodology consisted of secondary data collection, in-field farmer discussions, questionnaire administration, and planning at the grassroots level.

From this research ENDA established that traditional LLVs of maize and small grains are grown in remote, drought-prone areas; that these grains play a significant role in the local economy; and that communal farmers were enthusiastic about participating in a grassroots initiative to produce, store, and distribute indigenous seed. So the component of a seed exchange program among participating farmers in different areas was added to the project. This necessitated the additional establishment of demonstration plots to evaluate the performance of the LLVs.

Farmers played a significant role in conserving plant genetic resources in situ by:

- actively participating in collecting and preserving LLVs;
- sharing their knowledge of LLV diversity, thus making it possible to capture all the different alleles;
- doing on-farm characterization and evaluation work and identifying preferred crop characters (of particular value in subsequent variety improvement);
- establishing seed improvement programs and seed distribution and supply systems.

ENDA believes in a participatory model of development-action to ensure that all relevant technologies are learned by all participants, and to maximize the chances that projects continue and develop even when outside assistance has come to an end. The Indigenous Seeds Project was therefore implemented with full farmer involvement.

A total of 116 LLVs of sorghum, pearl millet, and finger millet were collected from Manicaland, Mashonaland East, and Matebeleland South and North. These included 34 pearl millet, 55 sorghum, and 27 finger millet LLVs. Also collected were 11 open-pollinated maize LLVs.

A selected number of these LLVs were multiplied in 1985/86 and distributed to farmers. The technique of mass selection in order to improve the seed was used in the following areas:

Manicaland Province	- Chipinge District	- Checheche Ward
Midlands Province	- Zvishavane District	- Mototi Ward
Matebeleland South	- Plumtree District	- Empandeni Ward
Mashonaland East	- Mutoko District	- Nyamutsahuni and Kawere Wards

In its seed improvement program, ENDA emphasizes the importance of working on-farm. After the 1992/93 season, two selected LLVs of sorghum (Chibonda, Mu-chayeni) and two pearl millet LLVs (Tsholotsho Bearded, Hangariya) were sent to the Research and Specialist Services for evaluation of their performance.

Farmer participation in selection work

The LLV material collected was subject to thorough selection and accession. Groups of farmers, particularly women, were involved in the selection process. They were competent in identifying such crop accessions characters as: preferred husk and seed color; size of grain; ease with which the husk can be removed; cooking quality; palatability; storage quality; and suitability to different types of soil and terrain. Negative genotypic or phenotypic resemblance to a known character was considered, but the most important feature was homogeneity of the resultant material. This work provided accurate information on the characters present in the material and those preferred by users.

Six villages in each ward, consisting of 100 households, participated. Farmers in each project area elected a ward seed committee, which was asked to assist the local coordinator in selecting plot holders. These were involved in many activities: germplasm characterization, evaluation, agronomic trials, seed improvement, and organizing meetings of farmers for specific activities. The project thus became community-oriented and had a beneficial effect on households' socioeconomic status.

Indigenous Seeds Project Phase II

In this second phase the research priority is to facilitate the growth of seed supply systems which can be alternatives to the present formal system.

ENDA trains farmers to multiply and use the elite seed stock best suited to their conditions. The farmer is encouraged to continue to use his/her improved LLVs. This ensures the effective use of the superior germplasm without any serious risk of losing hitherto unexplored superior germplasm present in the LLV population.

Varieties developed from locally adapted LLVs could also be used as control entries in the national crop improvement program, to enhance the process of selection of varieties to be released.

Objectives of the second phase are:

1. To characterize (on-farm) all collected germplasm.
2. To assess its overall agronomic performance in comparison with nationally released varieties.
3. To assess and investigate the socioeconomic, cultural acceptability, and sustainability factors involved in establishing a local small grains seed multiplication, distribution and supply system.
4. To establish communal farmer shareholder seed companies.

In 1993/94 the controlled seed multiplication of LLV small grains was in progress in the four project areas, and 24 t was multiplied by the 24 participating villages. Some of the LLVs proved to be fairly high-yielders (Table 1).

The Indigenous Seeds Project facilitates formal seed exchange among communal farmers, a reform that creates options alternative to the present monopolistic seed supply system. It conserves the locally-produced LLVs in regard to varietal performance, and there appears to be a small yield gap between the improved varieties and the LLVs tested. Improved varieties mature earlier than LLVs, and therefore have the benefit of attaining physiological maturity when rainy seasons are short (see Table 1 for comparison: sorghum SV 2 matures in 115 days and pearl millet PMV 2 in 85-90 days).

Small Grains Seed Multiplication Program

During the 1992/93 season ENDA was approached by the Seed Co-op Company of Zimbabwe to subcontract smallholder farmers in the communal areas to produce

Table 1. Average yield and duration of sorghum and pearl millet LLVs in five locations, Zimbabwe, 1993/94.

Crop	Variety	Days to maturity	Location[1]	Average yield ($t\ ha^{-1}$)
Sorghum	Muchayeni	122	Mutoko Kawere NR IV	0.725
	Chibonda	119		1.180
	Muswewehachi	128		1.083
	Muchayeni	122	Nyamutsahuni NR IV	1.123
	Chibonda	119		1.065
	Muswewehachi	128		0.615
	Mukadziusaenda	110	Chipinge NR IV	1.108
	Muswewehachi	130		0
	Mutode (short)	107		0.900
Pearl millet	Nyakashiri	113	Mutoko NR IV	1.015
	Bandara	107		0.318
	Tsholotsho bearded	110	Plumtree NR V	0.415

1. NR = Natural Region: NR IV - annual rainfall 400-650 mm;
NR V - annual rainfall < 400 mm.

seed of sorghum variety SV 2, pearl millet variety PMV 2, finger millet variety FMV 2, and groundnut varieties Bibiano Branco and Falcon. The major task was to provide smallholder farmers in the semi-arid areas of Zimbabwe and other SADC countries with small grains because most commercial seed producers offer only hybrid maize, soybean, groundnut, and wheat. Only a few large-scale commercial farmers are engaged in the bulk production of sorghum seed. And, because of problems associated with seed production, no Zimbabwean commercial farmer has participated in pearl millet seed bulking. The main reasons are the low yield of the crop, the possibility of severe bird attack, and the need to harvest by hand.

National and export seed requirements for sorghum and pearl millet, based on demand projections, are shown in Table 2. Tables 3 and 4 indicate data for seed sales records in Zimbabwe and for export, and show to what extent smallholder farmers contribute to the bulking of small grains seed.

Up to 1994 smallholder farmers have contributed an insignificant amount of sorghum seed but as much as 90% of pearl millet seed. ENDA has not been meeting its targets in small grains production for several reasons:

a) No staff were allocated specifically for seed bulking work, which made monitoring difficult.
b) Few smallholder farmers used fertilizers because they were recovering from the 1991/92 drought.

Table 2. National and export seed requirements, Zimbabwe, 1993/94-1995/96.

Crop	Seed requirement[1] (t)			Produced by commercial farmers (t)		Produced by small-holder farmers via ENDA contract (t)	
	93/94	94/95	95/96	92/93	93/94	92/93	93/94
Sorghum							
SV 2	2000	2000	2000	84.85	1540	30	4
Pearl millet							
PMV 2		400	1450	0	0	15	20
Finger millet							
FMV 2		200	100	0	0	10	0.35
Groundnut							
Bibiano Branco		350				10	13
Falcon		500					66

1. Requirement based on demand projections.
Source: Seed Co-op Company: 1994/95 Seasons Estimated Sales Report.

Table 3. Sorghum seed sales (t), Zimbabwe, 1985/86-1993/94.

Sales (local)	Drought relief	DC 75	SV 2	% change (SV 2)	Produced by smallholder farmers	% of total
1985/86	0	65.48	0	0		
1986/87	0	76.9	0	0		
1987/88	0	36.6	58.45	0		
1988/89	0	61.55	61.95	5.98%	0	0
1989/90	0	100	48.05	-22.43%		
1990/91	0	77.5	69.3	44.22%		
1991/92	0	164.75	93.75	35.28%		
1992/93	400.6	131.1	34.55	-63.14%	30	26.12
1993/94	229.7	114.8	114.85	232.4%	4	0.26
Carry-over 31/03/94		16.75	0			
Estimated 1993/94 production		360	1545	1245.23	4	0.26%
Total availability		376.75	1545			
Estimated local sales 1994/95		250	395			
Estimated export sales 1994/95		56.75	1150			
Carry-over		70				

Table 4. Pearl (PMV) and finger (FMV) millet seed sales (t), Zimbabwe, 1991/92-1993/94.

Sales (local)	Drought relief	PMV 2	FMV 1	FMV 2	Total	Change (%)	Produced by ENDA	% of total
1991/92	0	14.1	0	0	14.1			
1992/93	112.15	0	0	0	0	-100%	25	
1993/94	245.5	7	0	0	7		20.4	17.3
Carry-over 31/03/94	0	66.2	25	0	66.2			
Estimated 1993/94 production	0	60	25	0	85		20.4	17.3
Total available	0	126.2	25	0	151.2			
Estimated local sales 1994/95	0	126.2	25	0	151.2			
Estimated export sales 1994/95	0	0	0	0	0			
Carry-over	0	0	0	0	0			
Required production 1994/95		840		75	915			

c) Farmers in communal areas have an average of 2.5 ha arable land; in resettlement areas ±5 ha arable; and in small-scale commercial farming areas ±50 ha. Thus the hectarage sown for seed crops by individual farmers varies, and some competent farmers are limited by the area of land available to them.

In the 1994/95 season it is planned that ENDA will subcontract 2100 farmers to produce 575 t of sorghum seed (SV 2), 475 t of pearl millet seed (PMV 2), 50 t of finger millet seed (FMV 1), and 475 t of LLV pearl millet and sorghum.

Small Grains Milling Project

Since 1986 ENDA has been complementing its efforts in promoting small grains production by introducing small grains dehulling and milling systems in rural areas with marginal rainfall, in order to remove bottlenecks in small grains processing, and diversify ownership in the milling industry.

ENDA developed the dehullers to suit the rural farmers' conditions by modifying large-scale dehullers. By 1994 71 systems were operational, and ownership ranges from individual women to women's groups and businessmen. They are located across target zones in Manicaland, Matebeleland North, Matebeland South, and Midlands provinces. A marketing test for sorghum and pearl millet meal has been started, with a view to finding new ways of selling small grains.

Summary of Achievements in these Projects

ENDA has:

- Helped significantly in harnessing the erosion of germplasm in the semi-arid areas together with communal farmers.
- Developed and implemented small grains seed characterization and multiplication programs with communal farmers.
- Conserved in-situ and ex-situ germplasm.
- Formed small grains seed committees at ward level that are responsible for the production and distribution of seed.
- Introduced dehuller technology into small grains production areas of Zimbabwe (where 33% of the new systems are owned by women as individuals or groups).
- Encouraged the production of small grains in marginal rainfall areas.
- Raised household incomes through the production of seed.
- Established backup seed-production plots in areas of better rainfall patterns.
- Investigated strategies for marketing small grains products.

The Future

Though these achievements are being complemented by the government's policy on food security for marginal rainfall areas, much remains to be done to change the current status of small grains in the marketing scenario in Zimbabwe. Whenever an excess of small grains is produced, smallholder farmers have few advantageous ways of disposing of the surplus.

The multiple choices that arise in using small grains products must be made known to a wider public. If such knowledge adds value to the crops they might compete better in the market with maize, which currently has a price advantage of 60%. And an upward price movement would help to motivate farmers to produce environmentally appropriate crops in marginal rainfall areas.

Studies on Sorghum-Based Products in Botswana

O Ohiokpehai and M Kebakile[1]

Abstract

In order to popularize the use of sorghum and pearl millet in Botswana, attempts were made to produce attractive and ready-to-eat food products from sorghum and millet flour after abrasive milling. Sorghum pasta, instant beer powder, health food powder, fermented sorghum (dry ting*) powder and a nonalcoholic 'malt' drink were produced and evaluated. The production processes were improved to permit the food and beverage product to be prepared in small-scale enterprises for income generation. Also, the unbalanced diet of the most* vulner-*able in the society was investigated. Sorghum flour-product was fortified with legumes found in Botswana and neighboring countries and fried or steamed to improve their nutrient intake for growth and development during critical stages in their lives. The study shows that there is potential in the use of sorghum and millet for food and beverage production.*

Introduction

In Africa, sorghum is used extensively. Palmer (1992) stated that we are the product of our geography. It is easier to grow wheat and barley in Europe and north America than sorghum in Africa. So we remind ourselves: sorghum is the natural cereal of the African continent and other semi-arid regions of the world.

Why is there a problem with sorghum? One reason is that modern research and technology seem to have neglected sorghum. However, it is still possible to change this situation if we work together to produce the quantity and quality of sorghum needed for beverages and food that can alleviate hunger and malnutrition in many African and Asian countries.

In most parts of the developing world, research on sorghum should reflect the needs of people rather than scientific curiosity (Palmer 1992). And in Botswana, where harsh climatic conditions are not favorable for growing crops, there is a particular need to search for alternatives in the development of the rural populace.

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Ohiokpehai, O., and Kebakile, M. 1996. Studies on sorghum-based products in Botswana. Pages 235-247 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Sigwele (1993) reviewed the reasons why the government of Botswana switched from a food self-sufficiency policy in agriculture to one of food security at both household and national levels. The government realized that increases in food production alone were not sufficient to ensure permanent access to food. It became clear that the food self-sufficiency policy did not improve the livelihood of the poorest: mostly women, children, and the unemployed. So the food-security policy of Botswana currently supports effective domestic food production, external trade, and such backup activities as creation of the Strategic Grain Reserve and both agricultural and nonagricultural diversification—for the generation of employment and income that enables people to buy food at all times.

This governmental support for diversification has been interpreted by us as a mandate for the formation and nurturing of manufacturing enterprises in the area of food processing and engineering. Such technology enables food to be preserved economically and in a nutritionally complete and compact form, and should thus be promoted as a means of achieving long-term food security.

The Importance and Uses of Sorghum in Botswana

Introduction

Sorghum is grown for consumption by both smallholder villagers and urban dwellers. So a national production policy for the crop must take into account its use by the very poor as well as its use in manufacturing.

Botswana consumes 60 000 t of sorghum annually (Nicholson 1992). About half is produced within the country and the rest is imported, mostly from South Africa. In milling the domestic produce, the horizontal abrasive dehuller is used, with a range of products: malts, meal, grits, rice-like grains, and as animal feeds (Van Vuuren 1992).

There is a need to increase public awareness of the different food products that can be made from sorghum. This paper therefore describes postharvest production procedures, involving sorghum 'malt' drink, sorghum pasta, health food, improved sorghum beer powder, malted sorghum, dried *ting,* and sorghum-legume blends *(ting + ditloo;* sorghum + cowpea), that have been developed and tested by the Food Technology Research Service (FTRS). Also, the use of products from these foods in households and for income generation is discussed.

Commercial uses

Sorghum is used in making a wide range of soft and stiff porridges, fermented beverages, and fermented foods.

Enriched sorghum meal. This is used by both old and young in the form of stiff (*bogobe*) or soft (*metogo*) porridge. Sorghum flour is produced mainly by South

African companies and imported into Botswana. However, Foods Botswana, Serowe, produces some locally.

Sorghum malt (*momela*). This is also imported from South Africa as 'maltamella' or from Zimbabwe as 'maltabella'. In recent times Foods Botswana has produced small quantities for sale.

Sorghum malt for sorghum beer brewing. Some sorghum malt is produced for beer (*bojalwa*) making. The malt is produced by Shapane Malt Factory, Tuli Block, and Foods Botswana, Serowe. However, most good-quality malt is imported from South Africa.

Instant beer powder. This product consists of malted sorghum, pregelatinized maize, yeast, sugar, and preservatives. Most brands marketed in Botswana are produced in South Africa.

Weaning food. Tsabana is a weaning food (Institute of Brewing 1992) produced by Foods Botswana, Serowe. It is distributed free at government clinics to children aged 4-36 months.

Livestock feed. Some sorghum is used in animal rations in feeding poultry, cattle, and pigs.

Global Uses of Sorghum

There have been initiatives in utilizing sorghum and other small grains in the USA and African countries that will have a beneficial long-term effect on the way that sorghum is used. In Nigeria its use for brewing lager beer and for preparing baked products and weaning foods (Olatunji 1993; Aisien 1989) is noteworthy. Sorghum malt is also used for nonalcoholic and other alcoholic beverages (Ohiokpehai 1991).

In recent years there have been helpful improvements in the malting process (Ohiokpehai et al. 1992; Dewar and Taylor 1992). It is believed that modification of the malting/brewing procedure and use of appropriate sorghum cultivars will reduce the quantity of enzymes used in brewing with sorghum.

Rooney (1992) reported that in the USA new sorghum hybrids with white kernels, tan plant and straw glumes, and hard endosperm had been released. It is also reported that parboiling enhances sorghum and pearl millet milling yields, and that parboiling makes the production of couscous and fried rice products easier. Lekalake (1993) described the production of noodles from 100% sorghum flour: the flour is kneaded into a partly gelatinized flour to produce a dough which is rolled into noodles with a hand-operated extruder. Best results are obtained when a white food-type sorghum is used.

Research and development work by Gomez and Chigumira (Zimbabwe), Faure and Fliedel (CIRAD, France), and others has additionally added to our knowledge of potential uses of sorghum.

Special Technologies in the Food Industry

To maintain the momentum of this work on both traditional and 'new' products of sorghum, breeders must provide food technologists with appropriate varieties. Biochemists must use innovations in biotechnology, brewing, and animal science to assist in creating products that are acceptable to consumers in respect of color, flavor, texture, viscosity, and nutrition. And engineers must overcome the backlog of work in improving sorghum processing technology for food and beverage products.

Experimental Food Preparation with the Help of Enzymes

Use of enzymes in the food industry

Enzymes are biocatalysts found in a wide variety of living organisms. They catalyze most of the reactions occurring in nature. Enzymes are composed of long chains of amino acids, arranged strictly in an orderly sequence. Therefore they are proteins.

The manufacture of enzymes for food applications is subject to government control, and producers are required to adhere to strict guidelines. Enzymes are environment-friendly, safe for the consumer, and function optionally under mild changes in temperature, pH, pressure, and moisture content.

The most important aspect of enzymes is that very small quantities are needed for a reaction to take place. Sample reactions are as follows:

- Alpha-amylase: hydrolyses starch to sugar and dextrine.
- Neutral protease: hydrolyses protein to amino acids and peptides.
- Fungal amylase: hydrolyses starch to fermentable sugars and limits dextrine.
- Amyloglucosidase (AMG): hydrolyses alpha-linked dextrines to glucose.
- Cellulase: hydrolyses cellulose and other beta-linked glucose polymers to glucose.
- Beta-glucanase: hydrolyses beta-glucans to glucose.

Materials and methods used in the experiments

Ground pearl millet (from Senyanwe Mills, Senyanwe) purchased at a supermarket in Gaborone.

Ground sorghum (Segaolane variety supplied by Botswana Agricultural Marketing Board, Pitsane: pearl white grains with excellent dehulling ability). The sorghum was commercially ground by abrasive milling.

Cowpea (TVX-3236-016 variety supplied by the Department of Agricultural Research, Sebele).

Jugo bean, *ditloo,* and maize were bought in the open market at the Central Mall, Gaborone. The *ditloo* was hand-picked to obtain a uniform cream color. The grains were ground with a hammer-mill (Reduction and Sampling Equipment Co., South Africa).

Malted sorghum (was produced in the manner described by Ohiokpehai et al. 1992).

Other ingredients: ascorbic acid, tartaric acid, citric acid, benzoic acid, brewing salts, dried yeast, hops, caramel, stabilizers, etc. These ingredients were purchased from National Foods Products, Johannesburg.

The solar dryer used was developed and built by the Engineering Unit of the Botswana Technology Center, Gaborone.

Enzymes: termamyl activity, 120 L (temperature-stable, alpha-amylase): Novo Nordisk Ltd.

Neutrase (neutral protease) activity, 0.5 L: Novo Nordisk Ltd.

Fungamyl (fungal alpha-amylase) activity, 800 L, Novo Nordisk, Ltd.

Amyloglucosidase (AMG, glucoamylase) activity, 300 L: Novo Nordisk Ltd (liquid and powder forms).

Preparation of sorghum *ting*

An elderly lady was asked to produce ting as she would normally do at home. She supplied us with some of this ting prepared at home as a 'starter' for comparison. While she worked, we monitored the parameters that would assist us in making the product in the same way: temperature of the water and moisture content of the mixture at the beginning and end of fermentation.

When the fermented sorghum was produced without a 'starter', the pH was monitored for 50 h. The production process was as follows.

Flour (2808 g) was added to warm water (temperature 45-50°C, 2450 mL) plus 600 g of wet 'starter'. The mixture was thoroughly mixed and temperature and pH readings were recorded (pH 6-7 at 35-37°C), and the plastic container was then covered.

In order to ensure that fermentation would be achieved within 24 h in our pilot plant, at a temperature of 20-25°C, the container cover used during the summer was a blanket; but during the winter two blankets were necessary.

We attempted to take readings of the bright pink color of the finished product, using a spectrophotometer at 300 nm. But these readings were abandoned because they were not consistent. The finished product was also tasted by all the nationals in the laboratory, and the pH and moisture content were recorded when the completion of fermentation was certified.

To dry the ting the water was decanted by allowing it to drain at 22°C for 4 hours. After the initial learning process, the amount of flour was adjusted to 2000 g, water to 1800 mL, and starter to 450 g. The temperature and pH remained the same.

The produced *ting* was dried in the solar dryer cabinet with perforations at the bottom, designed to allow water to drain out and hot air to enter.

After drying, stiff porridge was prepared. But we found that this was not as sour as the original wet *ting.* This development prompted us to think of replacing the acids lost during drying. Ideally, lactic acid was the acid to add, but we decided to add tartaric acid at 2%. Tartaric acid is easy to purchase from shops in rural areas, and it was already being used by other producers. The process sequence is shown below:

- Sorghum grain
- Clean
- Abrasivemilling
- Add water (1:1) + 'starter'
- Mix well (mixture at 35-38°C, pH 6-7)
- Ferment (at 20-25°C for 24 h)
- Drain water (pH 3.5-3.7)
- Dry residue
- Grind residue
- Add vitamin C + benzoic acid + tartaric acid.

Sorghum health food (snack or breakfast cereal)

Sorghum flour was precooked with the addition of termamyl, neutrase, fungamyl, and amyloglucosidase at different temperatures and contact time (Jepsen 1993; Aisien 1989). The mixture was allowed to dry in the solar dryer. After drying the flour was ground, and citric acid, vitamin C, and preservatives were added. The product was packaged in poly bags of 200 g each.

Pasta production

Pasta was produced by the gradual addition of water to sorghum flour, with mixing to ensure even distribution. The amount of water added was just enough to allow for the mixture to form small balls.

Later, dough 'balls' were prepared by pressing the flour together. The dough balls were cooked in excess water for 30 min, cooled, and then cut into pieces with a knife. These pieces were placed in the extruder, and a small-sized die was used for extruding the noodles. A bench pasta-maker was used (Pasta Express Machine, Model X2000, Creative Technologies Corp. Brooklyn, NY).

The extruded noodles were cut, boiled, drained, and dipped in ice-cold water. They were separated, placed on an aluminum foil, and then dried at 50°C in the oven. Dried pasta was then packaged in poly bags. Detailed method of pasta production is as reported by Lekalake (1993). Also some of the noodles were fried and packed in poly bags.

Alcoholic powdered drink (instant beer powder)

This consisted of dry gelatinized sorghum and maize flour, sugar, dried yeast, manucol, AMG, brewing salts, vitamin C, and preservatives. Water was added at 5 L to 1 kg of powder. These ingredients were mixed well and packaged in poly bags.

Nonalcoholic 'malt' drink

Brewing of sorghum and millet mixture was carried out using AMG, brewing salts, food-grade acid, hops, caramel, manucol, and ascorbic acid, as reported by Jepsen (1993), in a modified process, as follows:

- Mashing (milled sorghum/millet)
- Mash filtration
- Wort boiling
- Trub separation
- Cooling
- Filtration
- Packaging
- Pasteurization
- Distribution.

Sorghum-legume blends (weaning foods or snacks)

Three sorghum-and-legume flour mixtures were prepared:

Ting + *ditloo* (fermented sorghum plus jugo beans, 50:50).
Sorghum 4- cowpea (70:30).
Tsabana sorghum + soybean (as standardized by the Institute of Brewing 1992).

These were formulated to compare with the commercially produced weaning food (Tsabana) which was developed by the Food Technology Research Service for the Ministry of Health. The protein content for the mixtures was 15%. We envisaged that these mixtures could be used as weaning foods and/or high-quality foods, after boiling or frying into *akara* or steamed cake at household and national level, for income generation.

The sorghum/cowpea blend was hydrated with water (57-60%) to make a paste. This paste was fried in small quantities in hot oil. During frying the balls floated on the oil and retained a flat structural integrity. They were regarded as ready for eating when their outer coats turned golden brown. Steamed cakes were also produced by placing the paste in a folded aluminum foil and boiling it in a pot.

Chemical analysis was carried out by the AOAC method (1990); and determination of the sorghum diastatic power (SDU) followed the method proposed by Morral et al. (1986).

Results

Dry fermented sorghum production

Experience gained by participating in the production of *ting* by traditional rural methods assisted greatly in improving the process and in producing a product acceptable to national consumers. It was important that the taste, color, and chemical composition of *ting* produced by us should be closely similar to locally-produced *ting* (see comparative data in Table 1). The pH level is particularly important because, in order to achieve an acceptable sour taste, it must be below 4.0 (cf Lorri [1993] for fermented maize from Tanzania).

Table 1. Chemical composition of fermented sorghum.

Sample	Moisture content (%)	Crude protein (%)	Fat (%)	pH	Titrable acidity
Sorghum	10.4	10.1	3.5		
Ting prepared at village level	8.7	15.8	2.5	3.7	1.5
Ting prepared by a national at FTRS	12.4	15.8	2.5	3.6	1.6
Ting prepared by FTRS staff	6.5	14.7	2.7	3.6	1.4

It was supposed that drying the fermented sorghum would make it easier for packaging. But it was found that drying reduced the sourness. This was restored by adding tartaric acid. Citric acid was also added to give zest, plus vitamin C and/or benzoic acid for preservation purposes.

Lorri and Svanberg (1993) have reported that the keeping quality of fermented foods is very good. So it was concluded that drying in the presence of preservatives would increase the shelf-life and make it easier to produce large quantities suitably packaged for sale. Lorri and Svanberg also indicated that fermented cereals have health-promoting values, though this is not yet proven in humans. Mensah et al. (1991) reported that there was an antimicrobial effect from fermented dough (maize) when diarrhea-causing pathogens were inoculated into them at pH <4.

Other sorghum products

In our quest to find new incentives for villagers to earn a livelihood through food processing, and thus be encouraged to remain in rural areas, we examined other sorghum products that can be marketed in Botswana.

Sorghum health food. The sorghum health food product had a 40% sugar content without the addition of sugar as compared with sorghum flour. The sugar is derived from the breakdown of starch to simple sugars with enzymes (termamyl and/or AMG). We envisage that this product could be eaten by both old and young, in sickness and health, as a snack or breakfast cereal.

Sorghum pasta. This pasta was prepared with water. However, with experience, it was found that milk can be used with or without the addition of eggs. This procedure will increase the nutritional quality of the product, but it will require hygienic conditions of preparation. We found that it was easier to produce noodles than any other shape if we subsequently wanted to fry the product. The flat pastas disintegrated during frying, so the noodles were fried over a low heat until golden. Work is continuing to improve the adhesiveness of our pasta, to give better products when they are fried.

Instant beer powder. This is cheaper than the ready-to-drink *chibuku* and is more convenient. Also, the FTRS formula is an improvement on the commercially produced instant beer powder which takes 24 h to ferment, whereas the FTRS beer takes only 5-6 h. Additionally, fermented commercial beer powder has a 3-4% alcohol content, but the FTRS one has 5%. And, by deleting the dried yeast and sugar content, a tasty nonalcoholic drink can be produced.

Malted sorghum. As already noted, when the Ohiokpehai et al. (1992) method for malting Segaolane sorghum was used (Table 2), the sorghum diastatic unit (SDU) was 43, with poor grain modification—an observation close to that reported by Gomez (1992).

Table 2. Chemical composition (%) of different sorghum products.

Food products	Moisture	Protein	Fat	Ash
Sorghum health food (snack)	10.4	10.4	1.2	
Sorghum pasta	11.2	8.8	1.8	1.4
Commercial instant beer powder	9.3	10.4	1.5	1.9
Malted sorghum	9.8	9.5	1.7	1.3

Rooney (1992) argued that sorghum malting for beverages and food was an efficient way to use sorghum. Malting improves the nutrients in sorghum by the gradual breakdown of starch and other components to give simple sugars and vitamin B by the reaction of growth enzymes in the moist grain. But he concluded that improved maltable varieties were needed.

Sorghum-legume blends (composite flours). Whatever attempt may be made to improve the protein of sorghum, it can never be as good as that from legumes. Dendy (1993) has stated that composite flours should not be used as a stop-gap procedure, but should be built into national grain policies. We cannot but agree with this. However, in Botswana a composite flour (Tsabana) has been successfully developed and commercialized with governmental support. So the mechanism for introducing composite flours is already in place, and this must be harnessed and enhanced—i.e., there is a need to enlarge the market for composite flour from which quality food products are made for popular consumption.

Discussion

From discussions with mothers and school children we learned that, though Tsabana was developed for children aged 4-36 months, people in all age groups now consume it. We feel it is our duty to make both government and people aware that suitable composite flour technology already exists for making bread or any other attractive products. Therefore, there is room for more composite flours.

Cowpea is a good source of protein and vitamin B. Jugo bean, on the other hand, is a complete food with high levels of crude fat that is amenable to processing.

The blends compare well with commercially produced Tsabana (Table 3). The blends were also fortified with vitamins, as is Tsabana.

Akara cakes made from hydrated mixtures fried in hot oil require a public awareness program to increase popular interest in the product. The same is true of the steamed cakes. But as Botswana nationals are used to eating *magwinya* (fat cake), which is similar to *akara,* its introduction into the market as a convenience food should not be difficult.

Table 3. Chemical composition (%) of food products, raw materials, and their blends.

Product/ raw material/ blend	Moisture	Protein	Fat	Ash
Sorghum	10.4	10.1	3.5	13
Jugo bean *[ditloo)*	10.1	17.3	6.7	3.4
Cowpea (TVX-3236-016)	9.3	27.5	2.0	3.2
Ting	6.5	14.7	2.7	1.4
Ting + *ditloo* (50:50)	10.4	14.7	5.5	1.3
Sorghum + cowpea (70:30)	9.7	15.7	2.4	1.6
Sorghum + soybean (commerc. produced by Tsabana)	11.5	15.7	5.1	1.0

The use of sorghum and wheat flour mix was suggested for making a traditional *matlebekwane* doughnut (Nicholson 1992)—a suggestion in agreement with other authors.

To further improve the fermented sorghum, *ting,* legume flour (*ditloo*) was added. These mixtures can be eaten as a thin porridge—cooked and sweetened—or extruded to make 'new' convenience foods.

The production of the 'malt' drink beverage is still in its infancy. But it is clear that it is a healthy source of simple sugars (glucose). With no addition of sugar, the economics of production would be very good and profitability high. Preliminary studies show that existing breweries will have no problem in producing it.

It is important to reiterate that careful hygiene, sanitation, and adequate pasteurization must be adhered to in the production of this very sweet drink. It is a good substrate for the development of microorganisms and therefore of infections (Jepsen 1993).

Conclusion and Future Work

It is imperative to promote technologies that can use small grains for food and nonfood products, in order to diversify and strengthen the income-generating agricultural processing sector. And a strong food technology and extension team must be in place, to increase public awareness about cereal processing. We consider the following R & D activities to be of priority importance in Botswana:

- A detailed study of the nutritional effects of cereal food products should be undertaken.
- More work should be done to study product shelf-life.
- More experimental products should be produced, together with suggestions about how to make them popularly acceptable.
- An easier way of measuring ingredients at village level should be devised. This will help in studying the household preparation of cereal products.
- Priority should be given to disseminating information on how to prepare or produce small grains food products.
- And a nationwide public awareness program about the uses of sorghum should be undertaken.

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Relaunch of Research Work on Sorghum in Western and Central Africa

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Abstract

A regional Workshop for agricultural research staff in western and central Africa was convened in Feb 1994 at Bamako to identify the constraints that hamper sorghum production in the main agroecological zones in the region. Participants representing 17 member countries of the Sorghum Network demonstrated the need for a regional approach to research in order to obtain data which can help transform traditional agriculture through the transfer of improved technologies.

Mainly in tabular form, the paper presents working-group assessments of constraints to and methods of technology transfer, proposals for the establishment of a regional Research Network Center for sorghum, and prioritized research projects for the Sudanian and Northern Guinea zones. A Steering Committee with seven members from Benin, Burkina, Chad, Mali, Niger, and Nigeria has already begun its work and has recommended a project concerning high-yielding cultivars adapted to the [Northern Guinea) zone for early attention.

Introduction

In the 17 countries of western and central Africa sorghum is cultivated on more than 10 million ha, out of 19 million ha for all Africa. Yields are generally low, and vary between 200 and 900 kg ha^{-1}.

Many efforts have been made to increase national levels of production. But there have been several constraints: relatively few national research staff, limited resources allocated for research work, the operational isolation of national agricultural research systems (NARS), and inadequate dissemination of on-farm research findings.

Faced with this situation, western and central African countries acknowledged the necessity to cooperate in organizing and reinforcing scientific and technical collaboration among NARS in order to achieve results that can transform traditional agricultural systems.

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Toure, A., and Dossou-Yovo, S. 1996. Relaunch of research work on sorghum in western and central Africa. Pages 249-264 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

A regional Workshop was therefore initiated and organized by the Malian Institute of Rural Economy (IER), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and the Sahelian Institute (INSAH), and was held in Bamako in February 1994. It was financially supported by USAID and the Special Program for African Agricultural Research (SPAAR), and was attended by 17 member countries of the Sorghum Network, as well as by representatives of CIRAD and ILCA (now ILRI). The Workshop's objectives were:

- to identify the main constraints of sorghum production across agroecological zones;
- to inventory on-going research activities with the aim of removing those constraints;
- to identify research opportunities and define priority research in the region's agroecological zones; and
- to set up a Steering Committee to oversee agreed activities.

This paper presents tabular summaries of the Workshop's deliberations, in which a participatory approach was emphasized.

Constraints to Sorghum Production and Working Groups

Based on papers from participants, a table of the main constraints to the transfer of technology in the three zones of the region was created (see Table 1), in relation to the following research areas:

- Genetic resources, seeds, and cultivars
- Climate, bio-agroclimatology
- Soil, agronomy
- Insects, diseases, and plant pests
- Postharvest technologies
- Socioeconomics.

Five Working Groups were formed with the following objectives.

Group 1: Institutional Development

- To establish the means by which research capacities in the region could be improved through efficient collaboration between NARS and international institutions or other NARS.
- To identify the necessary types of training and institutions that have the potential to give assistance to NARS in this field.
- To define the composition, size, function, and duration of the mandate of the Steering Committee.

Table 1. Importance of constraints to the transfer of technology across agroecological zones, and the availability of technologies which can remove them.

Constraints	Sahelian Zone		Sudanian Zone		Northern Guinea Zone	
	Importance of constraints	Availability of technologies	Importance of constraints	Availability of technologies	Importance of constraints	Availability of technologies
Seed						
High-yielding cultivars	+++	++	+++	++	++	+
Multiplication	+++	+	+++	+	++	+
Infrastructure/distribution	+++	+	+++	+	++	+
Abiotic factors						
Fertility	+++	+	+++	+++	++	++
Drought	+++	++	++	+++	+	++
Biotic factors						
Insect	++	+	+++	+	+++	+
Diseases	++	+	++	++	+++	++
Striga	++	+	+++	+	++	+
Birds	+++	-	++	-	++	-
Socioeconomic factors						
Access to inputs and equipment	+++	-	+++	+	++	++
Access to credit	++	++	+++	+	++	+
Consumer and user preferences	+	+	+++	++	+++	++
Processing and diversification of use	+++	+	+++	++	+++	++
Pricing	+	+	+++	+++	+++	++
Marketing/distribution			++	+++	+++	+

Group 2: Technology transfer and impact

- To identify elements for the evaluation of technologies (new cultivars, improved agronomic practices in traditional farming systems), based on agroecological zones.
- To take into account the importance of farmers' risks and different objectives in the process of technology adaptation.
- To evaluate the impact of innovations in the real world.
- To establish potential agricultural policies that facilitate the introduction of new technologies.

Groups 3, 4, and 5: Research constraints and opportunities across agroecological zones

- To thoroughly assess and prioritize research constraints and opportunities for each of the Sahelian and Northern Guinea agroecological zones.
- To design and categorize research projects into two categories based on constraints that have been identified: Category 1 = projects that can be started during the 1994 season; Category 2 = projects that can wait until the end of that period. Selected priority projects will then be subject to long-term planning.

Findings of the Working Groups are described in the following paragraphs and tables.

Institutional Development

The Research Network Center concept

Discussion on the need to re-establish NARS gave rise to the concept of a Research Network Center (RNC: *Pole* in French), to include all member countries of the previous network. Preconditions for hosting a RNC were defined as follows:

- To have medium- and long-term strategic plans.
- To have well-established national research teams and have, within those teams, a significant number of researchers of high scientific standing who are capable of undertaking region-wide activities.
- To have suitable infrastructures and equipment or have the capacity to develop them.
- To be able to offer agroecological conditions that are favorable to conducting one or several theme-based cooperative research projects.

The Sorghum RNC

This is perceived as a NARS that is open to regional collaboration. It must invest itself fully in the regional programming of research theme activities it coordinates, and it must ensure a distribution of responsibilities within other components.

Based on preceding experience, the Mali Sorghum Center was proposed as the host of the Sorghum RNC.

The group focused its discussion on the organization and functions of the RNC, on collaboration with participants, and on an interorganizational flow-chart. It proposed that the RNC should be primarily concerned with basic research for the development of knowledge, and with adaptation research, in which collaborating NARS would need to:

- open their research programs to the RNC,
- facilitate the circulation of information and researchers' mobility,
- implement research and training activities that have been selected by the RNC.

The group proposed a flow-chart composed of the Workshop, the Steering Committee, and the Coordinator of Programs.

The Steering Committee, with seven members, would be responsible for RNC management and for monitoring its functions.

The Coordinator would head the Programs Coordination office and would be responsible for:

- implementing research projects,
- the administrative and financial management of the RNC, and
- the secretariat of the Steering Committee and the dissemination of information.

Technology Transfer and Impact

The findings of this group are derived essentially from participants' general knowledge, without reference to specific data on the agroecological zones involved: see Tables 2 and 3.

Proposed Research Projects: Objectives, Activities, Results

Five projects and possible leading countries are listed in Table 4.

High-yielding and adapted cultivars (priority 1)

Objectives.

1. Increase and stabilize yields.
2. Identify adaptation factors and mechanisms.
3. Adopt high-yielding cultivars.

Activities.

1. On-farm trials of existing varieties.
2. Plant physiology studies on the use of resources and the development of high-yielding cultivars.

Table 2. Methods of technology transfer and impact evaluation.

Improved technologies	Transfer methods	Impact evaluation in time
Improved seeds	1. Organize seed multiplication in research centers or on-farm, taking into account seed production 2. Install distribution facilities 3. Ensure continuity of seed multiplication and distribution	1. Number of farmers who have received released seeds 2. Number of farmers who have actually sown the released cultivars 3. Cultivated area
Cropping techniques	Guarantee the availability and distribution of all needed inputs and equipment	Production increase
Abiotic factors (fertility and drought) and biotic factors	1. In collaboration with extensionists and village associations, demonstrate the potential and merits of new technologies 2. In collaboration with extensionists and village associations, demonstrate the potential and merits of resistant cultivars (to *Striga,* midge, etc.), using integrated pest management approach	1. Cultivated area 2. Production data 3. Stable yields 4. Increase in income 5. Number of farmers who have adopted the technologies introduced
Socioeconomic factors	1. Conduct socioeconomic surveys by multidisciplinary team of researchers to define the objectives of and constraints to on-farm adoption of new technologies 2. Develop and evaluate technologies in the field by multidisciplinary teams with the users' participation 3. Follow up of the progress with technologies in real world to obtain a feedback.	Comparison before and after the adoption of technologies or comparison between adopters and nonadopters: 1. Area cultivated 2. Increase in production 3. Increase in income
Information exchange	1. Workshops, conferences, meetings 2. Visits 3. Publications 4. Training programs	

Table 3. Concrete proposals for the Research Network Center.

Short-term (1-2 years): transition period	Long-term (more than 2 years)
Improved seeds	
Identify the countries and cultivars whose seeds must be multiplied	Publication of results
Establish a database on those seeds and other technologies	Training of technicians in seed technology
Cropping techniques	
Identify some improved cropping systems that have already demonstrated impact	Assistance in developing facilities for seed production
Collect results into a database	
Identify and evaluate in selected NARS of appropriate cultivars and technologies for *Striga* control	Determine the stability of improved cropping systems
Inventory improved cultivars and technologies introduced on-farm	
Conduct a thorough study on the use of sorghum	
Information exchange	
Organize a workshop at the end of the period to assess the results of the 1994/95 season	Exchange of results between all member countries
Arrange exchange visits between staff in Network member countries	
Set up an information database and publish periodically a news bulletin	
Fund training for technicians and researchers at research institutions in the region	
Disseminate results of *Striga* control to the other countries	

3. Socioeconomic studies (impact/adoption).
4. Screening of cultivars based on mechanisms that have been identified.
5. Tests of high-yielding cultivars that have been developed.

Table 4. Identification, by project, of evaluation indicators and of possible leading countries.

Projects	Cat.[1]	Indicators	Country
1. High-yielding and adapted cultivars	1	Increase of yield, number of cultivars, sown areas, production of improved seeds	Mali, Senegal, Mauritania, Niger, Chad, Burkina, Cameroon, Nigeria **Leader:** Mali, Burkina, Niger (CERAAS)
2. Integrated pest management	1	Resistant cultivars, adopted control methods	Same countries **Leader:** Niger, Mauritania, Mali
3. Improvement of sorghum-based farming systems	1	Resistant cultivars, adopted control methods, reduction of loss in production	Same countries **Leader:** Burkina, Senegal, Mauritania
4. Risks in the introduction of new technologies	2	Validation of models, change of research and extension approaches	Same countries **Leader:** Mali, Senegal, Chad
5. Processing and product improvement	2	New products Use of inputs Industrial processing	Same countries **Leader:** Mali, Senegal, Niger

1. Category 1: Can be started in 1994.
Category 2: After 1994.

Expected results.

1. Identification on-farrn of high-yielding cultivars.
2. Quantification of the efficiency of resource-use (light, moisture, nutrients) by different cultivars.
3. Improved methods of screening cultivars.
4. Awareness of criteria for farmers' acceptance of cultivars.
5. Distribution of high-yielding cultivars.

Integrated pest management of sorghum pests (priority 1)

Objectives.

1. Reduce loss in sorghum production and quality.
2. Develop methods of economical environment protection control.

Activities.

1. Assessment of crop losses.
2. Bioecological studies.

3. Screening of cultivars for resistance to smut, head bug, midge, stem borer and *Striga* attack.
4. Experimentation of control cropping techniques.
5. On-farm trials of integrated pest management.
6. Introduction and transfer of resistance.

Expected results.

1. Development of cultivars resistant to smut, head bugs, midge, stem borers, and *Striga.*
2. Identification of sources of resistance to crickets.
3. Development of appropriate cropping systems.
4. Development of integrated pest management methods.
5. Improved knowledge in bioecology and methodology.

Improvement of sorghum-based farming systems (priority 2)

Objectives.

1. Secure and increase sorghum production.
2. Improve natural resources management and thus promote conservation of the environment.

Activities.

1. Screening of cultivars against existing predators.
2. Trial testing drought stress.
3. Trial testing soil nutrient deficiencies.
4. Farming systems trial (fallowing, intercropping, rotations) testing drought stress.
5. Farming systems/soil trial: improved fallowing, intercropping, rotation.
6. On-farm trials of integrated systems.

Expected results.

1. Cultivars adapted to farming systems.
2. Cropping technologies adapted to soil and climatic conditions.
3. Improved utilization of resources.

Analysis of risks in the introduction of new technologies (priority 2)

Objectives.

1. Understand better the risks linked with the introduction of new technologies into the existing farming systems.
2. Assess the impact of new technologies in farming systems.

Activities.

1. Evaluation and adaptation of models in the Sahelian production system.
2. Exploitation of models developed to evaluate production risks.
3. Verification of projections.

Expected results.

1. Identification of sustainable technologies.
2. Risk assessment methodology.
3. Tools for the definition of research and development strategies.

Sorghum processing and its improvement in the Sahelian Zone (priority 2)

Objectives.

To stimulate urban production and consumption through the diversification of sorghum-based products.

Activities.

1. Studies of the economics of traditional food systems.
2. Identification and development of screening methods.
3. Development of new products.
4. Development of processes and equipment adapted to the making of new products.
5. Screening of cultivars.

Expected results.

1. Knowledge of technological characteristics required for various uses of sorghum.
2. Identification of cultivar characters required for processing.
3. Specific techniques and equipment used in various processing methods.
4. Development of new substitutes for imported products.
5. Increase of market shares.

Proposed Category 1 Projects for the Sudanian Zone

These are listed and described in Table 5.

Constraints and Research Opportunities in the Northern Guinea Zone

These are listed and described, with priorities and participating countries in Tables 6 to 8.

Table 5. Proposed Category 1 projects for the Sudanian Zone.

Constraints	Project	Activities	Specific objectives	Expected results	Evaluation indicators	Leading and participating countries	Future activities
Drought	1. Securing production	Farming techniques for water management	Optimization of the utilization of water	Improvement of cropping systems	Level and stability of yields and incomes	Leader: Mali, Burkina, Benin All the other countries	
		Assessment of climatic risks	Agroclimatic zoning	Wedging of cycles			
		Varietal screening	Identification of tolerant or resistant cultivars	Improved cultivars			Selection criteria for drought resistance
		Evaluation of technologies proposed	Yield analysis and analysis of risk control	Determination of efficient technologies			
Soils	2. Maintenance and restoration of fertility	Use of leguminous plants; erosion protection; use of organic matter; farming systems	Erosion control and improvement of fertility rate	Identification of technologies affordable by farmers	Physical and chemical status of soil; level and growth rate of yield	Leader: Nigeria, Mali, Burkina; All the other countries	Monitoring of the evolution of soil fertility

Continued

Table 5. *Continued*

Constraints	Project	Activities	Specific objectives	Expected results	Evaluation indicators	Leading and participating countries	Future activities
Crop diseases and pests	3. Crop protection measures	Evaluation of the effect of the diseases and pests on production: weeds, *Striga*; insects: bugs, shoot flies, midges, borers; diseases: anthracosis, smut, sooty stripe, molds, helminthosporiosis; control techniques	Establish control Identification of appropriate control options	Classification of diseases and pests based on the importance of their effect Resistant cultivars: cropping techniques; chemical treatments; integrated pest management	Level of crop losses	Leader: Nigeria, Mali, Burkina All the other countries	Epidemiological study and identification of new races
Extension methods	4. Improvement of technology adoption	Diagnostic study (economic and agronomic) of farmers' farming systems	Better knowledge of technology adoption; proposals for improvement	Identification of factors delaying research protocols	Profitability of technology adoption	Leader: Burkina, Mali All the other countries	
Socioeconomic environment	5. Analysis of socio-economic factors in production	Assessment of production targets	Contribution of sorghum to income generation and stabilization; sorghum consumption habits	Sorghum share in incomes; needs coverage rate; classification of forms of utilization	Distribution; pricing	Leader: Burkina, Mali, Ghana All the other countries	

Table 6. Sorghum production constraints and research opportunities in the Northern Guinea Zone.

Research areas	Constraints	Research opportunities
Genetic resources	• Local landrace varieties (LLVs) insufficiently collected and evaluated for each country • Lack of facilities for conservation	• Characterizing LLVs • Use of LLVs in cultivar improvement programs
Seeds	• Unavailability of seeds in sufficient quantity and quality	• Multiplication of breeder seed
Water deficit	• Drought at vegetative stage • Drought at grain-filling stage	• Development of cultivars resistant at the vegetative phase • Development of cultivars that survive end-of-season drought
Soil	• Low organic matter and nitrogen content • Low CEC and exchangeable cations • Low phosphoric content • Fragile soils • Low phosphoric content	• Improvement in soil fertility and productivity
Cultivar improvement	• Low yields • Susceptibility to pests	• Development of acceptable and high-yielding cultivars • Development of resistant cultivars (tolerant of biotic stress)
Synthesis of farming practices and bio-agroclimatology	• Insufficient characterizing of farming systems adopted by farmers	• Improvement of the productivity of sorghum-based farming systems
Processing	• Lack of appropriate cultivars for industrial processing	• Improvement of industrial utilization of sorghum
Socioeconomic factors	• Lack of socioeconomic data on pricing, marketing, credit system and storage	• Creation of databases

Table 7. Immediate and future research work on sorghum in the Northern Guinea Zone.

Immediate research	Future research
Main priorities	**Main priorities**
1. Seeds 2. Cultivar improvement	1. Soil 2. Farming systems 3. Processing 4. Socioeconomics
Secondary priority	**Secondary priority**
Genetic resources	Water deficit

Steering Committee Activities

During the Workshop, a seven-man Steering Committee was proposed for the transition phase, including one Chairman, a Coordinator, and five members constituting a multidisciplinary team.

Participants proposed that the Chairman of the Steering Committee be the Director General of the NARS hosting the RNC.

Donor agencies, subregional, regional, and international institutions were to be invited to participate in Committee meetings as observers. The Committee's role is to:

- finalize the work plan for the 1994 season,
- finalize the institutional document prepared by the Workshop,
- specify the Coordinator's responsibilities,
- disseminate information, and
- adopt the budget.

Members proposed were as follows:

Chairman: Oumar Niangado (Director General, IER, Mali)

Members: Ibrahim Magagi (Niger)
Sansan Da (Burkina)
Ndjekounkosse D. Yagoua (Chad)
Sigisbert Dossou-Yovo (Benin)
Kehinde A. Elemo (Nigeria)

Coordinator: Aboubacar Toure (Mali).

Based on the responsibilities assigned to the Steering Committee, two meetings were held to finalize the research activities and the budget for the 1994 season.

During the transition phase, the Steering Committee, after a thorough analysis of the projects proposed by Workshop participants, has decided to emphasize the verification of available technologies. For this reason only one project was selected for

Table 8. Objectives of future sorghum projects and activities in the Northern Guinea Zone.

	Projects				
		Expected results			
Research area	Objectives	1994	1997	Evaluation indicators	Future activities
1. Seeds	Produce breeder seed for accepted and recommended cultivars	Obtain necessary seed quantity and quality	Deal with the possible increase in demand for seeds	1. Tests of quality 2. Quantity of seeds produced	Continue the production of breeder seed
2. Cultivar improvement	Verify and validate performance on-farm of recommended cultivars	1. Analysis of agronomic performance of the cultivars 2. Socioeconomic analysis of farmers' reactions to cultivars	Identification of cultivars accepted and reasons of nonacceptance	Adoption rate of cultivars recommended	Impact assessment

Research projects: leading and participating countries

Project	Leading countries	Participating countries
1. Seeds	Nigeria, Mali, Burkina, Côte d'Ivoire	All countries having released cultivars
2. Cultivar improvement	Nigeria, Burkina, Mali	All countries

initial action: High-yielding cultivars adapted to the zone. It is composed of the following two main activities:

1. On-farm cultivar tests.
2. Multiplication of improved seeds.

The Sorghum Improvement Program at the Grain Crops Institute, South Africa

A J Pretorius, N W McLaren, J van den Berg, and W G Wenzel[1]

Abstract

The sorghum improvement program comprises five disciplines: agronomy, grain quality, plant pathology, entomology, and breeding. Plant pathology research emphasizes the seedling disease complex, ergot resistance breeding, and root and stalk rots. Entomological research is aimed at developing an 1PM system for stem borers and involves the use of host-plant resistance and insecticides. The breeding program is aimed at producing lines with increased malting quality and resistance to stem borers and aphids. The majority of accessions in the germplasm bank, comprising 3000 genotypes, have been evaluated for stem borer resistance. Research activities and results are described.

Introduction

The sorghum improvement program at the Grain Crops Institute comprises five disciplines: agronomy (cultivar evaluation), grain quality, plant pathology, entomology, and plant breeding. The overall aim of the program is to minimize production risks by the optimization of production practices and the adaptability of genotypes. The program is aimed at both commercial and smallholder farmers, and research goals are unique to each sector in terms of input costs and genotype requirements.

Agronomy (Cultivar Evaluation)

The information generated by the cultivar evaluation program plays an important role in the production plan of sorghum producers.

Commercial and new sorghum cultivars have been evaluated in standard cultivar trials (30-40 localities per year) for the past 20 years. Trials were planted over localities ranging from the drier western production areas with high temperatures, to

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Pretorius, A.J., McLaren, N.W., van den Berg, J., and Wenzel, W.G. 1996. The Sorghum Improvement Program at the Grain Crops Institute, South Africa. Pages 265-273 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

the wetter, eastern production areas with lower temperatures. Soil types varied from shallow, low-potential, sandy soils in the west, to soils with a high clay content in the east.

During the 1992/93 season, 31 of the 49 cultivars included in the national trials with grain sorghum were commercial cultivars, while 18 new cultivars were evaluated (Pretorius and Bruwer 1993). These entries included 'sweet' and bird-proof cultivars, and some with a tan plant color. During this season, which was characterized by high rainfall, high yields were obtained in all trials. A yield difference of 1.2 t ha^{-1} was observed between the highest-yielding cultivar (DC 75: 5.80 t ha^{-1}) and the lowest (SNK 3640: 4.60 t ha^{-1}). Both these cultivars are bird-proof.

An indication of yield potential in different rainfall areas is as follows: trial planted at Bethlehem in the eastern production area which gave a mean yield of 6.79 t ha^{-1} with a rainfall of 690 mm; a trial planted at Standerton in the central production area gave a mean yield of 2.38 t ha^{-1} with a rainfall of 496 mm.

Reliable cultivar recommendations can be made only after thorough statistical analysis of the data. Regression lines (Fig. 1) and yield reliability analyses have been used.

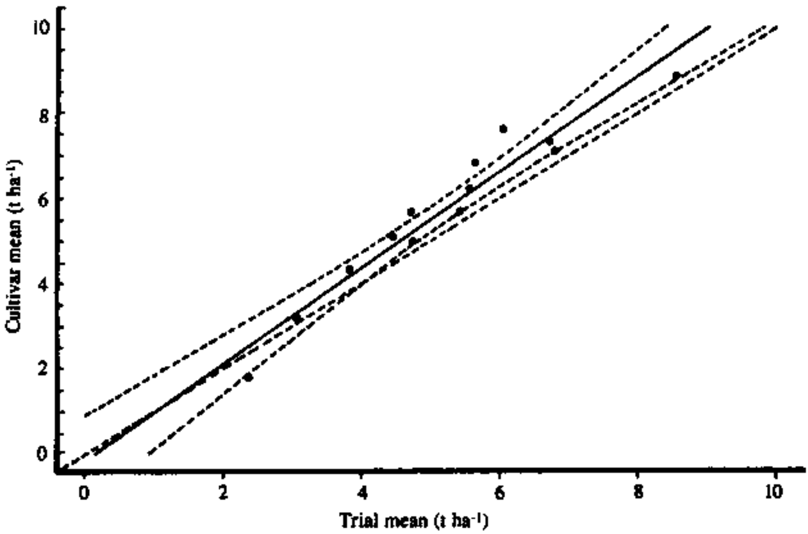

Figure 1. Regression lines showing the relation between mean yield potential of trial and hybrid yield of cultivar SNK 3003.

Grain Quality

Quality evaluation of sorghum is determined by market needs. Since the two main sorghum products for human consumption are sorghum beer and sorghum meal, all commercial and new cultivars are evaluated for beer (malting quality) and meal production.

Cultivars fall into three different classes depending on malting quality: malt-class grain sorghum (GM); low-tannin grain sorghum (GL); and high-tannin grain sorghum (GH). There are 12 cultivars in the GM class (sweet cultivars suitable for malting). There are four cultivars in the GH class (bird-proof cultivars suitable for malting).

The cultivars in the different classes vary in yield potential, length of growing season, and adaptation to different production areas. Sorghum suitable for malt production can therefore be produced in any production area.

Consumer preference, and the availability of processing equipment determine the characteristics of a sorghum meal. Preferences vary from fine to coarse meal, with color ranging from white (pericarp removed before milling) to red/brown (processed with the pericarp). Sorghum meal is also evaluated on the abrasive hardness index, and color of the decorticated grain. Only preliminary work was done on sorghum meal; more intensive evaluation will start in 1995.

Crop Protection

Plant pathology

Many diseases of sorghum have been identified in South Africa (Table 1), but few are of major economic importance. Research has emphasized seedling disease complex,

Table 1. Sorghum diseases identified in South Africa.

Disease	Causal organism	Reference
Anthracnose	*Colletotrichum graminicola*	Dyer 1951
Bacterial streak	*Xanthomonas holcicola*	Van der plank 1954
Charcoal rot	*Macrophomina phaseolina*	Cronje 1965
Downy mildew	*Sclerospora sorghi*	Doidge et al. 1953
Ergot	*Sphacelia sorghi*	
Leaf blight	*Exerohilum turcicum*	Doidge et al. 1953
Leaf blotch	*Phoma sorghina*	Van der plank 1957/58
Leaf spot	*Pseudomona syringae*	Pauer 1966
Maize dwarf mosaic	MDM virus	
Rust	*Puccinia purpurea*	Doidge & Bottemley 1931
Smuts	*Sphacelotheca cruenta*	Doidge et al. 1953
	S. reiliana	Doidge et al. 1953
	S. *sorghi*	Doidge 1924
Stalk rot	*Fusarium moniliforme*	

Source: Gorter 1977.

ergot, and, more recently, root and stalk rots. Disease-control research at the Grain Crops Institute has been aimed at integrating disease resistance, and crop production methods.

Seedling diseases. These are typified by pre- and postemergence damping-off and seedling blight. The latter is accompanied by various degrees of stunting which often results in plants failing to reach maturity. Primary isolates from infected seedlings are *Fusarium moniliforme, F. oxysporum,* and many *Curvularia* and *Drechsclera* spp. (McLaren 1987).

The incidence of seedling diseases is associated with seedling stress. This includes herbicide applications at suboptimal conditions, cold stress during the first 3 weeks of growth, and pH values of less than 5.

Tillage practices which concentrate crop stubble into the upper soil levels increase the concentration of soil bacteria and fungi, which in turn have been associated with increased damping-off and seedling blight (McLaren 1987).

Screening for disease resistance in sorghum genotypes is an on-going program. Resistance in many genotypes is associated with concomitant tolerance to such stress factors as low temperature and pH.

Ergot. This is regarded as the major disease of sorghum in South Africa. It is a particular problem in seed-production fields where male-sterility is used. Emphasis in the sorghum program has been on quantifying the relationship between climate and disease incidence (McLaren and Wehner 1990, 1992). Studies into disease control by means of fungicides have shown manipulation of flowering dates to be uneconomical and unreliable.

Root and stalk rots. Root rots are a particular problem where soil moisture is a limiting factor. Hitherto, the emphasis has been on defining the causal organisms (Moolman 1992). Screening for root-rot resistance is carried out in field trials where selection is based on root discoloration. Most genotypes are susceptible to root discoloration; only seven genotypes with significant resistance to the soil-borne pathogen complex have been identified.

Primary stalk rots are fusarium stalk rot (*Fusarium moniliforme*) and charcoal rot (*Macrophomina phaseolina*). As these are primarily diseases of senescing stalk tissues, genotypes with a 'stay-green' character are selected.

Entomology

Entomological research at the Grain Crops Institute is aimed at developing an integrated pest management (IPM) system for the most important sorghum pests in South Africa. This IPM system involves the use of host-plant resistance, and insecticides.

A number of pests are associated with grain sorghum in South Africa (Table 2). However, many of these are of minor importance and occur sporadically. Direct costs

Table 2. Insect pests of sorghum in South Africa.

Group	Type	Scientific name	
Aphids	Sorghum aphid	*Melanaphis sacchari*	(Homoptera: Aphididae)
	Maize aphid	*Rhopalosiphum maidis*	(Homoptera: Aphididae)
	Wheat aphid	*Schizaphis graminum*	(Homoptera: Aphididae)
Fly maggots	Sorghum midge	*Contarinia sorghicola*	(Diptera: Cecidomyiidae)
	Shoot fly	*Anatrichus erinaceus*	(Diptera: Chloropidae)
Beetles	Spotted maize beetle	*Astylus atromaculatus*	(Coleoptera: Melyridae)
	Black maize beetle	*Heteronychus orator*	(Lepidoptera: Pyralidae)
Stem borers	Maize stem borer	*Busseola fusca*	(Lepidoptera: Noctuidae)
	Chilo borer	*Chilo partellus*	(Lepidoptera: Pyralidae)
Cutworms	Black cutworm	*Agrotis ipsilon*	(Lepidoptera: Noctuidae)
	Brown cutworm	*Agrotis longidentifera*	(Lepidoptera: Noctuidae)
	Common cutworm	*Agrotis segetum*	(Lepidoptera: Noctuidae)
	Gray cutworm	*Agrotis subalba*	(Lepidoptera: Noctuidae)
Bollworm	African bollworm	*Helicoverpa armigera*	(Lepidoptera: Noctuidae)
Armyworms	Lesser armyworm	*Spodaptera exigua*	(Lepidoptera: Noctuidae)
	Armyworm	*Spodoptera exempta*	(Lepidoptera: Noctuidae)
Minor or sporadic pests	Wireworm larvae		(Coleoptera: Elateridae)
	False wireworm larvae		(Coleoptera: Tenebrionidae)
	Ground weevils	*Protostrophus* spp.	(Coleoptera: Curculionidae)

Source: Annecke and Moran 1982.

for insecticides used on sorghum amount to approximately R5 million (US$ 1.36 million) per year.

Stem borers. The most important pests of sorghum in the region are the stem borers, *Busseola fusca* (Lepidoptera: Noctuidae), and *Chilo partellus* (Lepidoptera: Pyralidae). Van den Berg et al. (1991) found *C. partellus* to be the more damaging of the two, when occurring in mixed populations in sorghum.

Chemical control of *C. partellus* was studied by Van den Berg and Van Rensburg (1991, 1992). They evaluated the efficacy of various insecticides for the control of larvae behind sorghum leaf sheaths.

Current research is aimed at the development of an IPM system involving the use of host-plant resistance and chemical control.

Commercial sorghum hybrids were evaluated for *C. partellus* resistance (Van den Berg et al. 1993). There was no antibiosis resistance, but large differences in tolerance were observed. Information on hybrid tolerance to damage, days to flowering, and yield potential under different environmental conditions, permit the recommendation of specific hybrids for sowing in certain production areas. This information system forms the basis of the IPM system that is being developed.

Aphids. Although many aphid species occur on sorghum in South Africa, only the honeydew aphid, *Melanaphis sacchari* (Homoptera: Aphididae) is of economic importance. The ecology of this pest was studied by Van Rensburg (1973). Chemical control is currently the only method for limiting pest damage.

In 1987 a resistance breeding program was implemented. Screening for resistance is done under natural infestation; many resistant sources have been identified. Resistant material is included in the breeding program.

Host-plant resistance to stem borers. The stem borer resistance breeding program involves annual evaluation of sorghum lines for resistance to *B. fusca* and *C. partellus* under artificial infestation. The acceptable selections are further evaluated for combining ability to develop A and R lines. Local evaluation of sorghum lines for resistance to *C. partellus* was initiated in 1987. Fifty-three relatively resistant lines have been identified (Van den Berg and Wenzel, in press).

The *B. fusca* program started in 1989. Sources of antibiosis against leaf feeding, and tolerance to damage have been identified (Van den Berg et al. 1994). However, many of the resistant sources are of tropical origin, and not agronomically suitable for South African conditions.

The importance of evaluating for borer resistance under local conditions was emphasized by Van den Berg and Wenzel (in print) who found that the stability of resistance varies between different geographical areas. For example, it was found that resistant ICRISAT inbred lines, such as IS 1044, suffered high leaf damage in local field trials. Similarly, lines reported as resistant to *C. partellus* in Kenya and India were susceptible under local conditions. However, there were also cases where inbred lines, which proved resistant locally, were susceptible in other countries.

Sorghum Breeding

The sorghum breeding program was initiated in 1983. The emphasis was on pest resistance, drought tolerance, and malting quality.

South African sorghum germplasm collection

This collection currently contains more than 3000 accessions, of which about one-third have been collected locally. The rest were obtained from ICRISAT, various African countries, Australia, Argentina, Taiwan, Japan, Europe, and different sorghum breeding stations in the USA, notably the Texas A & M University.

Grain quality

In South Africa, the primary market for sorghum is the beer industry. Locally collected accessions were identified as having double the malting quality, expressed as diastatic power, than the presently cultivated hybrids. Crosses were made between these accessions in order to improve their agronomic acceptability, and grain yield. With the same objectives, crosses were also made using imported high flower-extraction varieties.

Aphid resistance

Promising inbred lines and varieties have been identified (Wenzel and Bate 1987) with improved resistance to the sorghum aphid (*M. sacchari*). Since these lines were selected following natural infestation, it is not known whether their improved resistance is due to antibiosis or nonpreference. A newly developed aphid-resistant hybrid was evaluated in the 1993/94 season to determine its commercial worth.

Stem borer resistance

In order to develop high-yielding lines, and varieties with improved stem borer resistance, imported sources of resistance to C. *partellus* were used in crosses with locally adapted inbred lines. Progenies from these crosses yielded offspring with levels of antibiosis higher than those of the original sources. Efforts are now under way to improve their agronomy and yield potential.

Hybrid development program

Hybrids are developed from single crosses between A (female) and R (male) lines, selected for their superior combining ability or heterosis. Six newly developed A lines have been released to seed companies in 1993/94. The program is geared to release new A and R lines annually. Since the lines are selected at Potchefstroom, they usually exhibit improved drought resistance (Wenzel and Cilliers, in review).

Variety development program

A cooperative variety improvement program between the Grain Crops Institute and the National University of Lesotho was initiated in 1993. The objectives are to identify and develop adapted varieties with improved grain yield and quality. Varieties with resistance to the major pests and diseases, and adapted to low-input farm management, are needed.

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Pilot Project for Small-Scale Pearl Millet Seed Production in Namibia

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Abstract

At a meeting convened in 1993 by the Agricultural Development Centre (ADC) in the Omusati Region of Namibia, local farmers were invited to participate in a pilot project for the production and multiplication of pearl millet seed (Okashana 1 variety). Fifty farmers registered; but this number was later reduced to 10 after the suitability of their farms was assessed on-site in accordance with five criteria. These farmers were supplied with seed for sowing, but followed their normal crop management practices, with occasional guidance, and brought their crop to the purchasing center for machine threshing and Grade-1 quality assessment. An encouraging ±17 t of seed was produced from 70 ha of smallholder farmland.

Introduction

A small-scale seed production pilot project was launched in the Omusati Region of Namibia at the beginning of the 1993/94 season. The project was sponsored by FAO.

The project was designed to train selected farmers to become the future seed producers of the region. They would produce the seed that the government had hitherto been producing. The seed, Okashana 1, is a pearl millet variety that is of short duration, and is very suitable for Namibian conditions. If findings from the pilot project were encouraging, projects would be launched in the other two regions of the Agricultural Division North Central, which comprises the four Owambo Regions—Omusati, Oshana, Ohangwena, and Oshikoto.

It was expected that the selected farmers would form a seed cooperative, and then a seed company which would control all seed production and sales in the region.

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Activities

Farmer selection

A meeting of farmers in the Omusati Region was convened at the ADC location at Outapi, and methods for on-farm seed production and multiplication were explained to them. About 50 farmers registered themselves.

Seed distribution

Thereafter, the ADC carried out a survey of the registered farms to determine their suitability, according to the following criteria:

1. The farm should be situated so that the seed crop is at least 200 m away from neighboring *mahangu* (local landrace variety pearl millet) plots, thus avoiding contamination by cross-pollination.
2. The farmer should not be allowed to sow any other *mahangu* variety except the seed crop. He may, however, sow other crops, e.g., sorghum.
3. The seed to be used should be the basic seed supplied by the Directorate of Research.
4. The farmer's land should be fertile.
5. The crop should be protected against animals and other pests.

Each farmer was issued with seed sufficient to cover his/her land. Some farmers had to collect seed to sow for the second and even the third time because of losses from drought after sowing. Each farmer then managed his land in the normal way as in the past.

Farm visits

Various stages of crop growth were monitored during farm visits. Farmers were advised on the management of the crop. The need to rogue volunteer and other undesirable plants was emphasized, especially that of shibra (wild millet), which occurs commonly with the *mahangu* crop. The farmers were also advised to thin and weed early.

Harvesting and threshing

The farmers were advised to harvest in good time because of the susceptibility of Okashana 1 to postmaturity insect attack. The project included the provision of a thresher for use at basic cost. The crop was then brought to Mahenene Research Station for seed-cleaning. The crops were cleaned and graded, and only the Grade 1 crop was accepted as seed. This was paid for, and the farmer took back the remainder for consumption.

Conclusion

The results of the project were encouraging. Approximately 17 t of seed was produced from an area of 70 ha by some 10 farmers.

The seed was bought from the farmers at about N$37 000 (N$l = 1 Rand = US$ 3.5). It will be used as seed supply for the 1994/95 sowing season and sold to farmers in Omusati, Oshana, and Ohangwena/Oshikoto Regions.

It is recommended that the farmers' seed cooperative should be strengthened so that it can produce seed under government control.

A Review of Cultivar Release Procedures, Seed Production, and Extension Work for Sorghum and Pearl Millet in Zambia

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Abstract

Sorghum and pearl millet are important traditional cereal crops in Zambia. Statistics available on the production area and yield are unreliable and generally based on local landrace varieties (LLVs). The Sorghum and Millet Improvement Programme (SMIP) has developed and released such varieties and hybrids as Kuyuma, MMSH 375, ZSV 12, Kaufela, Lubasi, etc., for the different categories of farmers in Zambia. Cultivars released meet the stringent requirements of the Seed Control and Certification Institute (SCCI). But their adoption has been slow because of problems related to seed production and marketing: lack of trained extension personnel, and reluctance of the Zambia Seed Company to produce seed of such noncommercial crops as sorghum and pearl millet. However, limited efforts by SMIP to promote them in major production areas are beginning to pay off, as farmers learn the advantages in sowing improved cultivars.

Introduction

Sorghum and pearl millet are important traditional cereal crops in drought-prone areas of Zambia. Reliable statistics on the hectarage and production figures of these crops are not readily available and are difficult to verify. Best estimates given in Tables 1-3 have largely been based on LLVs and are derived from crop forecasts (Zambia Statistics Section 1992) and sales at cooperative unions. The situation is confusing, particularly when millets are considered. It is not easy to separate finger millet and pearl millet within the available statistics (Table 3). However, finger millet is predominantly grown in the higher rainfall areas with acidic soils in Region III, while most of the pearl millet is grown in the lower rainfall areas and sandy soils of Regions I and IIb.

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Table 1. National statistics on sorghum and millet: area sown, production, and sales, Zambia, 1981-93.

Year	Sorghum area ('000 ha)	Sorghum production ('000 90-kg bags)	Sorghum sales ('000 90-kg bags)	Millet area ('000 ha)	Millet production ('000 90-kg bags)	Millet sales ('000 90-kg bags)
1993	46.6	393.8	58.9	52.7	415.5	61.9
1992	40.3	144.5	7.4	66.6	533.7	122.5
1991	31.8	232.7	11.2	45.3	284.1	49.1
1990	48.5	217.7	2.3	58.7	350.5	1.5
1989	52.0	375.0	3.9	47.4	302.9	4.3
1988	47.5	253.0	30.8	44.1	299.9	6.0
1987	47.5	291.0	3.8	43.6	336.3	2.2
1986	59.6	499.9	9.9	18.5	129.6	3.2
1985	24.8	224.8	12.5	22.4	216.0	0.5
1984	21.8	166.3	3.2	19.0	150.0	0.2
1983	16.6	139.1	1.1	19.9	141.1	1.1
1982	21.5	155.4	1.7	-	-	-
1981	60.4	486.9	1.6	-	-	-

Source: Planning Division, Ministry of Agriculture, Food, and Fisheries, 1994.

Table 2. Sorghum in Zambia: area (ha), production and sales (90-kg bags) for 1992/93 and expected production figures for 1993/94, by province.

Province	Area sown in 1992/93	Area sown in 1993/94	Production 1992/93	Expected production 1993/94	Sales 1992/93	Retention 1992/93
Central	10 595	12 140	106 155	132 270	14 743	91 412
Copperbelt	3 497	9 634	26 647	91 688	3 580	23 067
Eastern	7 389	3 493	48 863	28 673	234	48 629
Luapula	1 502	1 120	24 012	3 691	9 522	14 490
Lusaka	1 276	2 425	28 262	5 582	10 530	17 732
Northern	2 621	513	23 758	6 416	53	23 705
N/Western	5 458	2 463	41 710	11 006	759	40 951
Southern	6 963	14 875	67 821	71 840	14 799	53 022
Western	7 262	8 582	26 638	38 503	4 799	21 859
Total Zambia	**46 563**	**55 245**	**393 866**	**389 669**	**58 999**	**33 486**

Source: Planning Division, Ministry of Agriculture, Food, and Fisheries, 1994.

Table 3. Millet in Zambia: area (ha), production and sales (90-kg bags) for 1992/93 and expected production figures for 1993/94, by province.

Province	Area sown in 1992/93	Area sown in 1993/94	Production 1992/93	Expected production 1993/94	Sales 1992/93	Retention 1992/93
Central	3 467	10 444	27 733	86 250	1 800	25 933
	205	810	2 198	12 520	1 002	1 196
Eastern	3 932	5 256	16 861	29 916	1 912	14 949
Luapula	8 466	3 727	71 084	57 467	8 589	62 495
Lusaka	14	0	142	0	0	142
Northern	17 998	37 355	205 625	408 202	37 962	167 663
N/Western	910	1 430	7 255	11 919	506	6 749
Southern	2 513	10 927	10 379	23 418	758	9 621
Western	15 149	12 353	74 216	66 347	9 413	64 803
Total Zambia	52 654	82 302	415 493	696 039	61 942	353 551

Source: Planning Division, Ministry of Agriculture, Food, and Fisheries, 1994.

It is estimated that 55 000 ha are devoted to sorghum and 82 000 ha are under both millets (see Tables 2 and 3). In terms of production the estimates are given as 36 000 t yr^{-1} for sorghum and 24 000 t yr^{-1} for sorghum and pearl millet respectively (Heemskerk 1991). Sorghum is widely grown in the country (Table 2). The bulk of the production is in Southern Province which accounts for about 26% of the sorghum area. Western Province accounts for about 16%, while Copperbelt and Central Provinces are also major sorghum producing areas. The rest of the country produces little sorghum (NCDP and ZATPID II 1989). Pearl millet, on the other hand, is predominantly grown on the sandy soils of regions I and lIb of Southern and Western Provinces (Table 3).

Andren et al. (1991) reported that seed production and distribution of improved sorghum and pearl millet cultivars were a major problem in the adoption of these crops by farmers. In terms of seed production, Moberg (1994) estimated that about 93 000 ha of both sorghum and millet were under cultivation and grain yields were estimated at 700 kg ha^{-1}. It is difficult to gauge progress under these circumstances, when such vital data of area and yield are not reliable. However, indications are that the use of improved cultivars is gaining momentum as their agronomic advantages are recognized and the establishment of formal markets is encouraged.

Cultivar Release Requirements

These requirement are stipulated by the SCCI (Muliokela 1990; Fredriksson 1990). All varieties in Zambia are released through a Variety Release Committee of the SCCI. The SCCI's main task is to ensure that only high-quality and certified seed is sold to farmers. The SCCI follows guidelines for the characterization of cultivars suggested by the International Union for the Protection of New Varieties of Plants (UPOV). The cultivar release procedures in Zambia therefore meet international standards. The functions of the Variety Release Committee are to screen new cultivars submitted by plant breeders for agronomic and produce value, and to phase out outdated cultivars. Botanical and agronomic data such as grain yield, time to maturity, resistance to diseases and pests, aspects of seed quality, postharvest use, and area of adaptation are required before a cultivar can be considered for release. The breeder is expected to submit a sample for independent tests by the SCCI, and each sample is assessed for a range of characters, as described below, in tests that last for at least 2 years. The Committee meets once a year in June/July before the crop-growing season begins. And quality control in its work is maintained through seed certification, documentation, laboratory assessment tests, and field inspections.

Cultivars Released by SMIP

The Programme has made much progress since its inception in 1983 by developing high-yielding and drought-tolerant cultivars for both smallholder and commercial farmers (Verma and Singh 1992), most of which were released in 1987.

Before 1983, however, two improved varieties, Framida and ZSV 1, had been officially released. Framida, selected in South Africa from a Chadian variety, has a soft endosperm and brown grains and is suitable for brewing. The variety is well known in Africa for its resistance to *Striga* (witchweed). ZSV 1 was introduced from ICRISAT Asia Center in India. It is a high-quality white-grain variety. Both varieties had reasonable grain yield potential but Framida was found to be susceptible to anthracnose and ZSV 1 was susceptible to maize mosaic virus. Both have therefore been withdrawn from the market.

Sorghum white grain cultivars

Sima (WSV 187). Released in 1987, this is a medium-tall and late-maturing (130 days), dual-purpose variety. It is known for its high-quality grain and its suitability for silage. It has large and hard grains and is ideal for dehulling and storage. It has high grain yield potential, up to 6 t ha^{-1}. It is recommended mainly for central and northern parts of the country but grows equally well on fertile soils in the south.

Kuyuma (WSV 387). Released in 1987, this is a short-stemmed, early variety (110 days), highly resistant to drought and suitable for combine harvesting. It has a grain yield potential of 4-6 t ha^{-1} and is recommended for dry zones (valleys and other drought-prone areas). It is also suitable for sowing by both smallholder and commercial farmers in the southern parts of the country. The variety is already popular among fanners in the valleys.

WSH 287. Released in 1987, this is an early (110 days), high-yielding, widely adapted hybrid. There are some seed production problems with this hybrid, so the seed is seldom available. An alternative white hybrid, MMSH 928, has therefore been pre-released for farmers' use.

MMSH 928. A hybrid prereleased in 1993 which is short, early-maturing and high-yielding. It is ideal for commercial farmers in Regions I and II.

ZSV 12. Released in 1993, this variety is recommended for northern high-rainfall areas. It is tolerant of acid soils and resistant to anthracnose. It is a tall variety with high-yield potential.

Sorghum brown grain hybrids

MMSH 413. Released in 1992, this hybrid is widely-adapted, high-yielding (6 t ha^{-1}), and early-maturing, especially suitable for brewing. It is not susceptible to bird attack and matures in about 120 days. It is recommended for both commercial and smallholder farming.

MMSH 375. Released in 1992, it is very widely adapted and high-yielding (6-7 t ha^{-1}) with lower levels of tannin than MMSH 413 and is suitable for brewing and livestock feed. The crop matures in 120 days and is recommended for both small-holder and commercial farming.

Sorghum forage hybrid

FSH 22. This was prereleased in 1993 and is a high-tillering hybrid that can be cut frequently, with thin, juicy, and sweet stocks which provide high-quality forage and silage.

Pearl millet varieties

WC-C 75. Released as ZMPV 871 in 1987, but withdrawn after the release of Kaufela.

ICMV 82132. Released as Kaufela in 1989. It matures in 105-110 days, has long, small panicles, is smut-resistant, and yields 1.5-2.5 t ha^{-1}.

Lubasi. Released in 1993, this variety is higher-yielding than Kaufela, especially in drier areas. It is shorter than Kaufela and has thick panicles. It is moderately resistant to downy mildew and smut.

Criteria for Cultivar Selection

The following are the characters sought in the selection of improved sorghum and pearl millet varieties and hybrids for release in Zambia. They should:

- give 30-50% higher grain yield than LLVs under marginal and improved field conditions;
- be earlier-maturing than LLVs (95-115 vs 120-140 days);
- be shorter in stature than LLVs and photoperiod-insensitive;
- have low-input requirements (optimum yield should be obtained with 30-40 kg N ha^{-1} + 20 P_2O_5 ha^{-1}) with a population of 60 000-90 000 plants ha^{-1};
- be well accepted for food and/or brewing, with a specific flavor, and have good storage qualities;
- be easy to pound because of their large or medium grain size;
- be broadly adapted to conditions in Regions I and II;
- require early sowing with the first well-established rains (because late-sown crops suffer from shoot fly (*Atherigona approximata*) damage in Region lIb; and
- be more resistant than LLVs to major diseases: downy mildew (*Sclerospora graminicola*), ergot (*Claviceps fusiformis*), and smut (*Tolyposporium penicillariae*).

The Role of SMIP

Until recently, the level of seed production of sorghum and millets was low, primarily because there was no market for the crops. The inexperience of extension staff in promoting the crops, and the reluctance of the Zambian Seed Company to produce noncommercial seed for an uncertain market added to the nonavailability of improved seeds to farmers. SMIP has actively promoted the use of improved varieties and hybrids by conducting a series of on-farm trials, field days, and demonstrations in the main sorghum and pearl millet production areas of Siavonga and Senanga.

Also, the performance of these new cultivars, and the increased frequency of drought seasons, has increased awareness of their good qualities among smallholder and commercial farmers. In comparison with maize, the improved sorghums have demonstrated their superiority in the drought-prone southern half of the country. In 1992, a year of extreme drought, new cultivars did not fail and gave a moderate grain yield of 1.5-2.0 t ha^{-1}. In the contrasting year of good rainfall (1993), the same cultivars produced grain yields of 4-6 t ha^{-1} with no-to-moderate additions of fertilizer.

As a result, the new cultivars have been popularized, but seed production became a major bottleneck in their adoption. So SMIP, in conjunction with Zambia Seed Company, recently started training farmers in the production of seeds, supported by the Farming Systems Research Team, Western Province (Lof and Nchemba 1994). The mechanics of seed production and distribution have thus been improving each year, after some initial difficulties.

Extension Activities

The role of extension workers, among others, is to carry research findings to farmers and report back the practical experience of farmers to researchers. The research branch of the Department of Agriculture adopted a problem-oriented approach from 1980, when provincial Adaptive Research Planning Teams (ARPTs) were formed. Almost all provinces had an ARPT whose activities are similar to those of a Farming Systems Research Team (FSRT). The work involves clustering farmers in groups or domains, and in each domain priority problems are identified through diagnostic surveys.

The extension apparatus in Zambia was generally designed to promote maize production because of the government's emphasis on that crop in the past. So both extension workers and farmers are conversant with technical information about maize production. The extension branch uses the Train and Visit (T&V) system to inform farmers about any new technology, based on recommendations formulated in liaison with FSRTs, who verify the production packages developed by Commodity Research Teams (see ARPT/IRDP NWP 1993).

However, ARPTs operate in all parts of Zambia except the Southern Province, an area that includes Siavonga, the main sorghum-producing area. And in some areas ARPT activities have come to a halt because they are donor-funded and therefore subject to uncertain financing. Also, for such traditional crops as sorghum and pearl millet a specific extension program is lacking.

So, in the absence of an established extension service for these crops, SMIP has added to its responsibilities informal promotion activities in areas where sorghum and pearl millet are important crops. Such work includes field days on farmers' fields, on-farm demonstrations, crop production units in schools, and village meetings in the presowing season. Recently SMIP has embarked on a training program for extension staff—work that is beginning to pay off, judging by responses from both the extension staff and farmers, and by evidence of an increasing demand for improved sorghum and pearl millet cultivars.

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Summary Papers

The Potential of Improved Sorghum Technologies in the Marginal Rainfall Areas of Swaziland

J Pali-Shikhulu[1], L M Nsibandze[2], and P Shongwe[3]

Introduction

The initial work reported in this paper is an attempt to show the superiority or otherwise of improved sorghum technologies over maize in the marginal agricultural areas, and to show how these can contribute to a food-security policy. This evidence is drawn from on-farm cultivar trials supported by farmer interviews, and a cropping systems evaluation trial conducted during the 1993/94 season.

Materials and methods

These trials were conducted in six areas (Mgamudze, Gilgali, Mliba, Nkambeni, Makhava, and Madvubeni) located in the lowveld moist sub-arid subzone of Swaziland. The objectives were: to introduce improved sorghum varieties to these marginal farming areas; to assess the performance of these improved technologies under farmers' management and/or resource conditions; and to evaluate farmers' perceptions and to identify their constraints.

Only 30% of the trials survived the drought during the crop establishment and early growth periods, which discouraged farmers from weeding and thinning, and depredations from livestock and birds.

Cooperating farmers were provided with seeds of the three released sorghum varieties (MRS 12, MRS 13, and MRS 94) and a maize hybrid, PHB 3435. The rest of the management inputs were provided by farmers: they were responsible for the preparation of trial fields, weed and fertilizer management, and bird-scaring. Where necessary the research staff carried out some weeding as well as pest control.

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Pali-Shikhulu, J., Nsibandze, L.M., and Shongwe, P. 1996. The potential of improved sorghum technologies in the marginal rainfall areas of Swaziland. Pages 289-293 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Grain yield (kg ha^{-1}) in on-farm cultivar evaluation trials in six areas of Swaziland, 1993/94.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Overall means
MRS 13	1000	480	500	0	20	0	620	540	630	420
MRS 12	1700	1100	940	940	660	130	610	440	340	750
MRS 94	1530	2290	1880	1820	1100	1300	2090	660	630	1470
PHB 3435	1470	763	700	1610	1530	400	1270	0	720	1050
Mean	1423	1135	1000	876	826	440	1148	410	580	920
SE	ns	±265.8	±104.8	±477.9	±93.3	±71.6	±153.1	±36.0	ns	
CV (%)	25	23	10	10	11	16	13	9	27	

Table 2. Grain yield (kg ha^{-1}) in the sorghum/cowpea intercropping trial, Lowveld Experiment Station, Swaziland, 1993/94.

Cropping system	Cowpea grain yield	Sorghum grain yield	Land equivalent ratio
Monocropped sorghum		1890	
Monocropped cowpea (low population)	1555		
Monocropped cowpea (medium population)	1500		
Monocropped cowpea (high population)	1580		
1 row sorghum:3 rows cowpea (low population)	1395	872	1.36
2 rows sorghum:2 rows cowpea (low population)	748	980	1.02
3 rows sorghum:1 row cowpea (low population)	255	1774	1.11
1 row sorghum:3 rows cowpea (medium population)	1264	663	1.16
2 rows sorghum:2 rows sorghum (medium population)	794	1023	1.07
3 rows sorghum:1 row cowpea (medium population)	419	1399	1.01
1 row sorghum:3 rows cowpea (high population)	1413	382	1.09
2 rows sorghum:2 rows cowpea (high population)	649	995	0.94
3 rows sorghum:1 row cowpea (high population)	313	1656	1.08
2 sorghum:2 cowpea intracropped (low population)	889	971	1.08
2 sorghum:2 cowpea intracropped (medium population)	1058	690	1.07
2 sorghum:2 cowpea intracropped (high population)	822	1074	1.09

Results and discussion

On-farm cultivar evaluation trials. The results of the nine successful trials, which are closely associated with crop management and rainfall distribution, are reported in Table 1. The following tentative conclusions can be drawn:

- Sorghum productivity in these marginal agricultural areas can be as high, if not higher, than that recorded for maize.
- The best yields were recorded by MRS 94 in the majority of the trials.
- MRS 13 was the cultivar most susceptible to bird damage.
- Farmers in general were unwilling to invest in fertilizer and labor for weed control, thinning, and bird-scaring.
- Many insect pests were observed during routine monitoring of on-farm trial expeditions. Those considered of economic importance were shoot fly (*Atherigona soccata*), maize aphid (*Rhopalsiphum maidis*), stem borers (*Chilo partellus, Busseola fusca*), pink borer (*Sesemia calamistis*), bollworm (*Helicoverpa armigera*), and sap-sucking bugs (*Dolycoris indicus, Nezara viridula*).

Sorghum/cowpea intercropping systems trial. The planned objectives of this trial were to identify systems that are productive, economically satisfactory, and most likely to contribute to household sustainability and food security. The focus was on sorghum as an associate crop. The two varieties used were MRS 94, a red sorghum, and a very short-duration cowpea line from IITA, IT 82D 889, which, if planted early enough, enables the farmer to grow two crops in a season.

Only the on-station trial conducted at the Lowveld Experiment Station survived, the results of which (Table 2) suggest the following conclusions:

- When intercropped, better yields were recorded when three rows of sorghum were grown with one row of cowpea. The least productive combination involved one row of sorghum to three of cowpea.
- In terms of biological efficiency, land equivalent ratios suggest that the best system is the crop combination involving one row of sorghum to three rows of cowpea: an LER 1.36 was recorded.

Partial budgets were constructed for the yield data (following Perrin et al. 1977), in which the cost of bird-scaring was the only cost that was varied. The subsequent budget revealed that the highest benefits accrue from the sorghum/cowpea intercropping combination with one row of sorghum to three rows of cowpea. The net benefits for these three systems were well in excess of E2000 ha^{-1}. Sorghum grown in monoculture recorded the least benefits and is clearly much less attractive for investment. A further analysis of the costs of production and their inclusion into the budget (Table 3) showed that sorghum as a sole crop cannot be regarded as an economic proposition because it yields a mere E200 ha^{-1} compared with the profitability achieved when it is intercropped even on a 3:1 ratio for sorghum and cowpea respectively. Indeed, the evidence shows that inter- and intracropping sorghum with cowpea can contribute significantly to total farm income.

Table 3. Budget analysis results from the sorghum/cowpea intercropping trial (Table 2).

Cropping system	Cowpea adj. yields (kg ha^{-1})	Sorghum adj. yields (kg ha^{-1})	Cowpea gross value (E)	Sorghum gross value (E)	Total gross output (E)	Total variable costs (E)	Net benefits (E)
1 1S:3C(AL)	1255	784	2510	392	2902	710	2192
2 2S:2C (AL)	673	882	1345	441	1787	610	1177
3 3S:1C(AL)	230	1597	459	798	1257	610	647
4 1S:3C(AM)	1138	597	2275	298	2573	710	1863
5 2S:2C (AM)	715	921	1429	460	1889	610	1279
6 3S:1C(AM)	377	1259	754	629	1383	610	773
7 1S:3C(AH)	1272	344	2543	172	2715	710	2005
8 2S:2C (AH)	584	896	1169	448	1616	610	1006
9 3S:1C(AH)	281	1491	563	745	1308	610	697
10 2S:2C (WL)	800	874	1600	437	2037	610	1947
11 2S:2C(WM)	592	621	1904	310	2215	610	1605
12 2S:2C(WH)	740	967	1479	483	1963	610	1353
Mono-sorghum	0	1701	0	851	851	810	241
Mono-cowpea	1400	0	2799	0	2799	710	2089

Conclusions

These preliminary results suggest that sorghum has considerable potential in marginal rainfall ecologies. While it is acknowledged that sorghum is not an important component of the diets of the rural Swazi, the attainment of reasonable yields by farmers in these areas can ensure some farm income on which households can depend for their food and other household requirements.

The results reported also indicate that farmers in these ecologies can minimize risks and maximize their output from their resources through intercropping sorghum with an improved cowpea that is not only determinate but is of short duration as well. The higher benefits accruing from intercropping can be used to compensate or pay for the labor hired or deployed in bird-scaring.

However, for these improved technologies to be adopted there is a need for a clearly defined sorghum marketing policy, which, according to farmers, is either absent or unfavorable.

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On-Farm Sorghum Technology Assessment by Farmers in Swaziland

P Shongwe[1]

Introduction

In Swaziland sorghum is grown by a few farmers for specialized uses. Maize accounts for 76% of the total cropland and sorghum 1.7% (Swaziland CSO 1989). However, in the marginal rainfall areas (dry Middleveld and Lowveld), where the annual rainfall is usually 600 mm or less, maize production is mostly a failure. The government, through the Ministry of Agriculture and Cooperatives, is encouraging farmers within this area to switch to sorghum because the climatic conditions are not favorable for maize production. The promotion of sorghum is an effort to promote food security at household level.

Sorghum research in Swaziland commenced in 1984/85 with the support of SADC/ICRISAT SMIP to introduce improved and adapted sorghum varieties that could improve yields and increase production through selection (breeding).

This paper is based on farmers' assessment of the 1993/94 cropping season of on-farm sorghum cultivar trials.

Objectives and methods

The objectives were:

- To assess farmers' perceptions of the on-farm sorghum trials.
- To identify farmers' observations on constraints on sorghum production.
- To assess and determine bottlenecks in the sorghum technology-transfer process.

The study was conducted from 4 to 12 Jul 1994 after the farmers harvested their crops. A formal survey with an interviewing schedule was used in guiding discussions. There were eleven questions relating to why farmers liked or disliked particular sorghum cultivars grown in the on-farm trials. In the responses requested there was a choice for 'yes', 'no', or 'not sure' centered around: high yield, density of plant stand, large grain and head size, tolerance of diseases, weeds, drought, and stalk borer, aphid, and bird attack, and whether or not fertilizer was applied. The farmers chosen for the

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Shongwe, P. 1996. On-farm sorghum technology assessment by farmers in Swaziland. Pages 295-297 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

study had participated in the on-farm sorghum trials which were conducted in the marginal rainfall areas of Swaziland. They were visited at their homesteads.

The study area comprised Mliba, Nkambeni, Madubeni, Makhava, Mgamudze, and Gilgal. Only eight farmers were interviewed.

Results and discussion

Cultivar characters assessed in the field. Because the number of farmers interviewed was very limited, only general conclusions can be drawn. The majority of farmers responded 'yes' to all the questions, and high yield, large grain size, and drought tolerance featured as the most important ones. About two-thirds of the farmers applied basal fertilizer.

In the 'no' responses about a quarter of the farmers were not satisfied with the head size, aphid tolerance, and crop stand. More than 80% of the farmers were not satisfied with bird tolerance.

In the 'not sure' group about a quarter of the farmers mentioned response to fertilizer, weed tolerance, and tolerance of stalk borer and disease. Many farmers do not use fertilizer because of the expense, and some think that fertilizer burns the plants.

The generally positive response implies that the cultivars are liked by this small group of farmers.

Production costs and marketing. Most of the farmers said that sorghum costs less than maize to produce because it does not require high rates of fertilizer application or much weeding and thinning. For such activities as land preparation, sowing, and weeding farmers said they had not hired any labor.

Some of the farmers complained about low prices in the formal markets. The Swaziland Milling Company offered in 1994 to buy a 70-kg bag of sorghum at E35.50 (= US$ 9.67). Farmers prefer to sell their produce in the informal, intrarural market where the price is US$ 13.08-19.07 per 70-kg bag.

Future plans. Farmers were additionally asked questions about the future, the main ones being:

- Do you want to adopt any of the cultivars?
- Which cultivar do you like: MRS 12, MRS 13, or MRS 14?
- Do you want to sow on-farm trials next season?

All farmers said they would like to adopt some of the tested cultivars the next season, MRS 13 being the preferred one. Most of them would also like to increase their area under sorghum production in excess of the size of the trial demonstration plot. All participants like the proposal to have another set of demonstration trials during the next season, mainly to gain more time for learning how to grow sorghum properly and to have access to improved seed.

But, although farmers were generally impressed by the plant stand, head size, and drought-tolerance of the tested cultivars, only one farmer said he wanted to grow sorghum on a larger scale. The remaining ones still wanted to grow maize, which they preferred to sorghum.

Conclusions

1. Farmers who participated in the on-farm trials liked the improved sorghum cultivars because of their high-yielding characters, large grain size, the capability of the crop to withstand drought, and its positive response to fertilizer applications.
2. Most or all of the cultivars were prone to bird damage, and this negatively affected farmers' motivation in growing sorghum.
3. Farmers who did not participate in the trials showed no interest in growing sorghum because of bird depredation; they were uninformed about the crop's uses when consumed and uncertain about the availability of a market.
4. Pure stands of sorghum and cowpea were preferred to intercropping systems.
5. Most farmers wanted to increase the number of demonstration plots for growing sorghum.
6. Farmers who did not participate in the trials agreed that sorghum can grow better than maize in their areas.

Recommendations

1. Sorghum is broadly viewed as a food-security crop in the country. So there is a need to increase the number of farmers who participate in future cultivar trials.
2. A sorghum cultivar that is tolerant of bird damage is required.
3. Farmers should be persuaded that sorghum is marketable.

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Sorghum and Pearl Millet Research in Mozambique: A New Approach

E M de Figueiredo[1]

Introduction

Sorghum and pearl millet have been studied in Mozambique to only a small extent. There are some references in the literature, but few are of current practical interest, or are concerned with technologies available to smallholder farmers who farm the largest areas of these two crops.

Since 1985, experimental cooperative trials conducted at one location in the south of Mozambique have identified good materials, which were recommended. However, the lack of a research program that covers the potential sorghum and pearl millet production areas, and satisfies the real needs of the target group (the family sector) led to the preparation in 1993 of the First National Sorghum and Pearl Millet Technology Transfer Workshop.

Since increasing the productivity of sorghum and pearl millet is essential to attain food security and establish farming systems in the drought-prone regions of our country, the Instituto Nacional de Investigacao Agron6mica (INIA) in its Medium-Term Plan defined sorghum as a priority crop in its research program.

State of sorghum and pearl millet

It is estimated that sorghum occupies 35%, and pearl millet 1.9%, of the total area sown to cereal crops, and the production of these two crops amounts to 29.7% for sorghum and 0.9% for pearl millet of total cereal production.

The average yield is 450 kg ha^{-1} and the main constraints are:

- weak research work on the two crops;
- lack of improved cultivars available to farmers; and
- poor extension service.

The principal constraints that affect the extension service are: lack of an infrastructure; lack of trained personnel; financial problems; and lack of adequate technological packages for extension.

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de Figueiredo, E.M. 1996. Sorghum and pearl millet research in Mozambique: a new approach. Pages 299-301 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Scientific information about these two crops has been insufficient for field application, mainly due to lack of research and qualified staff, financial problems, and, in recent years, insurance problems. However, some specific work, including the introduction and selection of lines/cultivars from ICRISAT Asia Center (India) and SADC/ICRISAT (Zimbabwe), has led to the identification and selection of the following improved cultivars: Mamonhe; SV 1; Macia; ANA; Kuyuma; SDSL 88298; and SDSL 89473.

Despite these problems, the regional strategy is to transfer and verify new technology, to place emphasis on a large cultivar evaluation program, on-farm trials, and related measures to facilitate the distribution and adoption of improved cultivars.

The coordinated sorghum and pearl millet program, inaugurated in 1993, combines the efforts of the seed company, SEMOC, and World Vision International, an NGO.

Impact of new technologies

The activities of SADC/ICRISAT SMIP for Mozambique are oriented to support the following goals:

- Promote the transfer of new technologies to the family sector.
- Develop a program to identify improved varieties and hybrids.
- Promote germplasm collection, evaluation, and exchange.

Related activities include:

- On-farm trials to verify the technologies under family-sector conditions.
- Train extension agents.
- Prepare technical recommendations for the family sector.
- Assist in seed production.
- Introduce new lines/cultivars.
- Identify, test, and select promising cultivars.

Improved cultivars available for sorghum

Elite varieties

Macia and Mamonhe	WSV 387 (Kuyuma)	SV 1 and SV 2

Promising varieties

Chokwe	SDSL 88298	SDSL 88473
SDSL 89420	SDSL 89566	SDSL 87049
SDSL 88003	SDSL 88004	Larsvyt 46-85
SV 3	SPV 351	SDSL 87046

The last 11 varieties are from SADC/ICRISAT SMIP.

Improved cultivars available for pearl millet

Elite varieties for field use

RMP 1 (PMV 1)	PMV 2	Okashana 1

Elite varieties for evaluation in on-farm trials

SDMV 89005	SDMV 90031	SDMV 91018

Varieties for multinational trials

SDMV 89004	SDMV 91402	SDMV 90004
ICMV 155	ICMV 88908	SDMV 92039
SDMV 92002	ICMP 88506	

Available resources

We rely on the collaboration of the following institutions:

- Direccao Nacional de Desenvolvimento Rural (DNDR).
- Direccao Nacional de Agricultura (DINA): coordination of agricultural policy.
- Seed evaluation and multiplication (SEMOC).
- World Vision: technical and financial collaborative research, extension, and training program.

Location of projects

The following provinces, where sorghum and pearl millet are economically important, have been prioritized, and their agroecological conditions have been noted.

Sorghum	Millet
Nampula	Tete
Manica	Zambezia
Tete	Cabo Delgado
Zambezia	

Priority activities

A diagnostic survey is needed to identify the possible limiting factors in each agroecological region. Unfortunately, this has not been done because of organizational problems.

Preliminary Evaluation of ICRISAT Sorghum Varieties at Sigaro, Zimbabwe

S B Zengeni[1]

Introduction

The objective of the trials conducted at Sigaro and other sites in Zimbabwe was to evaluate the performance of the ICRISAT varieties of sorghum and compare them with two locally grown open-pollinated varieties, a local hybrid, and an experimental hybrid.

Materials and methods

The following 12 sorghum varieties were introduced from the SADC/ICRISAT Sorghum and Millet Improvement Program (SMIP), and sown on 23 Nov 1993 at Sigaro farm, located 35 km from Harare. The other entries were Segaolane, SV 1, DC 75 and MR White (from Pacific Seeds).

1. SDSL 87049 dwarf
2. SDSL 87049 tall
3. SDSL 87046
4. SDSL 89566
5. SDSL 89544
6. SDSL 89569
7. SDSL 90147
8. SDSL 90152
9. SDSL 90181
10. SDS 2690
11. Larsvyt 46-85
12. Macia
13. SV 1
14. Segaolane
15. DC 75
16. MR White

The experiment was conducted in a fairly uniform field located at Sigaro farm which has red, clay, loamy soil. The environment was kept as uniform as practicable so that variations observed would be due to differences in the genotypes.

The entries were sown in a randomized complete block design with three replications. Plot size was 18 m^2, row length 6 m, and row and within-row spacing were 75 cm and 15 cm respectively. The estimated plant density was 162 500 ha^{-1}.

1. Research Manager, National Tested Seeds, PO Box 2705, Harare, Zimbabwe.

Zengeni, S.B. 1996. Preliminary evaluation of ICRISAT sorghum varieties at Sigaro, Zimbabwe. Pages 303-304 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

General agronomy included basal application of nitrogen (100 kg ha^{-1}), phosphorus (60 kg ha^{-1}) and potassium (50 kg ha^{-1}). The fertilizer was broadcast and disked in deeply before plowing. Nitrogen topdressing was applied 6 weeks after sowing. A granular insecticide was placed in the funnel as a precaution against attacks by stem borers (*Chilo partellus*). Two guard rows surrounded the trial to reduce edge effects. The trial was hoe-weeded twice during the growing period to keep it weed-free.

Six characters were studied and they included days to 50% flowering, days to maturity, plant height, standability, reaction to leaf blight (*Exserohilium turcicum*) and grain yield.

Results and discussion

Days to 50% flowering ranged from 64 to 79 and the average was 71 days. MR White, a dwarf hybrid from Pacific Seeds, was the earliest and SDS 2690 was the latest. Days to maturity followed the same general trend as flowering. Segaolane was the latest entry.

Leaf blight infection was widespread across the genotypes. DC 75 was the most susceptible entry with severe foliar symptoms. SDSL 87049 tall was the most tolerant entry.

The majority of the sorghum entries did not lodge. Entries which showed poor standability included DC 75, Larsvyt 46-85, SDSL 89566, and SDSL 90147.

Yields were generally high across the 16 genotypes. SDS 2690 gave the highest yield, 7.73 t ha^{-1}. This was significantly superior to the best control, DC 75. The other ICRISAT materials which outyielded DC 75 were SDSL 90152, SDSL 89544, and SDSL 89569. MR White gave a relatively good yield and SDSL 90181 gave the lowest grain yield.

The results are preliminary and show the performance of the sorghum entries when grown at a high altitude and in a high-rainfall area that is traditionally unsuitable for sorghum.

Development of a National Pearl Millet Breeding Program for Namibia

S A Ipinge[1], W R Lechner[2], and E S Monyo[3]

Introduction

Pearl millet accounts for 24% of total calorie intake as compared with 23% for maize and 13% for wheat (SADC Food Security Bulletin 1991). It plays an important role in the diet of Namibians and is widely grown in 7 of Namibia's 13 political regions which cover an estimated 355 200 ha of land (pers. comm. Namibia Ministry of Agriculture 1994). Except for the diminishing rainfall as one moves from the eastern part of Namibia (Caprivi) to western Omusati, most of the country's pearl millet belt lies in the same belt as the millet-growing areas of Zimbabwe, where improved SADC pearl millet materials have been developed and tested.

With support from the Namibian government and extra financial support from CIDA, SMIP assisted in the establishment of a pearl millet breeding program, concentrating initially on exploiting local germplasm and a few introduced cultivars that are adapted to Namibia's conditions.

Namibian pearl millet germplasm collection

Most of the pearl millet-growing areas were thoroughly covered during a germplasm collection mission jointly organized by the Ministry of Agriculture and SADC/ICRISAT from 18 Apr to 12 Jun 1991. A total of 1000 pearl millet accessions were collected. One batch was left in Namibia, a second was taken to Muzarabani in Zimbabwe for multiplication, and a third for long-term storage at ICRISAT.

Evaluation of the germplasm

The 750 accessions of the pearl millet germplasm collected in Namibia were evaluated during the 1991/92 cropping season at three different locations (Omahenene

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Ipinge, S.A., Lechner, W.R., and Monyo, E.S. 1996. Development of a national pearl millet breeding program for Namibia. Pages 305-309 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

and Mashare in Namibia and Muzarabani in Zimbabwe). Very useful variations were observed. Some of the collection grew to a height of 2-3 m and produced two to five stout basal tillers with thick stems. The heads were 30-40 cm long with conical to cylindrical panicles. They matured between 105 and 120 days.

The grains were gray, white, or a mixture of colors with partly corneous endosperm. Most of the accessions had medium to large grains. Selection of superior accessions was made from two locations in Namibia for the initiation of a breeding program.

Gene pool from the germplasm

Variability in the germplasm limited our choice of phenotypes on which gene pools were based, as follows.

Early-maturing gene pool (< 65 days to 50% flowering). This consisted of accessions that are commonly of short stature, have thin stems, and small- to medium-sized panicles and tillers (with some exceptions in which plants in this group have long panicles and thick stems, and are low tillering).

Medium-maturing gene pool (65-70 days to 50% flowering). Accessions are of medium duration, medium to tall plant height, medium stem diameter, medium to high tillering, medium to long panicle, and medium to large grains.

Late-maturing gene pool (70 days to 50% flowering). Accessions are of late maturity, tall height, thick stem, medium to low tillering, long panicle, medium to broad panicle diameter, medium to large seed size.

Large panicle gene pool. Accessions are of medium to late maturity, variable height, medium to thick stems, variable tillering, medium to long panicle, broad to very broad (including club head type) panicle, medium to large seed size.

Bristled gene pool. This includes all types of bristled panicles.

Reduced plant height gene pool. Accessions are of short height, but not dwarf, with variable stem thickness, tillering ability, panicle length and diameter, and seed size.

Main features of the breeding program adopted

From these gene pools we embarked on a breeding program that specifically defines two main areas of focus.

Short-term variety releases. These varieties are high-yielding, resistant to pests and diseases, and generally adapted to a wide range of Namibian ecological conditions. This work was achieved by growing a large population consisting of 5000 plants and making approximately 2000-2500 selfs. These self-pollinated plants were harvested after reliable data had been collected and evaluated on their yield performance, plant height, plant type, and days to 50% flowering. Composite populations were then formed:

- Namibia Drought-Tolerant Composite (NDTC), developed from the accessions that survived the 1992 drought at Muzarabani in Zimbabwe.
- Namibia Composite 90 (NC 90), developed in 1990 by random-mating eight varieties and two populations selected from the introductory nursery of SADC/ICRISAT SMIP breeding materials grown at Okashana, plus a bulk of 14 Namibian germplasm lines.
- Namibia White Grain Composite (NWGC), formed by random-mating 46 white-grain accessions from the Namibian pearl millet germplasm and an equal number from SADC White-Grained Composite. This is being formed to provide a source of agronomically elite lines with medium to large, hard, round, white grain, for the selection of varieties that can be commercially milled to produce a white meal or flour.
- Maria Kaherero Composite (MKC), based on a set of half-sib progenies taken from a farmer's field in Ruacana during the 1991/92 rainy season. The farmer had obtained seeds of Okashana 1 (ICTP 8203) during 1989/90 which he intersowed with his local landrace variety (LLV). Individual plant selection was carried out based on the Okashana 1 phenotype, but with emphasis on greater vigor and tillering ability than the original Okashana 1.

S_1 progeny selection is being carried out on all composite populations to improve productivity and grain quality traits, and to produce varieties of a wide range of phenotypes adapted to Namibian environments.

The SADC Early Bold Grain Composite (SDEBGC) and SADC White Grain Composite (SDWGC) are being utilized in the national program. The performance data of the four composite populations grown at Omahenene Research Station during 1993/94 are shown in Table 1.

Table 1. Performance data of four composite populations grown at Omahenene Research Station, Namibia, 1993/94.

	Days to maturity (50% flowering)	Potential yield (t ha^{-1})	
Population	Mean	Mean	Range
NC 90	63.38	2.03	0.3-4.0
MKC	62.12	2.04	0.3-3.9
SDWGC	60.71	2.11	0.4-4.0
SDEBGC	63.95	1.99	0.7-3.2

Long-term breeding of cultivars for quality attributes and a good milling profile. Though most Namibian pearl millet farmers now use open-pollinated varieties of composite populations, we are nevertheless developing a series of inbred lines that will constitute our pollinator sources for the development of hybrid pearl millet for commercial farmers.

The food-quality laboratory that is to be used in screening the varieties or composites for their quality traits may not always be available due to lack of resources or trained personnel, but consumer demand requires that we devise a way of testing the varieties for their needs. Also, the hybrid program requires that an appropriate service for the production, maintenance, and certification is in place to guarantee the quality of seeds that are delivered to farmers.

In 1994 seed production, distribution, and development is handled by the Ministry through researchers at research stations. But it is envisaged that a National Seed Service Unit will be formed to take over responsibility for seed bulking and distribution.

National cultivar testing

The system of testing now in operation in Namibia involves (a) advance national variety trials; (b) initial variety trials conducted each season; (c) regional collaborative variety and hybrid trials with SADC/ICRISAT SMIP. All these feed promising materials to the on-farm verification program. Six varieties identified through this system were under farmers' verification trials in 1994.

A total of 119 cultivars were selected for use in the national testing from the collaborative trials. SDMV 90016 and ICMV-F 86415 have yielded 12-16% more than the farmers' LLV in 2 years of testing (Table 2).

Two Okashana 1-based hybrids (SDMH 92012 and SDMH 92018) are among the materials selected for testing. These have shown a yield superiority of 15-23% over Okashana 1 at Omahenene Research Station (Table 3). The advantage of these topcross hybrids is that both Okashana 1 and the hybrids can be used as seed. Other promising hybrids are also indicated in Table 3.

Table 2. Performance data of elite varieties under Namibian conditions across seasons and locations.

	Mean yield[1] (t ha^{-1})	
Variety	1992/93	1993/94
Okashana 1	1.89(24)[2]	1.14(14)
SDMV 90016	1.77(16)	1.12(12)
ICMV-F 86415	1.69(11)	1.15(15)
Farmers' LLV		1.00

1. Yield averages across the three locations.
2. Numbers in parentheses indicate yield superiority over farmers' LLV.

Table 3. Performance data of selected hybrids under Namibian conditions across seasons and locations.

	Mean yield (t ha^{-1})	
Variety	1992/93[1]	1993/94[2]
SDMH 91004	2.57(13)[3]	1.89(38)
ICMH 88088	2.53(11)	1.30(-5)
SDMH 90005	2.36 (4)	1.56(14)
ICMH 87913	2.08(-8)	1.73(26)
SDMH 92012	-	1.57(15)
SDMH 92025	-	1.75(28)
SDMH 92018	-	1.69(23)
Okashana 1	2.27	1.37

1. Yield averages across three locations.
2. Yield averages across two locations.
3. Numbers in parentheses indicate yield superiority over the improved local (Okashana 1).

Conclusion

The potentially high-yielding LLVs identified through evaluation of local germplasm are already being improved for agronomic desirability by recurrent selection and through a process of limited backcrossing involving Okashana 1 and the SADC White Grain Composite. These materials are in their third backcross in 1994 and will form the nucleus of the breeding program.

Pearl Millet Shoot Fly Resistance Screening and Determination of Dates of Sowing in Zambia

E M Musonda[1]

Introduction

During the 1993/94 season, the sorghum/millet team decided to screen pearl millet for resistance to shoot fly attack and to determine the optimal date of sowing. This trial was conducted at Longe and Kataba in Western Province.

Materials and methods

Four improved cultivars and one local landrace variety were sown at Longe with four sowing dates and at Kataba with three sowing dates. The trials were sown 2 weeks after the normal sowing date to ensure maximum infestation. At sowing a basal fertilizer dressing of 200 kg 'D' compound ha^{-1} was applied, and 35-40 days later urea was applied at the rate of 100 kg ha^{-1} as a topdressing. At 25-30 days after emergence the following were observed:

- Number of plants $entry^{--1}$.
- Number of plants with deadhearts $entry^{--1}$.
- Percentage of deadhearts based on the total number of plants $entry^{-1}$.

Results

The results obtained (Fig. 1) indicate that sowing date I (27/11/93) had the lowest percentage of deadhearts, i.e., there was less pearl millet shoot fly damage as compared with the other two sowing dates (II: 12/12/93; III: 27/12/93) which had the highest percentage of deadhearts. The percentage for sowing date IV (11/01/94) in Longe was surprisingly low for unknown reasons.

As regards varietal reaction, the local landrace variety (LLV) performed well (Fig. 2), compared with the other varieties which, either in the second or third

1. Agricultural Research Officer (entomologist), Mount Makulu Central Research Station, PO Bag 7, Chilanga, Zambia.

Musonda, E.M. 1996. Pearl millet shoot fly resistance screening and determination of dates of sowing in Zambia. Pages 311-314 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

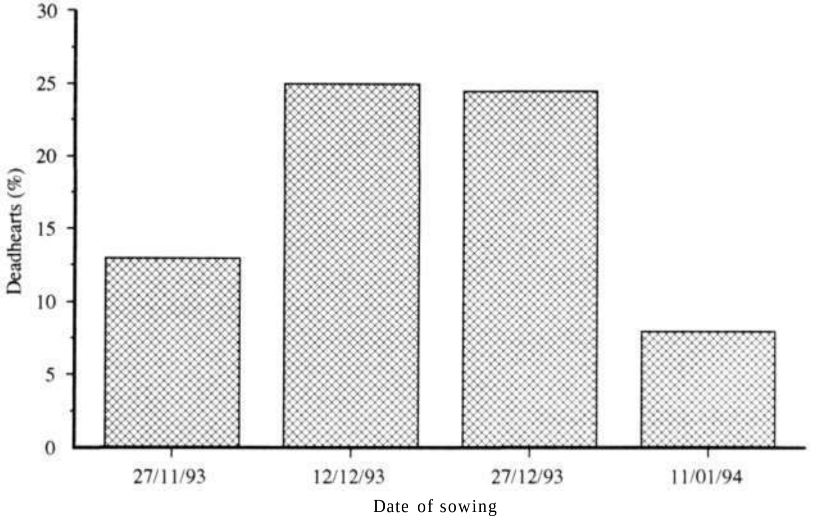

Figure 1. The effect of date of sowing on shoot fly damage, expressed as a percentage of pearl millet deadhearts, Longe, Zambia, 1993/94.

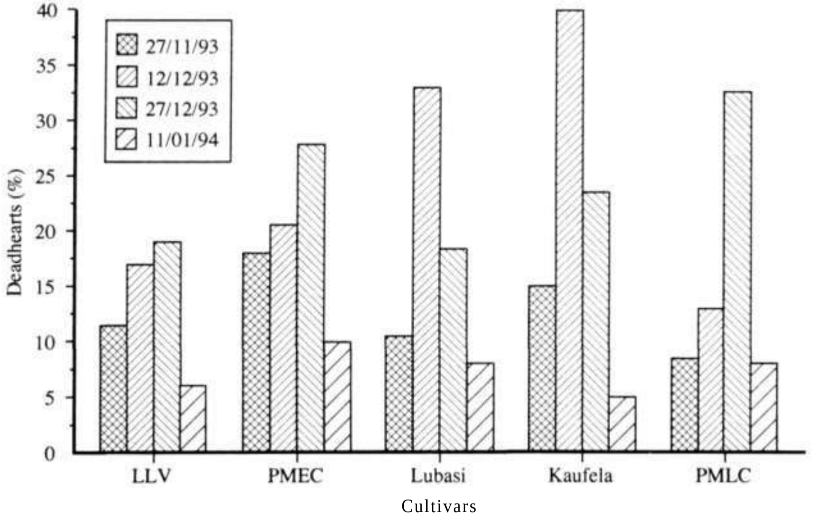

Figure 2. Performance differences between cultivars in relation to date of sowing, expressed as a percentage of pearl millet deadhearts resulting from shoot fly damage, Longe, Zambia, 1993/94.

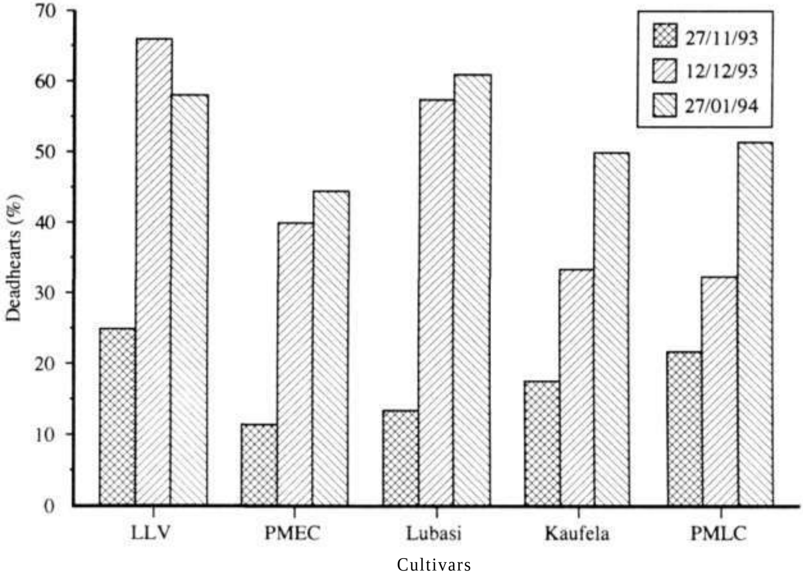

Figure 3. Performance differences between cultivars in relation to date of sowing, expressed as a percentage of pearl millet deadhearts resulting from shoot fly damage, Kataba, Zambia, 1993/94.

sowing, had more deadhearts than the LLV. At Kataba (Fig. 3) the short-duration cultivar PMEC performed better than all tested cultivars, followed by Kaufela and, lastly, the LLV, followed by PMLC and Kaufela.

Discussion

Percentage of deadhearts increased in relation to late sowing. So, delaying sowing causes more shoot fly damage.

Shoot fly damage in sowing date I was half that of sowing dates II and III (Fig. 1). This is because there is less shoot fly population at the onset of the rains.

Varietal reaction to pearl millet shoot fly at Longe (Fig. 2) indicates that three of the five tested cultivars—the LLV, the short-duration PMEC, and the long-duration PMLC—had less shoot fly damage in comparison with the medium-duration Lubasi and Kaufela which had more damage on the second sowing date. At Kataba (Fig. 3), PMEC, Kaufela, and PMLC performed better in terms of deadhearts than Lubasi and the LLV.

These data on varietal reaction to shoot fly attack, however, do not indicate which cultivar is more resistant than the others.

Conclusion

Sowing late causes loss of the crop due to damage by shoot fly. So, sowing early should be encouraged.

Sorghum Marketing and Utilization in South Africa

P R Skinner[1]

Introduction

In South Africa, industries that have maintained their control of the market by fixing prices at both ends came in for a great deal of criticism from proponents of deregulation, while those who adopted a more market-related approach have, by and large, been able to maintain a good deal of stability. Structured or phased deregulation has distinct advantages over simply stripping a government agency of all its statutory powers. So the time has come for agricultural industries to reconsider outdated marketing structures and policies to avoid being commercially bypassed.

So, what has actually changed?

First, there have been domestic pressures to increase marketing efficiency.

Secondly, there has also been a move towards market liberalization.

And, thirdly, South Africa is adjusting to greater pressures than before from international competition.

The Sorghum Board's deregulation

Since the inception of the Sorghum Board in 1986, it has actively encouraged direct farmer-access to the markets, largely by arranging a floor-price scheme in which the Board, as a last-resort buyer, purchased on average only 12% of the sorghum crop between 1986 and 1993. In 1994 the Board decided to opt for further deregulation by amending its marketing arrangements to cater for a voluntary-pool scheme for sorghum farmers. Remarkably, the Board has received a great deal of support for this arrangement, with some 60% of the crop flowing to it this year, thereby causing the voluntary centralization of surplus stocks.

The Board has been prepared to pay participants in the pool a minimum price for sorghum on the basis of an anticipated future market price. So, after deducting all costs relating to this voluntary pool, the Board will be able to make deferred payments to the participants.

1. Sorghum Board, PO Box 56650, Arcadia 0007, Pretoria, South Africa.

Skinner, P.R. 1996. Sorghum marketing and utilization in South Africa. Pages 315-319 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

By adopting these procedures the Board has been able to maintain its relevance within the South African sorghum industry—on the one hand ensuring stability of supply and, on the other, maintaining its status as the buyer of last resort.

Other functions of a statutory marketing organization

Promotion and advertising. Advertising campaigns, to actively encourage the use of sorghum, have been initiated by the Board in recent years, on radio and TV and in the press. Although relatively expensive, these campaigns have been effective in increasing per capita consumption levels. Future generic advertising should be strongly supported by brand advertising, and an Advertising and Promotions Working Group has been established to assist the Board in formulating its future strategy.

Research. It is welcome news that agricultural research is a priority concern of the new government, with more emphasis on developing agriculture than in the past. An urgent requirement is the strengthening of research on sorghum. And in 1994 the Board is publishing a manual covering all aspects of sorghum production for smallholder farmers.

The Board's role in sorghum research is mainly that of financier and facilitator, in the sense that research projects are considered on their merit and their value to industry. Agronomic research, which is conducted exclusively by the Agricultural Research Council (ARC) and more specifically by its Grain Crops Institute, is aimed at reducing risks, maximizing income, and setting standards.

Other research activities include those related to the manufacture and use of sorghum products, including extrusion technology and health aspects. In both instances the Board acts on recommendations from industry (i.e., farmers and manufacturers), which are assessed and forwarded on the basis of criteria established by the Board's Research Advisory Committee.

Two recent projects were the determination (a) of the milling qualities of commercial sorghum cultivars (an ongoing study), and (b) of tannin levels, with the aid of a rapid chlorox test for use under field conditions.

Market and product development. Manufacturers of sorghum products for human consumption generally purchase their sorghum during the harvesting season, and the Board consequently has to sell off most of its stocks into other sectors. These are termed alternative marketing channels, often comprising speciality markets, e.g., dog food and mixed poultry feeds. Invariably most surplus sorghum is disposed of in the livestock-feed sector, where it is used mainly in the manufacture of poultry rations.

Other market and product development work relates to the manufacture of milled sorghum (meal and grits), composite foods, and instant sorghum products (dry- and wet-based).

The Board has also assisted in establishing a Malting Technology Workshop by cosponsoring the first course in 1993. (Ms J Dewar, Foodtek, CSIR, PO Box 395, Pretoria 0001, South Africa, has data on future courses.)

Information service and database. This enables the Board to advise industry on most aspects of sorghum production, marketing, and processing. Information on agronomy (often related to production problems), mostly derived from the Agricultural Research Council, is disseminated to farmers via the Board's newsletter *Sorghum Forum.* This also covers marketing and other industry news, and is circulated free of charge to all sorghum producers and other industry members.

A new publication soon to be launched for members of the trade—*Info-Forum: Sorghum in Perspective*—will cover information on product volumes, the economy of sorghum, and international sorghum news. Retrospective data on production achievements in the manufacturing sector, published by the Board, are shown in Figures 1 to 3.

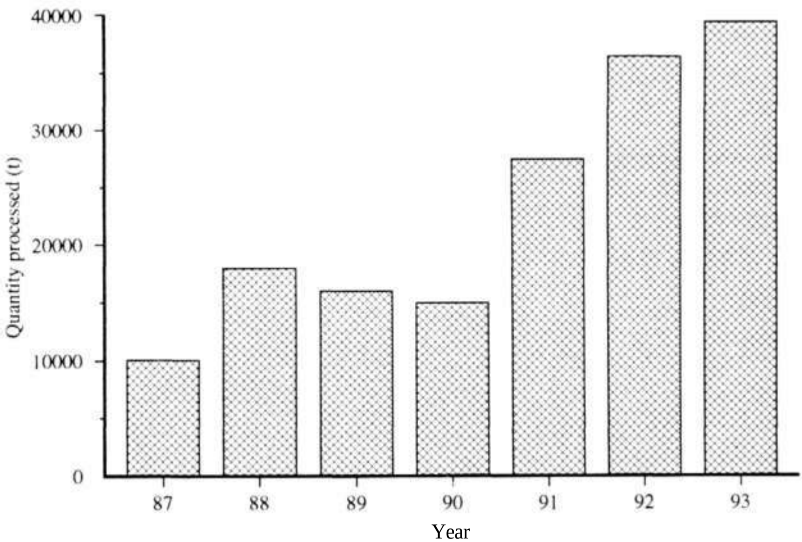

Figure 1. Sorghum volumes processed into various forms of meal in South Africa, 1987-93.

The future

To meet the needs of a growing population in South Africa and the subcontinent it is necessary to plan and organize the sorghum industry accordingly. The following points are an attempt to answer the question 'What is expected to happen in the industry?'.

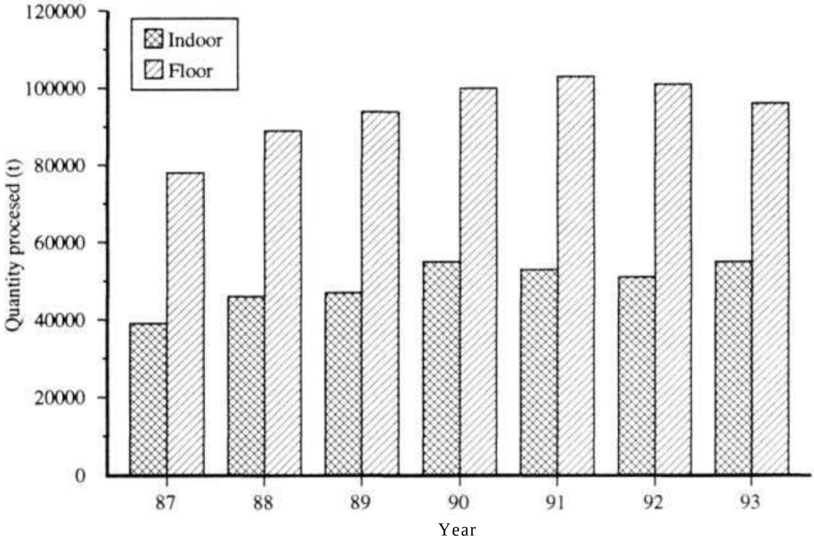

Figure 2. Sorghum volumes employed in the manufacture of indoor and floor malt in South Africa, 1987-93.

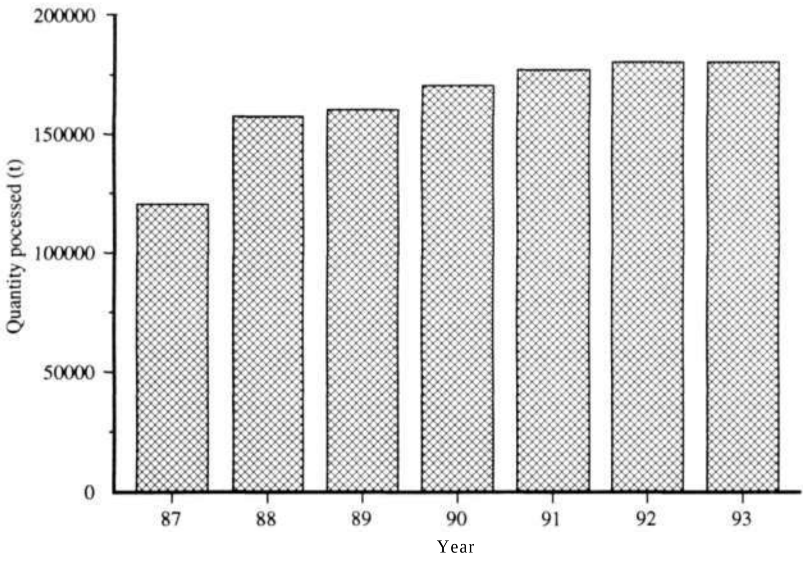

Figure 3. Sorghum volumes processed into various forms for human consumption in South Africa, 1987-93.

- Greater consumption will require more sorghum hectarage. The market will have to be demand-led, not vice versa.
- Seed breeders will play an important role in market-oriented production, not only in terms of quantities but also with regard to plant characters required for particular processes.
- More sophisticated, but affordable, sorghum products will have to be produced, and for this innovators in the food science sector are required.
- Training will be needed at several levels, to include courses on farming technology, malting, milling, and processing.
- Sorghum-related research will need maintenance and extension at all levels.
- Technology transfer, and method standardization, will be necessary throughout the industry.
- Communication will have to be improved within the industry—to include more meaningful participation by South African agriculturalists.

Finally, the Board expects that the sorghum industry will go from strength to strength. The present workshop represents another stone laid in the foundation of an industry which is destined for great things.

Zimbabwe Farmers' Union Activities in Promoting Small Grains Production in Zimbabwe

G S T Magadzire[1]

Introduction

The Zimbabwe Farmers' Union (ZFU) represents African farmers in the communal, resettlement, small-scale commercial, periurban plotholder, and emergent large-scale commercial subsectors. The smallholder farming sector represents about 1.3 million farmers.

The Union has a structure similar to that of local government, from the local to the national level. The local nuclei are clubs in communal areas in every village and associations in commercial areas. The clubs and associations form committees at area and district level, and the district committees form their provincial- and national-level committees. Additionally, the Union has Commodity Committees concerned with Grain and Oilseeds, Livestock, Cotton, Dairy, Horticulture, Tobacco, Tea, and Coffee.

Activities directly related to small grains

Club activities in liaison with small grains research and extension agencies are arranged at no cost and at short notice for extension, trial, and field demonstration functions.

Field days, agricultural shows, and crop-growing competitions related to small grains production are held at all levels, particularly in semi-arid regions in the country.

A ZFU bimonthly magazine circulated to communal farmers contains articles on small grains production.

The ZFU facilitates the marketing of small grains through brokering contracts and providing affordable transport services.

Some of the funds raised through levies on crop sales are channeled to small grains research programs.

Study handbooks on small grains are distributed for farmers' clubs.

The ZFU promotes the consumption of small grains through the provision of grinding mills.

1. President, Zimbabwe Farmers' Union, PO Box 3755, Harare, Zimbabwe.

Magadzire, G.S.T. 1996. Zimbabwe Farmers' Union activities in promoting small grains production in Zimbabwe. Pages 321-322 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

A Grains Commodity Association has been established specifically to promote the production of small grains.

The ZFU participates actively in the formulation of government policies relating to small grains production, with particular regard to producer prices and credit.

Seed Production and Certification: the Botswana Experience

W P Emmanuel[1]

Introduction

In Botswana the government controls the seed industry through the Seed Multiplication Unit (SMU) of the Ministry of Agriculture. Seed quantities increased from 33 t per season in the 1950s to over 200 t at the end of the 1970s.

Very small quantities were produced during 1981-84 due to severe drought.

The SMU, established around 1965/66, is the sole producer of improved seed for sorghum, maize, millet, cowpea, sunflower, and groundnut. Botswana is usually self-sufficient in sorghum seed, but has to import seed of other crops nearly every year. Hybrids are little-used since only commercial farmers can afford to purchase the expensive seed. A Seed Certification Act, passed by Parliament in 1976, provides for the regulation and control of seed production and distribution, and controls minimum standards for purity and germination in a certification scheme. The SMU is divided into three sections—Seed Production, Seed Testing Laboratory, and Seed Processing and Distribution.

Seed production

The *Botswana Handbook of Seed Certification Standards and Rules* states that seed multiplication is limited to designated varieties, and growers must register with the Authority.

Standards of seed quality have been established for basic and certified seeds of sorghum, maize, millet, cowpea, sunflower, and groundnut.

Basic seed. The production of this seed, started at Sebele Research Station in the late 1960s, is now produced by the SMU in collaboration with the Estate Management Unit. The latter provides the SMU with farm equipment and labor, but technical aspects such as seed inspection, roguing, and seed sampling remain the sole responsibility of the SMU.

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1. Assistant Agricultural Research Officer, Department of Agricultural Research, PO Bag 0033, Gaborone, Botswana.

Emmanuel, W.P. 1996. Seed production and certification: the Botswana experience. Pages 323-325 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Certified seed. Certified seed production is carried out through the use of contract seed growers. These were first used in 1970 by identifying 'master farmers'. However, due to seed-crop failures in 1982/83, the policy was changed so that most of the seed would be produced by a few big growers who had the resources to produce a crop even in a year of poor rainfall. Although the contracted area has been greatly increased since 1985/86, due to low rainfall, the SMU has been buying seed from noncontracted growers in order to meet the national demand.

The total production of seed of various crops since the 1982/83 season is shown in Table 1, and includes seed produced by contract growers as well as seed purchased by the SMU from other growers.

Table 1. Annual seed production (t), Botswana, 1982-88.

Season	Sorghum	Maize	Millet	Cowpea	Sunflower	Groundnut	Total
1982/83	1114	956	5	100	14	14	2203
1983/84	1647	1127	61	132	3	5	2975
1984/85	3448	732	5	36	13	11	4245
1985/86	4649	724	18	7	30	3	5431
1986/87	-	-	-	-	-	-	-
1987/88	6138	1264	50	51	7	69	7579

Source: Annual Reports for the Division of Arable Crops Research 1982-88.

In Botswana, new plant cultivars and other technologies are cleared by the Variety Recommendation Committee. Membership of the committee comprises people from agricultural research, agricultural extension, and the Botswana College of Agriculture.

Seed-testing laboratory

The laboratory is located at Sebele Agricultural Research Station. It is divided into a section for purity analysis and another for germination. While the laboratory is not yet a member of the International Seed Testing Association (ISTA), it uses the ISTA rules and the following methods in testing seed:

- Seeds are sampled in proportion to the number of bags in a seedlot.
- The working sample for purity analysis is separated into components of pure seed, other crop seed, weed seed, and inert matter.

Paper towelling is the method commonly used in germination analysis. On average, the seed testing laboratory tests 600 samples per season.

Seed processing and distribution

All basic and certified seed is processed at the two Sebele processing plants. One is an old-version Clipper plant with a processing capacity of 3 t h^{-1}. Another, a modern plant with a processing capacity of up to 8 t h^{-1} was installed in 1990. It has an airscreen cleaner, precision grader, indented cylinder, gravity table, and treater. Seed processing involves seed cleaning, separating and upgrading, treating, packaging, and labeling.

Since the inception of agricultural credit schemes, such as the Arable Land Development Programme (ALDEP), Accelerated Rainfed Programme (ARAP), and the Drought Relief Scheme, the national seed demand has increased. For instance, the national seed demand was 7000 t during the 1988/89 cropping season.

Seed distribution is carried out through the Department of Crop Production and Forestry (DCPF), Botswana Agricultural Marketing Board (BAMB), Botswana Cooperative Union (BCU), and, to a lesser extent, by the One Stop Service Centre for Agriculture (OSSCA). The bulk of the seed is distributed as free seed by DCPF under the Drought Relief Scheme. When this scheme began, farmers were issued with enough seed to plant up to 10 ha. During the cropping season 1993/94 farmers were issued with seed to cover up to only 5 ha. Crops that are covered under the Drought Relief Scheme include sorghum, maize, millet, and, to some extent, cowpea.

BAMB is the second major seed-distribution agency, and BCU is the third. Both organizations buy seed from the SMU at the wholesale price and sell it to the public at the market price. Seed prices are highly subsidized since they are set and controlled by the government. For instance, 10 kg of sorghum seed costs the local equivalent of about US$1.00 and is sold at about US$1.50.

The total distribution of seed of various crops since the 1982/83 season is indicated in Table 2.

Table 2. Annual seed distribution by agency (t), Botswana, 1982-88.[1]

Season	BAMB	BCU	DCPF	OSSCA	Research
1982/83	280	91	1808	-	6
1983/84	439	201	2300	-	49
1984/85	370	118	27839	-	100
1985/86	419	134	5718	2	74
1986/87	207	104	5708	8	14
1987/88	383	26	6677	20	32

Source: Annual Reports for the Division of Arable Crops Research 1982-88.
1. For an explanation of the acronyms, see the text.

Conclusion

There is an urgent need to develop the seed industry in Botswana. Commercial seed should be incorporated into the government's seed industry.

Sorghum Variety Evaluation, Release, and Seed Production in Swaziland

J Pali-Shikhulu[1] and S Simelane[2]

Introduction

This paper discusses the status of three sorghum varieties that have been released in Swaziland after evaluation.

The Agricultural Research Division of the Ministry of Agriculture and Cooperatives is responsible for all varietal tests; at present data from other tests are not accepted. Data from other NARS can be used only after the 1st year of testing under on-farm conditions. The stages of variety evaluation are depicted in Table 1.

Table 1. Investigation procedures in variety evaluation in Swaziland.

	Summer	Winter
Year 1	Introductory nurseries at one location Identify promising lines	
Year 2	Advanced evaluation trials: 1 low-potential location 1 high-potential location	Seed multiplication/ purification
Year 3	Elite variety trials: 6 on-station sites On-farm trials	Seed multiplication/ purification of best lines identified
Year 4	Elite variety trials Agronomy (seed rate, fertilizer, time of sowing, etc)	Seed multiplication/ purification of best lines identified Basic seed generation
Year 5	Elite variety trials On-farm trials	Foundation seed generation
Year 6	Release variety Agronomic recommendations Commercial seed production	

1. Cereals Agronomist, Malkerns Research Station, PO Box 4, Malkerns, Swaziland.
2. Swaziland Seed Quality Control Registrar, same address.

Pali-Shikhulu, J., and Simelane, S. 1996. Variety evaluation, release, and seed production in Swaziland. Pages 327-329 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Assessment and on-farm testing

The following aspects are assessed:

- yield
- maturity
- disease reactions to ergot, leaf blight, and downy mildew
- pests, especially stem borers
- plant type
- end-use characters
- farmer acceptability.

Agronomic tests include those for fertilizer, plant population, seed rates, and time of sowing.

Before release, varieties are tested under farm conditions. Best-adapted varieties are identified under low and variable production conditions. Also, farmers are able to evaluate these varieties against local landrace varieties.

Assembling and publication of data

The data collected are analyzed, and a dossier is prepared for each variety. The National Variety Release Committee then considers the dossier. Other NARS, regional programs, and private companies may be cited in support of the submission for release.

There should be enough foundation seed for continual, commercial seed production (Table 2).

Table 2. Status of varieties released in Swaziland.

					Quantities of seed (kg)		
Variety name	Local accession	ICRISAT accession	Year of first test	Year of release	Basic[1]	Foundation[2]	Commerce[3]
To be given	MRS 94	SDS 1594-1	1985	1991	50	200	7000
	MRS 13	SDS 1513	1985	1991	50	50	
	MRS 12	ICSV 112	1985	1992	50	200	

Sources:
1. Responsibility of SADC/ICRISAT SMIP or the Agricultural Research Division (ARD).
2. Responsibility of the ARD.
3. Swazi American Pioneer Seed Company.

The description of the distinctness, uniformity, and stability of the variety is prepared by the breeder, in collaboration with the national agronomist, and the Swaziland Seed Quality Control authorities. The descriptions include the range of variations to be expected in the cultivar. These characteristics are used subsequently in:

- monitoring the purity of the seed
- assessing the genetic purity by certification authorities
- ensuring that the seed is properly labeled.

Variety Release Committee

Membership of this committee consists of:

- Registrar of Quality Control
- Representative of farmers
- Representative of seed merchants
- Breeder from the University of Swaziland
- Plant Protection Officer
- Representative of seed producers
- Representative from Extension Services
- Representatives of Chief Research Officer
- A socioeconomist.

Information required by the Variety Release Committee

This includes:

- Method of identification
- Variety performance in comparison with standard variety
- Area of adaptation
- Proposed end-uses
- Amount of basic seed available for multiplication and distribution
- Recommended method of seed increase and maintenance
- Proposed method of seed distribution.

Variety promotion

Farmers are informed of the new variety through:

- Field days at the research station
- Farmer evaluation of on-farm trials and demonstrations
- Demonstrations; extension services, and NGOs
- Demonstrations conducted by the local seed company
- Seed extension by seed companies and merchants
- Marketing, distribution, and advertisements by seed companies.

Cultivar Release Procedures, Production and Distribution of Seed, and Extension Recommendations in Tanzania

H M Saadan[1] and S I Mndolwa[2]

Introduction

Although smallholder farmers in Tanzania account for 90% of food and cash-crop production, only 10% of them use certified seed (Lujuo 1994), because commercial seed companies focus on crops that provide quick returns and have high-volume value. The seed production program is under the mandate of the Tanzania Official Seed Certification Agency (TOSCA). Seed certification was established through the 1973 Seeds Regulation Act, Section 5(a), and subsequent regulations were added in 1975. The Agency functions under the Ministry of Agriculture with a Chief Certification Officer located at Morogoro.

Seed certification involves inspection of pedigree records of eligible crop cultivars to make available high-quality seeds and propagating materials of superior cultivars to ensure genetic identity.

'Certified Seed' includes all the seed grades: Breeder, Foundation, Registered, and Certified, and refers to seed that has been produced, processed, tagged, labeled, and sealed in accordance with the rules, regulations, and procedures of TOSCA or by any other officially recognized seed certification agency outside Tanzania.

Seed release procedures

The Variety Release Committee is a subcommittee of the Seed Production Committee. The required contents of a revised variety release report are as follows.

Introduction. Background information, which includes:

- Reasons for initiating the work
- When the work was begun

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2. Agricultural Research Officer, at the same address.

Saadan, H.M., and Mndolwa, S.I. 1996. Cultivar release procedures, production and distribution of seed, and extension recommendations in Tanzania. Pages 331-334 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

- Source of initial germplasm
- Literature review
- Individuals involved.

Materials and methods

- Identify the parental materials from which the cultivar to be released is derived
- Describe how the testing was done
- Indicate the method of data analysis and comparisons made
- State if any special nonstandard methods were used and whether they have been described clearly.

Results/data presentation

- Include data by season/location/experiment, etc., at least for the seasons
- Analyze combined data
- Check the soundness of combined data
- Include appropriate reference or control cultivars in each group of data so as to show the merits of the cultivar
- Check whether economic analysis is appropriate
- Exhaust all supportive data to defend the cultivar
- Check whether climate or soil data are required to emphasize the value of the new cultivar
- Analyze the information on farmers' acceptability
- Present data from on-farm/village-level tests
- Check whether the cultivar has been tested for stability.

Discussion and justification for release

- Describe the merits of the new cultivar regarding yield, pests, diseases, environment, available alternative cultivars, cash returns, methods of seed production, social value, nutritional status, storage qualities, etc.
- Indicate the area of release and conditions of production
- Indicate the method of seed maintenance, if different from other cultivars
- Indicate whether the cultivar has any shortcomings
- Indicate any special management requirements, e.g., plant density, extra weeding, etc.
- Indicate appropriate sowing dates.

Conclusion

- Prepare a concise, authoritative statement to indicate the need to release the cultivar
- Indicate which cultivar will be replaced from the current list of released/common cultivars
- Suggest an appropriate name (optionally deferred until after the cultivar has been accepted by Variety Release Committee).

Summary/abstract/synopsis

- Describe the cultivar concisely in a text form
- Indicate briefly the area of release and conditions of production.

Administrative preparations

- Fill in appropriate forms obtainable from the secretariat of the Variety Release Committee
- Notify TOSCA and the Seed Coordinator at least 2 months before the Committee's annual meeting of the intention to release the new cultivar
- Prepare a sample of the new cultivar for retention by TOSCA and the Curator of the National Plant Genetic Resources if it is released
- Check seed stocks to know how much is available for the production as breeder seed.

Seed certification

The Seed Production Committee shall:

- Serve as the advisory body to the Certification Agency
- Make proposals for release and multiplication of new cultivars
- Define eligibility requirements of seed stocks
- Recommend fees and prices related to seed certification.

Eligibility of growers and definition of seed grades

Government Seed Multiplication Farms and the Tanzania Seed Company (TANSEED) are involved in pedigree-grade seed production. Large numbers of contract growers and private seed producers are needed to meet the seed needs of the country.

Breeder grade (Green Label). Indicates seed recognized by the Commissioner of Crop Development of the Ministry of Agriculture.

Foundation seed (White Label). Restricted to Seed Multiplication Farms designated by the Ministry of Agriculture and the Seed Production Committee; and indicates the approved progeny of breeder seed.

Registered seed (Purple Label). Produced by TANSEED and Seed Multiplication Farms, including contract growers. Refers to the approved progeny of breeder and foundation seed.

Certified seed (Blue Label). Produced by TANSEED and Seed Multiplication Farms, including contract growers. Refers to the approved progeny of breeder, foundation, and registered seed.

Substandard seed (Yellow Label). Certified in this way because the seed forms part of a seedlot that does not meet normal certification standards.

Seed distribution

TANSEED, responsible for producing, processing, and marketing certified seeds, is a parastatal organization in the Ministry of Agriculture with 62.5% shares controlled by the National Agricultural and Food Corporation (NAGCO), and with 37.5% shares owned by the Commonwealth Development Corporation (CDC). Seed distribution is done through TANSEED branches, depots, Tanganyika Farmers' Association (TFA), and regional cooperative unions and stockists appointed by the company (Moshi and Nnko 1989).

Private seed companies have their own breeder seed. For example, Cargill multiplies its seed through contract growers, and processing and packaging are done at its Arusha plant. It sells its seed through stockists. In general, the seed distribution system in the country is not very efficient.

Extension recommendations

These relate to improved technologies that could increase farmers' productivity. Most of these technologies are developed at research stations and are evaluated across environments. Eventually they could be location-specific or have blanket recommendations. Technologies are scrutinized before being accepted as extension recommendations by the Variety Release Committee, the Fertilizer Recommendation Committee, and the Crop Protection Committee. In each of these, extension officers, NGOs, private companies, and scientists are involved.

Recommended technology is disseminated to farmers by the Regional Extension Officer through the District Extension Officer and village extension services. Other methods include radio, monthly magazines (e.g., Ukulima wa kisasa), pamphlets, and posters.

Although most of the technologies have been developed and evaluated across environments, the economic status of smallholder, resource-poor farmers has not improved. Therefore, researchers recommend that any technology developed should be assessed by farmers through on-farm evaluation.

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Involvement of Extension Staff in On-Farm Research in Singida Region, Tanzania

E D W Mlingi[1]

Extension staff

The following extension staff are employed in the Singida Region of Tanzania:

Village Extension Officers	342
Divisional Extension Officers	28
District Extension Officers	18
Extension Officers	23

As 236 090 farmers are reached by the extension service, there is a ratio of about 690 farmers to each Village Extension Officer.

Regional development goals

Crop production is expected to increase substantially by 1998 (see Table 1).

Table 1. Current (1994) and estimated (1998) production (kg ha^{-1}) of principal crops in Singida Region, Tanzania.

Crop	Production (1994)	Estimated production (1998)
Maize	2 050	3 250
Sorghum	1 800	2000
Millets	950	1 000
Paddy	2 000	4 500
Cotton	460	500
Sunflower	880	1 500
Tobacco	800	1 000
Groundnut	450	500
Total for the Region	428 665 (t)	653 370 (t)

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Mlingi, E.D.W. 1996. Involvement of extension staff in on-farm research in Singida Region, Tanzania. Pages 335-336 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Problems in agricultural development

- Lack of credit facilities for input procurement
- Lack, shortage, or untimely supply of farm inputs
- Shortage of qualified extension staff
- Lack of stockists for farm inputs
- Shortage of pasture land.

Problems in sorghum promotion and production

- Lack of a good marketing and distribution system
- Tannins in sorghum and millets diminish the industrial use of these crops
- Weak linkages between research, extension, industry, and NGOs
- Lack of adequate supplies, and poor quality, of sorghum and millet to the feed and beverage industries
- Lack, and untimely availability, of crop production inputs.

Extension-research linkages

With the inception of the National Agriculture and Livestock Extension Rehabilitation Project (NALERP) in 1989/90, extension officers were organized to visit farmers in their areas with recommendations for problem-solving, and were provided with transport and technical recommendation kits.

In 1994 two districts, Singida and Iramba, were involved in on-farm trials. The varieties under trial are SV and Tegemeo for sorghum, and those for pearl millet include Buruma 91001 and 91018.

Procedures for Cultivar Release and Seed Production for Sorghum and Pearl Millet in Zimbabwe

J N Mushonga[1] and N Mangombe[2]

Introduction

Sorghum and pearl millet are major summer crops in Zimbabwe. Both cereals are staple food crops for most resource-poor farmers located in the marginal-rainfall areas. They are also used as malt in both commercial and traditional opaque beer preparations. In addition, the cereals are used as livestock feed and their stovers as building materials. Although sorghum and pearl millet research dates back to the 1940s, serious research to improve both crops began only after independence.

Cultivar development

Before a newly-developed cultivar is released to farmers, it goes through the following stages.

Preliminary cultivar trial. Replicated trials are grown at two sites to compare the performance of a newly-developed cultivar with a standard control cultivar.

Intermediate cultivar trial. Promising genotypes from the preliminary cultivar trial are tested in replicated trials grown at five diverse sites. Population density, plant height, seed grain color, grain size, drought tolerance, days to maturity, and yield are noted.

Advanced cultivar trial. Cultivars performing well are tested in at least eight ecological zones for three consecutive seasons to determine a superior genotype.

On-farm evaluation. This is concurrent with advanced testing and gives information on the performance of the cultivar in farmers' fields.

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2. Plant Breeder, Crop Breeding Institute, at the same address.

Mushonga, J.N., and Mangombe, N. 1996. Procedures for cultivar release and seed production for sorghum and pearl millet in Zimbabwe. Pages 337-339 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Cultivar release procedures. On identifying the cultivar to be released, the breeder writes up a release proposal, which includes the following:

- Proposed name of the cultivar
- Yield data for several years
- Pedigree
- Agronomic characters
- Quality data
- Number of sites used for testing
- Rainfall data
- Number of years of testing.

Presentation to the Variety Release Committee. The proposal is considered by this Committee, with membership as follows:

- Director, Department of Research and Specialist Services (Chairman)
- Deputy Director, Crops
- Head, Crop Breeding Institute
- Deputy Director, Special Services
- Head, Plant Protection Research Institute
- Head, Seed Services
- Chief Research Officer, Crop Breeding Institute
- Director, Agricultural Extension and Technical Services
- General Manager, Grain Marketing Board
- Head, Rattray Arnold Research Station (Seed Coop Company)
- President, Zimbabwe Farmers' Union
- Chairman, Commercial Farmers' Union
- Head, Agronomy Institute
- Chairman, Seed Coop Company
- Industry representative for a specific crop
- The breeder proposing the cultivar
- The Secretary from Crop Breeding (to take minutes)

If the cultivar is approved, the breeder (a) submits at least 50 kg of breeder seed to the seed company responsible for bulking; and (b) applies to the Seed Services for registration of the cultivar under the terms of the Plant Breeders' Rights Act and the Seed Certification Scheme.

Procedures to develop certified seed

Breeder seed. The breeder releases breeder seed to the company, in this case Seed Coop Company of Zimbabwe. The breeder also maintains a stock of pure seed of the released cultivars.

Foundation seed A. The Seed Coop makes arrangements with some growers to produce foundation seed A from breeder seed. A Seed Services inspector inspects the crop of this foundation seed for its purity.

Foundation seed B. Seed of foundation seed A is used to grow foundation seed B. The Seed Coop maintains stocks of both foundation seed A and B.

Certified seed. Foundation seed B is then used to produce the certified seed.

Linkages in Planning and Implementing On-Farm Trials in Zimbabwe

D N Masendeke[1]

Introduction

Research institutions in Asian and African countries previously under colonial administration were focused on increasing the production of high-value export commodities. In Zimbabwe these commodities were tobacco, coffee, tea, cotton, maize, sugarcane, etc., grown exclusively by foreign settlers and companies. Extension activities were developed and geared to service these commercial clients, with the result that smallholder communal farmers benefited only from demonstrations developed for the commercial sector.

There were two separate extension departments: the Department of Conservation and Extension (CONEX), which catered for commercial farmers, and the Department of Native Agriculture, catering to smallholder African farmers (later renamed the Department of Agricultural Development: DEVAG). CONEX enjoyed close, well-informed, and personal links with research staff of the Department of Research and Specialist Services (DR&SS) as they both directed their efforts towards the same client—the large-scale commercial farmer.

Although both departments, CONEX and DR&SS, belonged to the same ministry, there was no formal link between the two. Extension staff were responsible for servicing communal farmers, but established formal and productive links with research staff only after independence in 1980.

Postindependence extension and research

After independence the government merged the two extension services, DEVAG and CONEX, into one to cater for all farming sectors. The result was the Department of Agriculture and Technical Extension Service (AGRITEX) in 1981. The new department's emphasis was to be on small-scale producers, i.e., communal farmers.

Research in Zimbabwe had largely ignored smallholder farmers' circumstances: the difficulties of farming in marginal areas with poor soils and low and erratic rainfall.

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Masendeke, D.N. 1996. Linkages in planning and implementing on-farm trials in Zimbabwe. Pages 341-343 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K., and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

The applicability of research findings (focused on the needs of better-placed commercial farmers) to the smallholder sector was therefore questionable.

The need to address agricultural problems in the harsh environments faced by smallholder farmers led to some off-station trials in these environments. This was the beginning of the now important and popular on-farm trials.

On-farm research first took the form of replications of on-station trials in communal areas to address the different environmental factors there: poor sandy soils, weed competition, and farmers' lack of resources. (Poor performance of improved technologies on smallholder farms had often been blamed on the farmers' poor management skills.)

Although on-farm trials were conducted with both research and extension staff playing their different roles, there was still no formal linkage between the two departments. This meant that, though AGRITEX was numerically four to five times bigger than the DR&SS, it could not use its local experience to emphasize the need for problem-oriented research. On-farm trials were not addressing location-specific problems, and researchers could not influence the content and type of demonstrations conducted by AGRITEX. The farmer's role could, at best, be described as a provider of land and labor.

Technology generation, transfer, and adoption linkages (Fig. 1)

The need to formalize linkages between the two departments resulted in the formation of the Committee for On-Farm Research and Extension (COFRE) in 1986. Its overall objective is to coordinate the farm research and demonstration activities of the DR&SS and AGRITEX through commodity subcommittees at national and regional levels. COFRE links researchers, extensionists, and farmers through its Regional On-Farm Research and Extension (ROFREC) Committees, and it performs the following functions:

1. Facilitates interaction between AGRITEX subject-matter specialists, field staff, and DR&SS researchers in identifying technical constraints in agricultural production in communal farming sectors, and prioritizes these problems for attention by research and/or extension staff. This is mainly done by conducting diagnostic surveys.
2. Translates research findings into technical recommendations.
3. Tests recommendations through on-farm trials to ensure their applicability, economic benefits, and reliability.
4. Vets all proposals for research or demonstration and recommends new projects for funding or the termination of existing projects.

Other organizations involved in the generation, transfer, and adoption of technology in semi-arid areas of Zimbabwe include farmers, SADC/ICRISAT SMIP, the DR&SS, and AGRITEX. NGOs additionally provide logistic support and develop post-production technologies, e.g., dehullers, grain storage facilities, and seed bulking.

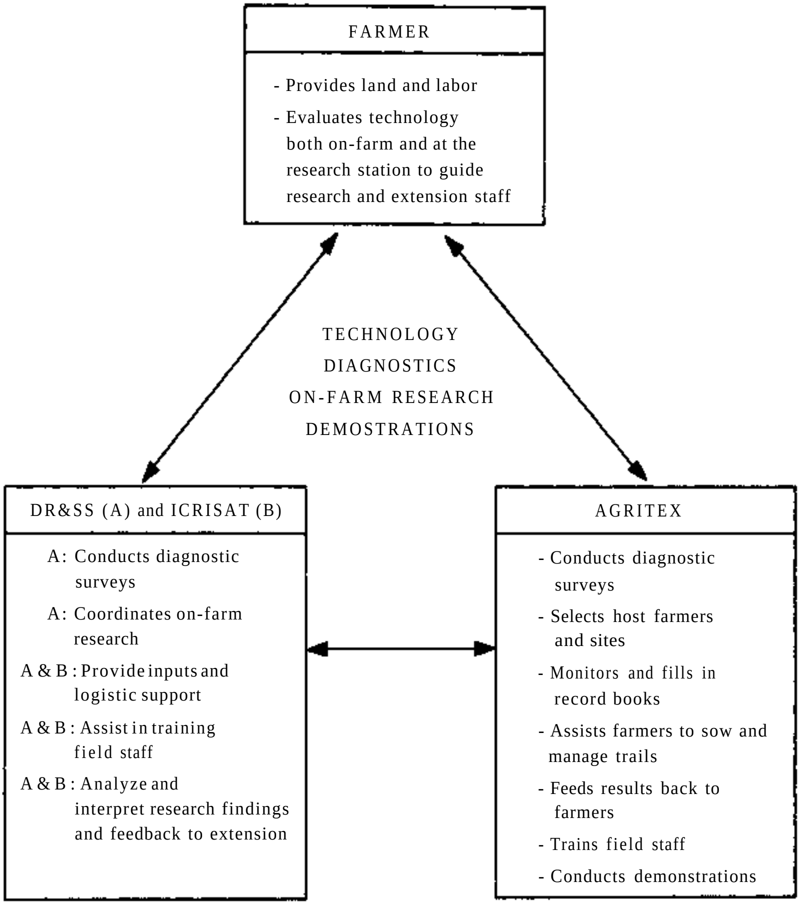

Figure 1. Technology generation, transfer, and adoption linkages.

Conclusion

If a national agricultural research and extension program is to meet the aspirations of smallholder farmers, it is necessary to develop a closely-linked mechanism that is devoid of bureaucratic interference that meets those needs, and that clearly shows what recommended technologies seek to address or achieve. And, since farmers' circumstances are dynamic, there is also a need to review the mechanism periodically, and make appropriate adjustments in the light of socioeconomic changes.

Appendices

Appendix 1: Closing Remarks

J N Mushonga[1]

The Chairman, the Botswana Government, the SACCAR Representative, USAID, CIDA, GTZ, Invited Guests, and all Participants:

It is a great pleasure for me to have this opportunity of saying a few words at this last moment in our deliberations.

It has persuaded me to reflect back to 1982-83 when initial missions were made from ICRISAT Center in India in search of a place to locate ICRISAT's southern Africa regional center. I remember clearly how the former Executive Director, Lee House, and I traveled to different parts of Zimbabwe until the present center was finally chosen as a suitable place to do research—a location that grew from one large house to what it is today.

And I find it interesting to remember the workshops that were organized by ICRISAT when only a handful of regional scientists had BSc and MSc degrees. Ten years later the standard and quality of papers has improved greatly, and almost every country has at least one PhD scientist.

This Workshop has been well attended, and the diversity in participants' disciplines is impressive.

So I feel the Workshop has been a success, with the following as points of achievement.

- Better presentations than during the last Workshop—probably an indication of success in the degree-training program.
- Participation by such different groups as extension and seed-company staff, NGOs, and farmers, which resulted in quality interactions of concern to us all.
- Involvement by the South African team and West African Network officials, which has been most welcome and has proved to be quite an eye-opener.

In spite of these successes, I feel SMIP still has guidance and action to offer in respect of:

- Training NARS scientists in the use of visual aids and in the efficient presentation of tables and graphs.
- Announcing such workshops as the present one well in advance, so that there is enough time to prepare for them.

On behalf of the Steering Committee and the NARS, I would like to thank the following:

- The Government of Botswana, for its warm welcome and all the assistance we received from our colleagues in the research and extension systems.

---

1. Out-Going Steering Committee Chairman and Head, Crop Breeding Institute, Department of Research and Specialist Services, PO Box CY 550, Causeway, Harare, Zimbabwe.

- The SACCAR Directorate and Management, for supporting us by their presence and guidance.
- Our donors—USAID, CIDA, and GTZ—who contributed generously to the implementation of this Workshop project.
- The SMIP Directorate and staff, for their inputs that have made this Workshop a success.
- Klaus Leuschner for successfully organizing and coordinating the Workshop.
- Sue Hall, the proceedings editor, for providing on time the backup services we needed.
- Barry Hall, for providing photographs.
- Irene Tapela, for her accounting work and related incidentals.
- Nomhle Bhebhe and Sehle Nyathi for providing us with super secretarial services.
- Kelebogile Seleke, from the Botswana NARS, for providing us with such good secretarial support.
- Sheraton Gaborone management and staff for creating a warm atmosphere for our comfort, and for their excellent food and service.
- All the participants, for their presentations and attendance at such an important Workshop.
- And, last but not least, I want to thank my colleague and incoming Steering Committee Chairperson, Chris Manthe, for welcoming the NARS scientists, and for giving all of us the assistance we needed. I wish him good luck during his term of office.

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Appendix 3: Acronyms and Abbreviations

ADC	Agricultural Development Centre (Namibia)
AGRITEX	Department of Agriculture and Technological Extension Service (Zimbabwe)
AMG	amyloglucosidase
BMZ	Bundesministerium fur Wirtschaftliche und Entwicklung Zusammenarbeit (Germany)
CARD	Coordinated Agricultural Rural Development (Zimbabwe)
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIDA	Canadian International Development Agency
CIRAD	Centre de cooperation international en recherche agronomique pour le developpement (France)
COFRE	Committee for On-Farm Research and Extension (Zimbabwe)
CV	coefficient of variation
dATP	2'-deoxyadenosine 5'-triphosphate
dCTP	2'-deoxycytidine 5'-triphosphate
dGTP	2'-deoxyguanosine 5'-triphosphate
DNA	deoxyribonucleic acid
DR&SS	Department of Research and Specialist Services (Zimbabwe)
dTTP	2'-deoxythimidine 5'-triphosphate
ENDA	Environmental Development Activities (Zimbabwe)
EPA	extension planning area
FAO	Food and Agriculture Organization of the United Nations (Italy)
FMFI	farmer-managed farmer-implemented (trials)
FTRS	Food Technology Research Service (Botswana)
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit (Germany)
IDRC	International Development Research Centre (Canada)
IITA	International Institute of Tropical Agriculture (Nigeria)
ILRI	International Livestock Research Institute (Ethiopia/Kenya)
IPM	integrated pest management
LLV	local landrace variety
MAWRD	Ministry of Agriculture, Water and Rural Development (Namibia)
MRTC	Mvumi Rural Training Centre (Tanzania)
NARS	national agricultural research system(s)
NC	Nigerian Composite (sorghum)
NGO	nongovernmental organization

OBJ-7	a primer
OPV	open-pollinated variety
PCR	polymerase chain reaction
RAPD	random amplified polymorphic DNA
RCBD	randomized complete block design
R&D	research and development
RFLP	restriction fragment length polymorphism
RH	relative humidity
RIIC	Rural Industries Innovation Centre (Botswana)
RMFI	research-managed farmer-implemented (trials)
SADC	Southern African Development Community (Botswana)
SCCI	Seed Control and Certification Institute (Zambia)
SE	standard error
SMIP	Sorghum and Millet Improvement Program (SADC/ICRISAT, Zimbabwe)
SMU	Seed Multiplication Unit (Botswana)
syn	synonym
Taq	an enzyme
TOSCA	Tanzania Official Seed Certification Agency
tris-HCl	tris(hydroxymethyl) aminomethane
USAID	United States Agency for International Development
VEW	village extension worker (Tanzania)
WUE	water-use efficiency
ZFU	Zimbabwe Farmers' Union

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The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

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