CHAPTER 1: INTRODUCTION

Sorghum is a major crop of the semi-arid tropics of Africa and Asia, and is an important component in traditional farming systems and in diets of millions of people. The crop belongs to the elite handful of plants that collectively provide more than 85 % of all human energy. Wide diversity exists within the crop with different types of sorghum being grown in different parts of the world and the crop has great potential because of its diversity in use. Unfortunately, this potentially promising crop has not realized its full potential because of several drawbacks that have kept its production at lower levels as compared to other cereals.

According to The National Academy of Sciences (1996), the major drawbacks of sorghum include (i) lack of status, with the crop being regarded as a “coarse grain” fit for animal feed and being food of the peasant classes, (ii) regard as crop of low food value of 12 % protein, 3 % fat and 70 % carbohydrate, though it hardly differs from maize and wheat. It is regarded as food of low value mainly because of tannins which occur in the seed coats of brown sorghum grains and a large proportion of the protein is prolamine, an alcohol-soluble protein that has low digestibility in humans and (iii) difficulty in processing. These drawbacks together with abiotic stresses (low fertility and drought) and biotic stresses (pest and diseases) have contributed to low production of sorghum.

In Zimbabwe, low sorghum yields are attributed to the prevalence of drought, high variation in amount and distribution of rainfall, use of traditional and unimproved varieties, lack of access to seed of improved varieties and the HIV/AIDS epidemic

(Haussmann, Obilana, Blum, Ayiecho, Schipprack and Geiger, 1998). In addition, much of the rain received in the marginal areas of Zimbabwe (Natural regions IV and V), runs off leading to soil degradation and further aggravating the moisture constraints in these semi arid areas. Soil and water management practices are also crucial for efficient use of the limited and variable rainfall and to arrest land degradation. Furrow dikes (Tied ridges), which are small earthen dams formed periodically between the ridges of a ridge-furrow tillage system (Jones and Baumhardt, 2003) have the advantage of storing potential runoff on the soil surface, allowing the water to infiltrate. This decreases storm or irrigation runoff, increasing storage and plant available water in the soil. Nyamudeza and Mazhangara (1993) reported 11 to 351 percent yield increases in sorghum sown in tied furrows than on the flat. Various initiatives were also implemented in the past so as to improve crop productivity but food insecurity remains a major challenge in semi-arid and arid areas.

The Green Revolution, based on the use of improved varieties and inorganic fertilizers, had very little or no impact on crop productivity in the marginal areas in Africa. At the same time, contemporary breeding had very little impact on the adoption of improved sorghum varieties. This mismatch between contemporary breeding and farmers' needs requires Participatory Rural Appraisal (PRA) approaches so as to achieve demand driven research. Participatory Plant Breeding (PPB), one of the PRA approaches, intends mainly to answer the needs of small farmers living in poor and marginal areas for whom conventional breeding cannot offer suitable varieties (Trouche, 2005). A 30 % adoption rate of improved varieties has been recorded by ICRISAT and a survey by Musa and

Rusike (1997) showed that 35 % of the 132 000 hectares under sorghum was under improved varieties, with early maturing varieties being preferred.

The objectives of the study were:

1. To identify well adapted sorghum varieties that can be grown by farmers through participatory variety selection. These varieties must mature early, be drought and water stress tolerant, high yielding, have good agronomic characteristics and ease to process.
2. To establish a sorghum selection criteria through involvement of researchers, farmers and extension officers in variety evaluation and selection.
3. To investigate the effects of planting sorghum on tied ridges and on flat as a water conservation technique in sorghum production

The study was done based on the following hypotheses:

1. Experimental sorghum lines are better adapted for production as compared to current commercial varieties
2. Sorghum Selection Criteria used by farmers is different from the criteria used by researchers
3. Tied ridges can be used effectively as a water conservation technique in sorghum production

CHAPTER 2: LITERATURE REVIEW

2.1 Sorghum Production and Use

Sorghum is grown on forty-four million hectares in ninety-nine countries in Africa, Asia, Oceania and the Americas (www.icrisat.org). It is a major crop of the semi-arid tropics of Africa and Asia that are characterised by low, erratic and poorly distributed rainfall, terminal droughts and intermittent mid seasonal droughts (Haussmann *et al.*, 1998). It is an important component in traditional farming systems and in diets of millions of people in these areas. Murty, Tabo and Ajayi (1994), ranked sorghum as the fifth most important cereal after rice, wheat, maize and barley. Sixty percent of global agriculture, producing 15 % to 20 % of the world food is practiced in semi-arid areas. These semi-arid areas are home to a sixth of the world population and most of which are the poorest farming communities.

In Zimbabwe, sorghum is mainly grown by communal farmers and a few commercial farmers under rain fed conditions in Natural regions III, IV and V with 75 % of the communal areas receiving 450 to 500 millimeters of rainfall (Rao and Mushonga, 1987). Three to five out of ten years show crop yields far below average, resulting in insufficient food supply for approximately 50 % of the households. Use of drought tolerant varieties and good water conservation practices will ensure improved sorghum yields in these marginal areas.

2.2 Production Constraints of Sorghum

In semi-arid areas, low soil fertility, poor stand establishment, a high unpredictable drought stress pattern and high micro-variability within fields are major production constraints that also complicate sorghum improvement in these areas (Mushonga and Mudzana, 1989; Haussmann, Obilana, Blum, Ayiecho, Schipprack and Geiger, 1999). Drought induced food shortages are common throughout the SADC region and the two major reasons for these shortages are (i) crop failures of maize due to insufficient rainfall and (ii) continued use of traditional varieties that give poor yield and are susceptible to late season drought (Mgonja, 2003).

The low yield of sorghum in Zimbabwe has been attributed to the prevalence of drought (especially terminal drought), high variation in amount and distribution of rainfall, use of traditional varieties, lack of access to seed of improved varieties and HIV/AIDS epidemic (Haussmann *et al*, 1998, 1999; Mangombe, Gono and Mushonga, 1996). Sorghum is grown mainly by communal farmers and a few commercial farmers under rain-fed conditions in Natural Regions III, IV and V. About 75 % of the communal areas are located in Natural Regions IV and V where million of farmers are engaged in dry-land farming (Rao and Mushonga, 1987).

Besides being grown in marginal areas of Zimbabwe, sorghum production is also affected by a low variety adoption rate of 30 % and this is the third highest in the Southern Africa Development Community (SADC) after Swaziland (50 %) and Zambia (35 - 40 %) (ICRISAT, unpublished). The low adoption rates indicate that farmers are still utilizing traditional varieties despite overwhelming evidence of the superiority of improved varieties in terms of yield. Continued use of landraces that are very tall with lax and grass panicles that mature very late (Rao and Mushonga, 1987), and low adoption rates of improved varieties has negatively affected sorghum production. Continued use of the landraces may be due to several factors that include:

(a) Conducting selections at stations with optimum amount of fertilisers, weed control and water supply, often using well planned crop rotations (Ceccarelli, 1997). Critics argue that conclusions drawn from trials carried out on research stations do not necessarily reflect farmers' field conditions (Braun, Rajaram and van Ginkel, 1997).

(b) Release of genetically homogenous varieties to fit variety registration rules. On the other hand farmers need to spread the risk by growing several varieties (van Oosterhout, 1993; Mushita, 1993) or by growing mixtures of different morphological types in the same field, harvesting small quantities at different times to meet immediate food requirements (Rao and Mushonga, 1987).

(c) Release of new varieties based on average performance in trials conducted for a number of years and poor performance of improved varieties in a number of factors such as product utilisation, qualities including palatability, nutrition food, beer and storage.

On moderately sloping and light textured soils, much of the rain that falls in drylands runs off, leading to soil degradation and further aggravating the moisture constraints in semi arid areas (ICRISAT, 1996). Soil and water management practices are crucial for efficient use of the limited and variable rainfall, and to arrest land degradation. This can be complemented by the use of well-adapted sorghum varieties that fit into farmers' management systems and product use.

Various stakeholders have tried to address some of these constraints through various approaches including release of well adapted sorghum varieties that are tolerant to drought, acceptable taste, ease of processing, withstand bird damage and early to mature. Most of the emphasis was placed on contemporary breeding but this has led to release of varieties that were lowly adopted by farmers. The development and release of sorghum varieties demands the co-operation of various stakeholders. This has been tried in other crops with some success being recorded.

2.3 Research Approaches

2.3.1 Contemporary plant breeding

Contemporary breeding has had very little impact on the adoption of improved sorghum varieties despite their release by ICRISAT and National Agricultural Research Stations (NARS). Surveys and reports by van Oosterhout (1993), Mushita (1993), Mangombe *et al.,* (1996), Haussmann *et al.,* (1998) and Seed Co (http://www.samara.co.zw/seedco/grosorg.html) indicate that morphological characteristics (which breeders place more emphasis upon) always came last in terms of rankings as compared to gastronomic and agronomic characteristics that were either first or second depending on area. Very few breeders select in sub-optimum or stress conditions. Breeders and agronomists put more emphasis on yield and rely on indirect selection traits that are easy, cheap and quick to measure so that high selection intensities can be realized in early generation testing and these traits must be highly heritable and closely correlated to the target trait, that is, yield (Haussmann *et al.*, 1998). These criteria have led to the release of varieties that have low adoption rates by farmers.

In Zimbabwe, a small sorghum breeding programme commenced in 1960 made its first release of brown grained types used for brewing opaque beer. More recently, however emphasis has been placed on white-grained sorghum for human consumption (Havazvidi and Tattersfield, 2006). Estimates made in Zimbabwe indicated that 35 % of the 132 000 hectares under sorghum was under improved varieties (Musa and Rusike, 1997). Heinrich and Mangombe (1995) observed that farmers' preferences were biased towards early maturity rather than mean yield. The farmers did not show preference towards hybrids in the trial despite their dominance in the grain yield rankings. Variety, SV-2 was preferred because of its early maturity. Sorghum and Millet Improvement Program (SMIP), a 20 year program initiated by SADC member states in 1983 till 2003, also saw release of 49 sorghum and pearl millet varieties in the SADC region (ICRISAT, unpublished). Despite all the improved varieties, farmers still grow traditional varieties.

The release of improved varieties was also accompanied by research trials aimed at developing water conservation and management systems. According to Jones and Baumhardt (2003), furrow dikes (tied ridges) have the advantage of storing potential runoff on the soil surface allowing the water to infiltrate thus decreasing storm or irrigation runoff and increasing storage and plant available water in the soil. Nyamudeza and Mazhangara (1993) reported that sowing in tied furrows always gave higher sorghum yields than sowing on the flat on vertisols, paragnesis and alluvial soils during trials running for six seasons (1983/84 to 1989/90) with percentage increases ranging from 11 % to 351 %. In a similar trial, Osmanzai, Chisenga, Verma, Saddan, Chambo, Letayo and Chirwa (1992) also proved that sorghum hybrids had the highest water use efficiency, followed by improved varieties with traditional varieties having the lowest water use efficiency.

Commendable research has been done on improving sorghum varieties and water management techniques but farmers are still reluctant to adopt these technologies. This shows the existence of a gap between researchers and farmers in technology development and dissemination. This gap can only be closed by the participation of various stakeholders in developing and disseminating technologies. This requires a paradigm shift on the part of researchers towards “demand driven” research.

2.3.2 Participatory Rural Appraisal

Participatory Rural Appraisal is a system whereby all stakeholders of a particular crop are consulted and involved in decision making during the various stages of implementing a research project. Project diagnosis, planning and designing, experimentation, and adaptation and validation must promote participation of relevant stakeholders.

2.3.2.1 Participatory Crop Improvement/Participatory Breeding

Participatory Breeding intends to answer the needs of small farmers living in poor and marginal areas for whom conventional breeding cannot offer suitable varieties (Trouche, 2005). One form of PRA is Participatory Crop Improvement (PCI). A participatory research approach would enable local people to share, enhance and analyse their knowledge on a crop so that they can plan and act together with the scientists. Participatory Crop Improvement approaches encourage increased farmer participation and scientists become aware of the philosophy of "farmers first" and its effectiveness (Witcombe, 1999). According to Trouche (2005), PCI usually has four objectives:

(a) Gains in productivity, including increases in quality and product value.

(b) More effective breeding made through closer consideration of the demands and preferences of farmers and other stakeholders and of environmental conditions.

(c) Dynamic conservation of biodiversity

(d) Strengthening the capacities of farmer groups and organisations

There are two types of Participatory breeding which are Participatory Plant Breeding (PPB) and Participatory Variety Selection (PVS). Participatory Plant Breeding refers to activities in which farmers select plants or seeds from and within a genetically variable population or variety while PVS is the term for the activities in which farmers evaluate and select from among released or pre-released or advanced varieties (Almekinders and Louwaars, 1999; Trouche, 2005). Participatory Plant Breeding (PPB) aims to fully integrate farmers and other stakeholders of the production chain into the whole process of variety development decentralizing, towards farm fields, the most important steps of selection and evaluation.

Involvement of farmers through PVS is key to adopting improved crop varieties. On station selection trials can become on-station demonstration and participatory selection trials. Special field days maybe organized at which farmers are invited to evaluate the material. These special field days stimulate farmers' interest and there is an opportunity for the farmers to take some seed of selected materials. The breeder's interest is in obtaining a clear picture of the farmers' selection criteria, which should be involved in future breeding objectives. Participatory Variety Selection can be in form of Community Trials that can be hosted by one farmer, at a school, or at a site where people have easy access to. Eight to 25 different varieties can still be comfortably monitored and distinguished in one researcher or community-managed experiment.

Observations in PVS trials commonly include several of agronomic yield and quality characteristics. Group discussions with farmers are helpful to prioritize, add or delete characteristics. According to Ashby (1990); Almekinders and Louwaars (1999), aids to PVS include:

(a) Absolute evaluation whereby each variety is selected or rejected by averaging scores by farmers.

(b) Matrix ranking whereby alternatives are ranked from best-liked to least-liked. This is suitable for exploring the importance to the farmers of different variety characteristics.

(c) Pair wise ranking whereby each variety is judged better or worse compared to the local comparison variety or compared to all others in a set.

Participatory approaches led van Oosterhout (1993), to recognize three groups of characteristics used by farmers to describe varieties. These are:

(i) Agronomic – maturity period, soil and water requirements, tolerance to weeds, insects, pathogens and drought during the growing season as well as susceptibility to bird damage.

(ii) Gastronomic – threshability, ease of winnowing, pounding and milling, good taste for beer and sadza (traditional thick porridge), color of resulting food products, time required in cooking, keeping quality or the cooked grain, texture of endosperm and suitability for use in multiple food products and storage quality.

(iii) Morphological –grain and fodder yield, plant height and tillering potential.

A participatory research and extension approach called the Mother – Baby trial, in which farmers, researchers, extension, seed companies and rural development agents evaluate maize varieties in farmer fields in different agro-ecological zones has resulted in the release of Open Pollinated maize varieties, ZM421 and ZM521 regionally. According to Kwazira (2007), Mother-Baby trials facilitated adoption of superior and appropriate maize varieties that raise and stabilize maize yields in poor farming sectors. The same approach can be done for sorghum.

The participatory approaches are not a substitute for careful agronomic and economic evaluation of technology, but is an essential complement which provides information on how farmers weigh agronomic, economic, and socio-cultural considerations to arrive at their own conclusions about the usefulness of a new technology in their particular farming circumstances (Ashby, 1990).

CHAPTER 3: MATERIALS AND METHODS

3.1 Project Sites

Chiredzi Research Station (CRS) and Gwebi Variety Testing Centre (GVTC) were the two sites used.

(a) Chiredzi Research Station

Chiredzi Research Station, at an altitude of 429 meters above sea level is located 21^{o}33′S and 31^{o}30′E in Masvingo province. The research station is characterised by hot and dry weather conditions with an average of 500 mm of rainfall per annum. The dominant soil type is the dark reddish brown clays derived from basic gneiss of the Trianlge. P2 series called paragneiss soils (CSRI, 1979). The land used for the project has been fallow for more than three years and had loamy/brownish soils. Rainfall was unevenly distributed at Chiredzi Research Station during the 2006/07 season with February receiving most of the rain. Total rainfall of 315.3 mm was received during the trial period. A total of 42.3 mm of irrigation water was applied in two cycles, at planting and at top dressing (30 Days After Planting).

(b) Gwebi Variety Testing Centre

Gwebi Variety Testing Centre at an altitude of 1448 masl is located 17^{o}40′S and 30^{o}55′E in Mashonaland West province. The research station is located in Natural Region IIa characterized by an average annual rainfall of 750 – 1000 mm. The dominant soil type is the moderately deep, reddish brown to grayish brown soils of the Salisbury. 5S series derived form argillaceous meta-sediments and some on volcanics and meta-volcanics

(CSRI, 1979). The land used for the project has been fallow for the previous season with a soil pH of 4.6 $CaCl_2$ scale and of medium grained/strong clay soil texture (Table 3.1). Gwebi Variety Testing Centre received rainfall that was unevenly distributed during the 2006/07 season with January receiving most of the rain. A total of 372.5 mm of rain was received during the trial period.

Table 3.1: Soil analysis results for CRS and GVTC

Characteristic		**Chiredzi**	**Gwebi**
Colour		Loamy/Brownish	Dark brown/brownish
Texture		Medium grained/Sandy Clay Loam	Medium grained/Strong clay
Soil pH		6.8	4.6
Conductivity		350	N/a
Minimum N ppm	Initial	26	28
	After	37	73
Available P_2O_5 ppm		71	44
Exchangeable cations	Potassium	1.19	0.21
	Calcium	13.97	8.12
	Magnesium	2.94	4.92
	Total Chromium	18.1	13.3
Required nutrients	Nitrogen	40 – 60	40 – 60
	Phosphorous	35 – 45	35 – 45
	Potassium	20 – 30	20 – 30
Fertilizers	Compound D	8:14:7	8:14:7
	A. Nitrate	34:0:0	34:0:.0
Suggested Fertilizer rate	Compound D	300	300
	A. Nitrate	50 – 75	50 – 75
	Lime	0	2 000

3.2 Germplasm Used in the Project

Sixteen sorghum lines (Table 3.2) were used in the project and these lines included three commercial varieties, Macia, Sila, SV-4 and Sima. The rest were experimental lines from Crop Breeding Institute (National breeding programme) and ICRISAT.

Table 3.2: List of sorghum lines used in the project and their sources

Sorghum line	Source of Seed
1. NL 2023	Crop Breeding Institute
2. Macia*	Seed Co Zimbabwe
3. NL 2040	Crop Breeding Institute
4. SDSL 89473	ICRISAT-Zimbabwe
5. SV-4*	Crop Breeding Institute
6. NL 2018	Crop Breeding Institute
7. NL 2031	Crop Breeding Institute
8. NL 2041	Crop Breeding Institute
9. NL 2026	Crop Breeding Institute
10. Mahube	ICRISAT-Zimbabwe
11. NL 2034	Crop Breeding Institute
12. Sila*	Seed Co Zimbabwe
13. NL 9847	Crop Breeding Institute
14. NL 9809	Crop Breeding Institute
15. Sima*	ICRISAT-Zimbabwe
16. NL 2006	Crop Breeding Institute

**Macia and Sila are marketed in Zimbabwe by Seed Co, SV-4 a Crop Breeding Institute (Government bred) variety being marketed by Prime Seeds, Agpy and ARDA. Sima is a Zambian variety obtained through ICRISAT.*

3.3 Experimental Design

A Split plot arrangement in a randomized complete blocks design was used, with the two water management systems (flat and tied ridges) as the main plot factor and the sixteen sorghum varieties being the subplot factors. The trial was replicated three times. A gross plot size of 5 m by 10 rows by 1 m was planted.

3.4 Soil Sampling and Land Preparation

Ten soil sub-samples were taken from the one hectare project area using a soil auger to a depth of 30 centimeters. A 1 kg composite sample was then constituted and sent to Chemistry and Soils Research Institute of the Department of Agriculture Research and

Extension (AREX) for a complete soil analysis and recommendations on fertilizer application. Results of the analysis are as shown in Table 3.1. The recommendations were used during project implementation.

The land was disc ploughed and a disc harrow was used to make a fine tilth. Tied ridges were manually constructed on half of the land. The ridges were about 35 cm in height with the ties being constructed after every 2.5 m across two ridges.

3.5 Fertilizer Application, Planting and Seeding Rates

Furrows spaced 1 m were opened on both, the flat and on tied ridges. Compound D (8 % N:14 % P_2O_5:7 % K_2O) was used as a basal fertilizer at a rate of 300 kg/ha as recommended by Chemistry and Soils Research Institute (CSRI) except for CRS where half the rate (150 kg/ha) was applied because of adverse climatic conditions experienced at Chiredzi. The fertilizer was banded into the furrows before planting.

Planting was done on the 10th of January 2007 at CRS while planting was done on the 18th January 2007 at GVTC. A seeding rate of 10kg/ha was used with the seed being drilled along the furrows.

3.6 Crop Management

The crop was thinned 15 days after emergence (DAE) to an intra-row spacing of 15 cm. Top dressing with Ammonium Nitrate (34.5 % N) was done 30 DAE at a rate of 75 kg/ha as recommended rate by CSRI (Table 3.1) except for CRS where 50 kg/ha was applied.

The total fertilizer units applied per hectare as basal and topdressing fertilizers were 46.875 kg N; 42 kg P_2O_5; 21 kg K_2O at Gwebi while 27.75 kg N; 21 kg P_2O_5; 10.5 kg K_2O were applied at Chiredzi.

Re-ridging of the ties and ridges was done twice at 30 DAE and at 60 DAE. Weeding on both water management systems (Flat and Tied ridges) was done 14 DAE, 30 DAE and at 60 DAE.

Cabaryl 85 % WP was used to control grasshoppers that were feeding on the crop after about five weeks after emergence at CRS.

3.7 Record Taking

A net plot of 4 m by 6 rows by 1m was used with 50 cm being left out at each end along the 5 m plot and two outer rows being left out on either side of the plot. The net plot area was used for record taking and yield component analysis.

Rainfall and temperature records were taken during plant growth and records on different plant characteristics were taken using standard guidelines as recommended by the International Board for Plant Genetic Resources (IBPGR) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (1993). Plant characteristics recorded were:

- Days to 50 % Anthesis: Number of days from planting to the date when 50 % of the net plot plants had flowered.

- Days to 95 % maturity: Number of days from planting to the date when 95 % of the net plot plants reached physiological maturity.
- Number of lodged net plot plants at harvest
- Stand count at harvest: Number of plants per each plot at harvest
- Head exertion at maturity: Distance (cm) between flag leaf sheath and last internode on the stem (just below the head/panicle)
- Number of grains per panicle: Actual number of grains per panicle average of five panicles from the net plot.
- Thousand Grain Weight (TGW): Mass (g) of 1000 grains of sorghum
- Grain yield per net plot: Mass of harvested grains per net plot (g)
- Grain moisture: Grain moisture at harvesting measured by a Dickey-john HM Grain Moisture Tester (Auburn Illinois 62615)

3.8 Participatory Variety Selection

(a) Farmer Sorghum Selection Criteria and Field Discussions

Six farmers (five males and one female) and three Extension officers were selected from Chikombedzi in Chiredzi South district. Chikombedzi is one of the areas in the district where sorghum is a major crop while farmers were selected with the assistance of extension officers, on the basis of being consistent annual growers of sorghum and the three extension officers qualified by virtue of being the resident extension personnel in the area (Appendix 18).

Farmers and Extension officers were invited to Chiredzi Research Station on the 17th May 2007. The six farmers, three extension officers and seven researchers from Chiredzi Research Station had group discussions where the objective of the project was outlined. Participants were requested to rank twelve sorghum characteristics as shown in Appendix 20, according to their priority and comment on the desired performance of the variety under each of the twelve characteristics. Discussions were also done in the field as part of Participatory Variety Selection with an absolute evaluation approach (Almekinders and Louwaars, 1999) being adopted. Absolute evaluation approach is whereby each variety is selected or rejected by farmers on the basis of its characteristics. The participants moved from plot to plot making recommendations about the varieties on the basis of agronomic appearance, head size, grain size and plant height. Agronomic appearance included general plant appearance, plant vigour and general plant healthiness.

(b) Organoleptic tastes

Organoleptic tastes were conducted at Chikombedzi and none were done at Gwebi. In Chikombedzi, these were held at Headman Chauke `s homestead on the 23rd August 2007. Two kilogrammes of sorghum grain samples from each of the sixteen varieties harvested at CRS was milled to produce whole meal sorghum flour. A hammer mill was used to grind samples of sorghum to produce whole sorghum flour. No dehusking was done on the samples. Sadza was then cooked for the sixteen different varieties and dished into plates that were numbered.

Fourteen farmers, including six members of the study project and their eight neighbours participated in the exercise. Each of the fourteen farmers (ten males and four females) was given an organoleptic questionnaire on which to comment about the taste of each of the sixteen varieties (Appendix 21). A spoonful of cooked sorghum sadza (thick porridge) was served to each and every participant and comments were noted on the questionnaire. This was repeated until all the sixteen varieties were served. Grain samples of the sixteen varieties were displayed for the participants to determine their grain colour.

3.9 Trial Randomization and Data Analysis

BSTAT ‘s PBDGN computer package was used to randomize the project trial. Data was analysed using Genstat 5 Release Version 3.2 for Windows (Lawes Agricultural Trust, Rothamsted Experimental Station, 1995) with data being subjected to relevant Analysis of Variance (ANOVA) appropriate to the Split Plot Design.

Test of suitability of data to the model was done with variables that violate the ANOVA assumptions being transformed.

- Logarithmic transformations to base ten ($Log_{10} X$) were used to transform data on:
    - i) Number of grains/panicle
    - ii) Stand count at harvest
    - iii) Thousand Grain Weight
- Number of lodged plants at harvest data was transformed using the formula

$Log_{10}(X+1.5)$

- 11.5 units were added to Panicle exertion data for Chiredzi to make all figures positive

  $(X+11.5)$

- Grain yield (kg/ha) was calculated for each plot (using Microsoft Excel), before Analysis using the formulae:

  Yield (kg/ha) at 12.5 % moisture basis = [10*X * (100 – Y)] / [(100 – Z)*W]

  Where; X: Mass of harvested grains per net plot in grammes

  Y: Grain moisture at harvest for each plot

  Z: Recommended Grain Marketing Board moisture content (12.5 %)

  W: Harvested Net plot area (m^2)

- Percentage lodging: Calculated before analysis using the following formulae:

  Lodging (%) = (Lodged plants/plot at harvest)/(Stand count at harvest)*100

- LSD was used to separate means at 0.05 % probability level.

Chapter 4: RESULTS

4.1 Agronomic Characteristics

4.1.1 Flowering

Results for days to anthesis are summarized in Table 4.1. Significant differences in days to flowering ($P<0.001$) were observed among sorghum lines at both CRS and GVTC. Flowering ranged from 55 days for Mahube to 87 days for Sima and NL 2041 at Chiredzi while at Gwebi it ranged from 46 days for NL 2040 to 59 days for SDSL 89473. There were no differences in days to flowering between varieties grown under tied ridges and on flat.

4.1.2 Maturity

Highly significant differences ($P<0.001$) in maturity existed among sorghum lines at both sites while differences in maturity due to water management system were significant ($P<0.05$) at CRS (Table 4.2). Mahube was the earliest maturing line (82 days) at CRS under both water management systems. At Gwebi, Mahube and NL 2031 (125 days) were the earliest maturing varieties. Sima was the latest at CRS, while NL 2026 and SV-4 were the latest at Gwebi.

4.1.3 Plant height

Plants were taller at GVTC with an average of 137 cm while at CRS the average plant height was 111 cm. The tallest variety at GVTC was SDSL 89473 (173 cm) while at CRS, Sima (181 cm) was the tallest. Mahube was short at both sites with 81 cm at CRS and 120 cm at GVTC. Significant differences (P<0.001) existed among varieties at both sites (Table 4.3).

Table 4.1: Days to Anthesis for the sixteen sorghum lines grown under Tied ridges and on flat at two sites during the 2006/07 season

	Chiredzi			**Gwebi V.T.C**		
Variety	**Flat**	**Ridges**	**Mean**	**Flat**	**Ridges**	**Mean**
1. NL 2023	81.00	81.67	81.33	52.67	49.00	50.83
2. Macia	75.67	75.33	75.50	54.00	52.67	53.33
3. NL 2040	77.00	75.67	76.33	46.33	45.33	45.83
4. SDSL 89473	76.00	73.33	74.67	60.33	57.67	59.00
5. SV-4	78.00	73.67	75.83	55.00	55.00	55.00
6. NL 2018	87.00	85.67	86.33	54.00	52.33	53.17
7. NL 2031	78.00	75.33	76.67	48.00	46.67	47.33
8. NL 2041	87.00	87.67	87.33	51.33	51.00	51.17
9. NL 2026	81.67	77.00	79.33	54.00	54.33	54.17
10. Mahube	54.67	55.33	55.00	50.00	47.67	48.83
11. NL 2034	76.67	71.67	74.17	52.00	50.00	51.00
12. Sila	84.33	76.67	80.50	54.00	55.00	54.50
13. NL 9847	77.33	72.33	74.83	55.00	55.00	55.00
14. NL 9809	86.33	83.67	85.00	54.67	55.67	55.17
15. Sima	87.00	87.00	87.00	54.00	56.00	55.00
16. NL 2006	77.33	75.00	76.17	50.00	49.00	49.50
Mean	79.06	76.69	77.87	52.83	52.02	52.43
Chiredzi Summary statistics						
	Management system		Variety		Interaction	
SED	1.281		1.714		2.674	2.424^{+}
L.S.D. (5%)	5.513		3.429		5.481	4.849^{+}
P. Value	NS		***		NS	
CV (%)	2.0		3.8			
Gwebi V.T.C Summary statistics						
SED	0.691		1.006		1.542	1.423^{+}
L.S.D. (5%)	2.974		2.013		3.139	2.847^{+}
P. Value	NS		***		NS	
CV (%)	1.6		3.3			

$^{+}$: Except when comparing means with the same level(s) of management

Table 4.2: Days to Maturity for the sixteen sorghum lines grown under Tied ridges and on flat at two sites during the 2006/07 season

	Chiredzi			Gwebi V.T.C		
Variety	**Flat**	**Ridges**	**Mean**	**Flat**	**Ridges**	**Mean**
1. NL 2023	115.67	120.33	118.00	142.00	136.67	139.33
2. Macia	105.00	107.67	106.33	141.00	139.00	140.00
3. NL 2040	116.67	118.00	117.33	132.33	127.00	129.67
4. SDSL 89473	116.33	119.00	117.67	134.67	143.67	139.17
5. SV-4	116.00	110.33	113.17	145.00	141.00	143.00
6. NL 2018	122.67	124.33	123.50	139.00	137.67	138.33
7. NL 2031	116.67	117.67	117.17	125.00	125.67	125.33
8. NL 2041	119.00	124.67	121.83	125.00	131.67	128.33
9. NL 2026	118.33	119.00	118.67	145.00	141.00	143.00
10. Mahube	82.67	82.00	82.33	125.00	125.00	125.00
11. NL 2034	119.33	118.67	119.00	136.33	137.00	136.67
12. Sila	119.67	121.67	120.67	142.33	137.67	140.00
13. NL 9847	116.33	116.33	116.33	141.00	142.33	141.67
14. NL 9809	123.33	124.33	123.83	138.33	131.00	134.67
15. Sima	125.33	125.67	125.50	134.00	139.00	136.50
16. NL 2006	117.00	118.00	117.50	131.33	120.00	125.67
Mean	115.62	116.73	116.18	136.08	134.71	135.40
Chiredzi Summary statistics						
	Management system		Variety		Interaction	
SED	0.235		1.714		2.674	2.424^{+}
L.S.D. (5%)	1.010		3.429		5.481	4.849^{+}
P. Value	*		***		NS	
CV (%)	0.2		3.8			
Gwebi V.T.C Summary statistics						
SED	1.119		4.000		5.590	5.657^{+}
L.S.D. (5%)	4.813		8.001		11.175	11.315^{+}
P. Value	NS		***		NS	
CV (%)	1.0		5.1			

$^{+}$: Except when comparing means with the same level(s) of management

Table 4.3: Plant height (cm) for the sixteen sorghum lines grown under Tied ridges and on flat at two sites during the 2006/07 season

	Chiredzi			Gwebi V.T.C		
Variety	Flat	Ridges	Mean	Flat	Ridges	Mean
1. NL 2023	109.47	121.40	115.43	126.7	130.0	128.3
2. Macia	90.00	98.40	94.20	128.3	136.7	132.5
3. NL 2040	127.73	124.53	126.13	133.3	128.3	130.8
4. SDSL 89473	106.93	112.33	109.63	166.7	180.0	173.3
5. SV-4	112.80	105.67	109.23	156.7	135.0	145.8
6. NL 2018	85.73	85.73	85.75	123.3	111.7	117.5
7. NL 2031	113.73	118.53	116.13	150.0	158.3	154.2
8. NL 2041	108.00	120.87	114.43	136.7	145.0	140.8
9. NL 2026	117.73	123.20	120.47	141.7	131.7	136.7
10. Mahube	79.67	81.80	80.73	120.0	120.0	120.0
11. NL 2034	86.53	95.20	90.87	126.7	121.7	124.2
12. Sila	121.67	130.60	126.13	140.0	126.7	133.3
13. NL 9847	94.07	109.80	101.93	128.3	150.0	139.2
14. NL 9809	104.20	113.00	108.60	123.3	135.0	129.2
15. Sima	188.27	175.20	181.73	150.0	170.0	160.0
16. NL 2006	94.27	109.27	101.77	125.0	128.3	126.7
Mean	108.80	114.10	111.45	136.0	138.0	137.0
Chiredzi Summary statistics						
	Management system		Variety		Interaction	
SED	1.465		5.508		7.684	7.790$^+$
L.S.D. (5%)	6.303		11.019		15.306	15.583$^+$
P. Value	NS		***		NS	
CV (%)	1.6		8.6			
Gwebi V.T.C Summary statistics						
SED	2.44		9.98		13.89	14.12$^+$
L.S.D. (5%)	10.48		19.97		27.76	28.24$^+$
P. Value	NS		***		NS	
CV (%)	2.2		12.6			

$^+$: Except when comparing means with the same level(s) of management

4.1.4 Plant Lodging

CRS experienced higher percentages of lodging as compared to GVTC. Site mean of 9 % was observed at CRS with Mahube having the highest lodging percentage of 46. At

Gwebi, NL 9847 had the highest lodging percentage of 3. Lodging was significant among varieties at CRS ($P<0.001$) and management system contributed significantly to varietal lodging at CRS ($P<0.05$). Appendix 1, shows lodging percentages of the 16 varieties at the two sites.

4.1.5 Head exertion

CRS experienced poor head exertion among the varieties with a range of –3 cm (NL 2018) to 15 cm (Mahube). Head exertion was significantly affected by water management system at CRS ($P<0.05$) and significant differences due to varieties were also observed ($P<0.001$). There were also some interaction effects on head exertion at CRS ($P<0.05$). All varieties had good exertion at GVTC with differences among varieties being significant at $P<0.01$. Appendix 2 summarizes the head exertion of the sixteen varieties.

4.2. Yield Characteristics

4.2.1 Number of grains/ear

There were significant differences in the number of grains per ear among varieties at CRS ($P<0.001$) and at Gwebi ($P<0.05$). Sila had the highest number of grains/ear with 1865 grains whilst Mahube had the lowest with 500 at CRS. At Gwebi, NL 9809 had the highest with 4103 grains/ear as compared to NL 2026 with 1921 grains. Interaction effects were also significant at GVTC ($P<0.05$). Table 4.4 summarizes the results on grains/ear.

Table 4.4: Number of grains/ear for the sixteen sorghum lines grown under Tied ridges and on flat at two sites during the 2006/07 season

	Chiredzi			Gwebi V.T.C		
Variety	Flat	Ridges	Mean	Flat	Ridges	Mean
1. NL 2023	689	971	830	2285	2443	2364
2. Macia	734	801	768	3409	1836	2622
3. NL 2040	824	905	865	3106	1879	2493
4. SDSL 89473	651	920	786	5000	1040	3020
5. SV-4	851	892	872	1998	2508	2253
6. NL 2018	1089	1612	1351	3536	2783	3160
7. NL 2031	763	780	771	4368	3590	3979
8. NL 2041	999	803	901	3591	3248	3420
9. NL 2026	1009	927	968	1784	2058	1921
10. Mahube	574	427	500	3992	1399	2695
11. NL 2034	779	1142	961	3249	3061	3155
12. Sila	2082	1648	1865	4196	2231	3214
13. NL 9847	946	675	810	4021	3498	3759
14. NL 9809	528	661	595	4061	4145	4103
15. Sima	956	761	858	2914	1888	2401
16. NL 2006	736	1119	928	3354	2493	2924
Mean	888	940	914	2401	2924	2968
Chiredzi Summary statistics						
	Management system		Variety		Interaction	
SED	0.0336		0.0959		0.1355	0.1356+
L.S.D. (5%)	0.1444		0.1918		0.2710	0.2712+
P. Value	NS		***		NS	
CV (%)	1.4		5.7			
Gwebi V.T.C Summary statistics						
SED	0.0597		0.1046		0.1551	0.1479+
L.S.D. (5%)	0.2568		0.2092		0.3128	0.2958+
P. Value	NS		*		*	
CV (%)	2.1		5.3			

+: Except when comparing means with the same level(s) of management

4.2.2 Thousand Grain Weight

Significant differences on TGW were observed among varieties at CRS (P<0.001) while interaction effects were significant at GVTC (P<0.05). Sima had the largest grains with a

TGW of 31,5 grammes at CRS while at Gwebi NL 2006 and NL 2031 had the largest seeds with a TGW of 26 grammes (Appendix 3).

4.2.3 Grain Yield

Sila, a commercial variety by Seed Co had the highest yield at Chiredzi (2383 kg/ha) followed by NL 2041 (2244 kg/ha). At GVTC, NL 2231 had the highest yield followed by NL 2041. Sima, Sila and SV-4 had reduced yields at GVTC as compared to CRS. Management system had significant effects on grain yield ($P<0.001$) at CRS with a mean of 1844 kg/ha observed under flat while 1291 kg/ha was observed on the ridges. Significant differences ($P<0.001$) also exist among varieties at both Chiredzi and Gwebi. At GVTC, interaction effects were also significant ($P<0.05$). Results are summarized in Table 4.5.

Table 4.5: Grain yield (kg/ha) for the sixteen sorghum lines grown under Tied ridges and on flat at two sites during the 2006/07 season

	Chiredzi			Gwebi V.T.C		
Variety	Flat	Ridges	Mean	Flat	Ridges	Mean
1. NL 2023	1501	1146	1323	2083	2378	2231
2. Macia	1578	1331	1455	1142	1012	1077
3. NL 2040	2650	1232	1941	1844	745	1295
4. SDSL 89473	1806	1177	1491	2201	511	1356
5. SV-4	2074	1455	1764	529	407	468
6. NL 2018	1565	1259	1412	1828	1864	1846
7. NL 2031	1717	1089	1403	2136	1546	1841
8. NL 2041	2617	1871	2244	1106	3147	2126
9. NL 2026	1615	1348	1482	560	314	437
10. Mahube	1347	1054	1201	470	1045	758
11. NL 2034	1466	927	1197	1075	1717	1396
12. Sila	2558	2209	2383	975	440	708
13. NL 9847	1963	1421	1692	2074	1449	1762
14. NL 9809	1293	979	1136	1110	1186	1148
15. Sima	1948	1022	1485	263	391	327
16. NL 2006	1799	1143	1471	2040	1486	1763
Mean	1844	1291	1568	1340	1227	1284
Chiredzi Summary statistics						
	Management system		Variety		Interaction	
SED	21.1		234.7		322.0	331.9[+]
L.S.D. (5%)	90.7		469.4		644.1	663.9[+]
P. Value	***		***		NS	
CV (%)			8.9			
Gwebi V.T.C Summary statistics						
SED	97.0		421.2		584.9	595.7[+]
L.S.D. (5%)	417.5		842.6		1169.2	1191.6[+]
P. Value	NS		***		*	
CV (%)	9.3		56.8			

[+]: Except when comparing means with the same level(s) of management

4.3 Participatory Variety Selection (PVS)

Figure* 4.1*: Participatory Variety Selection discussion photos at Chiredzi Research Station. Top left: a Participant busy evaluating the different sorghum varieties. Top Right: Mr. Livombo giving his views about the sorghum varieties. Bottom Left: Part of the Group involved in discussions in the field and bottom right: Group photo taken after the field discussions

4.3.1 Participatory Variety Evaluation

General agronomic characteristics, head size, grain size and plant height were the characteristics used to evaluate the sixteen varieties at Chiredzi Research Station on the 17th May 2007. Nine of the varieties were regarded as having good agronomic characteristics. Three varieties, NL 2034, SDSL 89473 and NL 2018 had big head sizes while the same varieties together with Sila were regarded as having large grain sizes. Varieties NL 2018 and Sima were the tallest. A summary of characteristics for the sixteen varieties is shown in Table 4.6.

Table 4.6: Characteristics of the sixteen varieties as described by participants during the Field discussions on 17th May 2007 at Chiredzi Research Station

Variety	Agronomic score		Head size			Grain size		Plant height		
	Poor	Good	Small	Medium	Big	Small	Large	Short	Tall	Very Tall
1. NL 2023	X		X			X		X		
2. Macia		X	X			X		X		
3. NL 2040	X			X		X			X	
4. SDSL 89473	X				X		X		X	
5. SV-4	X		X			X		X		
6. NL 2018		X			X		X			X
7. NL 2031		X		X		X		X		
8. NL 2041	X		X			X		X		
9. NL 2026		X	X			X		X		
10. Mahube		X		X		X		X		
11. NL 2034		X			X		X	X		
12. Sila		X	X				X	X		
13. NL 9847		X	X			X		X		
14. NL 9809	X		X			X		X		
15. Sima		X		X		X				X
16. NL 2006	X		X			X		X		

4.3.2 Farmer Sorghum Selection Criteria

Results of participatory variety selection are summarized in Table 4.7. Early maturity, high grain yield and white grain colour were the three most important sorghum characteristics for farmers in Chikombedzi.

Table 4.7: Matrix ranking for the twelve sorghum characteristics according to priority by fourteen Chikombedzi farmers and Extension staff

Trait	Total score	Order of priority	Remarks about the characteristics (%)		
Maturity	23	1	Early (92.9)	Medium (7.1)	Late (0)
Yield	28	2	High (85.7)	Moderate (14.3)	Low (0)
Grain colour	58	3	White (78.6)	Red (7.1)	Brown (14.3)
Pest Tolerance	63	4	High (71.4)	Moderate (7.1)	Poor (21.4)
Taste	64	5	Good (92.9)	Moderate (7.1)	Poor (0)
Head size	64	5	Big (100)	Moderate (0)	Small (0)
Grain size	67	6	Large (92.9)	Medium (7.1)	Small (0)
Bird Tolerance	78	7	High (64.3)	Moderate (21.4)	Poor (14.3)
Disease Tolerance	86	8	High (64.3)	Moderate (14.3)	Poor (21.4)
Weevil Tolerance	92	9	High (78.6)	Moderate (7.1)	Poor (14.3)
Plant height	94	10	Short (85.7)	Tall (14.3)	Very Tall (0)
Exertion	116	11	Good (92.9)	Moderate (7.1)	Poor (0)

4.3.3 Organoleptic Tastes

Sima was the most preferred variety in terms of taste after 14 farmers tasted the 16 different sorghum sadza dishes. The second most preferred variety was NL 2026 while SV-4 was third. All the best three were white-grained varieties (Table 4.8).

Table 4.8: Organoleptic taste results as described by Farmers from Chikombedzi on 23rd August 2007

Variety	Taste (% of respondence)			Priority ranking (Taste)	Grain colour
	Very Good	Good	Bad		
1. NL 2023	27.3	45.4	27.3	4	Brown
2. Macia	18.2	54.5	27.3	6	White
3. NL 2040	18.2	63.6	18.2	5	Brown
4. SDSL 89473	27.3	45.4	27.3	4	Red
5. SV-4	36.4	36.4	27.3	3	White
6. NL 2018	9.1	18.2	72.7	8	Brown
7. NL 2031	0	54.5	45.4	11	Brown
8. NL 2041	0	81.8	18.2	10	Brown
9. NL 2026	45.4	36.4	18.2	2	White
10. Mahube	9.1	9.1	81.8	9	Red
11. NL 2034	9.1	27.3	63.6	7	Brown
12. Sila	18.2	54.5	27.3	6	White
13. NL 9847	18.2	54.5	27.3	6	Brown
14. NL 9809	0	45.4	54.5	12	Brown
15. Sima	72.7	27.3	0	1	White
16. NL 2006	9.1	27.3	63.6	7	Red

Chapter 5: DISCUSSION

Low amount of rainfall, that was unevenly distributed, was received at both CRS and GVTC (315 and 372.5 mm, respectively). This was lower than the expected average rainfall of 500 mm for CRS and 1000 mm for GVTC. The erratic nature of the rains did not allow the received water to accumulate within the tied ridges and this might have led to no advantages being realized from the use of this water conservation technique at both sites. The accessibility of water to plant roots was also strained under tied ridges because not adequate water accumulated in the ridges throughout the trial period. The non-accumulation of water in the ridges cancelled out the benefits of the technology. Two irrigation cycles were applied at critical crop stages (Planting and fertilizer application) at CRS because of the erratic nature of the rains received during the season. This is typical of Chiredzi Research Station.

At Gwebi, the soil was acidic with a pH of 4.8 and analysis by CSRI recommended a liming rate of 2000 kg/ha. This was not done and this could have affected nutrient availability to the plants. Though there were no significant differences in the two water management systems, it was observed that the weed density was higher on the flat than on tied ridges and extra labour costs were incurred in re-ridging activities at both sites.

The results confirm the wide genetic diversity that exists within sorghum as indicated by the National Academy of Sciences (1996). All observed characteristics showed significant differences ($P<0.001$) between sorghum varieties confirming the existence of a wide genetic variability in the germplasm used in the study.

5.1 Agronomic Characteristics

Early maturity was regarded as of high importance by farmers in the study given the low amount of rainfall received in sorghum growing areas and the erratic nature of rainfall. Farmers indicated that an ideal variety must be able to mature within sixty to ninety days in Chikombedzi. Mahube was the earliest maturing variety at both locations, maturing after 82 days at CRS and 125 days at GVTC. The current commercial varieties, Macia (106 days at CRS and 140 days at GVTC), Sila (121 days at CRS and 140 days at GVTC) and SV-4 (113 days at CRS and 143 days at GVTC) were medium to late maturing.

The other agronomic characteristics such as plant height, lodging percentage and ear exertion are also important for realization of maximum yields. Short plants tend to have good standability thereby reducing losses due to lodging. High lodging percentages will lead to plant damage by termites and rotting of grain on the ground thereby causing yield reductions. It is therefore important to ensure that a sorghum variety blends these desirable agronomic characteristics into one. Too tall varieties such as Sima cause difficulties when harvesting especially when heads are to be cut by sickles.

Good ear exertion is also important because it allows healthy grains to develop within the ear. Poor exertion provides a conducive environment for pests and disease development thereby affecting both yield and quality of the grain. Good exertion also allows easy harvesting of the ear when sickle harvesting. Ear exertion is also affected by the amount of moisture received. Moisture stress during flowering and ear emergence results in poor exertion. It is therefore critical that this period coincide with periods of adequate moisture. Mahube had the best ear exertion at both sites (Appendix 2).

5.2 Yield Characteristics

Yield components include grain size as indicated by Thousand Grain Weight, ear size and number of grains per ear. These were also identified as important traits during the PVS discussions. Sila (1648 grains) had the highest number of grains at CRS and it was the best yielding variety at that site, with a yield of 2383 kg/ha. Sila had relatively large grain with a TGW of 23 grammes. This variety tends to balance all these yield components into one. The best yielding experimental variety at CRS, NL 2041 (2244 kg/ha) had a mean of 901 grains/ear with a TGW of 23 grammes. On the other hand, the lowest yielding variety, NL 9809 (1136 kg/ha) had the second lowest number of grains (595) at CRS. At GVTC, NL 2023 had the highest yield of 2231 kg/ha, relatively high TGW of 24 grammes with 2364 grains/ear. Generally, there is a positive relationship between number of grains per ear, TGW and grain yield.

Grain yield of white varieties was severely affected by bird damage at GVTC. White varieties are prone to bird damage as compared to red varieties. Red varieties contain high levels of tannin that causes them to be less preferred by birds. Bird damage is one of the major constraints in sorghum production in Zimbabwe and without effective bird scaring, significant yield losses will be realized. Bird scaring results in extra cost to sorghum production. Currently there are no genetic sources of resistance to bird damage and this is a major challenge to researchers to explore for sources of resistance.

5.3 Participatory Approaches

5.3.1 Participatory Variety Evaluation

General consensus among the participants was used during the evaluation. Good agronomic characteristics included plant vigour and general plant appearance**.** Three of the commercial varieties (Macia, Sila and Sima) were good agronomically. Six of the experimental lines were also good. Big ear size and large grain size are traits of importance to farmers and these were also evaluated. SDSL 89473, NL 2018 and NL 2034 had big ear sizes while the same varieties together with Sila were large grained. This confirms results obtained on station at both CRS and GVTC. Sila emerged as one of the best yielders at CRS because of its big grain size (Table 4.5).

Participants in the study agreed that shortness is ideal as far as plant height was concerned. This allows ease of harvesting with a sickle and at the same time it reduces chances of lodging. Only two varieties were very tall, NL 2018 and Sima.

5.3.2 Farmer Selection Criteria

Usually, breeders regard yield as the most important selection criteria. Early maturity, tolerance to diseases and pests, tolerance to drought, grain colour, plant height, lodging, bird damage and suitability for human consumption (as food or brewing purposes) or livestock feed are some of the characteristics considered to be important by breeders.

The diagnostic exercise with farmers resulted in early maturity being of the highest priority. Early maturing varieties can fit in the short growing seasons experienced in most sorghum growing areas where rainfall is low and erratic. A variety that utilizes the little amount of rain received is therefore ideal. Grain colour was third in terms of priority ranking with most of the participants (79 %) preferring white-grained varieties (Table 4.7). The rest of the farmers preferred red or brown grained varieties mainly because of their tolerance to bird damage. Plant height was ranked tenth (Table 4.7) by farmers though it is usually regarded as a trait of importance by breeders. The participatory approaches enables breeders to incorporate input from various stakeholders when developing breeding objectives. This will result in better suited varieties being developed and adopted by farmers.

5.3.1 Organoleptic tastes

Organoleptic tastes are rarely done by conventional breeders during variety selection. According to Chikombedzi farmers, there are several factors that might influence the taste of a certain sorghum variety. These include the way the sadza is cooked, the type of sorghum flour used, the type of relish served with the sadza and the experience of the cooker. Non-dehusked and dehusked sorghum grain before milling, results in different taste of sorghum sadza mainly due to the role played by the grain testa. Sorghum sadza must be left for some time beside a hot fire for simmering, so as to avoid stickiness. Some people would not prefer to eat it soon after cooking. Serving the sorghum dish with either vegetables or beef will automatically affect taste. Mature women tend to prepare sorghum dishes better than teenagers, mainly because of the level of concentration that is devoted to the exercise.

Chikombedzi farmers would prefer any variety that has better taste than Gangara, a local red grained variety. Gangara is preferred by the old generation because it is regarded as being "heavy" and results in one having a full stomach for a longer duration. The young generation say it presents difficulties during excretion. Sima was ranked first by the farmers in Chikombedzi after all the farmers had a chance to taste a spoonful of sadza of each of the sixteen varieties. The experimental variety NL 2026 was second after Sima. No relish was served with the dish. All the top three varieties are white-grained indicating farmer preference to white-grained varieties (Table 4.8).

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- A wide genetic variability exist among the sorghum varieties used in the study. Varietal differences were all significant for the observed characteristics. There is great potential in trying to identify sorghum varieties that meet the needs of farmers.
- There is no single variety that had all the desirable characteristics. For instance, the earliest maturing variety Mahube, had small grains and was low yielding. On the other hand Sima the best variety in terms of taste, white grained and a moderate yield potential but was medium to late maturing. Only varieties that do not compromise much in most of the desirable characteristics must be recommended for production.
- There was no advantage in planting either on flat or under tied ridges. This maybe due to the erratic nature of the rains received that could not allow water to accumulate within the ridges.
- Participatory approaches allows participation of all stakeholders in technology generation and dissemination. This improves technology adoption since stakeholders feel part and parcel of the system. For instance, Sila, a Seed Co variety released in 2005, was unknown to farmers in Chikombedzi. Participatory approaches also allows researchers to exchange germplasm with farmers and develop research strategies that are demand driven.

- Differences exist between farmer and researcher selection criteria. Yield is normally considered of the highest priority by researchers but the study established that farmers in Chikombedzi regard early maturity as more important than yield.

5.2 Recommendations

5.2.1 To the researchers/Breeders

- Technology generation, dissemination and adoption can only be effective when all stakeholders are involved through participatory approaches. On farm and on station trials must compliment each other.
- There is need to develop sorghum varieties that satisfy the needs of farmers in terms of agronomic, yield performance and taste. This can be achieved by improving the undesirable traits in some of the improved varieties. For instance, shorten maturity period in Sila, Macia, SV-4 and Sima.
- There is need to identify genetic sources of resistance to bird damage given the constraint especially on white varieties. Farmers prefer white grain varieties but these are prone to bird damage.
- There is need to repeat the same study during a different season in order to make conclusive recommendations especially on the water management techniques and possible release of some promising experimental lines such as NL 2026, NL 2023 and NL 2041.

- A cost benefit analysis must be done in order to establish the economic benefits of some water conservation techniques such as tied ridges, given the extra demand on labour.

5.2.2 To the farmers

- There is need to improve sorghum yields through the use of improved varieties such as Sila, Macia and SV-4 because of their high yield potential and white grain.

- Early planting with the first effective rains will maximize water use given that most of the current commercial varieties are medium to late maturing.

- Bird scaring must be done effectively especially if white-grained varieties are grown because this might affect sorghum yields.

- Participation in technology generation and dissemination is of paramount importance so that their needs are included in the research strategy and there is easy access to new technologies.

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Appendices

Appendix 1: Percentage lodging for the sixteen sorghum lines grown under Tied ridges and on flat at two sites during the 2006/07 season

	Chiredzi			Gwebi V.T.C		
Variety	**Flat**	**Ridges**	**Mean**	**Flat**	**Ridges**	**Mean**
1. NL 2023	2.84	6.29	4.57	0.397	0.000	0.198
2. Macia	8.43	14.77	11.60	0.000	0.135	0.067
3. NL 2040	1.99	3.36	2.67	0.000	0.000	0.000
4. SDSL 89473	22.22	31.61	26.91	0.000	0.287	0.144
5. SV-4	6.08	10.00	8.04	0.000	0.000	0.000
6. NL 2018	0.68	0.00	0.34	0.000	0.000	0.000
7. NL 2031	3.89	6.98	5.43	0.000	0.342	0.171
8. NL 2041	0.91	1.68	1.30	0.000	0.000	0.000
9. NL 2026	9.42	11.44	10.43	0.000	0.000	0.000
10. Mahube	38.95	46.14	42.54	0.000	0.000	0.000
11. NL 2034	3.63	6.97	5.30	0.000	0.000	0.000
12. Sila	5.85	6.76	6.31	0.000	0.000	0.000
13. NL 9847	2.52	6.04	4.28	0.000	0.571	0.286
14. NL 9809	0.22	0.83	0.52	0.000	0.000	0.000
15. Sima	3.54	4.70	4.12	0.235	0.235	0.117
16. NL 2006	2.04	4.55	3.30	0.000	0.000	0.000
Mean	7.08	10.13	8.60	0.039	0.083	0.061
Chiredzi Summary statistics						
	Management system		Variety		Interaction	
SED	0.625		2.745		7.684	7.790^{+}
L.S.D. (5%)	2.690		5.491		15.306	15.583^{+}
P. Value	*		***		NS	
CV (%)	8.9		55.3			
Gwebi V.T.C Summary statistics						
SED	0.0541		0.1551		0.2192	0.2194^{+}
L.S.D. (5%)	0.2329		0.3103		0.4385	0.4389^{+}
P. Value	NS		NS		NS	
CV (%)	107.9		437.1			

$^{+}$: Except when comparing means with the same level(s) of management

Appendix 2: Head exertion (cm) for the sixteen sorghum lines grown under Tied ridges and on flat at two sites during the 2006/07 season

	Chiredzi			Gwebi V.T.C		
Variety	Flat	Ridges	Mean	Flat	Ridges	Mean
1. NL 2023	3.13	-4.00	-0.43	7.33	7.40	7.37
2. Macia	7.07	0.07	3.57	5.60	9.20	7.40
3. NL 2040	6.73	-2.53	2.10	5.03	11.97	8.50
4. SDSL 89473	7.73	3.37	5.55	9.47	11.23	10.35
5. SV-4	1.97	0.50	1.23	6.83	6.13	6.48
6. NL 2018	-2.73	-2.63	-2.68	3.67	5.57	4.62
7. NL 2031	1.40	-2.10	-0.35	8.70	10.73	9.72
8. NL 2041	5.20	3.03	4.12	8.40	10.20	9.30
9. NL 2026	3.27	4.40	3.83	8.27	8.50	8.38
10. Mahube	12.07	18.13	15.10	6.93	14.67	10.80
11. NL 2034	0.47	-5.07	-2.30	3.80	4.27	4.03
12. Sila	3.07	-0.37	1.35	3.47	7.47	5.47
13. NL 9847	1.70	-3.50	-0.90	7.33	8.67	8.00
14. NL 9809	4.30	5.40	4.85	4.03	6.90	5.47
15. Sima	4.53	2.57	3.55	4.07	6.43	5.25
16. NL 2006	0.27	5.23	2.75	7.23	9.27	8.25
Mean	3.76	1.41	2.58	6.26	8.66	7.46
Chiredzi Summary statistics						
	Management system		Variety		Interaction	
SED	0.508		2.040		2.839	2.885[+]
L.S.D. (5%)	2.187		4.080		5.675	5.770[+]
P. Value	*		***		*	
CV (%)	4.3		24.2			
Gwebi V.T.C Summary statistics						
SED	0.957		1.839		2.694	2.601[+]
L.S.D. (5%)	4.119		3.679		5.416	5.202[+]
P. Value	NS		**		NS	
CV (%)	15.7		42.7			

[+]: Except when comparing means with the same level(s) of management

Appendix 3: Thousand Grain Weight (g) for the sixteen sorghum lines grown under Tied ridges and on flat at two sites during the 2006/07 season

	Chiredzi			Gwebi V.T.C		
Variety	Flat	Ridges	Mean	Flat	Ridges	Mean
1. NL 2023	18.67	18.67	18.67	23.57	24.73	24.15
2. Macia	16.67	19.00	17.83	19.13	27.20	23.17
3. NL 2040	18.00	19.33	18.67	27.27	22.50	24.88
4. SDSL 89473	14.00	14.67	14.33	24.20	13.70	18.95
5. SV-4	20.00	17.67	18.83	27.27	20.10	23.68
6. NL 2018	22.00	20.00	21.00	16.87	24.00	20.43
7. NL 2031	16.00	16.00	16.00	24.50	27.60	26.05
8. NL 2041	23.00	22.67	22.83	26.60	23.00	24.80
9. NL 2026	23.33	12.67	18.00	19.87	20.13	20.00
10. Mahube	10.00	13.00	11.50	19.37	21.20	20.28
11. NL 2034	17.33	15.33	16.33	25.93	23.53	24.73
12. Sila	23.33	23.33	23.33	24.50	22.17	23.33
13. NL 9847	16.33	18.00	17.17	23.40	26.97	25.18
14. NL 9809	17.33	28.00	22.67	23.33	26.33	24.83
15. Sima	38.67	24.33	31.50	21.27	19.23	20.25
16. NL 2006	18.67	17.33	18.00	25.00	27.23	26.12
Mean	19.58	18.75	19.17	23.25	27.23	23.18
Chiredzi Summary statistics						
	Management system		Variety		Interaction	
SED	0.0396		0.0644		0.0967	0.0911[+]
L.S.D. (5%)	0.1706		0.1289		0.1956	0.1823[+]
P. Value	NS		***		NS	
CV (%)	3.9		8.9			
Gwebi V.T.C Summary statistics						
SED	0.02044		0.0555		0.0787	0.07849[+]
L.S.D. (5%)	0.08794		0.11102		0.15144	0.15700[+]
P. Value	NS		NS		*	
CV (%)	1.9		7.1			

[+]: Except when comparing means with the same level(s) of management

Appendix 4: ANOVA Table for Days to 50 % Flowering at Chiredzi Research Station

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	122.313	61.156	1.55	
Management	1	135.375	135.375	3.44	0.205
Error	2	78.813	39.406	4.47	
Variety	15	5334.833	355.656	40.35	<.001
Management x Variety	15	136.292	9.086	1.03	0.438
Error	60	528.875	8.815		
Total	95	6336.500			

Appendix 5: ANOVA Table for Days to 50 % Flowering at GVTC

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	15.396	7.698	0.67	
Management	1	15.844	15.844	1.38	0.361
Error	2	22.937	11.469	3.77	
Variety	15	1057.990	70.533	23.21	<.001
Management x Variety	15	50.990	3.399	1.21	0.360
Error	60	182.333	3.039		
Total	95	1345.490			

Appendix 6: ANOVA Table for days to maturity at CRS

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	3.15	1.57	1.19	
Management	1	29.26	29.26	22.12	0.042
Error	2	2.65	1.32	0.12	
Variety	15	9158.82	610.59	55.38	<.001
Management x Variety	15	140.57	9.37	0.85	0.620
Error	60	661.54	11.03		
Total	95	9995.99			

Appendix 7: ANOVA Table for days to maturity at GVTC

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	310.90	155.45	5.18	
Management	1	45.38	45.38	1.51	0.344
Error	2	60.06	30.03	0.63	
Variety	15	3754.62	250.31	5.22	<.001
Management x Variety	15	632.29	42.15	0.88	0.591
Error	60	2879.71	48.00		
Total	95	7682.96			

Appendix 8: ANOVA Table for head exertion at CRS (transformed data: X+6)

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	54.54	27.27	4.40	
Management	1	133.01	133.01	21.45	0.044
Error	2	12.40	6.20	0.50	
Variety	15	1568.69	104.58	8.38	<.001
Management x Variety	15	408.80	27.25	2.18	0.017
Error	60	748.87	12.48		
Total	95	2926.31			

Appendix 9: ANOVA Table for head exertion at GVTC

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	1.12	0.56	0.03	
Management	1	138.48	138.48	6.30	0.129
Error	2	43.99	21.99	2.17	
Variety	15	386.76	25.78	2.54	0.005
Management x Variety	15	118.68	7.91	0.78	0.694
Error	60	608.77	10.15		
Total	95	1297.79			

Appendix 10: ANOVA Table for No. of grains/panicle at CRS (Transformed: $Log_{10}x$)

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	0.24484	0.12242	4.56	
Management	1	0.01196	0.01196	0.45	0.573
Error	2	0.05374	0.02687	0.98	
Variety	15	1.58691	0.10579	3.85	<.001
Management x Variety	15	0.31561	0.02104	0.77	0.708
Error	60	1.64688	0.02745		
Total	95	3.85995			

Appendix 11: ANOVA Table for No. of grains/panicle at GVTC (Transformed: $Log_{10}x$)

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	0.06271	0.03135	0.37	
Management	1	0.50045	0.50045	5.85	0.137
Error	2	0.17096	0.08548	2.61	
Variety	15	1.06702	0.07113	2.17	0.018
Management x Variety	15	0.90609	0.06041	1.84	0.049
Error	60	1.96870	0.03281		
Total	95	4.67593			

Appendix 12: ANOVA Table for Thousand Grain Weight at CRS ($Log_{10}x$)

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	0.03762	0.01881	0.50	
Management	1	0.00558	0.00558	0.15	0.738
Error	2	0.07545	0.03773	3.03	
Variety	15	0.90325	0.06022	4.84	<.001
Management x Variety	15	0.26926	0.01795	1.44	0.158
Error	60	0.74715	0.01245		
Total	95	2.03832			

Appendix 13: ANOVA Table for Thousand Grain Weight at GVTC ($Log_{10}x$)

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	0.030751	0.0153	1.53	
Management	1	0.000015	0.000015	0.00	0.972
Error	2	0.020050	0.010025	1.08	
Variety	15	0.219617	0.014641	1.58	0.106
Management x Variety	15	0.255842	0.017056	1.851.01	0.049
Error	60	0.554466	0.009241		
Total	95	1.080742			

Appendix 14: ANOVA Table for Plant height at CRS

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	1044.96	522.48	10.14	
Management	1	673.10	673.10	13.07	0.069
Error	2	103.01	51.51	0.57	
Variety	15	48154.29	3210.29	35.27	<.001
Management x Variety	15	1429.76	95.32	1.05	0.423
Error	60	5461.73	91.03		
Total	95	56866.86			

Appendix 15: ANOVA Table for Plant height at GVTC

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	142.2	71.1	0.50	
Management	1	94.0	94.0	0.66	0.502
Error	2	284.9	142.4	0.48	
Variety	15	20341.4	1356.1	4.54	<.001
Management x Variety	15	3426.8	228.5	0.76	0.710
Error	60	17939.6	299.0		
Total	95	42228.9			

Appendix 16: ANOVA Table for Grain yield at CRS

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	449681.0	224840	21.08	
Management	1	7315525.0	7315525	685.98	0.001
Error	2	21329	10664.0	0.06	
Variety	15	11567050.0	771137	4.67	<.001
Management x Variety	15	2089989.0	139333	0.84	0.627
Error	60	9913347.	165222		
Total	95	3135692.0			

Appendix 17: ANOVA Table for Grain yield at GVTC

Source	d.f	s.s	m.s	v.r	F.pr
Rep	2	1866889.	933445.	4.13	
Management	1	303585.	303585.	1.34	0.366
Error	2	452000.	226000.	0.42	
Variety	15	34056409.	2270427.	4.27	<.001
Management x Variety	15	15453126.	1030208.	1.94	0.037
Error	60	31938082.	532301.		
Total	95	84070092.0			

Appendix 18: Participatory Variety Selection: Field discussion Participants

Date: **17/05/07**

Venue: **Chiredzi Research Station**

Name	**Designation & Institution**
Tegwe Soko	Student/University of Zimbabwe
Samson Makondo	Farmer/Chikombedzi
Joram Yingwani	Farmer/Chikombedzi
Phillip Chauke	Farmer/Chikombedzi
Elmon Chauke	Extension Worker/AREX-Chikombedzi
N. Paswani	Extension Worker/AREX-Chikombedzi
K. Kunedzimwe	Extension Worker/AREX-Chikombedzi
Josephat Livombo	Farmer/Chikombedzi
Florence Zimbango	Farmer/Chikombedzi
Edward Livombo	Farmer/Chikombedzi
R. Phiri	Extension Worker/AREX-Chikombedzi
Terrence Dube	Researcher/Chiredzi Research Station
Tapiwa Chitakunye	Researcher/Chiredzi Research Station
T. Marimbe	Researcher/Chiredzi Research Station
V. Nyika	Researcher/Chiredzi Research Station
N. M. Takawira	Head/Chiredzi Research Station
Nathan Damu	Researcher/CIMMYT

Appendix 19: Organoleptic tastes participants

Date: **23/08/07**

Venue: **Headman Chauke `s Homestead in Chikombedzi**

Name	**Designation**	**Sex**
Tegwe Soko	Student	Male
Elmon Chauke	Extension Officer	Male
Prince Matova	AREX Researcher	Male
Terrence Dube	AREX Researcher	Male
Philip Chauke	Farmer & Headman	Male
Raphael Phiri	Extension Officer	Male
Luxmore Pahlela	Farmer	Male
Samson Makondo	Farmer	Male
Hlayisi Makondo	Farmer	Male
Joram Yingwani	Farmer	Male
Petros Dhumela	Farmer	Male
Kenias Ngomungomu	Farmer	Male
Aaron Makondo	Farmer	Male
Edward Livombo	Farmer	Male
Josphat Livombo	Farmer	Male
Flossy Zimbango	Farmer	Female
Grace Nkomunkomu	Farmer	Female
Khetani Makondo	Farmer	Female
Rose Makese	Farmer	Female

Appendix 20: Farmer Sorghum Selection Criteria Questionnaire

A. Personal information

NAME: ……………………………………

Sex/Gender: …………………………………..

AGE: ……………………………………

DESIGNATION: ………………………………………

Marital Status: ………………………………………

B. Rank the following sorghum selection criteria in order of importance (Indicate prefernce)

Criteria	Rank	Remarks (Delete the accepted)		
Maturity		Early	Medium	Late
Yield		High	Moderate	Low
Tolerance to bird damage		High	Moderate	Poor
Grain colour		Red	Brown	White
Taste		Good	Moderate	Poor
Tolerance to diseases		High	Moderate	Poor
Tolerance to pests		High	Moderate	Poor
Head size		Big	Medium	Small
Grain size		Large	Medium	Small
Tolerance to weevils		High	Moderate	Poor
Plant height		Very Tall	Tall	Short
Head exertion		Good	Moderate	Poor

Other criteria/Traits

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Appendix 21: Organoleptic taste questionnaire

1. **Taste each and every sorghum dish and give your comment on the variety as compared to others (Tick the selected comment).**
2. **Rank your best three varieties according to taste**
3. **Look at the given grain sample and give the colour of the grain against the variety number.**

Variety	**Remarks/Comment**			**Rank**	**Grain colour**
	Very good	Good	Bad		
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
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Other comments

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