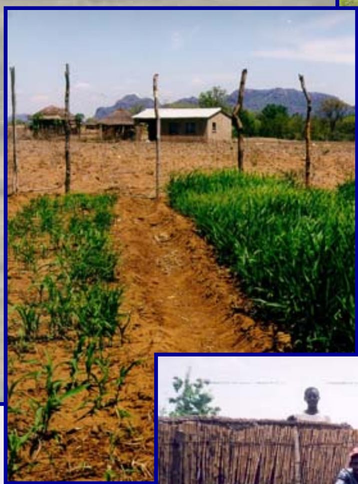
Transplanting Sorghum and Millet as a Means of Increasing Food Security in Semi-Arid Low-Income Countries (R7341)



Final Technical Report


Transplanting sorghum and millet as a means of increasing food security in semi-arid, low-income countries (R7341)

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1 Executive summary

This project investigated the feasibility of increasing food security by transplanting sorghum and pearl millet from a nursery to minimise the risk of failed crops or patchy stands, so achieving an improvement in yield during years when the rain is late, and providing a ‘safety net’ when the rains are erratic.

The concept was tested in a low-input dryland system by raising sorghum and pearl millet seedlings in nurseries using small amounts of water before the rainy season, and transplanting them at the onset of the rains. Seedlings may be:

- grown in small irrigated nurseries using minimal water before the rains and transplanted into the fields when the rains are fully established.
- grown in rainfed nurseries and transplanted into areas with residual moisture following the receding waters of lakes, reservoirs and ponds, or the late spate of seasonal rivers.

The project results confirm that transplanting within this system is a practical option which will enable farmers to maximise the growing season and minimise the risk of failed crops, patchy stands and reduce the costs of re-planting. Early crops are important to farmers as they break the hunger gap; transplanting early crops breaks this hunger gap two to three weeks earlier, and yield more (often double) than normal direct-sown crops, providing food when it is in short supply and very expensive in the market place. Yields of late crops (including those which are photoperiod sensitive) are higher due to improved establishment, increased vigour and the ability to escape *Striga* infestation.

We have shown that women are particularly interested in transplanting of sorghum and pearl millet as feeding the household is mostly their responsibility. In their opinion being able to harvest even two days earlier would make a difference, being able to do so two to three weeks earlier is a major breakthrough in their uncertain environment.

The initial focus was on food security and reduction of risk for subsistence farmers in semi-arid countries where shortage of water is the most serious constraint on production. It is now clear that transplanting has wider application in the context of global climate variability and change. Despite efforts to breed for drought and other abiotic stresses, uncertainty associated with onset of rain continues to be a major constraint across the spectrum from the poorest to the richest farmers. Irrigation comes at a price, and transplanting is a means of conserving water and managing unpredictability at all levels. The technique also has the advantage of having been successfully modified from existing indigenous practices and is suited to the needs of the poorest of the poor. Any improvement in their livelihoods will contribute towards environmental sustainability.

We have devised a farmer-focussed "ripple" method of disseminating transplanting based on the experiences of adapting a generic technology to local conditions gained in this project. Clearly it is important that this type of activity, which directly impacts on the poorest farmers (80% of farmers who conducted the trials in each of the three districts in Ghana received higher yields from their transplanted crop and in many cases the yield was doubled) and has enormous potential for further demonstrable benefits, remains a priority intervention despite changes in focus of support programmes.

2 Background

2.1 Researchable constraints addressed

The main challenges for farmers in semi-arid and arid areas of the tropics and sub-tropics, are poor food security, yield instability and risk of crop failure. These are associated with the biggest physical constraint to crop production in these areas: erratic and unreliable rainfall resulting in shortages of water. Under these conditions there is a considerable risk of failed crops, patchy stands and high re-planting costs. If rains fail or finish early farmers may have to re-sow, this is risky as the season may not be long enough for the crop to reach maturity, and the harvests may be small or even fail completely. This risk is amplified by the fact that farmers generally have limited funds and even if funds are available may be constrained by lack of seed supply. Some programmes have been initiated to conserve water for supplementary irrigation during the growing season, however this project was based on the premise that supplementary water can be used more efficiently if applied at the beginning rather than the end of the season, to ‘extend’ the effective growing season in short duration areas.

2.2 Previous research

In many semi-arid areas crop stands are improved by filling gaps with seedlings from overcrowded parts of the field. This is practised in Zimbabwe where Harris[1] and Chivasa *et al*. (1998)[2] found that 97% of surveyed farmers gap filled sorghum in this way, they also used the overcrowded thinnings to plant extra areas if good early rains persisted into the middle of the season. The practice of moving seedlings from one area to another can be taken a stage further by setting up nurseries then ‘transplanting’ into the field. Wien (1997)[3] describes this term ‘transplanting’ as ‘raising seedlings in

[1] DFID Project R6395, Seed Priming.

[2] CHIVASA, W., HARRIS, D., CHIDUZA, C., NYAMUDEZA, P. AND MASHINGAIDZE, A.B. (1998). Agronomic practices, major crops and farmers’ perceptions of the importance of good stand establishment in Musikavanhu Communal Area, Zimbabwe. *Journal of Applied Sciences in Southern Africa* **4(2)** 9-25.

[3] WIEN, H.C. (1997). Transplanting. In Wien, H.C. (Ed) *The Physiology of Vegetable Crops*. Cab International pp 37-67.

specialized containers or confined field areas and then transferring them to the place where they will produce the harvest product.' Transplanting is most common in areas where the growing season is short as the planting of seedlings rather than seed results in an earlier harvest. It also allows more efficient use of seed, control over plant spacing and maximises the use of available water sources (Wein, 1997)[3].

In most rice growing countries the use of cereal nurseries is commonplace. In addition examples of low technology transplanting of other crops, which do not require specialised machinery, exist in many other parts of the world. One such area is around the shores of Lake Chad in Borno State, NE Nigeria, where farmers sow sorghum nurseries at the edge of the lake after the heavy rains subside. When they are approximately thirty to forty days old seedlings are transplanted into the bed of the lake where the crop matures using the residual moisture remaining as the waters recede (Olabanji *et al.*, 1996)[4]. All members of the family, men, women and children participate in the transplanting activities and the sorghum plantations extend as far as the eye can see. Similarly, this process is carried out in the Mora region of Cameroon. Here nurseries are established during the rainy season then transplanted at the end of the rains, made possible by the sandy clay loams and clay soils which have good water holding capacity (Chantereau and Nicou, 1994)[5].

In some areas transplanting allows double cropping to take place providing an additional food crop within a year. In Nigeria, *Dauro* millet is one of three types of millet grown but is the only type to be raised in nursery beds and seedlings later transplanted into the production field. The transplanting makes it possible for double cropping during the rainy season with early maturing groundnut and cowpea, which are harvested before the *Dauro* millet is transplanted (Labe *et al.*, 1987)[6]. In Vietnam, the National Maize Research Institute has developed a low-cost maize production

[4] OLABANJI, O.G., TABO, R., FLOWER, D.J., AJAYI, O., USHIE, F., KAIGAMA, B.K. AND IKWELLE, M.C. (1996). Production and Management: Survey of *Masakwa* sorghum growing areas in Northeastern Nigeria. *International Sorghum and Millet Newsletter* **37**.

[5] CHANTEREAU, J. AND NICOU, R. (1994). Sorghum. The Tropical Agriculture series. MacMillan London pp 4-11.

[6] LABE, D.A, EGHAREVBA, P.N., YAYOCK, J.Y. AND OKIROR, S.O. (1987). Effect of planting methods on the performance of Dauro millet. *Maydica* **32(4)** 287-299.

system on the Red River Delta based on transplanting maize into soils previously used exclusively for rice. This maize transplanting has allowed an additional food crop to be grown in a year providing an average of 5 tonnes per hectare of maize, in addition to the two rice crops normally sown (Uy, 1996)[7].

In general, indigenous but largely unquantified information suggests that where transplanting is practised an improved stand is established, the crop is harvested earlier and the yield per hectare is increased. Much of the quantifiable data that exists on transplanting is based mainly on high-tech short season vegetable growing. However where data within a semi-arid extensive farming systems does exist, trials frequently support this indigenous knowledge, with transplanting often producing higher yields when compared to direct seeding (millet; Labe *et al*., 1987[5], Mercer-Quarshie, 1979[8] and maize; Khehra *et al*., 1990[9]). Conversely some trials have revealed that transplanting actually reduces yields when compared to direct sowing (sorghum; Dahatonde, 1996[10], maize; Carranza and Vicuna, 1978[11]).

2.3 Identification of demand

During the 1980s Dr Ian Robinson, Director of CAZS, observed farmers growing Masakwa sorghum using residual moisture around Lake Chad in NE Nigeria, Tsombe farmers intercropping transplanted pearl millet in NW Benin and later opportunistic gap filling in Zoba Debub, Eritrea (Robinson, 1993)[12]. He recognised that these

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[7] UY, T.H. (1996). Transplanting maize on wetland: A technical manual based on a successful case-study in Vietnam. FAO, Rome.

[8] MERCER-QUARSHIE, H. (1979). Transplanting and direct planting of late millets (Pennisetum typhoides (Burm) Stapf and Hubbard) in northern Ghana. *Ghana Journal of Agricultural Science* **12** 85-90.

[9] KHEHRA, A.S., BRAR, H.S., SHARMA, R.K., DHILLON, B.S AND MALHOTRA, V.V. (1990). Transplanting of maize during the winter in India. *Agronomy Journal* **82** 41-47.

[10] DAHATONDE, B.N., TURKHED, A.B. AND JADHAO, S.L. (1996). Performance of sorghum and bajra crops under different Methods of Planting. *PKV-Research Journal* **20(1)** 65-66.

[11] CARRANZA DE LA, P.A. AND VICUNA, L.M.L. (1978). Effect of transplanting different populations of maize on the efficiency of water utilization under seasonal conditions. *Universidad Autonoma Agraria Antoniio Narro: Research Advances* **78**.

[12] ROBINSON, W.I. (1993). Eritrean agricultural rehabilitation mission report for Oxfam Belgique, CAZS, Bangor, UK.

techniques could have a wider application and could potentially improve food security. This recognition lead to a Centre for Arid Zone Studies (CAZS)-funded pilot study in 1998.

The pilot study was funded with the aid of a generous donation from the famous Kenyan born musician and ex-Bangor student Mr Roger Whittaker, *via* the University of Wales Bangor Development Trust Fund. In 1998 another ex-Bangor student, Mr Michael Griffiths, tested the feasibility of transplanting sorghum under semi-arid conditions in Zimbabwe at the Save Valley Experiment Station, Chipangayi and with the Rural Unity For Development Organisation (RUDO), Masvingo. The results of his study established that the technique was feasible and the idea was worth pursuing. On this basis funding was secured from the DFID Flexibility Fund in 1999 for a 3-year project (R7341) to test the idea further, initially in Zimbabwe (1999), and later extended to Ghana (2001).

3 Project Purpose

The purpose of the project was to investigate if it is possible to transplant sorghum and pearl millet to minimise the risk of failed crops or patchy stands, thereby increasing food security *i.e.* achieving an improvement during years when the rain is late, and providing a ‘safety net’ of plants when the rains are erratic.

The project in the first instance targeted food security and reduction of risk for subsistence farmers in semi-arid countries where shortage of water is the most serious constraint on production. It is now clear that transplanting has wider application in the context of global climate variability and change. Despite efforts to breed for drought and other abiotic stresses, uncertainty associated with onset of rain is a major constraint across the spectrum from the poorest of the poor to the richer farmers. Irrigation comes at a price, and transplanting is a way to conserve water and manage unpredictability. The technique has the added advantage of having been successfully modified from existing indigenous practices and is suited to the needs of the poorest of the poor.

4 Research activities

The first two years of the project were conducted in Zimbabwe; on-station trials took place at the Save Valley Experiment Station, Save Valley, Chipangayi in S. East Zimbabwe, managed by the Department of Research and Specialist Services (DR&SS), Ministry of Agriculture (Figure 4.1); on-farm trials were conducted by farmers in the Chivi, Gutu and Masvingo Districts, Masvingo Province, under the supervision of the Rural Unity for Development Organisation (RUDO) a local, previously Oxfam affiliated, but currently CAFOD affiliated NGO (Figure 4.2). However due to the political problems in Zimbabwe during 2000/2001, and uncertainty as to whether trials could continue, extra funding was secured in early 2001 to extend the project activities to Ghana for a further two seasons.

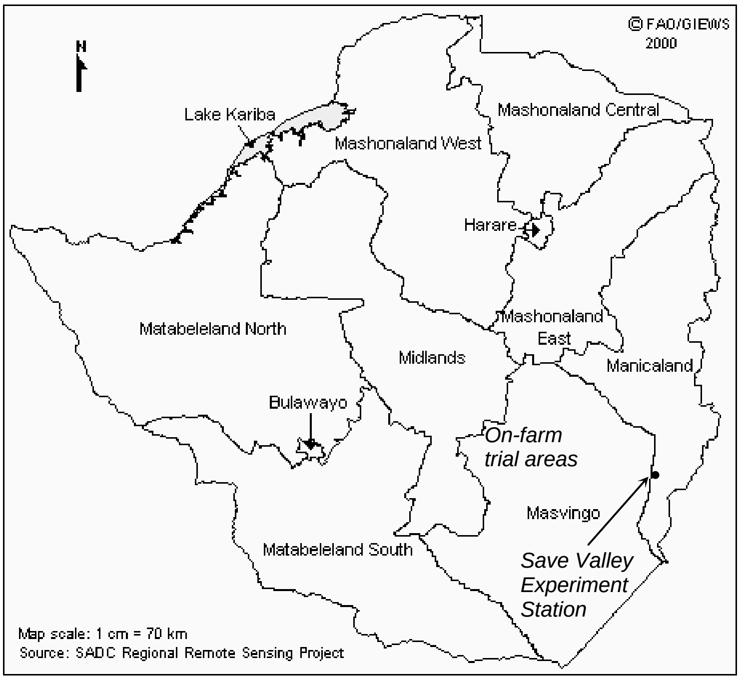

Figure 4.1. Provincial Map of Zimbabwe.
(Source: www.fao.org/giews/english/basedocs/zim/zimtoc1e.htm)

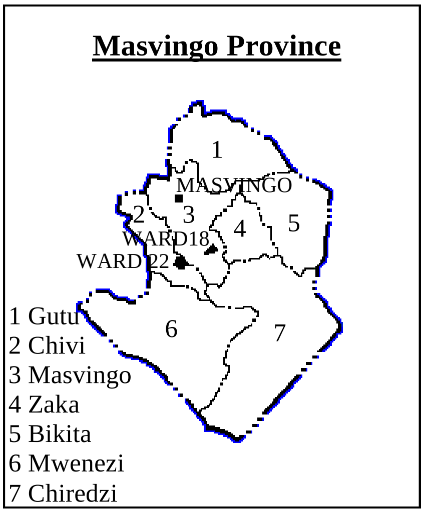

Figure 4.2. District map of the Masvingo Province showing Gutu, Chivi and Masvingo Districts.

In Ghana the on-station trials were conducted at the Manga Research Station, Bawku West, Upper-East Region run by the Savannah Agricultural Research Institute (SARI), part of the Council for Scientific and Industrial Research (CSIR). On-farm trials were carried out by farmers under the supervision of SARI, Ministry of Food and Agriculture (MOFA) and Action Aid staff, around Zebilla in Builsa District and Navrongo and Sandema in Bawku West District, Upper-East Region (Figure 4.3).

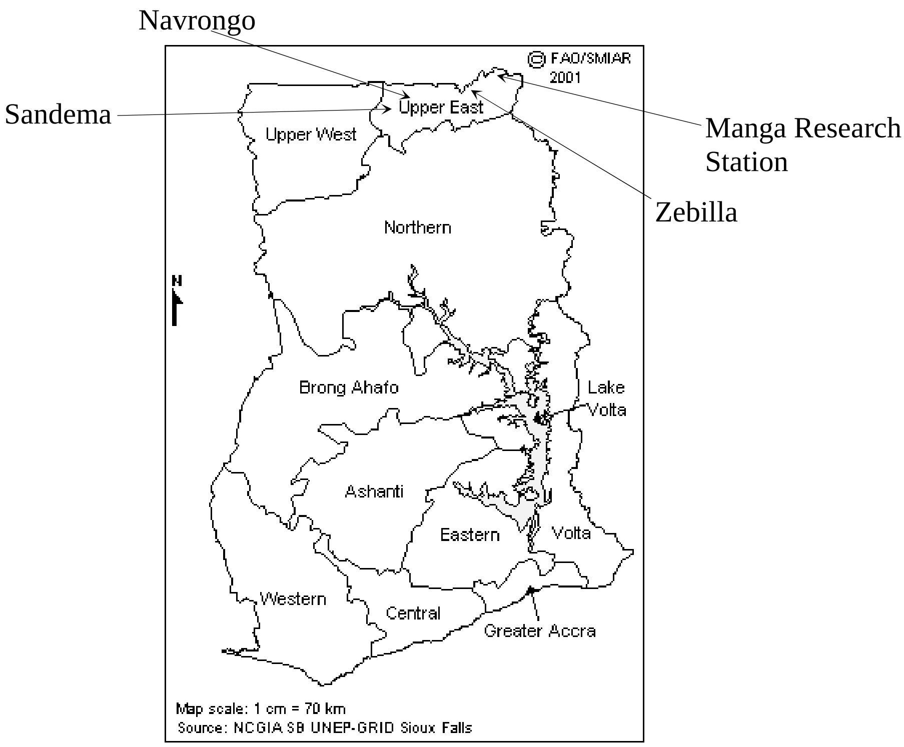

Figure 4.3. Provincial Map of Ghana, showing position of Manga research Station and on-farm trial areas.
(*Source:www.fao.org/WAICENT/faoinfo/economic/giews/french/basedocs/gha/ ghatoc1f.htm*)

4.1 Study of existing rainfed farming systems

This study was designed to provide a framework of knowledge on the functionality and dynamics of the existing rainfed farming systems in Zimbabwe and Ghana, and to determine the feasibility and impact of transplanting on those systems. In order to acquire the relevant information a number of participatory and rapid rural appraisal techniques were conducted with farmers that were participating in the on-farm transplanting trials.

In Zimbabwe groups of up to 10 farmers from Mashate, Daitai, Gutu, Chivi, Chikarudzo and Charumbira, were consulted. The farmers from Gutu and Chivi were separated into male and female groups, however there were few men involved in the trials from Mashate and Daitai therefore those groups were of mixed gender. The combined Chikarudzo and Charumbira group was exclusively female.

In Ghana the data was collated with groups of farmers participating in the on-farm trials from around Zebilla, Sandema and Navrongo. Here mixed groups compiled the seasonal calendars, but separated male and female groups of up to 10 members provided information on labour demands and food availability. The female groups provided seed prices over the year, as they were responsible for market activities and thus were the ones who knew the prices.

4.1.1 Participatory/rapid rural appraisal techniques

4.1.1.1 Preference ranking

Farmers were asked to rank the top five crops cultivated in their areas in order of importance, to score each crop out of 10 and give reasons for the ranks and scores. This provided information on the relative importance of the different crops cultivated in each of the on-farm trial areas, identified the importance of sorghum and pearl millet in relation to the other crops, and highlighted reasons for the crop importance.

4.1.1.2 Pairwise-ranking

Pairwise-ranking exercises were conducted with farmers to determine the main problems related to rainfed agriculture, and to establish whether transplanting could address some of these problems. The farmer groups were initially asked to list the main problems associated with rainfed agriculture, which were written along the horizontal, and repeated along the vertical axes of a matrix. The farmers were then asked to choose the major problem from each pair of problems listed in the matrix, and the result recorded. The number of times that each problem was noted in the matrix was then totalled and recorded in a score column. The scores were then converted to ranks with the problem appearing most frequently ranked first.

4.1.1.3 Seasonal calendar

Seasonal calendars of a number of activities were constructed with farmer groups, namely: the cropping sequences from land preparation to harvest for the main rainfed crops grown, labour demands of men and women, food availability, and in Ghana seed prices for sorghum and pearl millet over the year. These seasonal calendars provided further background information on the current rainfed farming systems which then enabled the effects of transplanting activities on general cropping sequences, annual labour demands and changes in food availability, to be more accurately determined.

After establishing that farmers understood the 12-month calendar charts were constructed for each activity on large flip-chart paper placed on the ground, with the months of the year written along the horizontal axis. The calendar for the cropping sequences was filled in crop-by-crop noting the time of sowing, weeding and harvesting, and any other activities mentioned by farmers. The labour demand and food availability charts were constructed by asking the groups to give each month a score from one to 10, the highest values being the most labour demanding and when most food was available. The farmers worked though the year starting with the four most demanding/food available months, then the four least demanding/food available months, and then the remaining ones. In Zimbabwe farmers were literate and wrote the number in each month. In Ghana where some members of the groups were illiterate stones were used so that a visible chart was produced with up to a maximum of 10 stones in each column (Plate 4.1.1). For the seed pricing activity in Ghana the prices related to the standard container (approximately 2½kg) that was used to purchase seed in the market. When all the data was collected the information from the individual sections were collated into one seasonal chart to allow sections to be crosschecked and for presentation.

Plate 4.1.1. Male farmer group from Teshie and Ankpaliga in Ghana, with their constructed labour chart.

4.1.1.4 Semi-structured interviews

In addition to the specific activities described above, semi-structured interviews were conducted with groups of farmers and local development/agricultural/extension workers throughout the three study years. These interviews provided further information to crosscheck records and to build on the results already gathered during the activities described above. The results of these interviews are incorporated into the narrative text under the specific activity headings in the following results section.

4.2 On-station trials

All trials followed a similar randomised 4-block design, comparing transplanted seedlings with direct-sown seed. Each trial included transplanting age as a treatment in addition to other treatments such as nursery plant density and leaf cutting at transplanting, specified in each trial. In order to provide seedlings of the appropriate age at transplanting a series of $1m^2$ nurseries were established approximately every 10 days, starting 6-8 weeks before the expected main rains. All nurseries were bunded to prevent water flowing away (Plates 4.2.1 and 4.2.2). Nurseries were watered by hand the day before sowing then as and when required to maintain plant health, all amounts of water added were recorded.

Plate 4.2.1. On-station nurseries, Manga Research Station, Ghana.

Plate 4.2.2. On-station nurseries, Save Valley Experiment Station, Zimbabwe.

Following a significant amount of rainfall seedlings were transplanted from nurseries into field plots. Field plots were not bunded so that excess water during the rainy season could drain away. At the same time as seedlings were transplanted, plots were also direct-sown with seed to compare the transplants with the normal practice of dry direct sowing. The direct-sown seed was sown at the time of transplanting rather than at the time of nursery sowing due to insufficient rainfall being unable to support plant growth before the start of the rainy season.

Both nursery and main plots included an outer guard row from which no measurements were recorded. Throughout the trial, and at harvest, various measurements including time to flowering and maturity, and grain and stover yields were recorded; exact details are described under country and individual trial sections. In Zimbabwe due to ovens and accurate balances being available at the research station, yield data was adjusted to 12% moisture content for sorghum and pearl millet using the following equation:

$$\text{Moisture content} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

$$12\%\ \text{moisture content} = \frac{\text{Fresh weight}}{\text{Moisture content}} \times 12$$

To calculate the total dry weight of stover from a sub-sample the sub-sample dry weight was expressed as a percentage of the sub-sample fresh weight, then that percentage found of the total fresh weight i.e.

$$\text{Total dry weight} = \frac{\text{sub-sample dry weight}}{\text{sub-sample fresh weight}} \times \text{total fresh weight}$$

Yield data harvested from the plots was converted to values per hectare for consistency throughout the trials. For Zimbabwe the total plot size was 5 m x 5 m with inter-row spacing of 1 m and inter-plant spacing of 30 cm. The actual harvested area was 3 m x 3.9 m with a maximum of 39 plants. This population density converts to 33,333 plants ha^{-1}. To convert the plot harvested area into ha^{-1} the following equation was used:

Zimbabwe:

$$\text{Yield } (t\ ha^{-1}) = \frac{\text{Yield (kg harvest area}^{-1})}{11.7} \times 10$$

$$\text{Population } (ha^{-1}) = \frac{\text{Number (harvest area}^{-1})}{11.7} \times 10{,}000$$

(11.7 derived from actual harvested plot area of 3.9m x 3m)

For trials in Ghana the total plot size was 5 m x 3 m with an inter-row spacing of 0.75 m and inter-plant spacing of 30 cm for early millet and 40 cm for late millet, early sorghum and late sorghum. Harvest data was recorded from two inner rows plus mistakenly four plants from the guard rows were included, therefore the actual harvestable area for early millet was 5.1 m x 1.5 m with a maximum of 34 plants converting to a population density of 44,444 plants ha^{-1}, and for the other crops 5.2 m x 1.5 m with a maximum of 26 plants converting to a population density of 33,333 plants ha^{-1}. To convert the plot harvest figures into ha^{-1} the following equations were used:

Ghana:

Early millet:

$$\text{Yield } (t\ ha^{-1}) = \frac{\text{Yield (kg harvest area}^{-1})}{7.65} \times 10$$

$$\text{Population } (ha^{-1}) = \frac{\text{Number (harvest area}^{-1})}{7.65} \times 10{,}000$$

(7.65 derived from actual harvested plot area of 5.1m x 1.5m)

Rest of crops: $$\text{Yield (t ha}^{-1}) = \frac{\text{Yield (kg harvest area}^{-1})}{7.8} \times 10$$

$$\text{Population (ha}^{-1}) = \frac{\text{Number (harvest area}^{-1})}{7.8} \times 10{,}000$$

(7.8 derived from actual harvested plot area of 5.2m x 1.5m)

4.2.1 Zimbabwe

All nurseries were prepared on ploughed then levelled land. The day before each sowing date the nurseries were watered with 30 litres of water. Nurseries were then watered daily when there was no rainfall and all amounts added were recorded. During nursery growth plant heights and leaf number of 10 plants per nursery were recorded once a week for the first trial, reduced to five plants per nursery for the second and third trials. Plant numbers were reduced from 10 to five because due to the large number of plots it was difficult to measure all plots on the same day and it was considered that five would provide sufficient replication.

Following a significant amount of rainfall 75 seedlings closest to 20, 30 and 40-days-old were transplanted into 5 m x 5 m plots at a inter-row spacing of 1 m and inter-plant spacing of 30 cm, equal to the suggested sorghum and millet plant spacing in Zimbabwe and approximate population density of 30,000 plant ha^{-1}. Concurrently the direct-sown plots were sown with five seeds per position at the same plant spacing as the transplanted plots, thinned to one per position after emergence.

All measurements and harvest data were recorded on 39 plants within guard rows. The actual measurements of this area were 3.9 m x 3 m giving an actual plant population ha^{-1} of 33,333. Stand counts in the main plots were recorded daily for the first two weeks and at harvest. Directly after transplanting and two weeks after direct plots were sown, plant heights, leaf number and tiller number of 10 (trial one) or five (trial two and three) marked plants per main plot were recorded every week throughout their growth period up to flowering. Time to flowering and maturity was also recorded for all main plots. The point of flowering was taken to be when 50% of the plots main tillers were at some stage of anthesis, and the time of maturity when 80% of the grains in the plot were difficult to break with fingernails. At harvest a number of measurements were taken from each plot including: harvest date, total number of plants, number of heads, weight of heads, weight of grain (fresh and dry) and weight of stover (fresh and dry).

4.2.1.1 Trial one. Effect of seedling age at transplanting on growth and yield of transplanted compared to direct-sown sorghum and pearl millet (September 1999 – May 2000).

Two varieties of pearl millet: PMV2 and PMV3, and two varieties of sorghum: Macia and Muchayeni were tested. PMV2 is an improved variety of medium height, high tillering, medium maturity (80-90 days) and with a yield potential of 2.8 t ha^{-1}. PMV3 is early maturing (75-80 days) with white coloured grain and has a yield potential of 2.0 t ha^{-1}. Both pearl millet varieties are recommended for Natural Regions IV and V (Monyo, *unpub.*[13]). Macia is a dwarf-semi-dwarf variety, mostly non-tillering with creamy white grain, semi-compact large bulbous inflorescence, and a yield potential of 3-6 t ha^{-1} (Obilana, *unpub.*[14]). Muchayeni is a local tall variety with white grain and an open inflorescence.

Seed of each variety was sown in nurseries on the 26th September, 6th October, 16th October, 26th October, 5th November, 16th November and 26th November. These dates provided a total number of 112 nurseries (7 dates x 4 varieties x 4 blocks). All nurseries were sown with excess seed then thinned to 1000 plants m^{-2} following emergence. Nurseries were sown in 20 rows with an inter-row spacing of 5cm (thinned to 50 plants per row) to provide an even distribution throughout the plot. The actual nurseries used for transplanting were those sown on the 26th October, 5th November and 16th November. Seedlings from each sowing date were transplanted block by block on the 10th and 11th December providing seedling ages of 45/46-, 35/36-, and 24/25-days old, and at the same time plots were direct-sown with seed. The total number of main plots was 64 ((4 varieties x 3 transplanting ages x 4 blocks) + (4 varieties x direct-sown x 4 blocks)).

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[13] MONYO, E.S. *Description of pearl millet cultivars under demonstration at Matopos 1997/98*. SADC/ICRISAT Sorghum and millet improvement program.

[14] OBILANA, A.B. *Description of improved sorghum varieties and hybrids*. SADC/ICRISAT sorghum and millet improvement program.

4.2.1.2 *Trial two. Effect of nursery density and seedling age at transplanting on growth and yield of transplanted compared to direct-sown sorghum and pearl millet (September 2000 – May 2001).*

Similar varieties of sorghum and pearl millet were used to those in trial one *i.e.* Macia sorghum, PMV2 and PMV3 pearl millet. However Muchayeni was replaced with Mutode, a local late maturing red sorghum with an open inflorescence, due to Mutode being more widely grown for its use in local beer production, and due to a difficulty in obtaining Muchayeni seed. In addition to nurseries being established every 10 days to provide three ages of seedlings at transplanting, nurseries were also sown at three different densities. Final plant densities of 200, 500 and 1000 plants per m^2 were obtained by over-sowing in rows then thinning to the required plant numbers after emergence. Due to even plant spacing between and within rows being required the actual densities varied slightly from the 200, 500 and 1000 plants per m^2 as shown in Table 4.2.1.

Table 4.2.1. Plant density and spacing used for nurseries.

Density (m^{-2})	No. rows	No. plants/row	Spacing	Area used
196	14	14	7cm x 7cm	98cm x 98cm
484	22	22	4.5cm x 4.5cm	99cm x 99cm
1024	32	32	3cm x 3cm	96cm x 96cm

From conducting trial one it was observed that the rains are generally more consistent in December, therefore nursery establishment started later in trial two so as to reduce the unnecessary workload. Nurseries were sown on the 25th October, 6th November, 15th November and 24th November. A total of 192 nurseries were sown (4 varieties x 3 densities x 4 dates x 4 blocks). The actual nurseries used for transplanting were those sown on the 6th November, 15th November and 24th November. Seedlings from each of the three nursery densities (200, 500 and 1000 plants m^{-2}) from each sowing date were transplanted on the 14th December providing seedling ages of 38- 29- and 20-days old, and at the same time plots were direct-sown with seed. A total of 160 plots were used ((4 varieties x 3 transplanting ages x 3 nursery densities x 4 blocks) + (4 varieties x direct sown x 4 blocks)).

4.2.1.3 *Trial three. Effect of nursery density and seedling age at transplanting on growth and yield of transplanted compared to direct-sown sorghum and pearl millet (September 2001 – May 2002).*

Despite a majority of funds begin diverted to Ghana from 2001 due to political instability in Zimbabwe, some funds were provided for the on-station trials to be conducted under the supervision of Dr P. Nyamudeza the research station manager, who conducted a third trial similar to that of trial two. As results from trial two had not shown any major differences between nursery densities and to reduce costs, the 500 plants m^{-2} density was removed in this trial, leaving only the 200 and 1000 plants m^{-2} densities.

Nurseries were sown on the 13th November, 23rd November, 3rd December and 13th December. A total of 128 nurseries were sown (4 varieties x 2 densities x 4 dates x 4 blocks). The actual nurseries used for transplanting were those sown on 23rd November, 3rd December and 13th December. Seedlings from each of the two nursery densities (200 and 1000 plants m^{-2}) from each sowing date were transplanted on the 30th December providing seedling ages of 37- 27- and 17-days old, and at the same time plots were direct-sown with seed. A total of 112 plots were used ((4 varieties x 3 transplanting ages x 2 nursery densities x 4 blocks) + (4 varieties x direct sown x 4 blocks)).

4.2.2 Ghana

Trials were set up with the same randomised 4-block design as used in Zimbabwe, and a similar protocol was used. All nurseries were sown at a density of 1000 plants m^{-2}. The nurseries were initially to be sown at an inter-row spacing of 5 cm i.e. 20 rows per nursery 50 plants per row, similar to that used in Zimbabwe. However the soil in Ghana was not as fine as in Zimbabwe and it was difficult to sow in rows so close together. The spacing used was therefore 10 cm between rows, giving 10 rows per nursery, 100 plants per row.

Due to restrictions in land availability at the research station main plots were reduced to 5 m x 3 m. Seedlings were transplanted at an inter-row spacing of 75 cm with an inter-plant spacing for early millet of 30 cm, and 40 cm for late millet, early sorghum and late sorghum, equivalent to a population density of 44,444 plants ha^{-1} for early millet and 33,333 plants ha^{-1} for the other crops. Similar to Zimbabwe direct-sown plots were sown with seed at the time of transplanting, five seeds per position thinned to one following germination at the same densities as the transplants.

Growth measurements both in nurseries and main plots were the same as those taken in Zimbabwe, as were stand-counts. However due to a lack of drying ovens and accurate balances at the research station it was not possible to take exact sub-sample measurements as in Zimbabwe. The harvest data from each plot was therefore restricted to: harvest date, total number of plants, weight of heads (fresh and sun-dry), number of heads, weight of seed and weight of total stover (fresh and sun-dry).

4.2.2.1 Trial one. Effect of seedling age and leaf cutting at transplanting on growth and yield of transplanted compared to direct-sown sorghum and pearl millet (April – December 2001).

The pearl millet varieties used for the trials were Manga-nara (early maturing in 70-75 days) and Foek (late maturing), and sorghum varieties Kapaala (early) and Mankaraga (late). In addition to three seedling ages being transplanted a further treatment of leaf cutting was added. This treatment was applied at the time of transplanting by extending the leaves of the seedling vertically then removing the top third.

Nurseries were established every 10 days on the 20th April, 30th April, 10th May, 20th May, 30th May and an extra one for early millet of 14th June. A total number of 80 nurseries were sown (5 dates x 4 varieties x 4 blocks). Seedlings were transplanted closest to 20, 30 and 40 days old for late millet, early and late sorghum and 10, 20 and 30 days old for early millet. However due to problems at the research station early and late sorghum were transplanted later at ages closest to 40, 50 and 60 days old. The actual nurseries used for transplanting for early millet were 20th May, 30th May and 14th June; for late millet were 10th May, 20th May and 30th May; and for early and late sorghum were 20th April, 30th April and 10th May. Seedlings from each sowing date were transplanted on the 22nd June providing seedling ages of 8- 23- and 33-days old for early millet, 23- 33- and 43-days old for late millet, and 43- 53- and 63-days old for early and late sorghum, and at the same time plots were direct-sown with seed. The total number of main plots was 112 ((4 varieties x 3 transplanting ages x 2 cutting treatments (cut and uncut leaves) x 4 blocks) + (4 varieties x direct sown x 4 blocks)).

4.2.2.2 Trial two. Effect of seedling age and leaf cutting at transplanting on growth and yield of transplanted compared to direct sown sorghum and pearl millet (April – December 2002).

Trial two was a repeat of trial one. Due to the error of transplanting the sorghum at 40, 50 and 60 days old in trial one it was decided to transplant the sorghum and late millet at ages nearest to 20, 30, 40 and 50 days old in trial two. This allowed an overlap of 2 ages (40 and 50 days old) from trial one to be compared plus the correct ages of 20 and 30-days-old to be added. The early millet transplanting age was maintained as in trial one at nearest to 10, 20 and 30 days old. The actual nurseries used for transplanting early millet were 11th May, 21st May and 31st May, and were 1st May, 11th May, 21st May and 31st May for early sorghum, late millet and late sorghum. Seedlings from each sowing date were transplanted on the 15th June, providing seedling ages of 35-, 25- and 15-days-old for early millet, and 45-, 35-, 25- and 15-days-old for the other crops. At the same time plots were also direct-sown with seed. The total number of main plots required was therefore 152 ((early millet x 3 ages x 2 treatments (cut and uncut leaves) x 4 blocks) + (3 varieties x 4 ages x 2 treatments x 4 blocks) + (4 varieties x 2 treatments (direct at transplanting and farmers practice) x 4 blocks)).

4.2.3 On-station trial - statistics

Analysis of variance (ANOVA) was used to analyse the on-station data. The assumptions of a normal distribution, linear relationship, and equal variance were checked on all data before ANOVA was performed. A normal plot was drawn to check for a linear relationship (expected normal quantiles against residuals) and equal variability by plotting a fitted value plot (fitted values against residuals). If the graph showed random scatter, i.e. there was no pattern to the plotted points, and there was approximately equal variability above and below the zero line, then the data was assumed to have a linear relationship and equal variability. To check the data followed a normal distribution the normal scores were plotted against the residuals. If the plotted points followed approximately a straight line, the data was assumed to follow a normal distribution.

Due to the nature of the on-station trials design *i.e.* having a factorial experiment with an additional control, advice on analysing the data was sought from Eleanor Allan, Director of the Statistical Services Centre, University of Reading, and Christopher Whitaker from the School of Informatics, University of Wales, Bangor. It was decided that GENSTAT statistical program should be used, as it was easier to analyse this design using the biological based program. The general analysis of variance option was used in the ANOVA section and the following formulas applied:

1. **Variety x treatment / age –** for on-station trial one in Zimbabwe.
2. **Variety x treatment / (density x age) –** for on-station trials two and three in Zimbabwe.
3. **Treatment / (leaf cutting x age)** – for on-station trial one in Ghana due to varieties being separated out not randomised together.
4. **Treatment / (leaf cutting x age) –** for on-station trial two in Ghana.

Where;

- Variety = the variety of sorghum or pearl millet (sorghum and pearl millet trials were analysed separately),
- Treatment = Transplanted or direct sown,
- Age = Age of seedling at transplanting,
- Density = Density of nursery seedling transplanted from,
- Leaf cutting = Leaves of transplanted seedlings cut or intact.

These formulas allowed the treatments of age, nursery density and leaf cutting to be nested within the treatment of transplanted or direct-sown, thereby in effect only relating to the transplanted but allowing the comparison of the direct-sown treatment.

4.3 On-farm trials

Concurrent with on-station trials, on-farm trials were conducted by farmers to test the technique under normal farming conditions. Following initial farmer meetings, which introduced the project, further meetings were held with interested farmers to explain the details of the trial. Farmers themselves decided who wanted to be involved in conducting the trials; the only pre-requisite was they had to have access to water out of season.

Prior to the rainy season the farmers established two or more nurseries approximately 10-20 days apart. Recommendations regarding the nursery establishment were to sow the seed close to a given date, at high density, in rows. Thereafter the farmers elaborated on the basic idea to produce a nursery that suited their own needs (Plate 4.3.1). The time of transplanting from the nurseries to the field after the beginning of the rains was left to the farmers' discretion but it was suggested it should be after heavy rainfall. In addition to transplanting the farmers were asked to direct-sow a similar sized area to the transplanting area for comparison, at the time that they would normally sow their sorghum or millet. Farmers were asked to keep basic records of sowing, transplanting and harvesting dates and yields. Where possible farmers also recorded extra information for example, nursery watering regimes, manure application and time spent conducting activities. One literate farmer from each area was also chosen to record rainfall measurements using a rain gauge that was provided.

Farmers were visited throughout the trials to check on progress and discuss any difficulties encountered. In addition field days were held at nursery and post-transplanting stages to share information between farmers and introduce the technique to other interested farmers. Post-harvest discussion workshops were held with farmers in each area to collate information and opinions, as well as a final end of season workshop with representatives from the farmer groups, project staff and local institutions.