Transplanting Sorghum and Millet as a Means of Increasing Food Security in Semi-Arid Low Income Countries
Transplanting sorghum and millet as a means of increasing food security in semi-arid, low income countries.

A Project Update

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**SUMMARY**

Increasing food security and reduction of risk continues to be a recurring theme in agricultural development programmes of the new millennium. Erratic and unreliable rainfall and resulting shortages of water are the most serious physical constraints to crop production in semi-arid areas. Under these conditions there is a considerable risk of failed crops, patchy stands and high re-planting costs. Consequently programmes have been initiated to conserve water for supplementary irrigation during the growing season.

This project however is based on the premise that supplementary water can be used more efficiently if applied at the beginning rather than at the end of the season, to ‘extend’ the effective growing season in short duration areas. It is suggested that some proportion of sorghum and millet crops can be raised in nurseries using small amounts of water before the rainy season then transplanted at the onset of rains. Besides providing seedlings to alleviate the problem of patchy stands and replanting costs, this could be a way of reducing the growing period in the field, thus providing an earlier harvest and providing an extra dimension to food security.

The application of the transplanting technique to a dryland agriculture cropping system is currently being investigated with subsistence farmers in semi-arid regions of Zimbabwe, Ghana, Ethiopia and Eritrea. This update focuses on work in Zimbabwe and Ghana where on-station and on-farm trials have confirmed that transplanting sorghum and millet into a dryland agricultural system is a viable option. On-station trials have indicated that for most of the sorghum and pearl millet varieties tested, transplanted plants (varying from 20 to 40 days old at transplanting) flower and mature from 5 to 25 days earlier than the ‘normal’ direct sown seed and yields of transplanted crops are similar if not higher, offering an earlier harvest when food reserves are low and prices high. A majority of the participating farmers conducting on-farm trials found similar results and have responded very positively to the transplanting technique, despite initial reservations concerning labour requirements.
ACKNOWLEDGEMENTS

Many people have been involved in this transplanting project so far whose hard work and determination have made the project, and its results possible. First and foremost we must thank Mr Roger Whittaker who via the University of Wales Bangor Development Trust Fund initially funded the CAZS pilot study and to DFID who currently fund this project.

We are grateful to Mr Wellington Mudzamiri at RUDO and Dr Phibion Nyamudeza, Mr Mutema and Mr Mapfumo at the Save Valley Experiment Station, who despite difficult circumstances have maintained effective on-farm and on-station trials in Zimbabwe. Also to Mr Akwasi Abunyewa, Mr Kasei and Dr Atokple at SARI in Tamale, Mr Paulinius Tertobiri and Mr David Afribeh at Manga Research Station, Mr Peter Ayoreko from Action Aid in Zebilla and Dr Quist from the Ministry of Agriculture, Builsa in Ghana, who’s combined enthusiasm for the project has inspired farmers, without whom we could not have tested the concept.

Thanks also go to all the heads of departments, institutions and organisations who have allowed their staff to be involved in the project including Mr Eliam Mahohoma director of RUDO in Zimbabwe, Dr Salifu Acting Director of SARI in Tamale, Ghana and Dr Tanzubil Head of Manga Research Station in Ghana. Our sincere acknowledgements extend to all the extension and field workers who have worked hard to provide support and advice to farmers conducting the on-farm trials, and to the many labourers who have made the on-station trials possible. Ultimately our gratitude must be expressed, from the project team in the UK, Zimbabwe and Ghana as a whole, to all the farmers involved in the trials who have given up their valuable time and resources to test the technique under their own farming conditions.
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INTRODUCTION

The problem

The main challenges for farmers within the semi-arid and arid areas of the tropics and sub-tropics, are poor food security, yield instability and risk of crop failure. These challenges 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. In consequence, programmes have been initiated to conserve water for supplementary irrigation during the growing season, however this project is 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.

Background

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 Chivasa et al. (1998) 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. This idea 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) describes this term ‘transplanting’ as ‘raising seedlings in 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 allows 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). 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 have subsided. At approximately thirty to forty days old seedlings are transplanted into the bed of the lake where the crop matures using residual moisture left as the waters recede (Olabanji et al., 1996). This activity includes all members of the family, men, women and children 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).

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). Similarly in Vietnam, the National Maize Research Institute has developed a low-cost maize production 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

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an average of 5 tonnes per hectare of maize, in addition to the two rice crops normally sown (Uy, 1996). 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, Mercer-Quarshie, 1979 and maize; Khehra et al., 1990). Conversely some trials have revealed that transplanting actually reduces yields when compared to direct sowing (sorghum; Dahatonde, 1996, maize; Carranza and Vicuna, 1978).

The evolutionary convergence of transplanting techniques to exploit favourable growing conditions suggest that the technique may have application elsewhere and provide a buffer against adverse conditions threatening food security.

The solution

This project aims to test the concept of transplanting sorghum and pearl millet within a low-input dryland agricultural system. It is suggested that raising sorghum or pearl millet in nurseries using small amounts of water before the rainy season, then transplanting

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seedlings at the onset of the rains extends the growing season in short duration rainfall areas. Seedlings may be:

i. grown in small irrigated nurseries using minimal water before the rains and then transplanted into the fields when the rains are fully established.

ii. 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.

Besides providing seedlings to alleviate the problem of patchy stands and replanting costs, this reduces the growing period in the field, thus providing an earlier harvest, alleviating the problem of a short duration rainfall and providing an extra dimension to food security.
THE TRANSPLANTING PROJECT

During the 1980’s 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). He recognised that these techniques could have a wider application and could potentially improve food security. This recognition lead to the establishment of a Centre for Arid Zone Studies (CAZS) funded pilot study in 1998.

Pilot Study

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 the basis of the work funding was secured from the DFID flexibility fund in 1999 for the current 3-year project (R7341), to test the idea further.

Current Project

The current project tests the transplanting technique at three levels; on-station trials, on-farm trials and controlled environment trials. The on-station trials are taking 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. At the same time on-farm trials are being 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. Thus far 2 seasons of trials have been accomplished in

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Zimbabwe and despite political problems in the country the final year of trials is currently underway.

Due to the political problems in Zimbabwe and earlier uncertainty as to whether trials could continue, extra funding was secured in early 2001 to extend the project activities to Ghana for a further 2 seasons. Thus far one season of trials have been conducted in Northern Ghana. On-station trials are taking place at the Manga Research Station, Bawku, Upper-East Region run by the Savannah Agricultural Research Institute (SARI), which is part of the Council for Scientific and Industrial Research (CSIR). On-farm trials are being undertaken by farmers under the supervision of SARI, Ministry of Food and Agriculture (MoFA) and Action Aid in the Builsa and Bawku West Districts, Upper-East Region. Concurrently controlled environment trials have been conducted at the Pen-y-Ffridd field station, University of Wales, Bangor, UK.

All project areas both within Zimbabwe and Ghana are typified by low and erratic rainfall. Trial areas in Zimbabwe are characterised by agro-ecological regions IV and V as described by Vincent and Thomas (1961)\(^\text{12}\). These are low-lying areas with between 450-650mm of rainfall per annum, subject to periodic seasonal droughts and severe dry spells during the rainy season. In Ghana the Upper-East Region although experiencing high annual rainfall figures of between 900-1120 mm per annum, suffer from a higher annual water loss by evapotranspiration, together with a high occurrence of site-specific drought spells and soils that possess a poor water holding capacity (Kasei, 2001)\(^\text{13}\). Despite these poor growing conditions, smallholder grain and fodder cropping exists extensively in these areas.

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Project Purpose

The overall aim of the project is to target food security and reduction of risk of crop failure for subsistence farmers in semi-arid countries, where shortage of water is the most serious physical constraint to crop production. The project will establish whether transplanting within a semi-arid dryland agricultural system is a viable option for maximising the growing season and minimising the risk of failed crops, patchy stands and costs of re-planting. The project will also assess the socio-economic/ergonomic costs and possible impact of adopting transplanting within a dryland farming system.

Project Objectives

In order to achieve the purpose the project has been divided into three phases:

Phase 1. Characterisation of the physical and socio-economic constraints to the adoption of transplanting and other non-standard techniques for improving crop establishment as a means of increasing food security.

Phase 2. Analysis of the suitability of locally available varieties and landraces to transplanting. This includes controlled environment experiments at Bangor in the UK as well as on-station and participatory on-farm studies in Zimbabwe and Ghana.

Phase 3. Identification of areas for the application of transplanting techniques and development of optimal methodological strategies with farmers.
Project Activities

On-Station trials
Thus far 2 seasons of trials have been conducted in Zimbabwe and 1 season in Ghana. 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, specified in each trial. In order to provide seedlings of the appropriate age at transplanting a series of 1m² nurseries were established approximately every 10 days starting 6-8 weeks before the expected main rains. All nurseries were bunded and prepared on ploughed then levelled land (Plates 1 and 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 1. On-station nurseries, Manga Research Station, Ghana.](image1)

![Plate 2. On-station nurseries, Save Valley Experiment Station, Zimbabwe.](image2)

Following a significant amount of rainfall (at least 60mm) seedlings were transplanted from nurseries into 5m x 5m field plots at an inter-row spacing of 1m and inter-plant spacing of 30cm equal to 30,000 plant ha⁻¹. In Ghana plot sizes were reduced to 3m x 5m due to space restrictions but plant spacings were maintained. 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, these plots were thinned to the same plant spacing as the transplants after emergence. The direct sown seed was sown at the time of transplanting rather than at the time of nursery sowing due to lack of rains before the time of transplanting.
Throughout the trial and at harvest various measurements were taken from plants excluding the guard rows. These included weekly measurements of plant heights, leaf number and tiller number, time to flowering and maturity, plant survival numbers and grain and stover yields.

**Zimbabwe**

*Trial 1. Effect of seedling age at transplanting on various growth characteristics (September 1999 – May 2000)*

Two varieties of pearl millet and 2 of sorghum were tested. Pearl millet varieties PMV2 (medium height, medium maturing in 80-90 days) and PMV3 (early maturing in 75-80 days), and sorghum varieties Macia (short height, early to medium maturing in 115-120 days) and Muchayeni (a local late maturing variety) were used. Nurseries were sown in rows and thinned to 1000 plants per m². Actual seedling ages at transplanting were:
1. SD1 (sown 26th October) transplanted at 45/46 days old.
2. SD2 (sown 5th November) transplanted at 35/36 days old.
3. SD3 (sown 16th November) transplanted at 24/25 days old.
4. Dry seed sown to compare with the transplants (control).

*Trial 2. Effect of nursery density and seedling age at transplanting on various growth characteristics (September 2000 – May 2001).*

PMV2 and PMV3 pearl millet and Macia sorghum were used however Muchayeni was replaced with Mutode a local red sorghum which is much more widely used by farmers in the area. In this trial an additional treatment of nursery density was tested. At each sowing date nurseries of each variety were thinned to 200, 500 and 1000 plants per m². Actual seedling ages at transplanting from each nursery density were:
1. SD1 (sown 6th November) transplanted at 38 days old.
2. SD2 (sown 15th November) transplanted at 29 days old.
3. SD3 (sown 24th November) transplanted at 20 days old.
4. Dry seed sown to compare with the transplants (control).
Ghana

**Trial 1. Effect of seedling age and leaf cutting at transplanting on various growth characteristics (April - November 2001).**

The pearl millet varieties used for the trials were Manga-Nara (early millet), Foek (late millet), and sorghum varieties Kapaala (early sorghum) and Mankaraga (late sorghum). All nurseries were sown at a density of 1000 plants per m$^2$. At transplanting the leaf cutting treatment was applied to some seedlings by extending the leaves vertically then removing the top half. Actual seedling ages at transplanting were:

**Early millet**
1. SD1 (sown 20$^{th}$ May) transplanted at 33 days old.
2. SD2 (sown 30$^{th}$ May) transplanted at 23 days old.
3. SD3 (sown 14$^{th}$ June) transplanted at 8 days old.
4. Dry seed sown to compare with the transplants (control).

**Late millet**
1. SD1 (sown 10$^{th}$ May) transplanted at 43 days old.
2. SD2 (sown 20$^{th}$ May) transplanted at 33 days old.
3. SD3 (sown 30$^{th}$ May) transplanted at 23 days old.
4. Dry seed sown to compare with the transplants (control).

**Early and late sorghum**
1. SD1 (sown 20$^{th}$ April) transplanted at 63 days old.
2. SD2 (sown 30$^{th}$ April) transplanted at 53 days old.
3. SD3 (sown 10$^{th}$ May) transplanted at 43 days old.
4. Dry seed sown to compare with the transplants (control).

**On-farm trials**
Concurrently with on-station trials, on-farm trials were conducted by farmers to test the technique under farming conditions. Following initial farmer meetings, which introduced the project, further meetings were held with interested farmers to explain the details of the trials. Farmers themselves decided who would be involved in conducting the trials; the only pre-requisite was they had to have access to water out of season. One farmer from each area also recorded rainfall measurements using a rain gauge that was provided.
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. The time of transplanting from the nurseries to the field after the beginning of the rains was left to the farmers’ discretion. 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. 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, manure application, time spent conducting activities. 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.

**Zimbabwe**

**Trial 1. September 1999 – May 2000**

Initial on-farm trials in Zimbabwe were limited to 25 farmers in the Chivi and Masvingo Districts, Masvingo Province so that personal contact could be maintained with all the farmers throughout the season. Following discussions with the local NGO, RUDO it was decided that each farmer should receive 2kg of Macia sorghum seed; ½kg for the 1st nursery, ¼kg for the second nursery and 1kg for dry planting at the time of normal practice, on the understanding that 4kg would be returned to the project at harvest to maintain a seed bank for further trials. Examples of farmers’ nurseries are shown in plates 3 and 4.

**Trial 2. September 2000 – May 2001**

Trials followed a similar pattern to trial 1 however due to increased interest by farmers in surrounding areas the number of farmers involved in the trials was expanded to 75 covering three districts: Chivi, Masvingo and Gutu within the Masvingo Province.
Ghana

Trial 1. May 2001 – November 2001

In Ghana on-farm trials were conducted in the Builsa and Bawku West Districts in the southwest and northeast parts of the Upper-East Region respectively. Following discussions with participating farmers it was decided for the first year to restrict nursery sizes to 1m² and transplanted plots to 10m x 10m (which were measured by Ministry of Agriculture and Action Aid facilitators) although farmers could do more if they wished. The farmers were also asked to direct sow a 10m x 10m plot adjacent to the transplanting area, according to the normal practice. Farmers could transplant early millet, late millet or sorghum, or a combination of them and would use their own seed due to differences in varieties used. Additionally it was suggested this would maintain self-motivation and interest. It was recommended that nurseries be sown on 16th – 18th April, 26th – 28th April and 6th – 8th May to provide a sequence of nurseries, with the dates flexible to suit the farmer’s own circumstances. The design of nurseries was many and varied as illustrated in Plate 5.
Plate 5. Various types of nurseries established by farmers in Ghana.
Project Results to date

On-Station

Various results were recorded throughout the period of the on-station trials as described earlier. The results shown below, taken from the 2000/2001 trials in Zimbabwe, highlight the main differences between transplanted and direct sown plants associated with time to maturity and yields.

Figure 1 shows time to maturity of Macia sorghum for direct sown seed compared to three transplanted seedling ages. The results are expressed both as the period from the time of transplanting to maturity, and the period from the time of sowing to maturity i.e. including the time spent in the nurseries. From the time of transplanting all three ages of transplanted seedlings mature earlier than the direct sown seed by at least 9 days (p=0.001). However for the overall time to maturity from the time of sowing i.e. including time spent in the nurseries, all transplanted seedling ages took longer to mature than the direct sown seed (p=0.001).

![Figure 1. Time taken for Macia sorghum to reach maturity, from the time of transplanting and from the time of sowing. Direct sown seed, SD1 = 38 days old at transplanting, SD2 = 29 days old at transplanting, SD3 = 20 days old at transplanting. Error bars = +1 standard error.](image)

These differences suggest that the transplanted seedlings suffer from a ‘transplanting shock’ where the plant is adapting to its new environment after being transplanted causing an overall increase in time to maturity when compared to a non-transplanted plant.
However in real terms the time spent in the nurseries is before the start of the rains at a time when direct sown seed in the field could not germinate due to lack of moisture. Therefore although transplanted seedlings suffer a check in plant growth or ‘transplanting shock’ under natural conditions they still mature earlier than direct sown seed thus providing an earlier harvest as anticipated. Plate 6 shows the transplanted plants maturing earlier than the direct sown on the station.

Figure 1 also shows there are differences in time to maturity between the different transplanted seedling ages. From the time of sowing, the 38-day-old seedlings mature later ($p=0.036$) than 29-day-old, and the 29-day-old seedlings mature later ($p=<0.001$) than 20-day-old. This suggests that the older the seedling is at transplanting the greater the transplanting shock and the longer the period of growth check experienced by the plant. Conversely from the time of transplanting, as expected, the general trend shows the older seedlings mature earlier, with the 38-day-old seedlings maturing significantly earlier ($p=0.03$) than the 20-day-old seedlings. Therefore although older seedlings suffer a greater check in plant growth compared to younger seedlings, the difference in age outweighs the difference in period of growth check, and in the field the older seedlings mature earlier.

Plate 6. Transplanted Macia sorghum (left) maturing much earlier than direct sown Macia sorghum (right), on-station Zimbabwe.
Similar results were observed for pearl millet varieties (Figure 2). Again all three ages of transplanted seedlings matured earlier than the direct sown when measured from the time of transplanting, and after the direct sown from the time of sowing (p=<0.001). In this case from the time of transplanting both 38 and 29-day-old seedlings mature significantly (p=0.003) earlier than the 20-day-old seedlings, although they do not significantly differ from each other. From the time of sowing 38-day-old seedlings mature significantly later than 29 and 20-day-old (p=<0.001), but there are no significant differences between 29 and 20-day-old seedlings. In this example the shock periods were higher than for Macia sorghum with 38, 29 and 20-day-old seedlings experiencing approximately 32.5, 21.5 and 19 days check in growth.

Despite the transplanting shock experienced by the transplanted seedlings the yield was not compromised and was actually found to be considerably higher in transplanted crops when compared to direct sown. Figure 3 shows that yields of transplanted Macia sorghum were 0.58±0.169t ha⁻¹ higher than direct sown plants. For PMV2 pearl millet the differences were even greater with transplanted plants yielding 0.77±0.262t ha⁻¹ more than direct sown plants. For sorghum this increase in yield was attributed mainly to an improved plant stand, with more transplanted seedlings surviving to harvest, and due to a slight increase in the number of heads per plant. For pearl millet there was no difference in

![Figure 2. Time taken for PMV3 pearl millet to reach maturity, from the time of transplanting and from the time of sowing. Direct sown seed, SD1 = 38 days old at transplanting, SD2 = 29 days old at transplanting, SD3 = 20 days old at transplanting. Error bars = +1 standard error.](image-url)
the plant survival, the increase in yield was attributed to a larger increase in the number of productive heads per plant.

![Graph](image1.png)  
**Figure 3.** Macia sorghum, yields of transplanted and direct sown plants from 5m x 5m plots expressed as tons per hectare. Error bars = +1 standard error, p=0.02

![Graph](image2.png)  
**Figure 4.** PMV2 pearl millet, yields of transplanted and direct sown plants from 5m x 5m plots expressed as tons per hectare. Error bars = +1 standard error, p=0.001

No significant differences were detected in sorghum or millet in time to maturity or yields between seedlings transplanted from the different nursery densities.

**On-Farm**

In a majority of cases on-farm trials supported those results found in the on-station trials. Farmers often experienced improved stands, harvested the transplanted crops earlier and obtained higher yields. In Zimbabwe most farmers harvested their transplanted sorghum crop 5-20 days earlier than their direct sown crops, which provided seed at a time when prices are high and food is in short supply (Plate 7).
Plate 7. Mrs Maunganidze with her on-farm trial (Chivi District, Zimbabwe). Transplanted sorghum (left) is a better stand and is maturing much earlier than the direct sown (right).

Figure 5 shows individual farmers yields for transplanted and direct sown early millet from Ghana. Of the 19 farmers 17 received higher yields from the transplanted crop compared to the direct sown (Plate 8). The reasons for the reduction in yield for the two farmers will be reviewed in the post-discussion workshop to be held in Ghana.

Figure 5. Individual farmer results for early millet grain weight (t ha⁻¹ based on figures from 10mx10m plots) of transplanted and direct sown plants plus the mean of all the farmers’ results (Zebilla, Bawku West, Upper East Region, Ghana). Difference between the means is significant at $p=0.024$. 
When stover weights were compared 80% of the farmers also received higher stover weights from transplanted crops compared to direct sown.

Results for sorghum transplanting were similar to the early millet (Figure 6). In this case 15 of 19 farmers received higher yields for transplanted sorghum compared to direct sown. Other records of panicle number and weights suggested that these increases in yield resulted from larger panicles and/or increased number of heads.

Figure 6. Individual farmer results for sorghum grain weight (t ha$^{-1}$) based on figures from 10mx10m plot of transplanted and direct sown sorghum plants plus the mean of all the farmers’ results (Wiaga, Builsa District, Upper East Region, Ghana). Difference between the means is significant at $p=0.003$. 
BENEFITS AND PROBLEMS OF THE TECHNIQUE

During discussions with farmers who had been involved in the on-farm trials a number of benefits and problems associated with the transplanting technique were highlighted. Of these the main ones are listed below.

Benefits

- **Earlier harvest**: this is particularly important as this is the lean period for farmers when food reserves are low and grain prices are high. It is also important for those areas that experience short rainfall patterns, or when rains finish early.
- **Higher yields**: bigger panicles and more heads per plant.
- **Conserves seed**: when comparing a transplanted plot with a normal broadcasted plot of the same area, less seed is required in the nursery to provide enough seedlings compared to broadcasting.
- **Labour is reduced at other times**: although transplanting from nurseries to the field is time consuming labour is actually reduced at other times, for example weeding, which is reduced due to seedlings having a head start over weeds.
- **If nurseries are secured they are easy to supervise**: nurseries are quite small so pests can easily be spotted and manure can be applied directly to the seedlings.
- **Improved germination in the nursery**: compared to a direct sown field germination is improved, possibly due to more frequent watering and better supervision as described above.
- **Flexibility in time of transplanting**: seedlings do not have to be transplanted at the first rains, which can often be unreliable, they can be left in the nursery until a more convenient time as long as seedlings do not become too old to transplant. This may have the greatest benefit for farmers who do not own an ox and plough as generally the start of the rains is the busiest time when land must be prepared as soon as possible to provide a long enough season for the crop to mature. Farmers who do not have an ox and plough often have to wait until other farmers have finished ploughing their own land, which may result in late sowing and possible problems of the crop reaching maturity if the season is short. If this is the case those farmers can leave the seedlings to grow in the nurseries until the demand for ploughs is reduced and the crop should still be able to mature in time. Similarly if the rains are late seedlings can be left in the nursery until the rains start and should still mature if the season is short.
- **Surplus nursery seedlings can be sold to other farmers.**
Problems

❑ **Birds eating germinating seeds**: this is a particular problem in the nurseries as they are the only crops being sown at this time of the season. Some farmers reduced the bird damage by mulching, also due to high density sowing there were still adequate numbers of plants for transplanting.

❑ **Animal damage to unsecured nurseries**: this is a particular problem because at this time early in the season animals are roaming freely as no other crops are being grown.

❑ **Source of water too far from the nursery**: some farmers’ nurseries were situated more than 30 minutes walk from a water source, which hampered frequent watering.

❑ **Termites eating seedlings**: termites are a constant problem for many of the farmers involved in the trials and attack most crops. To reduce damage in nurseries one farmer suggested that when nurseries were watered daily i.e. when they were constantly wet, termites were not such a problem.

❑ **Transplanting from the nursery to the field is laborious and time consuming.**

**CHECKLIST OF ELEMENTS CRITICAL TO THE SUCCESS OF TRANSPLANTING**

From discussions with both farmers and local institutions involved in the trials, a checklist of the main factors that are critical to the success of the transplanting technique has been compiled:

1. Reliable perennial source of water must be available for nurseries.
2. Water source must be conveniently situated for watering nurseries.
3. Either sorghum, millet, or both should normally be grown by farmers; this is a technique to be used by sorghum and millet farmers, it is not a package for introducing sorghum and millet into new areas.
4. Rainfall should be low and the distribution erratic; there is not much to be gained by this type of transplanting in high-potential areas unless double cropping is the main aim.
5. Labour must be available for transplanting seedlings from nurseries to the field.
GUIDELINES FOR TRANSPLANTING

From experience and data provided by the trials so far, a list of guidelines for successful transplanting has been produced. These guidelines are based on current and on-going project work where some processes are still under investigation, and are therefore not exhaustive.

Nursery Management

The optimum transplanting age of seedlings is 25-40 days, nurseries should therefore be sown approximately 25-40 days before the expected start of the rainy season. A series of nurseries may be sown to provide a bank of seedlings of various ages to accommodate variability in the season start date.

Nursery beds construction can vary but suggested guidelines are:

- Nurseries should be located as near as possible to a water source and to the field into which seedlings will be transplanted.
- Nurseries should be fenced to protect seedlings from animal damage.
- Ideally the nurseries should be provided with some shade particularly at the hottest time of the day to reduce heat damage to the seedlings.
- Beds should be bunded to reduce water runoff.
- Sowing densities of nurseries should be approximately 1000 plants per m$^2$, and should be sown in rows. The size of beds depends on the size of the area to be transplanted, however it is estimated that a 5m x 6m nursery at a plant density of 1000 plants m$^2$, should provide sufficient plants for approximately 1ha at 30,000 plants ha$^{-1}$.
- Mulch may be used on the nurseries to reduce bird damage to the seeds and seedlings, although termites may be attracted to the mulch if they are a problem in the areas concerned.
- Manure or fertiliser should be added to the seedbed in low fertility soils depending on what is available according to the normal practice.
- Nurseries should be watered when required. For the first few days, up to and after emergence, nurseries may need watering twice a day until seedlings have established a root system below the soil surface, which may dry to a crust in high temperatures.
Transplanting

- Transplanting should be carried out after the beginning of the rainy season. There should be at least one day’s rain (preferably two or more) prior to the day of transplanting, and it should be conducted in late afternoon or evening on a cloudy or rainy day to reduce evapotranspiration.

- When seedlings are removed from the nursery the root damage should be kept to a minimum and dug up from at least 15cm depth.

- Root exposure between removal from the nursery and transplanting in the field should be kept to a minimum, the more wilted the seedlings are at transplanting the less and slower the chance of recovery. The damage to exposed roots can be minimised by protecting with moist leaves or sacking.
CONCLUSIONS

The response to transplanting sorghum and millet has been very positive. On-station trials have shown that transplanted seedlings from 20-40 days old, despite transplanting shock, mature earlier than direct sown seed. Of these seedling ages the 30 and 40-day-old seedlings matured the earliest. In addition transplanted crops often produced higher grain and stover yields due to improved stands and an increase in the number of productive tillers per plant. The results also suggest that variations in nursery density up to 1000 plants per m² have no effect on time to maturity or yields. On-farm trials have shown similar results to the on-station with a majority of farmers obtaining earlier harvests, higher yields and an increase in stover weights from the transplanted crops compared to broadcasted direct sown seed.

Generally farmers agree that the benefits of transplanting outweigh the problems encountered. Initially reservations were expressed by workers/reviewers within the development field regarding increases in labour requirements. However although some farmers expressed the opinion that transplanting from the nursery to the field is laborious and time consuming, they also suggest that this is counteracted by the reduction of labour at other times of the year, for example weeding. Therefore as long as labour is available for the actual day of transplanting it is not considered a constraint to the transplanting technique. Cost-benefit analysis is being conducted to verify this belief. Similarly some farmers in Ghana were initially doubtful that early millet could be transplanted as they did not gap fill this crop, however on-farm trials, conducted by many of those farmers, have shown that in a majority of cases early millet can be transplanted in this way.

Thus far results have shown that the transplanting of sorghum and millet in semi-arid areas is possible and has many benefits over the normal practice of broadcasting. The results suggest that the growing period in the field is reduced and that an earlier, often larger, harvest is obtained. However these results are based on two seasons of data from Zimbabwe and one from Ghana and are therefore not yet conclusive. There is still another season of both on-station and on-farm trial data to be obtained from Zimbabwe and Ghana, which will further consolidate results. The technique therefore is still being developed and refined and should not be introduced to new areas without a trial period. However results so far do suggest that this technique could be used to alleviate the
problem of a short duration rainfall and offer fresh opportunities to exploit residual moisture thereby providing extra dimensions to food security.
**CONTACTS AND INFORMATION**

We are currently establishing a transplanting network so that information on trial experiences and ideas can be shared. If you would like to join the network please contact Einir Young and Andrea Mottram using the contact details below. If you are currently conducting on-station or on-farm trials it would be very useful for the network if you could fill in an information sheet similar to that attached in Appendix 1. An electronic version of the information sheet can be sent to you on request. We also have a website at [www.bangor.ac.uk/transplanting](http://www.bangor.ac.uk/transplanting) which is continually updated and provides further information regarding the project.

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