Transplanting Sorghum and Millet as a Means of Increasing Food Security in Upper East Region of Ghana

A Project Summary

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

Project Summary – Ghana

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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. 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 reduces 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 has been investigated with subsistence farmers in semi-arid regions of Zimbabwe, Ghana, Ethiopia and Eritrea. This update focuses on work in 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 and on-farm trials have indicated that transplanted early sorghum and pearl millet varieties (varying from 10 to 40 days old at transplanting) flower and mature from 5 to 25 days earlier than the 'normal' direct-sown seed, offering an earlier harvest when food reserves are low and prices high. Eighty-percent of farmers conducting on-farm trials also received higher yields from their transplanted crops of both early and late varieties, and in many cases this increase was double that of normal yields. Participating farmers conducting on-farm trials have therefore responded very positively to the transplanting technique, despite initial reservations concerning labour requirements.

ACKNOWLEDGEMENTS

Many people have been involved in the transplanting project in Ghana, 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 have funded this project.

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Additionally we would like to thank the District Agricultural Development Officers; Mr C.B. Ayiwo in Kasena-Nankana and Mr D. Alabadek in Builsa, and all the extension staff and field workers including Mr J. Mbod, Mr A. Atuyire, Mr A. Apinya, Mr E. Ayoma, Mr V. Akamtoganya, Mr I. Acquah and Mr J. Abanka who have worked hard to provide support and advice to farmers conducting the on-farm trials. Additionally to Mr D. Afrebeh and the many Manga research station staff who have made the on-station trials possible.

Many thanks also to all the heads of departments, institutions and organisations who have been involved in the project and who have aided project staff including Dr A.B. Salifu Acting Director of SARI in Nyampala, Tamale, Dr P.B. Tanzubil Head of the SARI Manga Research Station in Bawku and Mr S. Abdul-Rahman Programme Manager for Upper East Region, Action Aid.

Ultimately our gratitude must be expressed 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 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. 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)[1] 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 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)[2] 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 results in an earlier harvest. It also allows more efficient use

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[1] 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.

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

of seed, control over plant spacing and maximises the use of available water sources (Wein, 1997)[2].

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)[3]. 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)[4].

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)[5]. 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 an

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[3] 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**.

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

[5] 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.

average of 5 tonnes per hectare of maize, in addition to the two rice crops normally sown (Uy, 1996)[6].

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[7] and maize; Khehra *et al.*, 1990[8]). Conversely some trials have revealed that transplanting actually reduces yields when compared to direct sowing (sorghum; Dahatonde, 1996[9], maize; Carranza and Vicuna, 1978[10]).

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 has tested the concept of transplanting sorghum and pearl millet in a low-input dryland agricultural system. Raising sorghum or pearl millet in nurseries using small amounts of water before the rainy season, then transplanting seedlings at the onset of the rains extends the growing season in short duration rainfall areas. Seedlings may be:

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

[7] 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.

[8] 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.

[9] 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.

[10] 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**.

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.

As well as 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 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)[11]. He recognised that these 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.

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 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).

Project in Ghana

The transplanting project in Ghana has tested the technique at two levels, on-station trials and on-farm trials. The on-station trials were conducted at the Savannah Agricultural Research Institute (SARI) Manga Research Station, Bawku, Upper-East Region. SARI is part of the Council for Scientific and Industrial Research (CSIR). On-farm trials were undertaken by farmers under the supervision of SARI, Ministry of Food and Agriculture (MOFA) and Action Aid in the Builsa, Bawku West and Kasena-Nankana Districts, Upper-East Region.

Although rainfall in the Upper-East Region is high with annual rainfall between 900-1120 mm per annum, there is a water deficit due to higher annual water loss by

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

evapotranspiration, together with a high occurrence of site-specific drought spells and soils that posses a poor water holding capacity (Kasei, 2001)[12]. Despite these poor growing conditions, smallholder grain and fodder cropping exists extensively in these areas.

Rainfall

Monthly rainfall figures were recorded at Manga Research Station during the 2001 season, shown in Figure 1. The annual total for 2001 for this area was 910.6mm.

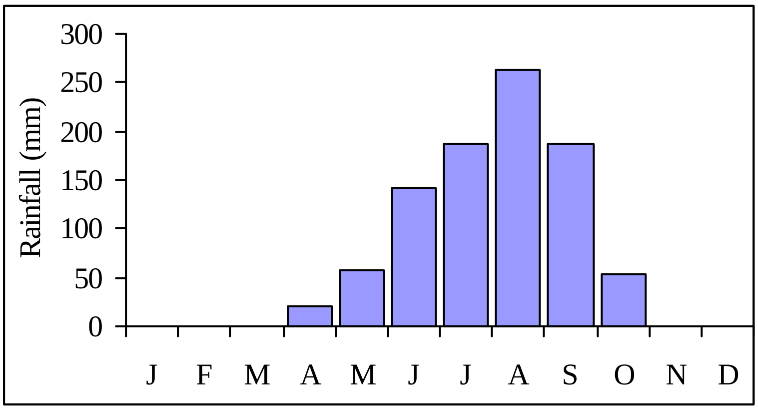

Figure 1. Monthly rainfall recorded at Manga research station 2001.

Further analysis of the daily rainfall figures for the rain period from April to October showed that the rains did not stabilise until the beginning of June. Previously the rains stabilised in April/early May and this shift, attributed to Global Change, causes increased uncertainty to subsistence farmers without access to irrigation.

[12] KASEI, C.N. (2001). Agroclimatic constraints on sorghum and millet production in the Upper East Region of Ghana. Presentation at the sorghum and millet transplanting workshop march 2001, held at Savannah Agricultural Research Institute (SARI), Nyankpala, Ghana.

Project Purpose

The overall aim of the project was to determine whether transplanting sorghum or millet could improve food security and reduce the 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 results confirmed that 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 also assessed 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 activities were 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. Including 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

All trials followed a similar randomised 4-block design, comparing transplanted seedlings with direct-sown seed. Each trial included age of seedling at transplanting and leaf cutting treatments. In order to provide seedlings of the appropriate age for transplanting a series of 1m^2 nurseries were established at approximately 10-day intervals starting 6-8 weeks before the expected main rains. The spacing used was 10 cm between rows, giving 10 rows per nursery, 100 plants per row. All nurseries were bunded and prepared on ploughed then levelled land (Plate 1). Nurseries were watered by hand the day before sowing then as and when required to maintain plant health. The amount of water added was recorded.

Plate 1. On-station nurseries, Manga Research Station, Ghana.

Following a significant amount of rainfall seedlings were transplanted from nurseries into 5m x 3m field plots at an inter-row spacing of 1m. Inter-plant spacing for early millet was 30cm and for late millet early and late sorghum was 40cm. 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 sown with five seeds per position 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:

- Plot harvest date,
- Total number of plants per plot,
- Weight of total number of heads per plot at harvest (fresh weight) and after drying in the sun (sun-dry/storage weight),
- Percentage bird damage per plot,
- Weight of total seed per plot,
- Weight of total stover per plot at harvest (fresh weight) and after drying in the sun (sun-dry weight).

Trial 1. Effect of seedling age and leaf cutting at transplanting on growth and yield of transplanted sorghum and pearl millet, compared to a direct-sown control (2001).

The pearl millet varieties used for the trials were Manga-nara (early maturing in 70-75 days) and Foek (late millet), and sorghum varieties Kapaala (early) and Mankaraga (late). In addition to 3 seedling ages at transplanting 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 14th June (early millet only). A total number of 80 nurseries were sown (5 dates x 4 varieties x 4 blocks). Seedlings were to be 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 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)).

Trial 2. Effect of seedling age and leaf cutting at transplanting on growth and yield of transplanted sorghum and pearl millet, compared to two direct-sown controls (2002).

Trial 2 was a replicate of trial 1 with an additional treatment of direct-sown plots being sown both at the time of transplanting and at the time of farmers normal sowing time. The time of 'farmers normal sowing time' was taken to be when a majority of farmers from the surrounding area were sowing. This was the 2nd June for early millet and the 5th June for early sorghum.

The early millet transplanting age was the same as in trial 1 at nearest to 10, 20 and 30-days-old, whereas for the other crops adjusted to approximately 20, 30, 40 and 50-days-old. Seedlings from each sowing date were transplanted on the 15th June and at the same time plots were also direct-sown with dry 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)).

On-farm trials

Farmers conducted on-farm trials in parallel to on-station trials, to test the technique under normal farming conditions in the Upper East Region. In the first year farmers from Ankpaliga and Teshie near Zebilla in the Bawku West District, and Wiaga and Fumbisi near Sandema in the Builsa District participated. More farmers were involved in the second year of trials from Pungu near Navrongo in the Kassena-Nankana District. 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.

Following discussions with participating farmers it was decided for the first year to restrict nursery sizes to $1m^2$ and transplanted plots to 10 m x 10 m (which were measured by Ministry of Agriculture and Action Aid facilitators) although farmers could nurser and transplant more if they wished. The design of the nurseries was left to the individual farmer (Plate 2). The farmers were also asked to direct-sow a 10 m x 10 m plot adjacent to the transplanting area, according to the normal practice for comparison. Farmers could transplant early millet, late millet or sorghum, or a combination of them and would use their own seed due as a number of different varieties were used. Additionally it was suggested this personal investment by the farmer would maintain self-motivation and interest, and lead to improved uptake of the technique after the end of the project.

Extension officers in each of the areas discussed with farmers the best time to transplant from the nurseries to the field. Extension officers also assisted farmers with basic records of sowing, transplanting and harvesting dates and yields. 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.

Plate 2. Various types of nurseries established by farmers in Ghana.

Farmer-trial 1. May 2001 – November 2001

Twenty-two farmers in Ankpaliga and eight in Teshie in the Bawku West District, and 19 in Wiaga and 11 in Fumbisi in the Builsa District conducted the first trials. It was recommended that nurseries be sown on the 16^{th} – 18^{th} April, 26^{th} – 28^{th} April and 6^{th} – 8^{th} May to provide a sequence of nurseries, with the dates flexible to suit the farmer's own circumstances.

At the end of the season group meetings were held with the participating farmers in each community to discuss the trials and to collate information. Conducting a SWOT analysis of the transplanting technique focused trial discussions. The groups of farmers was asked to list all the strengths and weaknesses of the transplanting technique, the opportunities i.e. how to improve upon the technique and the threats or constraints i.e. the threats to the success of the technique (Table 1, Page 20).

Farmer-trial 2. May 2002 – November 2002

During the second season 19 farmers in Ankpaliga and six in Teshie in the Bawku West District, and 21 in Wiaga and 13 in Fumbisi in the Builsa District participated in the trials. A further 30 farmers from three communities in Pungu near Navrongo; Punyoro, Manchuru and Yitonia also conducted trials. The suggested dates for sowing nurseries was around the 20^{th} April for early millet and 25^{th} April for sorghum and late millet then a further two nurseries at 15 day intervals after those dates. As in the previous trials these dates were flexible and if farmers wished they could establish more nurseries. Farmers also chose which crops they wanted to nurse and transplant.

Project Results to date

On-Station

Flowering/maturity

Flowering results from both trials showed that transplanted early millet (Manga nara) and early sorghum (Kaapala) flowered approximately 20 days and 10 days earlier than direct-sown crops that were sown both at the time farmers normally sow, and at the time of transplanting (Figure 2). These differences were maintained to maturity.

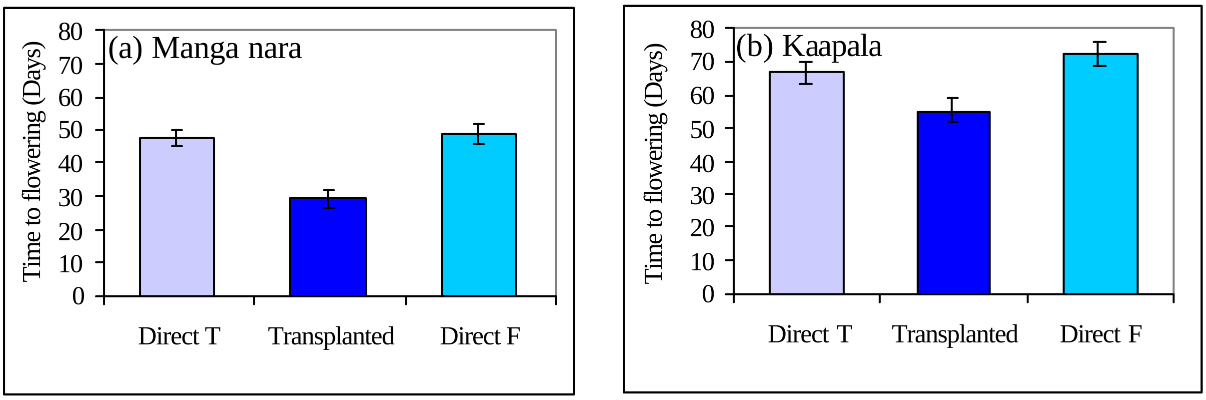

Figure 2. Days to flowering of transplanted compared to direct-sown (a) early millet, (b) early sorghum. Direct-sown both at the time of transplanting and the time farmers would normally sow. SED shown p<0.001 for early millet, and p=0.006 for early sorghum.
Direct-sown at time of transplanting (Direct T), Transplanted,
Direct-sown at normal farmer sowing time (Direct F).

Additionally, for the early crops, there was a significant difference in flowering time when measured from the time of transplanting for the different ages of seedlings at transplanting. Early millet seedlings closest to 10 and 20-days-old at transplanting, flowered and matured significantly earlier than the 30-day-old seedlings (Figure 3).

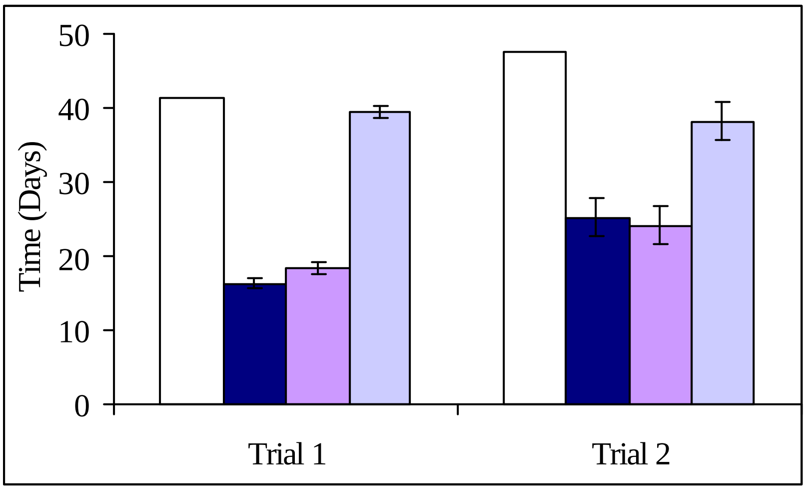

Figure 3. Days to flowering from the time of transplanting for the different aged early millet seedlings at transplanting from trials 1 and 2. SED for transplanted crops shown, p<0.001 for both trials. ☐Direct-sown, ■10-days-old at transplanting, ■ 20 -days-old at transplanting ☐30-days-old at transplanting

Early sorghum seedlings closest to 20, 30 and 40-days-old at transplanting flowered and matured significantly earlier than the 50-day-old seedlings, with the 20 and 30-day old seedlings flowering earlier than the 40-day-old seedlings (Figure 4).

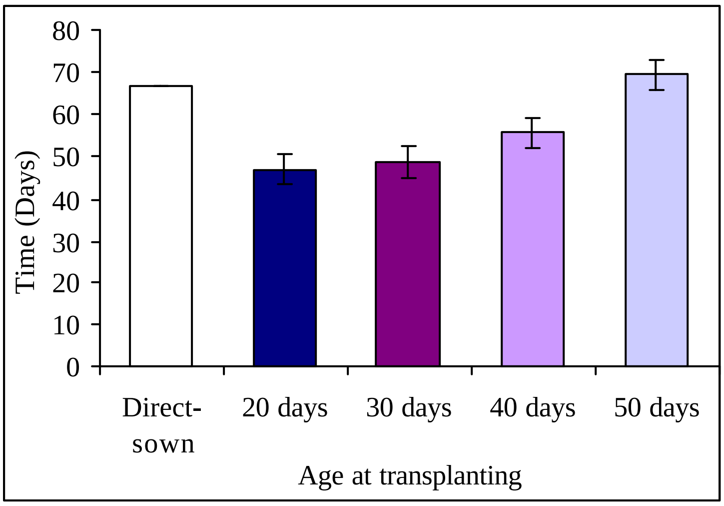

Figure 4. Days to flowering from the time of transplanting for the different aged early sorghum seedlings at transplanting. SED for transplanted crops shown, p<0.001. ☐ Direct-sown, ■20-days-old at transplanting, ■30-days-old at transplanting ■40 -days-old at transplanting, ☐50-days-old at transplanting.

The late millet (Foek) and late sorghum (Mankaraga) crops are photoperiod sensitive so there was no significant difference in flowering or maturity between the transplanted and direct-sown crops sown at the time of transplanting. The only significant difference was that the direct-sown at the farmers normal sowing time flowered and matured approximately 10 days later than the other two treatments this being due to the earlier sowing date and slow establishment (Figure 5).

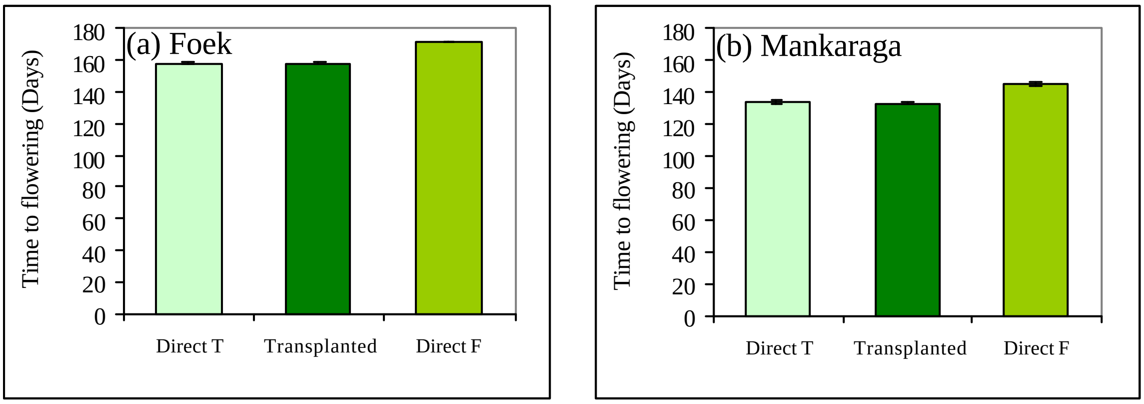

Figure 5. Days to maturity of transplanted compared to direct-sown (a) late millet, (b) late sorghum. Direct-sown both at the time of transplanting and the time farmers would normally sow. SED shown p<0.001 for both crops.
Direct-sown at time of transplanting (Direct T), Transplanted,
Direct-sown at normal farmer sowing time (Direct F).

Leaf cutting had no effect on the flowering or maturity of early or late crops.

Grain/stover yields

In addition to transplanted early crops maturing earlier than direct-sown, in most cases both the early and late transplanted crops also produced a higher yield, due to more heads and head weight per area (Figure 6 and 7). One inconsistency in the data, as shown in Figure 6b, is that direct-sown early sorghum produced more grain than the transplanted. This difference was mainly because this particular variety of sorghum is attractive to birds and the mature seed was eaten before harvest. The transplanted crop suffered more than the direct-sown as it matured earlier than the sorghum growing in surrounding fields. Further damage to on-station plots was caused by roaming animals that had not been tethered by farmers; again the transplanted crop was affected more than the direct-sown due to its earliness.

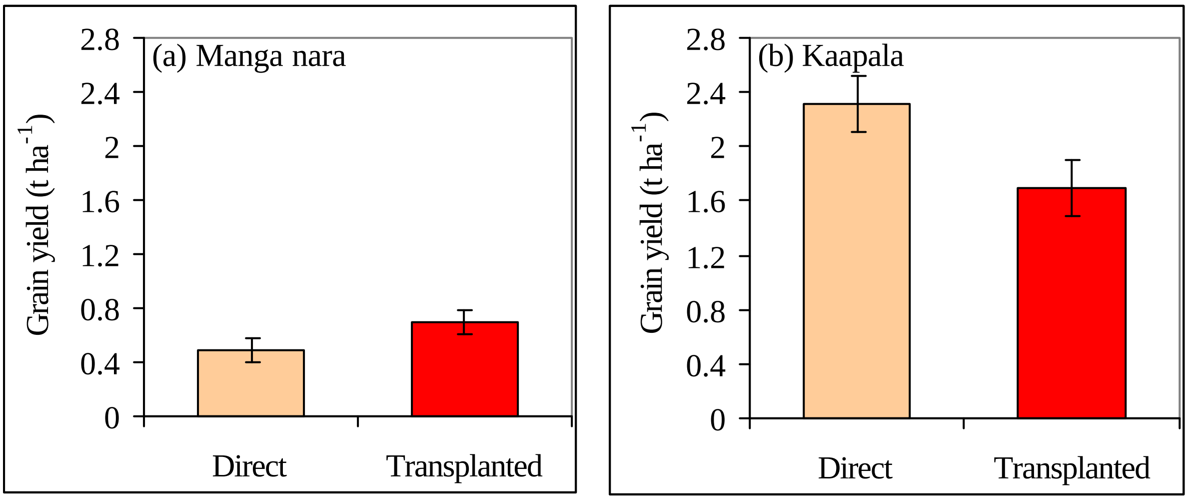

Figure 6. Grain yield (t ha^{-1}) of transplanted compared to direct-sown (a) early millet, (b) early sorghum. Direct-sown at the time of transplanting. SED shown p=0.04 for early millet, p=0.008 for early sorghum.
Direct-sown at time of transplanting, Transplanted.

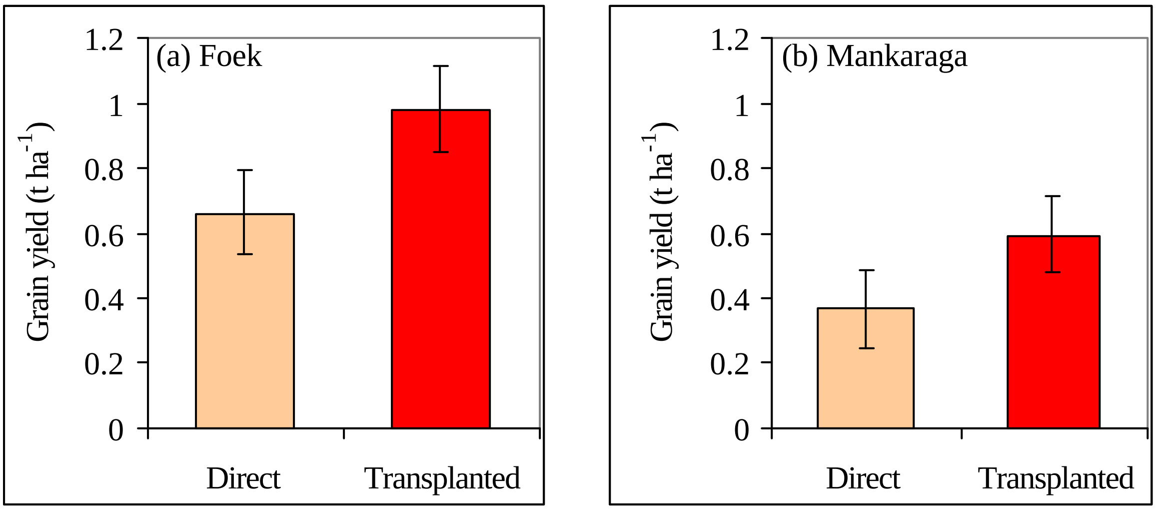

Figure 7. Grain yield (t ha^{-1}) of transplanted compared to direct-sown (a) late millet, (b) late sorghum. Direct-sown at the time of transplanting. SED shown p=0.03 for early millet, p=0.07 for early sorghum.
Direct-sown at time of transplanting, Transplanted.

Transplanted crops either produced more stover than direct-sown (Figure 8), or there was no significant difference between the treatments.

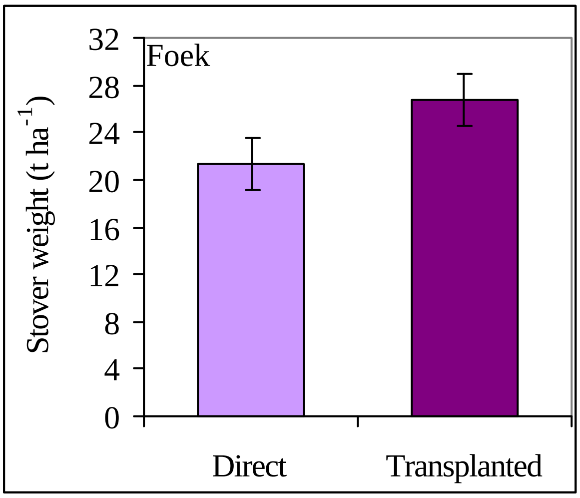

Figure 8. Stover weight (t ha^{-1}) of transplanted compared to direct-sown late millet. Direct-sown at the time of transplanting. S.E.D shown p=0.03.
Direct-sown at time of transplanting, Transplanted.

There was a significant difference in grain and stover yields, when measured from the time of transplanting, for the different ages of seedlings at transplanting. Results from both trials showed that early millet seedlings closest to 20 and 30 days and those closest to 30 and 40 days old for the sorghum and late millet, produced higher grain and stover yields. The results also showed that there was no significant benefit in terms of yield by cutting the leaves at transplanting.

On-Farm

In a majority of cases the results from the on-farm trials supported those of the on-station trials. Farmers often benefited from improved stands, harvested the transplanted crops earlier and obtained higher yields. Figures 9-11 show individual farmers' yields for transplanted and direct-sown early millet in Zebilla, sorghum in Wiaga/Fumbisi and late millet in Navrongo. All figures show a majority of farmers harvested higher yields from transplanted crops. Where this was not the case the individual farmers in a report-back session attributed it to overgrown nurseries or a drought period after transplanting. The difference seen in the field is illustrated in Plate 3.

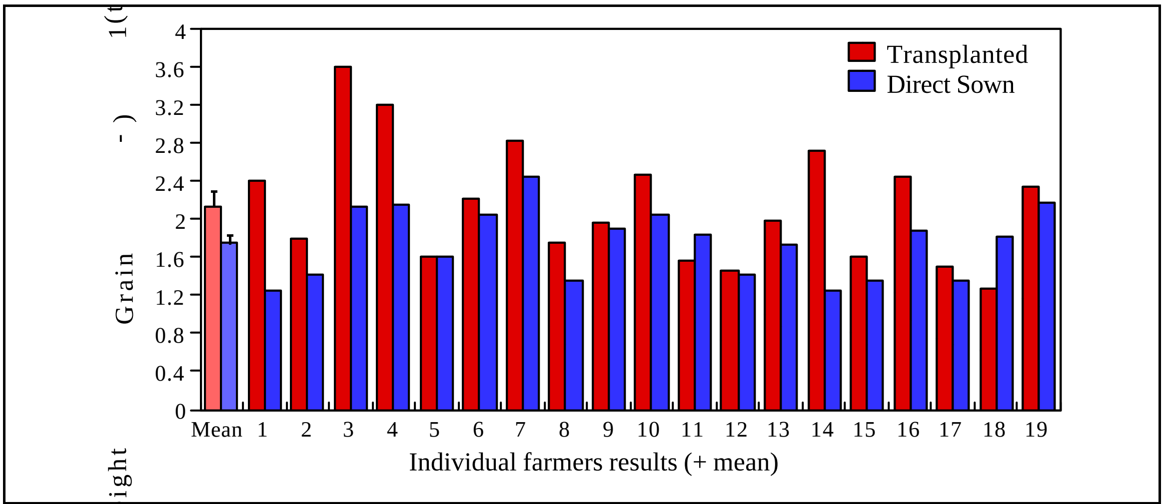

Figure 9. Individual farmer results for early millet grain weight (t ha^{-1} based on figures from 10mx10m plots) of transplanted and direct-sown plants plus the mean of all the farmers' results (Zebilla, Bawku West, Upper East Region). Difference between the means is significant at p=0.024.

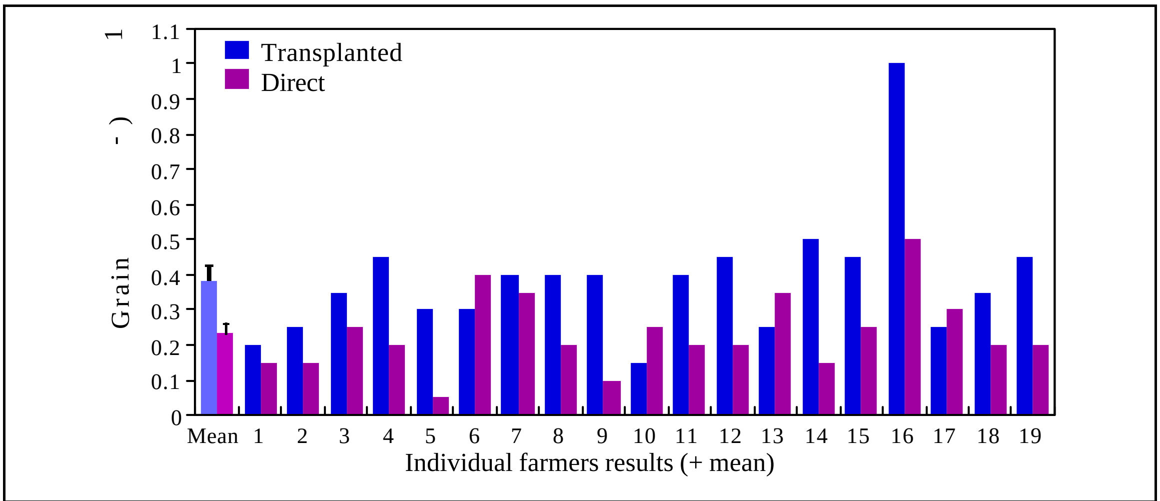

Figure 10. Individual farmer results for sorghum grain weight (t ha^{-1} based on figures from 10mx10m plot) of transplanted and direct-sown sorghum plants plus the mean of all the farmers' results (Wiaga, Builsa District, Upper East Region). Difference between the means is significant at p=0.003.

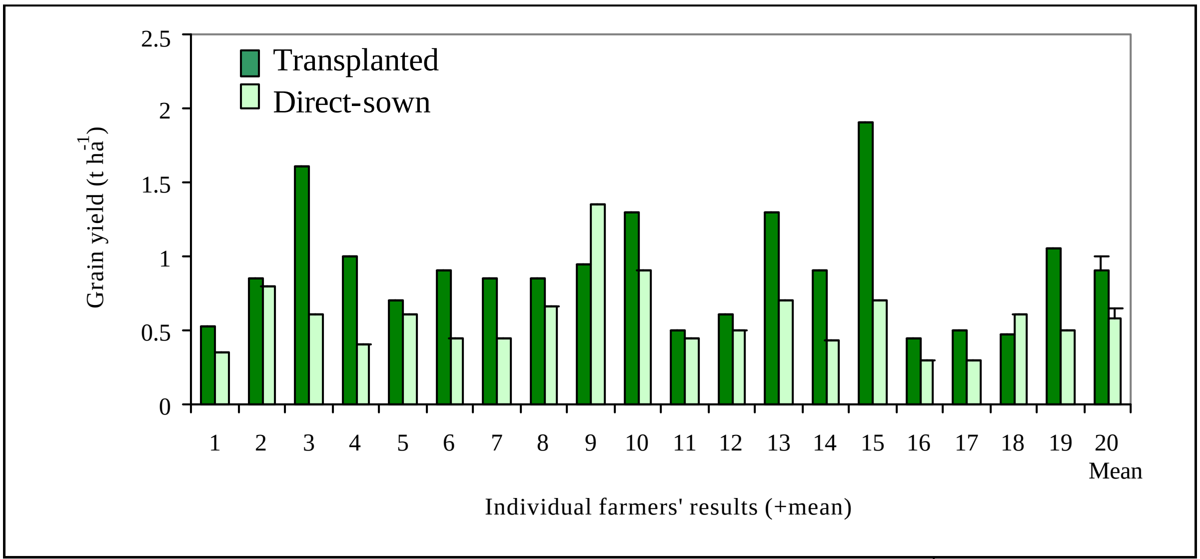

Figure 11. Individual farmer results for late millet grain weight (t ha^{-1}) based on figures from 10mx10m plot) of transplanted and direct sown sorghum plants plus the mean of all the farmers' results (Navrongo, Kasena-Nankana District, Upper East Region, Ghana).

The increase in yield can be attributed to larger panicles and/or increased number of heads When stover weights were compared, approximately 80% of the farmers also harvested more stover from transplanted crops compared to the direct sown. Farmers suggested that this was due to improved establishment, increased plant vigour, and a reduction in the effect of *Striga*. Farmers confirmed that transplanted early millet matured earlier than direct-sown, by approximately two weeks, which is particularly important as it coincides with the period when food stocks are low and prices are high. Transplanting is therefore a means of reducing the length of the hunger-gap

Plate 3a. Mrs Apangbun standing in her direct sown early millet field, Ankipaliga, Ghana.

Plate 3b. Mrs Apangbun standing in her transplanted early millet field. The stand is improved and plants are producing larger heads.

SWOT ANALYSIS

Table 1. A summary of the SWOT analysis carried out at the end of season workshop (Feb 2002) with farmers in Ghana.

Strengths	**Weaknesses**
Nurseries 1. Nurseries are easily managed due to their small size. 2. Germination improved compared to seed directly sown in the field. 3. Early sowing in the nursery prevents seed being eaten as food. 4. Seedlings grow quickly and are strong and vigorous. *Post-Transplanting* 5. Seedling survival after transplanting is good. 6. No need to re-sow/gap fill. 7. Leaves are green and plants strong and healthy. 8. Plants produce more tillers and stover, bigger heads, higher yields and better quality grain. 9. Plants harvested earlier (approx. 10 days) when market price is higher and food in short supply. 10. Labour is not required to scare birds from the field as seed is not sown directly. 11. Striga infestations reduced. 12. New knowledge/sense of happiness.	*Nurseries* 1. First nursery may overgrow if rains are late. 2. Fencing required to prevent attack from ground birds and animals. 3. Insect damage including ants. 4. Some water sources dried before the start of the rains. *At-Transplanting* 5. Labour requirement at transplanting. *Post-Transplanting* 6. Transplanted seedlings attacked by roaming animals as they are the only green matter at the start of the season. 7. Transplanted plants suffered more lodging than direct sown plants in a storm that hit when transplanted plants were larger.
Opportunities	**Threats**
Nurseries 1. Better fencing to restrict animal damage to nurseries. 2. Situate nurseries close to compounds to allow further protection from animals. 3. Covering seeds well by sowing at 3cm depth, avoiding previously ant-infested areas and applying ash in a ring around nurseries to reduce ant attack. 4. Water nurseries before sowing so as to charge the soil and reduce ant damage. 5. Trim leaves of seedlings to slow growth in the nursery if rains are delayed. *At-Transplanting* 6. Reduce water before transplanting to harden seedlings. 7. Cut leaves at transplanting to aid survival. 8. Reduce labour problem by ploughing with bullocks, hire and use family labour and possibly set up community nurseries. *Post-Transplanting* 9. Talk to land custodians/heads to apply restrictions on roaming animals earlier to reduce damage after transplanting.	*Nurseries* 1. No source of water for nurseries or source too far away. *At-Transplanting* 2. Not enough labour to carry out the transplanting process. *Post-Transplanting* 3. Long dry period within the growing season causing plants to die. 4. Termites destroying all seedlings. 5. For women in Sandema, difficult to expand transplanting area as men control the land.

THE PROS AND CONS OF TRANSPLANTING

During group discussions and the SWOT analysis conducted with farmers who were involved in the on-farm trials, the main benefits and problems associated with the transplanting technique were highlighted.

Benefits

- **Earlier harvest**: this is particularly important as the end of the dry season/beginning of the wet season 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 duration, or where there is an increasing trend for rains too finish early.
- **Higher yields**: bigger panicles and more heads per plant.
- **Reduces the effect of *Striga***: higher yields in *Striga* infested fields as the transplanted seedling has a head start over the germinating striga.
- **Conserves seed**: when comparing a transplanted plot with a normal direct-sown 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 requirement is reduced at other times, for example the need for weeding is reduced as seedlings have a head start over weeds.
- **If nurseries are secured they are easy to supervise**: nurseries are 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 are often unreliable. They can be left in the nursery while a farmer is busy with other activities until a more convenient time, as long as seedlings do not become too old to transplant (<30 days for early millet, <40 days for sorghum and late millet). This may be of 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 increase the risk of the

crop failing to reach maturity if the season is short. Such resource-poor farmers can allow their seedlings to grow in the nurseries until the demand for ploughs is reduced and the transplanted crop should still mature. Similarly if the rains are late seedlings may 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 green material at this time of the season. Some farmers reduced the bird damage by mulching, also high density sowing ensures there are 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 and owners are not compelled to tether animals until the main cropping season begins.
- **Source of water too far from the nursery**: some farmers' nurseries were situated more than 30 minutes walk from a water source, which made frequent watering problematic.
- **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. Others suggested a ring of ash around the nursery boundaries.
- **Overgrown seedlings**: If a series of nurseries are not established seedlings may overgrow in the nurseries whilst waiting for the rains, and become too old to transplant.
- **Transplanting from the nursery to the field is laborious and time consuming**.

CHECKLIST OF ELEMENTS CRITICAL TO THE SUCCESS OF TRANSPLANTING

Following discussions with farmers and local institutions participating 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, 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.
6. A series of nurseries should be established so that a supply of seedlings at the 'right' age is available when rains are sufficient for transplanting. Seedlings should be transplanted at 10-20 days old (optimum 20 days) for early millet and 20-40 days old (optimum 30-40 days) for late crops.

GUIDELINES FOR TRANSPLANTING

A list of guidelines for successful transplanting has been produced based on current and on-going work. Some processes are still under investigation, and the list is 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. Transplanting does not require any additional inputs outside farmers' 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 form a 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, which 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 in the period 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.
- Seedlings should be transplanted at 10-20 days for early millet, and 20-40 days for late crops.

CONCLUSIONS

The response by farmers and researchers to transplanting sorghum and millet has been very positive. On-station trials have shown that non-photoperiod sensitive transplanted seedlings, despite transplanting shock, mature earlier than direct-sown seed. The 10 and 20-day-old early millet seedlings and the 20 to 40-day-old early sorghum seedlings matured earliest. Transplanted crops often produced higher grain and stover yields due to improved stands and an increase in the number of productive tillers per plant. Harvest results showed that the 20 and 30-day-old early millet seedlings, and 30 and 40-day-old sorghum and late millet seedlings produced the highest yields. On-farm trials showed similar results to the on-station trials, with a majority of farmers obtaining earlier harvests and higher grain and stover yields from the transplanted crops compared to broadcasted direct-sown seed. On-farm trials also demonstrated that the effects of *Striga* infestation were greatly reduced by transplanting because the transplanted plants had a head start over the germinating *Striga*.

Farmers concluded that the benefits of transplanting outweigh the problems encountered. Before the project started reviewers and social scientists within the development field expressed reservations regarding increases in labour requirements. However, although most farmers report that transplanting from nursery to field is laborious and time consuming, they also claim that this is counteracted by the reduction of labour at other times of the year, for example weeding. The first weeding of a direct-sown crop includes thinning and gap-filling, whilst weeding the more accurately spaced transplanted crop is much more straight-forward. Therefore as long as sufficient labour is available for the actual day of transplanting it is not considered a constraint. Cost-benefit analysis is being conducted to verify this. Some farmers in Ghana initially did not believe that it was possible to transplant early millet, as traditionally they do not gap-fill this crop. However on-farm trials conducted by many of those sceptical farmers have shown that early millet can be successfully transplanted in this way, and they were excited by the flexibility this adds to their system.

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 growing period in the field is reduced and an earlier, often larger, harvest is obtained. It is concluded that transplanting is a technique that can alleviate the effects of a short duration rainfall and offer new opportunities to exploit available moisture, thereby providing new opportunities in the quest for 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. We also have a website at www.bangor.ac.uk/transplanting which is continually updated and provides further information regarding the project.

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