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Effects of Seedling Age on Transplanting Shock, Growth and Yield of Pearl Millet (*Pennisetum glaucum* L.) Varieties in Semi-arid Zimbabwe

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Abstract: Recent studies on pearl millet transplanting have shown that early harvesting is possible through establishment of nurseries and transplanting with early rains. These studies also showed that age of transplants and the time of transplanting are important issues requiring further consideration. The objective of the study was to investigate the effect of age of transplants on growth, yield and yield components of pearl millet. The study also quantified transplanting shock by comparing performance of transplants against non-transplants. The study was carried out over two seasons, the 2001/2002 and 2002/2003 seasons at Save Valley Experiment Station in a semi arid area of Zimbabwe. There were three factors in the experiment, three nursery sowing dates (2 November-SD_1; 12 November-SD_2 and 22 November-SD_3), variety and method of planting (direct or transplanting). Varieties used were PMV2 and PMV3. The design was a 3x2x2 factorial in a Randomised Complete Block Design replicated three times. Seeds of the two varieties were also sown on the day of transplanting (12 December-SD_4) resulting in two additional treatments. Days to flowering and maturity, dry weight, grains per panicle, 1000 seed weight and grain yield (kg ha^{-1}) were measured. There were significant sowing date × planting method interactions on time to flowering and maturity. Transplanting increased time to flowering and maturity while delayed sowing decreased time to flowering and maturity. Transplants had lesser dry weights compared to non-transplants though relative growth rate appeared to be the same between transplants and non-transplants. In the 2001/2002 season there was a significant ($p<0.05$) interaction between Sowing Date (SD) and planting method on yield. Thirty and 40-day-old transplants performed better than 20-day-old transplants. For non-transplants, delayed sowing reduced yields by about 900 kg ha^{-1} from SD_1 to SD_4. A similar trend was observed in the 2002/2003 season. Thirty-day-old transplants out yielded SD_4 non-transplants by 63 and 26% in the first and second seasons, respectively. It was concluded that for late planting (12 December onwards) transplanting with 30-day-old transplants may yield better than direct sowing in pearl millet.

Key words: Pearl millet, semi-arid tropics, transplanting shock, yield

INTRODUCTION

In recent years poor crop establishment in the semi arid tropics has received considerable attention, with some solutions being proposed. Seed priming, which involves soaking seed in water before planting, has been shown to improve stand establishment in maize, sorghum, pearl millet and chickpea (Chivasa, 2002; Harris *et al.*, 2001). However, seed soaking for 12 h in cotton has been shown to reduce final emergence percent in the south-eastern lowveld of Zimbabwe (Murungu *et al.*, 2004). Transplanting sorghum and pearl millet varieties grown in nurseries has also been shown to improve establishment in the field (Mapfumo, 2002).

Varieties have been shown to differ in response to various physical conditions imposed on them. For example, sorghum cultivars have been developed which avoid crusting effects by having faster shoot elongation

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(Soman *et al*., 1992). As crust strength increases with time after planting, the faster growing genotypes had better emergence. Observations on varietal response to transplanting were made in field trials with five sorghum genotypes in India, where the genotypes CSH-1 and Swarna withstood transplanting better than others (Krishnamurthy *et al*., 1974). They gave higher grain yield in association with higher mean dry weight per ear, grain weight per ear and 1000-grain weight. They also showed better growth in terms of dry matter accumulation and distribution in the ear, larger leaf area and higher dry matter production at the seedling and grain filling stages. This was in contrast to another genotype CBE-X, which gave high yields when directly sown, but was adversely affected by transplanting (Krishnamurthy *et al*., 1974).

Age of seedlings is an important consideration in transplanting. Onset of the rainy season in semi-arid tropics is highly variable. If nurseries are established early and the rains come late, plants may be too old to be transplanted. Old transplants have high transpiration rates due to greater leaf area and this may affect establishment. Delayed sowing or transplanting in sorghum reduced grain yield of two cultivars in drought prone areas of Western Africa. However, transplanting had less depressive effects than late sowing for both cultivars (Tenkouano *et al*., 1997).

The objectives of the study were to quantify the effects of transplanting shock on growth and yield in two pearl millet varieties. Different sowing dates were also used to determine any interactions between sowing date and age of transplants.

MATERIALS AND METHODS

Location: The study was carried out at Save Valley Experiment Station (SVES) in Chipinge district, Zimbabwe. The Station is 444 m above sea level and is at latitude 20E 21' S and longitude 32E 20' E. The soil is classified in the US Taxonomy as an Entic Eutrochrept and in the FAO system as a Chromic Cambisol. The soil is 100 to 150 cm deep and is a medium-grained sand loam. Mean annual rainfall is 482 mm, with a monomodal distribution (Fig. 1). Pan evaporation rates can exceed 13 mm d^{-1} during the rainy season.

Treatments and experimental design: The trial had three factors, sowing date (2 November-SD_1; 12 November- SD_2 and 22 November-SD_3), variety (PMV2 and PMV3) and method of planting (direct sowing and transplanting). The trial was a 3x2x2 factorial laid out in a Randomised Complete Block Design (RCBD) with three replications. In addition there were two other treatments, which were

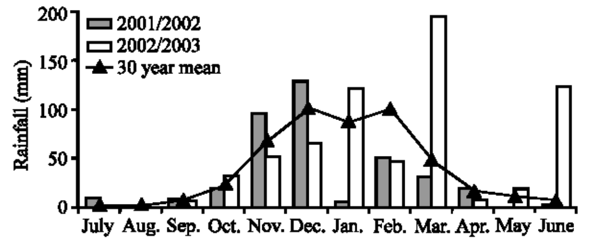

Fig. 1: Monthly rainfall patterns at Save Valley Experiment Station for the 2001/2002 and 2002/2003 seasons and the thirty-year mean

direct sowing of the two varieties on the day of transplanting (12 December, SD_4) giving 14 treatments. Transplanting from the 3 sowing dates was done on the same day. The transplants were 20, 30 and 40 days old on the day of transplanting.

Two improved varieties of pearl millet PMV2, a pearly white-grained short-medium season variety and PMV3 a short season pearly white-grained variety both from International Crop Research in the Semi-Arid Tropics (ICRISAT) were used. In the initial stages the trial had supplementary irrigation to ensure that the crop was sown on the desired date. After transplanting irrigation was discontinued.

The plots that provided transplants had four-times the required population before transplanting. Seed was drilled in rows 0.75 m apart and thinned to 7.5 cm between plants at 14 Days After Sowing (DAS). After transplanting, all plots had a between row spacing of 0.75 m and an in-row spacing of 0.3 m. The gross plot size was 10.5 m (14 rows)×5.25 m while the net plot area was 3 m (4 rows)×4.5 m. No fertilisers were applied to mimic the common practice in the study area.

Measurements: Measurements taken include, number of surviving plants two weeks after transplanting and plant heights at transplanting and weekly thereafter. Dry weight was measured from samples on two rows on either side of the six middle rows of each plot. Dry weight was measured at fortnightly intervals by drying samples at 105°C for 24 h. Days to 50% flowering were recorded as the number of days from sowing to anther dehiscence in 50% of the plants in the net plot. Time to physiological maturity was taken as the time from sowing to when the tip of seeds had turned pale brown. For transplanting treatments days to flowering and maturity were calculated as the number of days from transplanting to flowering plus the number of days in nursery. Number of grains per panicle, 1000 seed weight and grain yield (kg ha^{-1}) were also measured. Grain yield was adjusted to 12.5% moisture content.

Data analyses and presentation: Survival percentage data of plants per plot at 14 Days After Transplanting (DAT) and at harvest was transformed using the square root transformation before being subjected to residual maximum likelihood variance components analysis (REML). This method was preferred to analysis of variance (ANOVA) since the treatments were not balanced. Days to 50% flowering and maturity, number of grains per head, 1000 seed weights and grain yield data were also subjected to REML. Shoot dry weight was $\log_{10}$-transformed and together with plant heights they were subjected to ANOVA with time of measurement being treated as an additional factor. For shoot dry weight and plant heights, SD_4 was ignored to make the design balanced. Genstat release 7.1 was the statistical package used. Where transformation was done, back-transformed means are presented. Where transformation was not required, means and Standard Errors of the Difference (SED) are shown.

RESULTS

Number of plants at 14 DAT

2001/2002 season: Sowing date and planting method significantly (p<0.001) affected number of plants. There was a significant (p<0.05) interaction between SD and planting method. Stand counts were similar between SD_1, SD_2 and SD_3 with a reduction in SD_4 for non-transplants. Stand counts decreased with increasing age of transplants (Table 1). Variety had no effect on number of plants.

2001/2002 season: Sowing date significantly (p<0.001) affected number of plants at 14 DAT. There was a significant (p<0.05) SD by planting method interaction. A similar trend as in the first season was observed (Table 1). Variety had no effect on number of plants.

Dry weight accumulation

2001/2002 season: Sowing date and planting method significantly (p<0.001) affected dry weight accumulation. There were significant DAT by sowing date and DAT by planting method (p<0.01) interactions. During early growth SD_1 and SD_2 had greater dry weight (g/plant) than SD_3, this difference was however, not there in later growth stages (Fig. 2A). Non-transplants also had greater dry weights compared to transplants during early growth, the difference was no longer present in the later growth stages (Fig. 2B).

2002/2003 season: There was a DAT by planting method by variety interaction. Non-transplants also had greater dry weights compared to transplants during early growth.

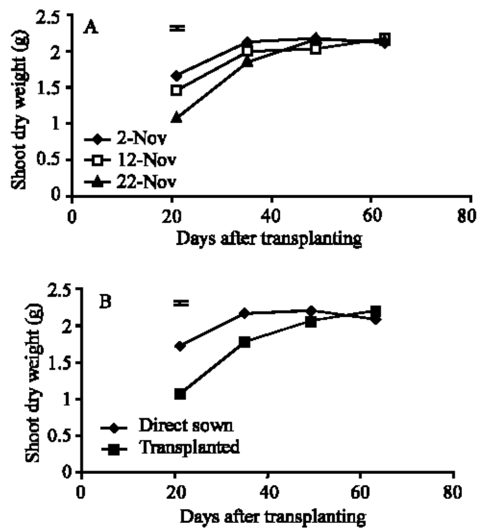

Fig. 2: Effect of sowing date (A) and planting method averaged over sowing date (B) on shoot dry weight accumulation in pearl millet in the 2001/2002 season. Means±SED are both on $\log_{10}$ scale

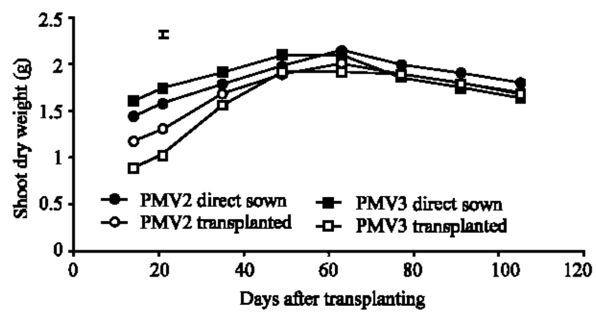

Fig. 3: Effect of planting method and variety on shoot dry weight accumulation in pearl millet in the 2002/2003 season. Error bar shows the SED. Means±SED are both on $\log_{10}$ scale

However, PMV3 had lower dry weights compared to PMV2 during early growth (Fig. 3).

Plant heights

2001/2002 season: There were significant (p<0.01) DAT by sowing date and DAT by SD by planting method interactions. For all the measurements, non-transplants had consistently greater plant heights than transplants at each sowing date (Fig. 4). Sowing date 1 and SD_2 transplants during early growth had greater plant heights than SD_3 non-transplants. However, SD_3 non-transplants ended up having greater plant heights than SD_2 transplants (Fig. 4).

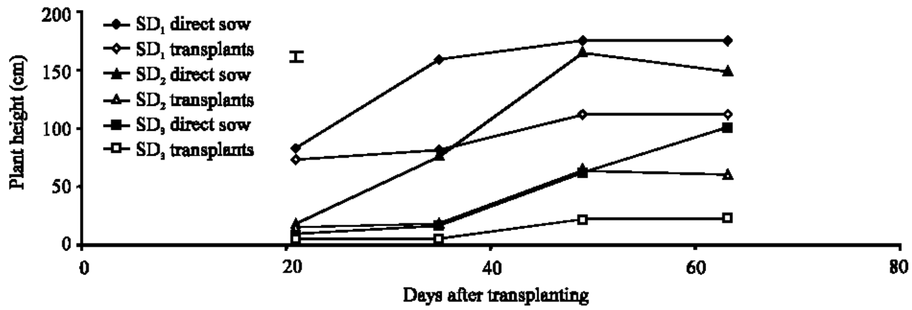

Fig. 4: Effect of sowing date and planting method on plant height in pearl millet in the 2001/2002 season. Error bar shows SED

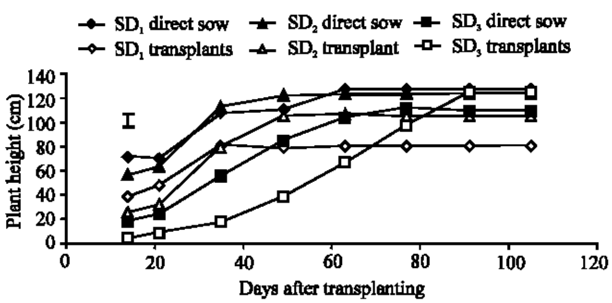

Fig. 5: Effect of sowing date and planting method on plant height in pearl millet in the 2002/2003 season. Error bar shows SED

2002/2003 season: A similar trend as in the previous season was observed (Fig. 5).

Days to flowering

2001/2002 season: Both SD and planting method had significant ($p<0.001$) effects on time to flowering. Variety had no significant effects on time to flowering. There were no significant interactions between the factors. Transplanting delayed time to flowering while delayed sowing tended to reduce time to flowering (Table 2).

2002/2003 season: A similar trend as in the first season was observed. Delayed sowing tended to reduce time to flowering except for SD_4. Transplants also had delayed flowering compared to non-transplants (Table 2).

Days to maturity

2001/2002 season: There was a significant ($p = 0.01$) interaction between SD and planting method. Varieties did not significantly ($p>0.05$) differ in their days to maturity. Transplanting increased time to maturity while delayed sowing reduced time to maturity. The decrease in time to maturity as sowing was delayed was greater for transplants compared with non-transplants (Table 3).

Table 1: Sowing date and method of sowing effects on pearl millet establishment at 14 DAT (% means across variety shown)

	Sowing date	Direct sown	Transplanted
2001/2002			
SED-5.2	1	99.1	86.2
	2	97.0	83.5
	3	99.5	70.4
	4	74.5	*
2002/2003			
SED-1.7	1	96.4	98.1
	2	98.0	96.6
	3	100.0	94.2
	4	88.3	*

* data not available

Table 2: Sowing date and planting method effects on time to 50% flowering in pearl millet (means across variety are shown)

	Sowing date	Direct sown	Transplanted
2001/2002			
(SED-2.4)	1	45.2	53.8
	2	46.0	52.2
	3	43.0	52.7
	4	40.2	*
2002/2003			
(SED-0.6)	1	47.5	48.5
	2	42.8	44.5
	3	42.8	46.3
	4	47.0	*

Table 3: Sowing date and planting method effects on time to maturity in pearl millet (means across variety are shown)

	Sowing date	Direct sown	Transplanted
2001/2002			
(SED-2.4)	1	90.3	106.0
	2	91.7	99.8
	3	89.3	92.8
	4	83.5	*

2002/2003 season: Sowing date, planting method and variety had no significant effects on time to maturity.

There was however, a significant ($p = 0.01$) SD by variety interaction on time to maturity. As planting was delayed there was an increase in days to maturity for PMV2 while PMV3 was not affected by delayed sowing (Table 4).

Grains per head

2001/2002 season: Sowing date and variety had significant ($p<0.001$) effects on number of grains per head.

Planting method had no significant effect on number of grains per head. Sowing date by planting method interaction was significant ($p<0.01$). As SD was delayed there was an increase in the number of grains per head for transplants. Transplants on SD_3 had the greatest number of grains per head. Delayed sowing tended to reduce number of grains per head for non-transplants (Table 5). PMV2 had an average of 2892 grains per head while PMV3 had an average of 2591 (SED-138.8).

2002/2003 season: Apart from the other treatments SD had significant ($p<0.01$) effects on number of grains per head. As planting was delayed there was an increase in grains per head. Sowing date one (SD_1) had 2016, SD_2 had 3328 and SD_3 had 3569 grains per head (SED-493.7). There were no significant interactions.

One thousand seed weights

2001/2002 season: Variety had a significant ($p<0.01$) effect on 1000 seed weights. There was however, a significant ($p<0.05$) SD by variety interaction. PMV3 grains were heavier than those of PMV2. Sowing date 2 for PMV3 had the heaviest grains while PMV2 grain weight was not affected by sowing date (Table 6).

2002/2003 season: All treatments had no significant ($p>0.05$) effects on 1000 seed weights. All interactions were also not significant.

Yield

2001/2002 season: Sowing date significantly ($p<0.01$) affected yield. Variety and planting method did not affect yield. There was however, a significant SD by planting method interaction. Delayed sowing reduced yield for non-transplants with SD_4 having the lowest yield. Among transplants, 30-day-old transplants gave the highest yield followed by 40-day-old transplants (Table 7).

Table 4: Sowing date and variety effects on time to maturity in pearl millet (means across planting method are shown)

	Sowing date	PMV2	PMV3
2002/2003			
(SED-3.0)	1	78.2	80.7
	2	76.1	81.4
	3	83.3	80.6
	4	*	*

Table 5: Sowing date and planting method effects number of grains per head in pearl millet (means across variety are shown)

	Sowing date	Direct sown	Transplanted
2001/2002			
(SED-196.3)	1	2802	1988
	2	2786	2785
	3	2980	3471
	4	2397	*

Table 6: Sowing date and variety effects on 1000 seed weights in pearl millet (means across planting method are shown)

	Sowing date	PMV2	PMV3
2001/2002			
(SED-0.6)	1	11.3	11.8
	2	11.3	12.5
	3	11.0	12.0
	4	*	*

Table 7: Sowing date and planting method effects yield (kg ha^{-1}) in pearl millet (means across variety are shown)

	Sowing date	Direct sown	Transplanted
2001/2002			
(SED-209.8)	1	2346	1807
	2	2009	2331
	3	2169	2184
	4	1428	*
2002/2003			
(SED-698.2)	1	685	730
	2	888	1070
	3	873	1026
	4	848	*

2001/2002 season: All treatments did not have significant ($p>0.05$) effects on yield. Thirty and 40-day-old transplants however, tended to yield better than 20-day-old transplants and delayed direct sowing (Table 7).

DISCUSSION

The first season had more or less a normal rainfall distribution, which approximated the thirty-year mean rainfall for the study area. The second season was characterised by much more rainfall towards the end of the season (March). So the differences in crop growth between the two seasons could be explained in terms of rainfall differences.

Direct sowing had a better crop establishment than the transplanted crop. This was because of the irrigation, which was done before transplanting. However, Mapfumo (2002) reported better crop establishment for sorghum transplants than direct sowing when no irrigation was applied. Sowing date 4 had the lowest stand counts for non-transplants because irrigation was discontinued just before transplanting resulting in moisture stress, which may have affected emergence. For transplants, as the sowing date was delayed, stand counts tended to decrease. This resulted in 20-day-old transplants having a better stand than 30 and 40-day-old transplants. This can be explained by the fact that 30 and 40-day-old transplants had more leaf area due to advanced growth, which, translated into a larger transpiring, surface area. Thus, 30 and 40-day-old transplants may have lost more water due to transpiration thereby reducing their survival rate after transplanting. However, the reduction in stand counts in older transplants did not result in a yield advantage for 20-day-old transplants (Table 7) implying that the reductions in stand counts in older transplants were not significant enough to reduce yields.

The delayed time to flowering for transplants compared to non-transplants could be the effect of transplanting shock. When plants are transplanted, mechanical injuries occur to the roots and also the firm root-soil contact is disturbed. Therefore transplants will require time to regenerate new roots and adapt to the new environment. This delays development processes, leading to delayed flowering and maturity for transplants. As sowing date was delayed, the time to flowering was also reduced in the 2001/2002 season with a while in the 2002/2003 season were SD_4 took longer to flower than SD_2 and SD_3. As sowing date was delayed pearl millet matured or flowered early due to the fact that the rainfall season ended early while late sowings had not yet matured. Late sowings will experience moisture deficits which when coupled with high temperatures in the semi-arid tropics will hasten growth and maturity. Moisture stress has also been shown to hasten maturity in wheat and barley (Fisher and Turner, 1978). The discrepancy in the 2002/2003 season where late sowing (SD_4) took longer to flower can be explained by rainfall distribution in that season where more rain was received in the later stages of the growing season (Fig. 1) which removed moisture stress conditions which may hasten maturity.

With respect to dry matter accumulation, earlier sowing dates had greater dry weights early in the season but later on in the season there were no significant differences in the dry weight among the sowing dates. However, early sowing dates had consistently greater plant heights than late sowings. This may suggest that late sowings partitioned their dry matter differently from early sowings. This may be explained by the fact that late sowings experienced more water deficit conditions as the rains ended early especially in the first season and also early sowings had the advantage of some early irrigation. It has been shown that the investment of a high proportion of assimilates in new photosynthetic tissue, such as a high leaf area to total dry weight maximises plant growth rate when water is not limiting. However, when water is limiting this ratio is usually lower and other strategies operate (Bunting, 1975). Soil water deficiency can double the root/shoot ratio; increase the absolute mass of roots in some situations (Bennet and Doss, 1960; Hsiao and Acevedo, 1974).

The ontogeny of pearl millet consists of three developmental phases: emergence to floral initiation (GS1) which determines the time to flowering, floral initiation to anthesis (GS2) which determines the number of seeds and anthesis to physiological maturity (GS3) which determines the seed weight (Eastin, 1972). In this study delayed sowing reduced number of seeds per head for non-transplants probably due to shortening of the GS2 stage. For transplants the number of seeds per plant increased with increased ages of transplants. This suggests that the transplanting shock observed with younger seedlings may be due to interruption of the GS2 phase. Tenkouano *et al*. (1997) found similar results while working with two sorghum varieties were the smaller number of grains per head for younger transplants was explained by the interruption of the GS2 phase. The reduced seed weights from delayed sowing can be explained by the hastened maturity of late sowings. Hastened maturity reduces Leaf Area Duration (LAD) and also the GS3 phase thereby curtailing assimilate supply to the grain before it reaches its potential. Delayed sowing reduced yield due to reduction in number of grains per head as sowing was delayed for transplants. Transplanting had less depressive effects on yield as the sowing date was delayed for both varieties due to a higher seed set. This suggests that for late planting, i.e., 12 December onwards, transplanting with 30-day-old transplants may yield better than direct sowing in pearl millet.

For late sowing use of transplants gives higher yields compared to direct seeding. Although transplanting resulted in less dry weight being produced this did not significantly affect yield. Transplanting could be done even when seedlings are 30 days old without affecting yield potential significantly.

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