Evaluation of bare-root methods for transplanting cocoa seedlings

F. M. AMOAH, K. OPOKU-AMEYAW, K. OSEI-BONSU & F. K. OPPONG
Cocoa Research Institute of Ghana, P.O. Box 8, New Tafo, Ghana

SUMMARY

Studies were carried out to evaluate various bare-root methods for transplanting cocoa seedlings. The objective was to find alternative methods to the ball-of-earth (polyethylene bag) method of transplanting cocoa seedling which is known to give very good establishment but is very expensive. The experiment involved three factors: (i) length of time after lifting seedlings from the soil (1, 2 or 3 days), (ii) with or without the application of clay-slurry to the roots, and (iii) eight different methods for packaging the uprooted seedlings in a 3 × 2 × 8 factorial experiment with the ball-of-earth method as a control. Seedling mortality was determined at 3-month intervals up to the 12th month whilst growth was measured at 12 months after transplanting. The experiment was repeated each year for 4 years. At the end of each year, less promising treatments assessed by percentage survival were eliminated. The following five bare-root treatments with a success range of 63 - 78 per cent were selected besides the ball-of-earth treatment which consistently had the highest mean survival of 92.5 per cent over the 4-year period: (i) roots wrapped in moist sack, leaves enveloped in clear polythene bag and seedlings planted on the same day; (ii) roots and leaves pruned, roots wrapped in moist sack, and seedlings planted on the same day; (iii) roots wrapped in moist sack and seedlings left in the shade and planted on the 2nd day; (iv) roots wrapped in moist sack, leaves enveloped in clear polyethylene bag, and seedlings left in the shade and planted on the 3rd day; and (v) roots and leaves pruned, roots wrapped in moist sack, and seedlings left in the shade and planted on the 3rd day. Verification of these treatments with farmer participation will help to determine their acceptance or whether to modify the different packages.

Original scientific paper. Received 30 Apr 98; revised 30 Mar 99.

RÉSUMÉ

AMOAH, F. M., OPOKU-AMEYAW, K., OSEI-BONSU, K. & OPPONG, F. K.: *Evaluation des méthodes de nu-racine pour la transplantation des semis du cacao.* Des études s'est déroulées pour évaluer les différentes méthodes de nu-racine pour la transplantation des semis du cacao. Le but était de trouver d'autres méthodes à la méthode de 'boule-de-terre' (sac en polyéthylène) de la transplantation des semis du cacao qui est bien connue pour le bon enracinement qu'elle donne mais qui est très chère. L'expérience comprenait trois facteurs: (1) la durée du temps après l'enlévement des semis du sol (1, 2 ou 3 jours), (2) l'application ou sans l'application de gadoue argileuse aux racines, et (3) huit différentes méthodes d'emballage des semis enlevés dans une expérience factorielle de 3 × 2 × 8 avec la méthode de boule-de-terre comme un contrôle. La mortalité de semis était déterminée à l'intervalle de 3-mois jusqu' à la douzième mois alors que les évaluations de la croissance étaient faites à 12 mois après la transplantation. L'expérience était répétée chaque année pour 4 ans. A la fin de chaque année, les traitements moins prometteurs, évalués par le pourcentage de la survie, étaient éliminés. Les traitements de cinq nu-racines suivants avec une variation de réussite de 63-78 pour cent étaient sélectionnés en plus de traitement de 'boule-de-terre, qui par conséquent donnait la plus moyenne survie de 92.5 pour cent au cours de la période de 4-ans. Ces traitements étaient: (1) les racines emballées en sac mouillé, les feuilles enveloppées dans un sac en polyéthylène transparent et le semis plantés le même jour; (2) les racines et les feuilles taillées, les racines emballées en sac mouillé et les semis plantés le même jour; (3) les racines emballées en sac mouillé et les semis laissés à l'ombre et plantés le lendemain; (4) les racines emballées en sac mouillé, les feuilles enveloppées dans un sac en polyéthylène transparent et les semis laissés à l'ombre et plantés le troisième jour, et (5) les racines et les feuilles taillées, les racines emballées en sac mouillé et les semis laissés à l'ombre et plantés le troisième jour. La vérification de ces traitements avec la participation des cultivateurs peuvent influencer leurs acceptance ou la modification des différents emballages.

Introduction

Cocoa farms are normally established either by planting seeds directly in the field (planting-at-stake) or by transplanting nursery-raised seedlings (Freeman, 1965). In general, planting-at-stake is more economical since it uses no special plant-growing facilities (Hartman & Kester, 1983). However, direct seeding may result in poor establishment as the young seedling has to compete with weeds for nutrients and moisture as well as being exposed to rodents and insect pests. Production of seedlings in the nursery, on the other hand, ensures higher efficiency, better plant growth and reduced loses through diseases, pests and adverse climatic conditions (Esan, 1981). Benstead (1950) showed that in Ghana the raising of seedlings in the nursery resulted in better establishment of plants and superior growth in the field. However, more labour is needed in the handling of seedlings up to the transplanting stage; thus, this practice is more expensive especially when the raised seedlings are transported with a ball-of-earth over long distances.

However, to reduce cost, cocoa seedlings may be raised in the nursery for about 6 months, after which they may be lifted from the soil and transplanted as bare-root plants rather than by the ball-of-earth method. Most cocoa farmers in Ghana are now planting cocoa either directly at stake or as bare-root plants with reduced rate of success compared to the ball-of-earth method.

Although there are good reasons to encourage the continued raising of cocoa seedlings in the nursery for some time before transplanting, there is the need to evolve a convenient and more efficient method for transplanting bare-root cocoa seedlings in the field to ensure better establishment.

This study aimed at reassessing the feasibility of using the bare-root method of transplanting to establish cocoa farms to make cocoa establishment successful, less cumbersome, and less expensive.

Materials and methods

The experiment was carried out at the Cocoa Research Institute of Ghana, Tafo, from June 1988 to June 1992. Table 1 shows the climatic data collected from the Tafo Meteorological Station during the experimental period (1988-1992)

The experimental treatments consisted of 3 × 2 × 8 factorial with the ball-of-earth (polyethylene bag) method as control, giving a total of 49. The length of time (days) after lifting seedlings were 1, 2 or 3 days designated as D1, D2 and D3, respectively. The second factor was application of clay-slurry to the roots (C1) or no application of clay-slurry to the roots (C2). The third factor consisted of the following eight different methods

TABLE 1

Climatic Data for Tafo (1988-1992)

	1988	*1989*	*1990*	*1991*	*1992*
Total annual rainfall (mm)	1343.2	1470.8	1231.5	1703.7	1343.8
Mean daily relative humidity at 1500 GMT	65.6	65.5	65.5	70.6	66.0

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Mean daily sunshine hours	4.9	5.9	5.8	6.6	6.8	4.8	2.8	2.8	3.4	5.7	7.0	6.4
Mean monthly maximum temperature (°C)	33.1	34.4	33.9	32.9	31.8	30.2	28.3	28.3	29.4	30.5	31.7	31.3
Mean monthly rainfall distribution (mm)	5.6	39.8	144.8	60.3	184.9	200.4	159.4	156.4	75.6	168.3	58.0	42.8

of packaging the lifted seedlings:

(i) Roots wrapped with moist sack (P1).
(ii) Roots and leaves pruned and roots wrapped in moist sack (P2).
(iii) Roots wrapped in moist sack as in (i) and leaves enveloped in clear polyethylene bag (P3).
(iv) Roots and leaves pruned, roots wrapped in moist sack as in (ii) and leaves enveloped in clear polyethylene bag (P4).
(v) Roots wrapped with moist straw (P5).
(vi) Roots and leaves pruned and roots wrapped in moist straw (P6).
(vii) Roots wrapped with moist straw as in (v) and leaves enveloped in clear polyethylene bag (P7).
(viii) Roots and leaves pruned and roots wrapped in moist straw as in (vi) and leaves enveloped in clear polyethylene bag (P8).

Mixed hybrid cocoa nursed in top forest soil in polyethylene bags measuring 17.5 cm × 25 cm were used. The field layout design was a randomized complete block with four replicates. The leaf-pruning treatment consisted of reducing leaf surface area by pruning the leaf number to three pairs per seedling, and further clipping off half of each leaf blade. Root pruning reduced the main tap root to half its length and trimmed the secondary roots. The lifted plants were kept under shade for the respective number of days before being transplanted. The clay-slurry was prepared by mixing clay and water and then smeared on the roots to completely coat them. The straw used in this study was from mowed lawns which had been sun dried for about 4 weeks.

The cocoa was first planted in June 1988 and repeated yearly for 4 years. It was planted in the morning between 8 and 10 am at a spacing of 1.5 m × 1.5 m, using 36 plants per plot. A temporary shade of plantain planted at 3 m × 3 m supplemented with *Glyricidia sepium* at 12 m × 12 m was established 3 months before planting the cocoa seedlings in each year. Seedling mortality was determined at 3-monthly intervals up to the 12th month after transplanting. Growth was measured on 12 randomly selected plants just before planting and at 12 months after transplanting. At the end of each year, less promising treatments assessed by percentage survival were eliminated. The threshold for elimination was set at 50 per cent for the 1st year and 60 per cent for the subsequent years.

Results

The effect of treatments on seedling survival assessed at the various intervals (3, 6, 9 and 12 months) followed the same trend. Hence, only data on seedling survival at 12 months after transplanting and girth (taken at 15 cm from soil level) and height increments after 1 year in each planting season are presented.

Table 2 shows the results of the 1st year trial (1988/89). The control (ball-of-earth method) was superior to all the other treatments in both percentage survival and growth of survived seedlings. In general, most treatments with clay-slurry applied to the roots (C1) performed poorly compared to those without clay-slurry (C2). Also, treatments with the roots wrapped in moist straw (P5-P8) recorded lower survival and growth rates. The number of days of keeping seedlings before transplanting did not affect seedling growth rate in this study. However, seedlings which were transplanted after 1 or 2 days generally had higher percentage survival than seedlings which were transplanted after the 3rd day. The mean percentage survival of seedlings planted with their bare roots in the 1st year trial was 49.8 per cent as against 94.5 per cent for seedlings planted by the ball-of-earth method. About 46 per cent of all the treatments (23 out of 49) had seedling survival percentage of 50 and above (Table 3). These treatments were selected for the 2nd year planting.

The control was again superior to all other treatments in percentage survival and seedling growth rate during the 2nd year (1989/90). Treatments involving moist straw and clay-slurry continually had lower percentage survival of seedlings.

TABLE 2

Percentage Survival, Girth Increment, and Height Increment - 1988/89 Experiment

(a) Percentage survival after 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	With	35.0	40.0	45.0	50.5	40.6	45.0	46.2	55.0	44.7
	Without	55.8	70.0	79.0	50.4	58.4	60.4	52.4	42.0	58.6
2	With	55.0	52.0	50.4	45.0	48.0	44.0	55.0	38.0	48.4
	Without	65.0	62.2	48.2	45.2	48.0	52.4	44.0	55.0	52.5
3	With	55.0	40.0	35.0	38.6	40.0	36.0	35.5	42.0	40.3
	Without	42.0	70.2	63.8	48.0	55.2	44.5	66.0	48.3	54.8
Means		51.3	55.7	53.6	46.3	48.4	47.1	48.9	46.7	
Control					94.5					
SED (144 df)						11.8				

(b) Girth increment (mm) at 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	With	8.8	8.2	8.8	9.2	9.0	8.6	8.5	11.5	9.1
	Without	9.6	10.2	12.3	8.5	9.2	9.8	8.5	7.5	9.5
2	With	8.0	9.8	9.5	11.2	10.6	9.6	8.0	8.0	9.3
	Without	9.0	8.8	8.5	8.2	7.5	9.8	8.4	8.5	8.6
3	With	11.0	8.2	9.5	8.3	9.4	8.2	8.4	8.0	8.9
	Without	9.6	12.2	10.0	8.6	10.5	8.6	10.2	9.0	9.8
Means		9.3	9.6	9.8	9.0	9.4	9.1	8.7	8.8	
Control					15.0					
SED (144 df)						3.2				

(c) Height increment (cm) at 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	With	42.1	40.2	39.2	43.4	42.1	45.6	51.2	42.4	43.3
	Without	46.2	58.3	56.3	50.5	48.2	47.4	47.6	53.2	51.0
2	With	48.1	42.4	50.2	42.3	39.8	40.6	51.2	50.6	45.7
	Without	44.6	48.2	41.3	39.7	52.5	51.3	46.7	52.1	47.7
3	With	55.3	52.4	50.7	46.9	44.5	40.4	45.2	49.7	48.1
	Without	50.2	60.2	54.5	48.7	55.3	49.4	44.2	51.6	51.8
Means		47.8	50.3	48.7	45.3	47.1	45.8	47.7	50.0	
Control					66.5					
SED (144 df)						9.8				

*P1, P2 ....., P8 as defined in materials and methods

TABLE 3
Percentage Survival, Girth Increment, and Height Increment - 1989/90 Experiment

(a) Percentage survival after 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	With	-	-	-	50.6	-	-	-	40.4	45.5
	Without	52.4	70.2	76.8	48.4	50.2	42.5	51.7	-	56.0
2	With	54.2	52.8	53.1	-	-	-	46.5	-	51.7
	Without	74.3	51.7	-	-	-	46.7	-	48.6	55.3
3	With	53.7	-	-	-	-	-	-	-	53.7
	Without	-	65.0	62.3	-	42.2	-	43.6	-	53.3
Means		58.7	59.9	64.1	49.5	46.2	44.6	47.3	44.5	
Control				88.5						
SED (63 df)					10.3					

(b) Girth increment (mm) at 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	With	-	-	-	8.8	-	-	-	8.6	8.7
	Without	9.9	10.2	9.9	8.2	10.1	9.0	11.5	-	9.8
2	With	9.8	10.4	9.6	-	-	-	8.9	-	9.7
	Without	11.1	8.8	-	-	-	9.2	-	8.4	9.4
3	With	9.9	-	-	-	-	-	-	-	9.9
	Without	-	11.5	10.2	-	9.8	-	9.7	-	10.3
Means		10.2	10.2	9.9	8.5	10.0	9.1	10.0	8.5	
Control				13.6						
SED (63 df)						4.6				

(c) Height increment (cm) at 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	With	-	-	-	60.2	-	-	-	65.7	63.0
	Without	52.4	55.7	58.4	48.2	52.6	62.6	49.3	-	54.2
2	With	58.4	54.7	49.6	-	-	-	51.7	-	53.6
	Without	63.4	49.6	-	-	-	58.6	-	50.1	55.4
3	With	70.3	-	-	-	-	-	-	-	70.3
	Without	-	60.4	55.8	-	52.6	-	53.2	-	55.5
Means		61.1	55.1	54.6	54.2	56.2	60.6	51.4	57.9	
Control				70.6						
SED (63 df)						10.5				

*P1, P2 ....., P8 as defined in materials and methods

Percentage survival tended to decrease the longer the lifted seedlings were kept before transplanting, although these differences were not significant. There were also no differences between treatments in the growth rate of the surviving seedlings. The mean survival percentage of the bare-root methods of transplanting was about 52.0 whilst the control was 88.5. Only about 26 per cent of the treatments (6 out of 23) had seedling survival of 60 per cent and above. These treatments were selected for the 3rd year (1990/91) planting. All these treatments including the control had percentage survival of 60 and above in 1990/91 (Tables 4 and 5) and hence all were included in the 4th year (1991/92) trial.

TABLE 4

Percentage Survival, Girth Increment, and Height Increment - 1990/91 Experiment

(a) Percentage Survival after 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	Without	-	67.5	73.2	-	-	-	-	-	70.4
2	Without	71.3	-	-	-	-	-	-	-	71.3
3	Without	-	64.2	61.3	-	-	-	-	-	62.8
Means		71.3	65.9	67.3	-	-	-	-	-	
Control				96.0						
SED (15 df)		9.2								

(b) Girth increment (mm) at 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	Without	-	8.5	9.4	-	-	-	-	-	9.0
2	Without	10.1	-	-	-	-	-	-	-	10.1
3	Without	-	9.6	8.8	-	-	-	-	-	9.2
Means		10.1	9.1	9.1	-	-	-	-	-	-
Control				10.2						
SED (15 df)										5.2

(c) Height increment (mm) at 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	Without	-	57.2	62.8	-	-	-	-	-	60.0
2	Without	61.3	-	-	-	-	-	-	-	61.3
3	Without	-	49.3	52.4	-	-	-	-	-	50.9
Means		61.3	53.3	57.6	-	-	-	-	-	
Control				63.6						
SED (15 df)		9.8								

*P1, P2 ....., P8 as defined in materials and methods

TABLE 5

Percentage Survival, Girth Increment, and Height Increment - 1991/92 Experiment

(a) Percentage survival after 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	Without	-	71.5	79.1	-	-	-	-	-	75.3
2	Without	65.7	-	-	-	-	-	-	-	65.7
3	Without	-	68.4	64.0	-	-	-	-	-	66.2
Means		65.7	70.0	71.6	-	-	-	-	-	
Control			92.0							
SED (15 df)				12.5						

(b) Girth increment (mm) at 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	Without	-	9.1	8.8	-	-	-	-	-	9.0
2	Without	8.6	-	-	-	-	-	-	-	8.6
3	Without	-	9.4	9.6	-	-	-	-	-	9.5
Means		8.6	9.3	9.2	-	-	-	-	-	
Control				9.8						
SED (15 df)		3.8								

(c) Height increment (cm) at 12 months

Days after lifting seedlings	*Coating with clay slurry*	*Various packaging methods**								
		P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*Means*
1	Without	-	64.2	63.4	-	-	-	-	-	63.8
2	Without	59.7	-	-	-	-	-	-	-	59.7
3	Without	-	66.8	56.4	-	-	-	-	-	61.6
Means		59.7	65.5	59.9	-	-	-	-	-	
Control		68.4								
SED (15 df)			8.8							

*P1, P2 ....., P8 as defined in materials and methods

In the 3rd- and 4th- year trials, the control had significantly higher survival rates than all the other treatments. The differences between all other treatments in both percentage survival and seedling growth rate were not significant. The mean percentage survival of the five bare-root methods without the control in 1990/91 and 1991/92 were 68.2 and 69.1, respectively.

Discussion

The results of this study have confirmed the superiority of the ball-of-earth (polyethylene bag) method for transplanting cocoa over the bare-root methods. However, the mean survival of 69 per

cent for the five selected bare-root methods indicates that they can be used to reduce cost and drudgery to the farmer. The various bare-root methods allow the farmer who cannot afford the ball-of-earth method of transplanting to cheaply gain acceptable success. Similar observations were made by Esan (1981) who stated that apart from being cheap and convenient, the bare-root methods of transplanting cocoa reduce the chance of mechanical and cultural transmission as well as the spread of soil borne pathogens and pests. It further allows the recycling of the top soil and polyethylene bags over and over again. Several researchers have also recommended the bare-root method of transplanting cocoa as being cheaper and more convenient than the traditional polyethylene bag method (Alvim, Lima Filho & Alfonso, 1981; De Souza *et al.*, 1981a; De Souza *et al.*, 1981b; Murray, 1954). These reseachers observed that with the application of 10 per cent mobileaf (an anti-transpirant), successes could be 90 per cent or more with the bare-root method.

In this study, however, anti-transpirants were not used as the cost of transplanting could increase and many farmers in Ghana may be unable to afford. There were no significant differences between the bare-root methods in seedling growth rate after 12 months. This confirms the observations made by De Souza *et al.* (1981a) that the bare-root methods of transplanting cocoa seedlings affect only the percentage success and not the growth of seedlings.

Despite the high success with the polyethylene-bag method, Donkor, Henderson & Jones (1991) observed farmer adoption rate of 23 per cent as against 26 per cent for the bare-root method, whilst a greater percentage of the farmers preferred direct seeding (planting-at-stake). However, direct seeding often results in high loss of seedlings due to attack by rodents and insects, competition from weeds for nutrients, moisture, and other growth factors as well as damage during weeding. The main constraint to the adoption of the polyethylene-bag method was the cost of polyethylene bags, nursery care as well as transportation difficulties due to the bulkiness of the bagged seedlings. With most cocoa farms in Ghana located at distances of about 1.6 km or more from nursery sites (Donkor *et al.*, 1991), the average farmer may be able to convey between 10 and 30 seedlings by head portage (depending on polyethylene-bag size). However, by the bare-root method, Esan (1981) reported that an unassisted farmer could conveniently transport over 1000 seedlings cheaply from the nursery to his farm, transplant his consignment onto the field within 2 days and still record over 90 per cent successful establishment.

It was observed in this study that the survival rates of bare-rooted seedlings during transplanting was dependent on the weather. Survival rates are higher if transplanting is followed by rains within 1 or 2 days. These observations suggest the possibility of developing a transplanting technology which allows for high seedling survival rates with reduced drudgery without incurring the constraints of seedling transportation. This could be possible through on-farm trials with farmers' participation so that their local knowledge in predicting the rains could be used. The technology could also be evaluated within the context of technical, cultural, and socio-economic considerations which may affect farmers' perspective of the bare-root method of transplanting cocoa.

Conclusion

The ball-of-earth (polyethylene-bag) method of raising cocoa is superior to the bare-root method in percentage survival of seedlings of 92.5 as against 69 for the bare-root methods. However, the bare-root method is cheaper and more convenient to the farmer and may be more cost-effective than the ball-of-earth method. The following bare-root methods were 63-78 per cent successful consistently over a period of 4 years: (i) roots wrapped in moist sack, leaves enveloped in clear polyethylene bag, and seedlings planted on the same day; (ii) roots and leaves pruned, roots wrapped in moist sack, and seedlings

planted on the same day; (iii) roots wrapped in moist sack, seedlings left in the shade and planted on the 2nd day; (iv) roots wrapped in moist sack, leaves enveloped in clear polyethylene bag, seedlings left in the shade and planted on the 3rd day; and (v) roots and leaves pruned, roots wrapped in moist sack, seedlings left in the shade and planted on the 3rd day.

These methods should be evaluated in on-farm trials with farmers' participation to develop a package that will be acceptable to the farmer.

Acknowledgement

The authors are grateful to Mr Kwabena Acheampong and Mr Robert Dorgbadji for assisting in data collection, Mr K. M. Brew for the analysis of results, and to Mrs Esther Ankrah for the preparation of this manuscript. This paper is published with the permission of the Executive Director, Cocoa Research Institute of Ghana.

REFERENCES

Alvim, R., Lima Filho, J. M. P. & Alfonso, E. C. A. (1981) Possibilidade de transplante do cacaueiro com raizes nuas. *Proceedings 8th International Cocoa Research Conference, Cartegena, Colombia,* 21-26.

Benstead, R. J. (1950) *Annual Report, West African Cocoa Research Institute* **1948/49,** 57-59.

Donkor, M. A., Henderson, C. P. & Jones, A. P. (1991) Survey to quantify adoption of CRIG recommendations. *Farming Systems Unit Research Paper 3. Cocoa Research Institute of Ghana.*

De Souza, J., Garcia, J. R., Muller, M. W. & Midlei, P. R. M. (1981a) Transplantio de mudas de cacaueiro com raizes nuas. *Proceedings of 8th International Cocoa Research Conference, Cartagena, Colombia,* 65-68.

De Souza, J., Garcia, J. R., Muller, M. W. & Midlei, P. R. M. (1981b) Influencia de idade de muda no desenvolvimento do cacaueiro apos o transplante. *Proceedings of 8th International Cocoa Research Conference, Cartagena, Colombia,* 69-72.

Esan, E. B. (1981) Studies on cocoa seedling (*Theobroma cacao* L.). Transportation from the nursery and bare-root transplanting into the field. *Proceedings of 8th International Cocoa Research Conference, Cartagena Colombia,* 15-20.

Freeman, G. H. (1965) Methods of raising cocoa seedlings in the nursery and their effect on subsequent growth in the field. *J. hort. Sci.* **40,** 341-349.

Hartman, H. T. & Kester, D. E. (1983) *Plant propagation principles and practices.* Englewood cliffs, New Jersey 07632, Prentice-Hall Inc.

Murray, D. B. (1954) An anti-transpirant for cocoa. *Imp. Coll. trop. Agric. Res. Rep.* **44.**