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## 1. INTRODUCTION

Cashew (*Anacardium occidentale*) is an important non-traditional export crop in Ghana. It is a direct source of income to the farmer and a source of foreign exchange for the country. Cashew exports contributed approximately US \$170 million in foreign exchange earnings to the Ghanaian economy in 2013 [1]. Cashew cultivation in Ghana began in the 1960s under the then government's savanna afforestation programme which resulted in the establishment of cashew plantations in the coastal savannah belts of the Greater Accra and the Central regions and the forest savannah transition of Brong Ahafo region [2]. In subsequent years, cashew production declined due to poor management practices and low prices. Cashew farms were subsequently abandoned despite its huge export potential. Since 1990, a renewed interest for cashew cultivation was demonstrated by farmers as a result of government's support for the industry in Ghana. This resulted in the increase in cashew cultivation and expansion of cashew farms in Ghana. Annual export of raw nuts reached 50,000 metric tonnes in 2013 [1]. In spite of this achievement, the crop is still challenged with field establishment difficulties which sometimes lead to high cost of production.

Most farms in Ghana are established either by direct seed planting or with seedlings nursed in polybags. Although direct seeding is one of the recommended field planting methods, technical advice has mainly emphasized the use of seedlings raised in polybags for establishing cashew farms because of some disadvantages associated with direct seed planting [3]. Direct seeding results in wastage of improved seeds during planting as farmers have to sow two or more seeds per hill in assurance against losses and possible mortalities [3, 4, 5]. However, in the case of seedlings nursed in polybags, the farmers have the chance to select vigorous and healthy seedlings for planting ensuring higher seedling survival and better plant growth after establishment. Seedlings may be raised in black polybags measuring 17.5 cm x 25 cm and transplanted onto the field after three months. Despite the usefulness of the polybag method, factors such as unavailability of topsoil, high cost of nursery and transportation affects polybag use [4].

The large polybags (17.5cm x 25cm) require approximately 3kg of soil per bag. This size may allow about 7 to 10 seedlings to be transported by head portage per person: thus increasing time and cost of transporting seedlings for planting. Again the quantity of soil needed to fill the bags creates pressure on the limited top soil. As top soil continues to be scarce in Ghana, there is the need to find alternative polybag size to utilize less volume of soil and reduce labour and time for transporting seedlings for establishing cashew farms. Earlier work [5, 6] demonstrated the feasibility of raising cashew and cocoa seedlings in smaller size bags. However the effect of the use of small size bags on establishment and plant development in the field is yet to be determined. Varying seedling age at transplanting will also determine the appropriate age to transplant cashew seedlings in small polybags to enhance survival. This study was therefore carried out to determine the effect of using small polybag sizes in nursing cashew seedlings, ease of seedling conveyance and on establishment and growth of cashew transplants in the field. It was also to determine the appropriate age to transplant the seedlings onto the field.

## 2. MATERIAL AND METHODS

The experiment was carried out at the Cocoa Research Institute of Ghana (CRIG) substation at Bole (9° 01' N, 2° 29' W, altitude 309m above sea level) in the Northern Ghana between 2010 and 2011. Bole is in the Guinea Savannah zone of Northern Ghana with mean annual rainfall and temperature of 1087 mm and 26.1°C, respectively. The soils are mainly Ferric Luvisols with smaller areas of Eutric Regosols and Lithosols [7]. The total annual rainfalls in

81 2010 and 2011 were 1351.3 mm and 1132.0 mm respectively; and temperatures (min-max)  
82 were (20.9-33.2) and (20.4-32.8) during the experimental periods (source: CRIG  
83 meteorological station, Bole).

84 Cashew seedlings were raised in four different polybags of sizes 17.5 cm x 25cm (large),  
85 14.0 cm x 17.8 cm (medium), 12.7 cm x 17.8 cm (small) and 10.2 cm x 17.8cm (smaller) at  
86 two different times in the nursery to obtain seedlings of 6 and 8 weeks old at the time of  
87 planting. The treatment combinations of polybag sizes and seedling ages were laid out in a  
88 randomized complete block design with four replications. Each treatment plot had thirty  
89 plants. The plants were spaced at 4 m x 4 m in plots measuring 24 m x 20 m.

90 Data collected included seedling survival (percentage), plant girth (mm), plant height (cm)  
91 and leaf number two years after field planting and the ease of transporting seedlings per  
92 person over a distance of 200 meters to the field (recorded as the average of the number of  
93 seedlings that could be carried per person over the distance). Plant survival was recorded 3  
94 months after transplanting because after this period plant mortality may be influenced by  
95 field maintenance operations. Plant girth was measured 10 cm from the ground using a  
96 veneer caliper and plant height was recorded using a metre rule. Measurements started at  
97 planting and were repeated at 3-monthly intervals over a period of two years.

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## 100 2.1 Data Analysis

101 Data were analyzed using ANOVA (GenStat 11.0 for Windows, VSN International) and  
102 treatment means compared using least significant difference (LSD) values. Data on leaf  
103 numbers was square root transformed before analysis.

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## 108 3. RESULTS

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### 110 3.1 Ease of seedling handling and portage.

111 The results show that handling of smaller bags was quicker than the other size bags (Table  
112 1). Average number of bags filled per person increased with a decrease in size of bag. The  
113 number of seedlings conveyed per person by head portage to the field (200 meters) was  
114 also higher with the smaller size bags compared to the large bags.

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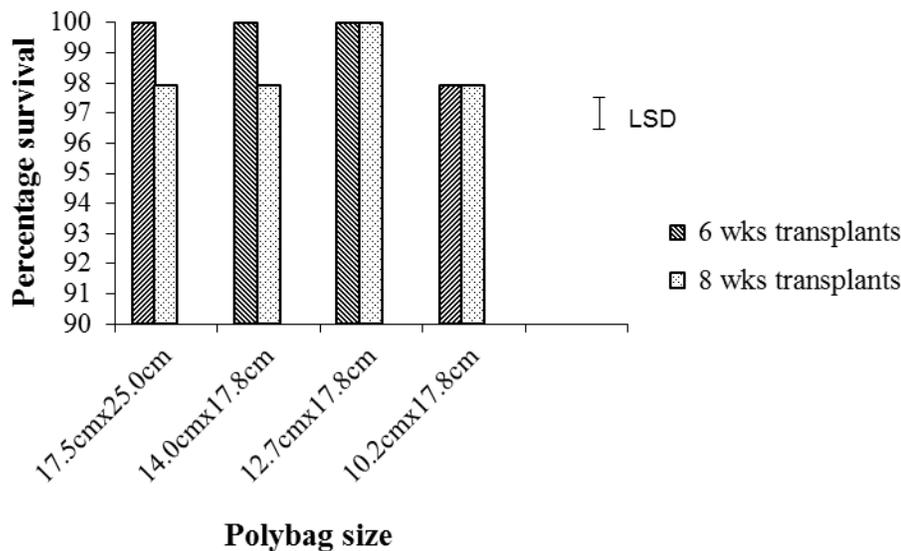
118 **Table 1. Average number of bags filled and seedlings conveyed per person.**

Polybag size	Average weight of filled bag (kg)	Average number of bags filled per person	Average number of bags carried per person
17.5 cm x 25.0 cm	2.6	400	10
14.0 cm x 17.8 cm	1.0	800	25
12.7 cm x 17.8 cm	0.8	1000	31

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### 3.2 Seedling survival

The size of bag in which the seedlings were nursed and seedling age at transplanting did not significantly ( $P > 0.05$ ) affect survival of cashew transplants in the field (Figure 1). Polybag size and seedling age interaction was also not significant ( $P > 0.05$ ). However seedlings transplanted at 6 weeks after sowing was observed to have higher survival than the eight weeks old seedlings after planting. Seedlings nursed with small polybag size (12.7 cm x 17.8 cm) recorded no mortalities either planted at 6 and 8 weeks after sowing.



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**Fig. 1. Effects of polybag size and seedling age at transplanting on plant survival.**

*LSD ( $P > 0.05$ ): polybag size: not significant, seedling age at transplanting: not significant, polybag size \* seedling age: not significant.*

### 3.3 Plant girth (mm)

140 Polybag size significantly ( $P < 0.001$ ) influenced the girth of cashew transplants two years in  
141 the field (Table 2). Plants raised in the large bag size (17.5 cm x 25 cm) had significantly ( $P$   
142  $< 0.001$ ) bigger girths compared to those raised in the smaller bags (10.2 cm x 17.8 cm)  
143 which recorded the least girth. Seedling age at planting did not significantly ( $P > 0.05$ )  
144 influence girth of cashew transplants in the field. Similarly polybag size and seedling age  
145 interaction on plant girth was also not significant ( $P > 0.05$ ).

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151 **Table 2. Effects of polybag size and seedling age at transplanting on plant girth (mm).**

Polybag size	Plant girth (mm)		Mean (Polybag size)
	6 weeks transplants	8 weeks transplants	
17.5cm x 25.0cm	17.7	17.8	<b>17.7</b>
14.0cm x 17.5cm	16.7	16.9	<b>16.8</b>
12.7cm x 17.8cm	15.9	16.3	<b>16.1</b>
10.2cm x 17.8cm	14.9	15.4	<b>15.1</b>
<b>Mean (seedling age)</b>	<b>16.3</b>	<b>16.6</b>	
<b>LSD</b>	: Polybag size	0.98**	
	: Seedling age	ns	
	: Polybag size * seedling age	ns	
CV(%)	:	20.4	

152 **LSD** = least significant difference, CV = Coefficient of variation, ns = not significant, \*\* = significant at  
 153 (P < 0.001)

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### 3.4 Plant height (cm)

157 The height of cashew transplants also showed significant differences (P < 0.001) between  
 158 the polybags used two years in the field. Similar to observations on girth, plants raised in  
 159 large bags (17.5 cm x 25 cm) were significantly taller, followed by medium (14.0 cm x 17.5  
 160 cm) bags which were not significantly different to those raised in the small bags (12.7cm x  
 161 17.8 cm) (Table 3). Plants raised with the smaller bags (10.2 cm x 17.8 cm) recorded the  
 162 least height. Again seedling age at transplanting did not significantly (P > 0.05) influence  
 163 plant height in the field. The bag size x seedling age interaction on plant height was also not  
 164 significant.

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**Table 3. Effects of polybag size and seedling age at transplanting on plant height (cm).**

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Polybag size	Plant height (cm)		Mean (polybag size)
	6 weeks transplants	8 weeks transplants	
17.5cm x 25.0cm	59.3	64.7	<b>62.0</b>

14.0cm x 17.5cm	58.8	59.1	<b>58.9</b>
12.7cm x 17.8cm	54.4	57.5	<b>55.9</b>
10.2cm x 17.8cm	50.5	52.9	<b>51.7</b>
<b>Mean (seedling age)</b>	<b>55.7</b>	<b>58.6</b>	
<b>LSD</b>	: Polybag size	4.37**	
	: Seedling age	ns	
	: Polybag size * seedling age	ns	
CV(%)	:	26.9	

170 *LSD = least significant difference, CV = Coefficient of variation, ns = not significant, \*\* = significant at*  
 171 *(P < 0.001)*

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### 3.5 Plant number of leaves

175 The number of leaves produced by cashew plants after transplanting was significantly  
 176 influenced by polybag sizes and seedling age at transplanting. Plants from the large bags  
 177 (17.5 cm x 25 cm) produced significantly (P < 0.001) higher number of leaves when planted  
 178 at 6 weeks or at 8 weeks after sowing (Table 4). Plants from the small bag size (12.7 cm x  
 179 17.8 cm) had less leaf numbers when transplanted at 6 weeks but produced more leaves  
 180 when planted at 8 weeks after sowing. Averagely leaves produced by cashew plants planted  
 181 at 8 weeks after sowing were significantly (P < 0.05) high compared to 6 weeks old  
 182 transplants.

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**Table 4. Effects of polybag size and seedling age at transplanting on leaf intensity per plant.**

Polybag size	Plant number of leaves		Mean (Polybag size)
	6 weeks transplant	8 weeks transplant	
17.5cm x 25cm	67.7 (8.1)	68.1 (8.1)	<b>67.9 (8.1)</b>
14.0cm x 17.5cm	57.1 (7.5)	60.9 (7.7)	<b>59.0 (7.6)</b>
12.7cm x 17.8cm	48.6 (6.9)	64.6 (7.9)	<b>56.6 (7.4)</b>
10.2cm x 17.8cm	56.1 (7.3)	57.6 (7.4)	<b>56.9 (7.4)</b>
<b>Mean ( seedling age)</b>	<b>57.4 (7.4)</b>	<b>62.8 (7.8)</b>	
<b>LSD</b>	: Polybag size	(0.38)**	

	: Seedling age	(0.27)*
	: Polybag size * seedling age	(0.53)
CV (%)	:	17.4

187 Values in parenthesis are square root transformation of the actual values. LSD = least significant  
 188 difference, CV = Coefficient of variation, \* = significant at ( $P < 0.05$ ), \*\* = significant at ( $P < 0.001$ ).

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#### 4. DISCUSSION

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Establishing farms with seedlings raised in polybags has considerable advantages. However its use by the cashew farmers' in Ghana has been low because of the invariably high cost involved in nursery care and in transporting seedlings to the field for planting [8]. The use of small polybags may be an alternative option which may be better accepted by cashew farmers because the cost of raising and transporting seedlings is low compared to large bags. It was observed in this study that, handling of the small bags was easier and less costly than the large bags. The medium to smaller polybags required less volume of soil to fill compared to the large bags. Thus about half the volume of top soil is required. More pieces of the smaller polybags could be filled in the working hours compared to the large bags. Therefore quantity of top soil and labor (man hours) required in filling the bags was also reduced. Labour and time for transporting the smaller polybags to the field was also less compared to the large polybags since more seedlings could be conveyed per person by head portage.

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Seedling survival after transplanting was not significantly influenced either by bag size or seedling age at transplanting. However, it was observed that seedlings transplanted at 6 weeks after sowing tended to give slightly higher survival than 8 weeks old seedlings. Similar trends were reported in earlier studies [9, 10]. This could be attributed to the observation that, at the time of transplanting many of the 8 weeks old seedlings had their roots penetrating the polybags and inevitably getting damaged during planting. This subjected those seedlings to greater transplanting shock thereby affecting establishment success. Damage to seedling tap root during transplanting has been observed as one of the main causes of transplanting failure common in older cashew seedlings [11]. It is reported [12] that shock of transplanting due to tap root damage is larger in older seedlings than smaller seedlings. Based on these observations, it would be reasonable to suggest that nursery periods of cashew seedlings raised in small polybags should not extend beyond 6 weeks. This is also an advantage since time and labour needed for nursery activities will be reduced. Seedlings raised in the small bag size (12.7cm x 17.8 cm) were observed to have survived better which may be attributed to ease of handling of the bags. It's small size ensured proper handling which prevented the contents of the bag from falling apart and breaking the brittle roots during planting. The successful planting of the seedlings with a ball of soil around the roots may have improved survival in the field. The rapid growth of cashew transplants raised in large polybag size (17.5 cm x 25.0 cm) in the field was expected. Similar findings [13, 14] were reported in mango and Indian sandalwood where larger containers produced better growth of seedlings. The relatively large volume of soil in the bag allowed the seedling roots to be exposed to more nutrients and soil moisture resulting in the initial rapid growth of seedlings which was still visible after planting in the field. It is also reported [15] that, seedlings raised in large bags have a well-developed root system contributing to better uptake of nutrient and water for vigorous plant growth. Although significant differences were observed in plant growth amongst the different polybag sizes in the field, subsequent performance cannot be predicted. The use of smaller bags is

233 envisaged for easy adoption by many cashew farmers to enhance seedling portage and  
234 establishment.

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## 238 5. CONCLUSION

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240 Cashew seedlings can be raised in polybag size 14.0 cm x 17.8 cm (medium) and 12.7 cm x  
241 17.8 cm (small) and transplanted into the field with high survival percentage. Seedlings  
242 raised in small bags are best transplanted at 6-weeks after sowing for higher establishment  
243 success. Seedling conveyance and handling was easy with the small polybags which is of  
244 benefit to the cashew farmer.

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248

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## 257 COMPETING INTERESTS

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259 Authors have declared that no competing interests exist.

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