Table 6: Mean leaf dry weight (g) of cocoa seedlings in different plant media, different poly bag sizes and their interaction

	3 months				6 months			
Media	Poly bag size			Mean	Poly bag size			Mean
	12.5x18.5	17.3x23.3	10.0x35.0		12.5x18.5	17.3x23.3	10.0x35.0	
S	2.1	4.3	3.2	3.2	4.7	11.6	5.6	7.3
CRH	1.2	1.1	2.4	1.6	1.7	3.6	4.6	3.3
CPH	1.1	1.2	1.1	1.1	1.3	2.6	2.4	2.1
CP	1.0	0.7	1.8	1.2	1.5	2.1	4.8	2.8
SD	0.7	1.0	0.9	0.9	1.3	1.1	1.9	1.4
S+CRH	2.8	5.7	3.4	3.9	5.2	13.5	5.9	8.2
S+CPH	2.8	2.9	3.1	2.9	5.7	15.1	7.1	9.3
S+CP	3.3	4.0	3.8	3.7	4.3	8.6	7.4	6.8
S+SD	1.7	2.2	2.0	2.0	4.0	5.6	5.1	4.9
CRH+CPH	1.2	0.5	1.4	1.0	1.3	4.6	6.1	4.0
CRH+CP	0.9	1.0	1.2	1.0	0.8	5.2	1.9	2.7
CRH+SD	1.0	0.8	0.8	0.8	1.1	3.0	1.2	1.7
CPH+CP	1.1	0.6	3.0	1.6	3.2	6.3	8.4	5.9
CPH+SD	0.6	0.7	1.0	0.8	2.7	3.9	3.4	3.3
CP+SD	0.8	1.2	0.8	0.9	3.3	3.5	1.9	2.9
Mean	1.5	1.9	2.0		2.8	6.0	4.5	
LSD (P≤0.05);	Media = 0.3				1.3			
	Poly bag size= 0.1				0.5			
	Media*Poly bag size= 0.5				2.1			

4.3.2Mean stem dry weight of cocoa seedlings in different growth media, different poly bag sizes and their interaction at three and six months after sowing

The mean stem dry weight of cocoa seedlings in the different media, different polybag sizes and their interaction are presented in Table 7.

Media effects: The type of potting media significantly affected mean stem dry weight. The highest stem dry weight was recorded by plants grown in S+CP and this was significantly different from all other treatments. The order of mean stem dry weight decreased as follows: CP+SD>CRH+SD>SD>CPH.

Poly bag effects: The results show that mean stem dry weight of seedlings grown in 17.3 cm x 23.3 cm and 10.0 cm x 35.0 cm were significantly ($p<0.05$) higher than those in 12.5 cm x 18.5 cm polybag size.

Interactive effect: The interaction between growth media and size of poly bag was significant ($p<0.05$). The seedlings grown in S+CP in 17.3 cm x 23.3 cm poly bag size recorded the highest mean stem dry weight and this was not significantly ($p<0.05$) different from those of S+CPH, S+CRH and S in the 17.3 cm x 23.3 cm poly bag size. The lowest mean stem dry weight was recorded in growth media CPH in 12.5 cm x 18.5 cm polybag size. The stem dry weight of seedlings produced in soilless media CRH+CP in poly bag size 17.3 cm x 23.3 cm and CPH+CP in polybag size 10.0 cm x 35.0 cm recorded stem dry weight of 7.4 g/plant and 6.4 g/plant respectively. This was however significantly higher than the other soilless media (Table 7).

Table 7: Mean stem dry weight (g) of cocoa seedlings in different plant media, different poly bag sizes and their interaction

	3 months				6 months			
Media	Poly bag size			Mean	Poly bag size			Mean
	12.5x18.5	17.3x23.3	10.0x35.0		12.5x18.5	17.3x23.3	10.0x35.0	
S	1.00	2.21	1.95	1.7	5.1	11.7	6.3	7.7
CRH	0.9	1.1	1.2	1.1	3.6	4.9	5.1	4.5
CPH	0.6	0.9	0.8	0.8	0.7	1.0	1.3	1.0
CP	1.0	1.4	1.1	1.2	2.6	1.2	6.1	3.3
SD	0.9	1.3	1.2	1.1	1.6	0.9	1.9	1.5
S+CRH	1.8	2.4	1.5	1.9	5.4	14.0	5.1	8.2
S+CPH	1.8	2.2	1.5	1.8	5.0	14.3	4.8	8.0
S+CP	1.7	1.8	2.0	1.8	5.9	14.3	9.8	10.0
S+SD	1.1	1.8	1.5	1.4	7.2	6.2	5.3	6.2
CRH+CPH	0.7	0.7	1.2	0.8	1.5	4.0	4.8	3.4
CRH+CP	1.0	1.0	1.4	1.1	0.8	7.4	2.1	3.4
CRH+SD	1.3	0.8	1.2	1.1	1.8	2.2	2.1	2.0
CPH+CP	0.9	0.8	1.3	1.0	3.7	3.5	6.4	4.6
CPH+SD	0.6	1.3	1.1	1.0	2.4	3.5	2.5	2.8
CP+SD	0.8	1.3	1.1	1.1	3.7	1.9	1.5	2.4
Mean	1.1	1.4	1.3		3.4	6.1	4.3	
LSD (P≤0.05);		Media = 0.2				1.7		
		Poly bag size= 0.1				0.7		
		Media*Poly bag size= 0.4				2.8		

4.3.3 Mean root dry weight of cocoa seedlings in different growth media, different poly bag sizes and their interaction at three and six months after sowing

The mean root dry weight of cocoa seedlings in the different media, different polybag sizes and their interaction are presented in Table 8.

Media effects: Results in Table 8 shows that the highest mean root dry weight was recorded by seedlings grown in S+CP followed by S+CRH and this was not significantly ($p<0.05$) higher than S and S+CPH. The lowest mean root dry weight was recorded by CPH.

Poly bag effect: The size of poly bag affected the mean root dry weight of cocoa at six months. The highest mean root dry weight was recorded in the 10.0 cm x 35.0 cm polybag size and this was not significantly ($p<0.05$) higher than the 17.3 cm x 23.3 cm polybag size. The 12.5 cm x 18.5 cm polybag size recorded the lowest mean root dry weight (Table 8).

Interactive effect: Data in Table 8 indicates that media and polybag size interaction was significant on the mean root dry weight of the cocoa seedlings. Plant media, CP in the 10.0 cm x 35.0 cm poly bag size recorded the highest mean root dry weight of 8.3 g/plant and this was not significantly different from those in S+CP and S+CRH. However, this was significantly ($p<0.05$) different from S+CP and S. The seedlings grown in soilless media CRH+CP and CPH+CP in poly bag size 17.3 cm x 23.3 cm produced heavier root weight than S+SD and the other soilless growth media (Table 8).

Table 8: Mean root dry weight (g) of cocoa seedlings in different plant media, different poly bag sizes and their interaction at three and six months after sowing

	3 months				6 months			
Media	Poly bag size			Mean	Poly bag size			Mean
	12.5x18.5	17.3x23.3	10.0x35.0		12.5x18.5	17.3x23.3	10.0x35.0	
S	0.6	0.9	1.0	0.8	4.1	6.2	4.4	4.9
CRH	0.8	0.8	1.5	1.1	1.7	3.0	4.2	3.0
CPH	0.4	0.6	0.8	0.6	0.5	0.7	0.7	0.6
CP	1.0	1.0	1.8	1.3	1.9	2.1	8.3	4.1
SD	0.8	1.0	0.8	0.9	1.3	1.1	2.5	1.6
S+CRH	0.8	0.9	1.0	1.0	3.6	6.8	5.4	5.3
S+CPH	0.8	0.7	1.0	0.8	2.3	6.4	4.1	4.3
S+CP	1.1	1.0	2.3	1.5	4.3	6.1	6.8	5.7
S+SD	0.7	0.5	1.1	0.7	3.2	4.7	4.3	4.1
CRH+CPH	0.5	0.5	0.9	0.6	1.2	3.2	3.8	2.8
CRH+CP	1.1	1.0	1.2	1.1	1.3	5.5	1.7	2.8
CRH+SD	0.9	0.8	1.3	1.0	1.4	2.6	2.1	2.0
CPH+CP	0.8	0.6	0.8	0.8	2.4	4.0	4.9	3.8
CPH+SD	0.4	0.7	0.8	0.7	1.3	2.9	2.4	2.2
CP+SD	0.8	1.2	1.1	1.0	3.2	2.5	2.8	2.9
Mean	0.8	0.8	1.2		2.3	3.9	3.9	1.7
LSD (P≤0.05);		Media = 0.2			1.1			
		Poly bag size= 0.1			0.4			
		Media*Poly bag size= 0.3			1.7			

4.3.4 Mean dry matter of cocoa seedlings in different growth media, different poly bag sizes and their interaction at three and six months after sowing

The mean dry matter of cocoa seedlings in the different media, different polybag sizes and their interaction are presented in Table 9.

Media effect: The growth media significantly ($p<0.05$) affected dry matter production of the cocoa seedlings. The highest mean dry matter (22.5 g/plant) was produced in S+CP and the lowest total dry matter (3.7 g/plant) was recorded by CPH. There was however no significant difference between S+CP, S+CRH and S+CPH. The order of total plant weight in the soilless media mix also decreased as follows:

CPH+CP>CRH+CPH>CRH+CP>CPH+SD>CP+SD>CRH+SD (Table 9).

Poly bag effect: The highest mean dry matter weight was recorded in the 17.3 cm x 23.3 cm polybag size and was not significantly ($p<0.05$) higher than the 10.0 cm x 35.0 cm polybag size. The 12.5 cm x 18.5 cm polybag sizes recorded the lowest mean root dry weight (Table 9).

Interactive effect: The highest total dry matter was recorded by seedlings grown in S+CPH in the 17.3 cm x 23.3 cm poly bag size and this was significantly ($p<0.05$) higher than S. The order of total dry matter increased as follows: S+SD <S < S+ CP< S+CRH<S+CPH. The lowest dry matter was recorded by SD in the 17.3 cm x 23.3 cm polybag size (Table 9). In general, the total plant dry matter of cocoa seedlings in the interaction of soil based media mix and poly bag size recorded the highest weight and they were significantly heavier than those grown in the soilless media mix (Table 9).

Table 9: Mean dry matter weight (g) of cocoa seedlings in different plant media, different poly bag sizes and their interaction

	3 months				6 months			
Media	Poly bag size			Mean	Poly bag size			Mean
	12.5x18.5	17.3x23.3	10.0x35.0		12.5x18.5	17.3x23.3	10.0x35.0	
S	3.7	7.5	6.1	5.7	13.9	29.5	16.4	19.9
CRH	2.9	3.0	5.2	3.7	7.0	11.5	13.9	10.8
CPH	2.1	2.8	2.7	2.5	2.5	4.3	4.3	3.7
CP	3.1	3.1	4.8	3.7	6.0	5.4	19.1	10.2
SD	2.4	3.2	2.9	2.9	4.2	3.1	6.3	4.5
S+CRH	5.5	8.9	6.1	6.8	14.2	34.3	16.3	21.6
S+CPH	5.4	5.8	5.6	5.6	13.0	35.7	16.0	21.6
S+CP	6.1	6.8	8.0	7.0	14.6	29.0	23.9	22.5
S+SD	3.4	4.5	4.5	4.1	14.4	16.5	14.7	15.2
CRH+CPH	2.3	1.7	3.5	2.5	4.1	11.8	14.7	10.2
CRH+CP	3.0	3.1	3.8	3.3	2.9	18.2	5.7	8.9
CRH+SD	3.1	2.3	3.2	2.9	4.3	7.8	5.3	5.8
CPH+CP	2.8	2.0	5.1	3.3	9.3	13.8	19.7	14.3
CPH+SD	1.6	2.8	2.9	2.4	6.3	10.3	8.3	8.3
CP+SD	2.4	3.7	3.0	3.0	10.2	7.9	6.3	8.1
Mean	3.3	4.1	4.5		8.5	16.0	12.7	
LSD (P≤0.05);	Media = 0.4				3.6			
	Poly bag size= 0.3				1.4			
	Media*Poly bag size= 0.9				5.5			

4.3.5Mean shoot weight of cocoa seedlings in different growth media, different poly bag sizes and their interaction at three and six months after sowing

The mean shoot weight of cocoa seedlings in the different media, different polybag sizes and their interaction are presented in Table 10.

Media effect: Results in Table 10 indicates that the growth media affected the total shoot dry weight of cocoa seedlings. The highest total shoot weight of 17.3 g was recorded by S+CPH which was followed by S+CP recording a total shoot dry weight of 16.8 g. The lowest shoot dry weight of 2.9 g was recorded by SD and was not significantly different from CPH, CP, CRH+CP, CRH+SD, CRH+CP, CPH+SD and CP+SD. However, seedlings grown in CPH+CP produced higher shoot weight than the other soilless media (Table 10).

Poly bag effect: The highest mean shoot dry weight was recorded in the 17.3 cm x 23.3 cm polybag size and this was not significantly ($p<0.05$) higher than the 10.0 cm x 35.0cm polybag size. The 12.5 cm x 18.5 cm polybag size recorded the lowest mean dry shoot weight (Table 10).

Interactive effect: Significant ($p<0.05$) interaction was observed between the plant media and the polybag sizes (Table 10). The highest dry shoot weight of 29.3 g was recorded by S+CPH in the 17.3 cm x 23.3 cm poly bag size and this was significantly ($p<0.05$) higher than S. There was however, no significant difference between S+CPH and S+CRH. The lowest dry shoot weight was recorded by SD and their combinations and this was not significantly different from CPH, CP, CPH+SD and CP+SD.

Table 10: Mean shoot weight (g) of cocoa seedlings in different plant media, different poly bag sizes and their interaction at three and six month after sowing

	3 months				6 months			
Media	Poly bag size			Mean	Poly bag size			Mean
	12.5x18.5	17.3x23.3	10.0x35.0		12.5x18.5	17.3x23.3	10.0x35.0	
S	3.1	6.5	5.1	4.9	10.3	22.9	11.9	15.0
CRH	2.1	2.2	3.7	2.6	5.3	8.5	9.7	7.8
CPH	1.7	2.2	2.0	1.9	2.0	3.6	3.6	3.1
CP	2.1	2.1	3.0	2.4	4.2	3.3	10.8	6.1
SD	1.6	2.2	2.1	2.0	2.9	2.0	3.8	2.9
S+CRH	4.7	8.0	4.8	5.8	10.6	27.5	10.9	12.4
S+CPH	4.6	5.1	4.6	4.8	10.7	29.3	11.9	17.3
S+CP	5.0	5.8	5.7	5.5	10.2	22.9	17.1	16.8
S+SD	2.7	4.0	3.5	3.4	11.2	11.8	10.4	11.1
CRH+CPH	1.9	1.2	2.6	1.9	2.8	8.6	10.9	7.4
CRH+CP	1.9	2.1	2.6	2.2	1.6	12.7	4.0	6.1
CRH+SD	2.3	1.6	2.0	1.9	5.0	7.4	5.9	3.8
CPH+CP	2.0	1.4	4.3	2.6	6.9	9.8	14.8	10.5
CPH+SD	1.2	2.0	2.1	1.8	5.0	7.4	5.9	6.1
CP+SD	1.6	2.5	1.9	2.0	7.0	5.4	3.4	5.3
Mean	2.6	3.3	3.3		6.2	12.1	8.8	
LSD (P≤0.05);	Media = 0.3				2.5			
	Poly bag size= 0.2				1.1			
	Media*Poly bag size= 0.7				4.2			

4.3.6 Mean shoot /root ratio of cocoa seedlings in different growth media, different poly bag sizes and their interaction at three and six months after sowing

Data on the mean shoot/root ratio of cocoa seedlings in the different growth media, polybag size and their interactions are presented in Table 11.

Media effect: Seedlings in CPH recorded the highest shoot/root ratio and this was significantly ($p<0.05$) higher than all other treatments. No significant differences ($p<0.05$) were recorded between S+CPH, S+CRH and S as well as between S+SD, CRH+CPH, CPH+CP and CPH+SD. The lowest shoot/root ratio was recorded by CP (Table 11).

Poly bag effect: The results show that no significant differences were recorded between the poly bag sizes, 17.3 cm x 23.3 cm, 10.0cm x 35.0 cm and 12.5 cm x 18.5 cm (Table 11).

Interactive effect: Growth media and poly bag size interaction was significant at $p<0.05$. The growing medium CPH and poly bag size 17.3 cm x 23.3 cm recorded the highest shoot/root ratio (6.11) and this was significantly ($p<0.05$) higher than all other treatments. There was however no significant difference among S+CPH, S+CRH, S+SD, S and CPH+SD. The lowest shoot/root ratio was recorded in CP and poly bag size 10.0 cm x 35.0 cm (Table 11).

Table 11: Mean shoot/root ratio of cocoa seedlings in different plant media, different poly bag sizes and their interaction at three and six months after sowing

	3 months				6 months			
Media	Poly bag size			Mean	Poly bag size			Mean
	12.5x18.5	17.3x23.3	10.0x35.0		12.5x18.5	17.3x23.3	10.0x35.0	
S	4.8	7.3	5.4	5.8	2.6	3.7	2.7	3.0
CRH	2.5	3.1	2.4	2.7	3.1	2.8	2.4	2.8
CPH	4.1	3.6	3.0	3.6	4.3	6.1	5.3	5.2
CP	2.1	2.0	1.6	1.9	2.2	1.6	1.3	1.7
SD	2.0	2.2	2.6	2.3	2.4	1.7	1.6	1.9
S+CRH	5.7	8.8	3.9	6.1	3.1	4.0	2.1	3.1
S+CPH	5.8	7.6	4.6	6.0	4.6	4.6	3.0	4.1
S+CP	4.7	5.5	2.6	4.3	2.4	3.9	2.5	2.9
S+SD	4.2	7.8	3.3	5.1	3.5	2.5	2.4	2.8
CRH+CPH	4.0	2.3	2.8	3.0	2.3	2.9	2.9	2.7
CRH+CP	1.8	2.0	2.1	2.0	1.2	2.3	2.4	2.0
CRH+SD	2.6	2.1	1.5	2.1	2.2	2.0	1.7	1.9
CPH+CP	2.6	2.3	5.6	3.5	3.1	2.4	3.0	2.8
CPH+SD	3.1	2.8	2.6	2.8	4.0	3.0	2.4	3.2
CP+SD	2.1	2.1	1.7	2.0	2.2	2.1	1.4	1.9
Mean	3.5	4.1	3.1		2.9	3.1	2.5	
LSD (P≤0.05);	Media = 0.7			0.7				
	Poly bag size= 0.3			0.3				
	Media*Poly bag size= 1.2			1.3				

4.3.7 Mean leaf area (cm^2) of cocoa seedlings in different growth media, different poly bag sizes and their interaction at three and six months after sowing

Table 12 shows data on the leaf area of the cocoa seedlings in the growing media, polybag size and their interactions.

Media effect: The type of potting media significantly affected the leaf area of the cocoa seedlings. The leaf area of the cocoa seedlings grown in S+CPH produced the highest leaf area of 181.8 cm^2. This was significantly higher than all the other growth media excluding S. There was however no significant difference between S+CRH, S+CP, S+SD and CPH+CP. The lowest leaf area (58.8 cm^2) was recorded in SD (Table 12).

Poly bag effect: The size of poly bag affected the mean leaf area of cocoa seedlings at six months. The highest mean leaf area was recorded in the 17.3 cm x 23.3 cm polybag size and this was significantly ($p<0.05$) higher than the 10.0 cm x 35.0 cm polybag size. The 12.5 cm x 18.5 cm polybag size recorded the lowest mean leaf area (Table 12).

Interactive effect: Significant ($p<0.05$) interaction was observed between the plant media and the polybag sizes. The highest leaf area of 268.7 cm^2 was recorded by S+CPH in 17.3 cm x 23.3 cm poly bag size and this was significantly ($p<0.05$) higher than all the other media except S which recorded a leaf area of 242.9 cm^2. The leaf area of cocoa seedlings that grew in S in 17.3 cm x 23.3 cm poly bag was also significantly larger than those that grew CRH+CPH in 17.3 cm x 23.3 cm poly bag size. The lowest leaf area was recorded by CRH+CPH in 12.5 cm x 18.5 cm polybag size and this was not significantly different from CRH+CP and SD (Table 12).

Table 12: Mean leaf area (cm^2) of cocoa seedlings in different growth media, different poly bag sizes and their interactions

	3 months				6 months			
Media	Poly bag size			Mean	Poly bag size			Mean
	12.5x18.5	17.3x23.3	10.0x35.0		12.5x18.5	17.3x23.3	10.0x35.0	
S	60.8	63.3	97.6	73.9	142.6	242.9	125.3	170.3
CRH	97.4	54.4	61.7	71.2	105.2	139.1	131.4	125.2
CPH	122.0	80.5	96.2	99.6	112.1	110.8	109.8	110.9
CP	52.0	32.3	50.9	45.1	68.1	60.1	131.0	86.4
SD	45.1	48.7	43.9	45.9	62.5	54.4	59.6	58.8
S+CRH	77.0	102.7	109.3	96.3	101.3	187.2	114.8	134.4
S+CPH	59.1	101.0	93.3	84.5	122.7	268.7	154.1	181.8
S+CP	54.7	60.0	72.6	62.4	116.9	125.1	150.3	130.8
S+SD	61.4	56.5	56.4	58.1	152.3	169.7	125.6	149.2
CRH+CPH	107.4	83.4	161.2	117.4	48.9	182.8	144.3	125.3
CRH+CP	47.9	49.1	51.7	49.6	52.1	102.6	101.2	85.3
CRH+SD	48.3	48.6	55.3	50.7	56.0	114.2	99.9	90.1
CPH+CP	102.2	100.6	85.4	96.1	103.4	131.7	166.1	133.7
CPH+SD	130.7	90.2	107.1	109.3	117.8	97.2	144.9	119.7
CP+SD	49.3	60.8	49.7	53.3	85.2	104.4	88.1	92.2
Mean	75.1	68.1	79.5		96.4	139.3	123.2	
LSD (P≤0.05);		Media =7.5		10.7				
	Poly bag size= 5.1			4.5				
	Media*Poly bag size= 17.8			17.6				

4.3.8 Mean root length (cm) of cocoa seedlings in different growth media, different poly bag sizes and their interaction at three and six months after sowing

Significant differences were observed in the effects of growth media, polybag size and their interactions on the mean root length (cm) of cocoa seedlings as reported in Table 13.

Media effect: The type of potting media significantly affected the mean root length of the cocoa seedlings. The growing media S+CP, CPH+CP and CP resulted in significantly ($p<0.05$) higher root length of cocoa seedlings than S+CPH, S and S+CRH. The longest root length was observed in S+CP, this was significantly higher than S+CPH and S+CRH and the root length of S+CPH was also significantly higher than S+CRH. The root length of CPH+SD was the lowest (17.5 cm) and this was not significantly different from SD, CPH and CRH (Table 12).

Poly bag effect: The size of poly bag significantly affected the root length of cocoa seedlings. The 10.0 cm x 35.0 cm polybag size produced significantly ($p<0.05$) longer root length than the 17.3 cm x 23.3 cm and 12.5 cm x 18.5 cm poly bag sizes. The root length of seedlings in the 17.3 cm x 23.3 cm poly bag size was also significantly ($p<0.05$) higher than those in 12.5 cm x 18.5 cm polybag size (Table 12).

Interactive effect: Significant ($p<0.05$) interaction was observed between the plant media and the polybag sizes. The seedlings grown in S+CRH and the 10.0 cm x 35.0 cm poly bag size produced the longest root length (38.8 cm) and this was not significantly ($p<0.05$) different from S+CPH and CP in 10.0 cm x 35.0 cm poly bag size. The interaction between S, S+SD, CPH+CP, CRH+SD, CP+SD and the 10.0 cm x 35.0 cm poly bag size was the same and these were significantly different from the interaction between CRH, CPH, SD, CPH+SD and the poly bag size 10.0 cm x 35.0 cm. The shortest root lengths were observed in the interaction between S+SD and SD and the 12.5 cm x 18.5 cm poly bag size (Table 12).

Table 12: Mean root length (cm) of cocoa seedlings in different plant media, different poly bag sizes and their interactions

	3 months				6 months			
Media	Poly bag size			Mean	Poly bag size			Mean
	12.5 x18.5	17.3 x23.3	10.0 x35.0		12.5x18.5	17.3x23.3	10.0 x35.0	
S	14.5	23.6	16.5	18.2	16.4	20.9	35.1	24.1
CRH	17.8	18.1	28.4	21.5	14.5	18.3	24.8	19.2
CPH	12.3	20.5	20.9	17.9	15.0	18.2	24.9	19.3
CP	14.4	17.1	31.3	21.0	20.9	26.1	37.1	28.0
SD	15.0	16.6	24.1	18.6	14.2	13.6	30.0	19.3
S+CRH	18.5	19.2	27.8	21.8	13.8	15.4	38.8	22.7
S+CPH	12.6	17.2	23.0	17.6	21.3	16.5	37.7	25.2
S+CP	17.6	22.6	28.3	22.9	13.2	19.5	24.9	29.2
S+SD	19.1	23.9	25.1	22.7	10.1	13.3	32.0	18.4
CRH+CPH	12.1	19.3	20.8	17.4	15.6	19.9	30.0	21.8
CRH+CP	22.0	20.2	14.4	18.9	19.2	20.8	27.7	22.6
CRH+SD	16.5	21.7	27.9	22.0	14.4	23.1	33.0	23.5
CPH+CP	11.5	15.7	13.6	13.6	25.4	27.1	33.5	28.7
CPH+SD	11.8	14.9	28.3	18.3	10.9	15.7	25.8	17.5
CP+SD	24.6	21.2	20.2	22.0	15.3	16.0	34.5	22.0
Mean	16.2	18.8	23.9		16.0	19.0	31.3	
LSD (P≤0.05);		Media = 2.2		2.2				
		Poly bag size= 1.0		1.0				
		Media*Poly bag size= 3.8		3.6				

4.3.9 Mean relative growth rate of cocoa seedlings in different growth media, different poly bag sizes and their interaction at three and six months after sowing

Data on the mean relative growth rate of cocoa seedlings in the different growth media, polybag size and their interactions are presented in Table 13.

Media effect: The type of potting media significantly ($p<0.05$) affected the relative growth rate of the cocoa seedlings between the 3rd and 6th months. Plants in the growth media CPH+CP recorded a maximum relative growth rate of 0.4976 and this was significantly ($p<0.05$) different from those grown in soil only which recorded a relative growth rate of 0.4035 (Table 13).

Poly bag effect: The size of poly bag significantly affected the relative growth rate of cocoa seedlings. The 17.3 cm x 23.3 cm poly bag size produced significantly ($p<0.05$) higher relative growth rate than the 10 cm x 35 cm and 12.5 cm x 18.5 cm poly bag sizes. The relative growth rate recorded in 17.3 cm x 23.3 cm was 0.4063 as compared to the 0.3160 recorded in the 10 cm x 35 cm poly bag size (Table 13).

Interactive effect: Significant ($p<0.05$) interaction was observed between the plant media and the polybag sizes. The growth media, CPH+CP and 17.3 cm x 23.3 cm poly bag size recorded the highest relative growth rate of 0.6326 and this was not significantly different ($p<0.05$) from CRH+CPH, S+CPH and CRH+CP in 17.3 cm x 23.3 cm poly bag sizes. The lowest relative growth rate of 0.0575 was recorded by potting media, CPH in the 12.5 cm x 18.5 cm poly bag size. The order of mean relative growth rate decreased as follows: CRH+CPH>SD>CRH+SD>CPH>CRH+CP (Table 13).

Table 13: Mean relative growth rate of cocoa seedlings in different plant media, different poly bag sizes and their interaction on cocoa seedlings

RELATIVE GROWTH RATE OF COCOA SEEDLINGS IN DIFFERENT MEDIA AND POLYBAG SIZES

Media	Poly bag size			MEAN
	10cmx35cm	12.5cmx18.5cm	17.3x23.3cm	
S	0.3	0.4	0.5	0.4
CRH	0.3	0.3	0.5	0.4
CPH	0.2	0.1	0.2	0.1
CP	0.5	0.2	0.2	0.3
SD	0.3	0.2	0.1	0.1
S+CRH	0.3	0.3	0.5	0.4
S+CPH	0.4	0.3	0.6	0.4
S+CP	0.4	0.3	0.5	0.4
S+SD	0.4	0.5	0.4	0.4
CRH+CPH	0.5	0.2	0.6	0.4
CRH+CP	0.1	0.01	0.6	0.2
CRH+SD	0.1	0.1	0.4	0.2
CPH+CP	0.4	0.4	0.6	0.5
CPH+SD	0.3	0.5	0.4	0.4
CP+SD	0.2	0.5	0.3	0.3
Mean	0.3	0.3	0.4	

LSD (P≤0.05); Media = 0.09
Poly bag size= 0.04
Media*Poly bag size= o.16

4.3.10 Mean leaf weight ratio of cocoa seedlings in different growth media, different poly bag sizes and their interaction at three and six months after sowing

Data on the mean leaf weight ratio of cocoa seedlings in the different growth media, polybag size and their interactions are presented in Table 14.

Media effect : The type of potting media significantly ($p<0.05$) affected the leaf weight ratio of cocoa seedlings at three and six months after sowing. At three month after sowing, the potting media S+CPH recorded the highest mean leaf weight ratio of 0.5 and this was significantly($p<0.05$) different from all the other treatments. At the sixth month, S+CPH again recorded the highest mean leaf weight ratio of 0.6 and this was significantly higher than S and S+SD. However, no significant difference was observed among S+CPH, S+CRH and S+CP. The lowest mean leaf weight ratio (0.3) was recorded in SD and CP+SD (Table 14).

Poly bag effect: The leaf weight ratio was not significantly ($p<0.05$) in the 10 cm x 35 cm and the 17.3 cm x 23.3 cm. However, seedlings grown in 12.5 cm x 18.5 cm poly bag size produced the lowest mean leaf weight ratio (Table 14).

Interactive effect: Significant ($p<0.05$) interaction was observed between the growth media and the polybag size. Growth media, S+CPH and poly bag size 17.3 cm x 23.3 cm recorded the highest mean leaf weight ratio of 0.6 and this was not significantly ($p<0.05$) different from S+CRH, S+CP and CPH+CP in 17.3 cm x 23.3 cm poly bag sizes. The lowest mean leaf ratio (0.2) was recorded in CP and CRH+SD in the 12.5 cm x 23.3 cm poly bag. In general, S+CPH, S+CRH and S+CP were consistently significantly different from S and S+SD (Table 14).

Table 14: Mean leaf weight ratio of cocoa seedlings in different plant media, different poly bag sizes and their interactions

	3 months				6 months			
Media	Poly bag size (cm)			Mean	Poly bag size (cm)			Mean
	12.5x18.5	17.3x23.3	10x35		12.5x18.5	17.3x23.3	10x35	
S	0.4	0.4	0.3	0.4	0.5	0.5	0.6	0.5
CRH	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.4
CPH	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.5
CP	0.3	0.4	0.3	0.3	0.2	0.3	0.4	0.3
SD	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
S+CRH	0.4	0.4	0.5	0.4	0.5	0.6	0.6	0.6
S+CPH	0.5	0.6	0.6	0.6	0.5	0.6	0.6	0.6
S+CP	0.3	0.3	0.3	0.3	0.5	0.6	0.5	0.5
S+SD	0.3	0.4	0.4	0.3	0.4	0.5	0.5	0.5
CRH+CPH	0.3	0.4	0.4	0.4	0.3	0.5	0.4	0.4
CRH+CP	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
CRH+SD	0.3	0.4	0.2	0.3	0.2	0.3	0.3	0.3
CPH+CP	0.3	0.5	0.4	0.4	0.3	0.4	0.6	0.4
CPH+SD	0.2	0.4	0.4	0.4	0.3	0.4	0.4	0.3
CP+SD	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Mean	0.3	0.4	0.4		0.4	0.4	0.4	

LSD (P≤0.05); Media = 0.050.04
Poly bag size= 0.023 0.012
Media*Poly bag size= 0.09 0.08

4.3.11 Effects of growing media, poly bag size and their interactive effect on the mean leaf area ratio of cocoa seedlings at three and six month

Significant differences were observed in the planting media, polybag size and their interactions on the leaf area ratio of cocoa seedlings as shown in Table 15.

Media effect: The type of potting media significantly affected the leaf area ratio of cocoa seedlings at 3 months and 6 months after sowing. At 3 and 6 months, the planting media, S+CPH recorded the highest leaf area ratio of 11.9 and 26.8 respectively and was significantly ($p<0.05$) different from all other treatments (Table 14). The order of mean leaf area ratio decreased as follows; S+CPH>S+CRH>S+CP>S>CRH+CPH>CRH+CP>S+SD>CRH>CPH. The lowest leaf area ratio (12.2) was recorded by SD and this was not significantly different ($p<0.05$) from CP+SD (Table 15).

Poly bag effect: At 6 months, leaf area ratio was significantly affected ($p<0.05$) by the different poly bag sizes.The 17.3 cm x 23.3 cm polybag size produced significantly ($p<0.05$) higher leaf area ratio than the 10 cm x 35 cm and 12.5 cm x 18.5 cm poly bag sizes (Table 15).

Interactive effect: Significant ($p<0.05$) interaction was observed between the plant media and the polybag sizes. The potting media, S+CPH in 17.3 cm x 23.3 cm poly bag size recorded the highest leaf area ratio of 27.9 and the lowest leaf area ratio of 10.5 was recorded in media, SD in 12.5 cm x 18.5 cm poly bag size (Table 15). In general, the seedlings grown in the soil based media mixes produced higher RGR, LWR and LAR than those grown in the sawdust and its mixtures (Table 15).

Table 15: Mean leaf area ratio of cocoa seedlings in different plant media, different poly bag sizes and their interactions at three and six month after sowing

	3 months				6 months			
Media	Poly bag size (cm)			Mean	Poly bag size (cm)			Mean
	12.5x18.5	17.3x23.3	10x35		12.5x18.5	17.3x 23.3	10 x 35	
S	7.5	9.7	8.3	8.5	19.8	21.3	20.6	20.6
CRH	6.5	7.6	7.1	7.1	17.1	19.9	19.3	18.8
CPH	7.4	8.5	8.5	8.2	17.2	19.1	17.4	17.9
CP	5.4	6.7	6.9	7.3	13.2	17.4	16.2	15.6
SD	5.2	6.5	6.3	6.0	10.5	13.2	12.9	12.2
S+CRH	8.8	10.1	10.1	9.7	22.7	26.0	23.4	24.0
S+CPH	8.6	10.8	12.5	11.9	25.5	27.9	26.8	26.8
S+CP	8.8	10.0	9.1	9.3	21.7	20.7	21.5	21.3
S+SD	6.5	10.0	9.4	8.6	17.6	21.0	20.6	19.1
CRH+CPH	7.3	8.4	8.6	8.1	19.6	20.3	19.6	19.8
CRH+CP	6.1	7.9	7.3	6.5	12.2	13.9	14.9	13.6
CRH+SD	5.6	6.5	6.1	6.1	11.2	17.9	14.1	14.4
CPH+CP	7.6	9.5	8.7	8.6	18.9	20.4	19.8	19.7
CPH+SD	6.2	7.6	7.5	7.1	13.9	17.4	15.0	15.4
CP+SD	5.8	8.1	7.2	7.0	11.2	13.0	12.6	12.2
Mean	7.4	8.2	8.0		16.8	19.4	18.0	
LSD (P≤0.05);		Media = 0.72				1.0		
		Poly bag size= 0.29				0.5		
		Media*Poly bag size= 1.15				1.7		

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of media on the growth of cocoa seedlings

The soil based mixes produced the highest mean leaf weight, stem weight, shoot weight and leaf area of cocoa seedlings compared to soil only. The increase in these parameters is an indication of higher growth. Growth is measured as an increase in length, width, volume, fresh and dry weight of a plant. The results agree with Ogbodo (2009) who reported that plants of greater heights with larger leaf area intercept more sunlight faster which is required for photosynthesis to take place to promote growth than plants with smaller leaf area. The soil based mixes did not only have significant influence on the growth rate of the seedlings but also produced seedlings with a higher shoot and root dry weights. This may be due to the fact that the soil mixes had soil environmental conditions such as ideal pH and electrical conductivity that supported the growth and development of the seedlings.

The addition of rice husk, cocoa pod husk, cocopeat and sawdust to the soil had significant influence on the physical and chemical properties of the top soil (Shamshuddin *et al.*, 2004). In the present study the results show that seedlings grown in the soil and carbonated rice husk and/or cocoa pod husk media mix recorded the highest plant height, girth, leaf, leaf area, shoot dry weight, root dry weight and total dry matter weight as compared to the cocoa seedlings grown in soil only and soilless media. The cause of the difference in growth of the seedlings may be due to the differences in the properties of the media. Some soil properties that enhance plant growth are bulk density, water holding capacity, cation exchange capacity (CEC), porosity,

organic matter content, pH, total phosphorous , soluble Fe, exchangeable al and exchangeable K and Ca. (FFTC. 2008).

This is in agreement with Bot and Benites (2005), who reported that the addition of organic matter increases CEC and soil pH and decreases soil bulk density. The rice husk significantly reduced the bulk density of the soil due to its lighter weight. This is in agreement with the findings of Chan *et al.*, (2007) who showed that application of biochar improved soil properties such as decreasing bulk density, decreasing soil strength and increasing soil water retention. It also agrees with the findings of Griffin (2008), who reported that density of soil decreased upon application of organic matter to the soil.

In the soil and carbonated rice husk media mix, the rice husk had some influence on the water holding capacity of the soil. This agrees with Chan *et al.*, (2007) who reported that the addition of organic wastes such as rice husk to soils increases soil aggregation and soil water retention which in turn increases the water holding capacity of the soil. Thus, the addition of rice husk or cocoa pod husk to the soil in the media mix decreased the bulk density and increased the organic matter in the media which binds the soil particles together to retain water for better plant growth. The application of organic wastes improves soil structure and soil fertility which provides favourable conditions for plant growth and development. In the present work, the soil based media mix produced seedlings with the longer root length and higher root dry weight than those that grew in soil only or soilless media. This can be attributed to the fact that the organic residues that were added to the soil reduced the bulk density of the soil which loosened the soil and thereby increasing the air space of the media mix. This is in agreement with the observation of Graffin (2008) that organic matter such as rice hulls loosens the soil and increases the amount of pore space to support root growth. Thus, the decrease in density leads to an increase in air

space of the media and subsequently creating adequate pore space for roots to move through the soil to establish an effective feeding mechanism to support the seedling growth and development. The increase in soil porosity and soil water retention enhances the absorption of mineral nutrients, water and air by roots for their development (Ogbodo, 2009). Carbonated rice husk acts as soil conditioner by supplying and retaining nutrients which in turn improves the physical and chemical properties of the soil (Glaser *et al.*, 2002; Lehman and Glaser 2003; Lehmann and Rondon, 2005).

In the present study, the number of leaves, total shoot weight and total dry matter weight of soil and cocoa pod husk media mix were higher compared to the other growth media. The observation in this study is similar to that of Adejobi *et al*., (2013) who reported that the addition of organic materials such as cocoa pod husk and kola pod husk as nutrient sources produced a positive effect on cocoa seedlings. Ayanlaja (2002), Adejobi *et al.* (2011) and Moyin-Jesu (2008) reported that the use of organic residues helps in increasing and balancing soil nutrients with consequential increase in crop performance.

Thus adding cocoa pod husk to the soil will improve soil structure which will provide favourable environment for better plant growth. This is in agreement with El Sharkawi *et al.*, (2006), who reported that the application of organic matter alters the physical properties of the soil such as increasing soil aggregation, aeration and water holding capacity.

Soil and cocopeat media mix recorded a significant increase in the root and stem dry weight of cocoa seedlings. It was observed from the study that, plants grown in cocopeat and its mixes developed good root system which supported stem growth. The results of many experiments had revealed that cocopeat used alone or as a component of soil medium enhances root development due to its oxygenation properties (Treder and Nowak, 2002). This is in consistent with the

findings of Howard (1975) who reported that oxygen is needed to stimulate root development of plants in both soilless and soil based medium. The significantly higher root dry weight recorded by soil and cocopeat media mix may have been due to cocopeat having good physical properties such as high water content, low shrinkage, low bulk density and slow biodegradation (Evans *et al.*, 1996; Prasad, 1997). The results showed that cocopeat significantly increased the water holding capacity of the soil and decreased its bulk density. The cocopeat has a lighter weight and low bulk density which decreased soil bulk density and soil strength, thereby improving on soil porosity and at the same time enhancing root development (De Kreij and Leeuven, 2001: Treder and Nowak, 2002). The amount of total porosity of a rooting media is inversely proportional to the bulk density (Richard, 2006).

The incorporation of organic residues into soils significantly improves some properties of the soil namely: decreasing soil bulk density, soil strength as well as exchangeable aluminium and soluble iron and increasing soil pH, soil organic matter, total phosphorous, exchangeable potassium and calcium as well as the cation exchange capacity (Goodman and Ennos, 1999).

5.2 The effect of the different polybag sizes on the growth of the cocoa seedlings

Results from the study showed that polybag size had significant influence on root length development by the cocoa seedlings. Root length of seedlings decreased drastically with reducing polybag sizes. Research has shown that plant height, number of leaves, root and shoot dry weight and whole plant dry weights were increases by poly bag size. Annapurna *et al*., (2004) has reported similar results that larger containers produce better growth of Santalium album seedlings. This may have resulted from the large volume of growth media which increased nutrient availability as well as nutrient uptake in the larger poly bag size for the

development of root and primary shoots. A well-developed root system contributes to better uptake of nutrients and water leading to increased formation of proteins, amides, hormones and other organic substances (Singh, 2003).

In the present investigation, the growth parameters namely plant height, plant girth, number of leaves, shoot dry weight and root dry weight was significantly higher in 17.3 cm x 23.3 cm and 10 cm x 35 cm. These sizes provided greater volume of plant media with more nutrients which enhanced vigorous growth of the cocoa seedlings. The increase in plant height, number of leaves and leaf area also improved the rate of photosynthesis which consequently contributed to better growth and this confirms the report of Ouma (2005), who reported that plant height and height of canopy increased with increased container size. Root length was highest in the large sized polybags but differed significantly from the roots of the small sized poly bags only. Studies have shown that smaller poly bag seedlings develop deformed or J- shaped tap root (Cedamon et al., 2005). The seedlings that were raised in the small poly bags had limited space for root growth and this consequently affected general plant growth. Audet and Charest (2010) also reported similar findings in marigold. This may be due to limited space in the smaller poly bags which decreases rooting volume and restricts root growth and this consequently results in reduced plant biomass. The differences in the root length in the various polythene bag sizes may be due to differences in leaf growth and supply of photosynthate to the roots (Adu-Berko *et al*., 2011). It is also reported that better uptake of water and nutrients which enhanced vigorous plant growth was observed in seedlings raised in large bags (Abugre *et al*., 2011). The larger poly bags produce the best performance in plant growth and root length and weight was influenced by poly bag size with the 10cm x 35 cm outperforming the others. Thus, seedlings raised in the 10 cm x 35 cm are more likely to survive on the field than the 12.5 cm x 18.5 cm poly bag size.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

From the experiment conducted, the soil based media mixes significantly supported better growth of cocoa seedlings than the sawdust media mixes. The soil and cocoa pod husk media mix and soil and rice husk media mix were observed to be the best. However, the soil and cocopeat media mix also resulted in better root development as it produced the longest root length and root weight.

The sawdust media only and its mixtures in general did not support adequate growth of cocoa seedlings, however when added to soil, it supported the growth and development of the cocoa seedlings.

For the soilless media mix, the cocoa pod husk and cocopeat media mix and the cocoa pod husk and rice husk media mix performed better than the other treatments.

From the results, poly bag size had significant effect on the growth of cocoa seedlings at the nursery. The 17.3 cm x 23.3 cm and 10 cm x 35 cm poly bag sizes were observed to be the best that produced seedlings with the highest plant height, plant girth, root length and dry weights of the stem, leaves and roots. However, the best and most suitable poly bag size is the 10 cm x 35 cm as it produced the longest root length and highest root weight. Additionally, there was no root coiling and root penetration through the bottom of the poly bag in the 10 cm x 35 cm poly bag size. Moreover, a greater number of seedlings can be transported at a time compared to the

17.3 cm x 23.3 cm poly bag size which is much bigger and will occupy much more space compared to the 10 cm x 35 cm poly bag size.

6.2 RECOMMENDATIONS

1. Based on the performance of the cocoa seedlings at the nursery in this experiment, nursery operators could add cocoa pod husk and/or carbonated rice husk to the top soil for the raising of cocoa seedlings. However, considering that cocoa pod husk is more readily available on cocoa farms, the soil and cocoa pod husk mix is recommended as a growth media for raising cocoa seedlings at the nursery.
2. For the production of cocoa seedlings, the 10 cm x 35 cm polybag size may be used instead of the 12.5 cm x 18.5 cm poly bag size that is currently in use.

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APPENDICES

Appendix 1. Seedlings produce from soil based mixtures at three months

Plate 2. Seedlings produce from soil based mixtures at three months

Appendix 2. Root development from seedlings grown in soil and coco peat mixture at three months

Plate 3. Root development from seedlings grown in soil and coco peat mixture at three months

Appendix 3. Root development from seedlings grown in coco peat at three months

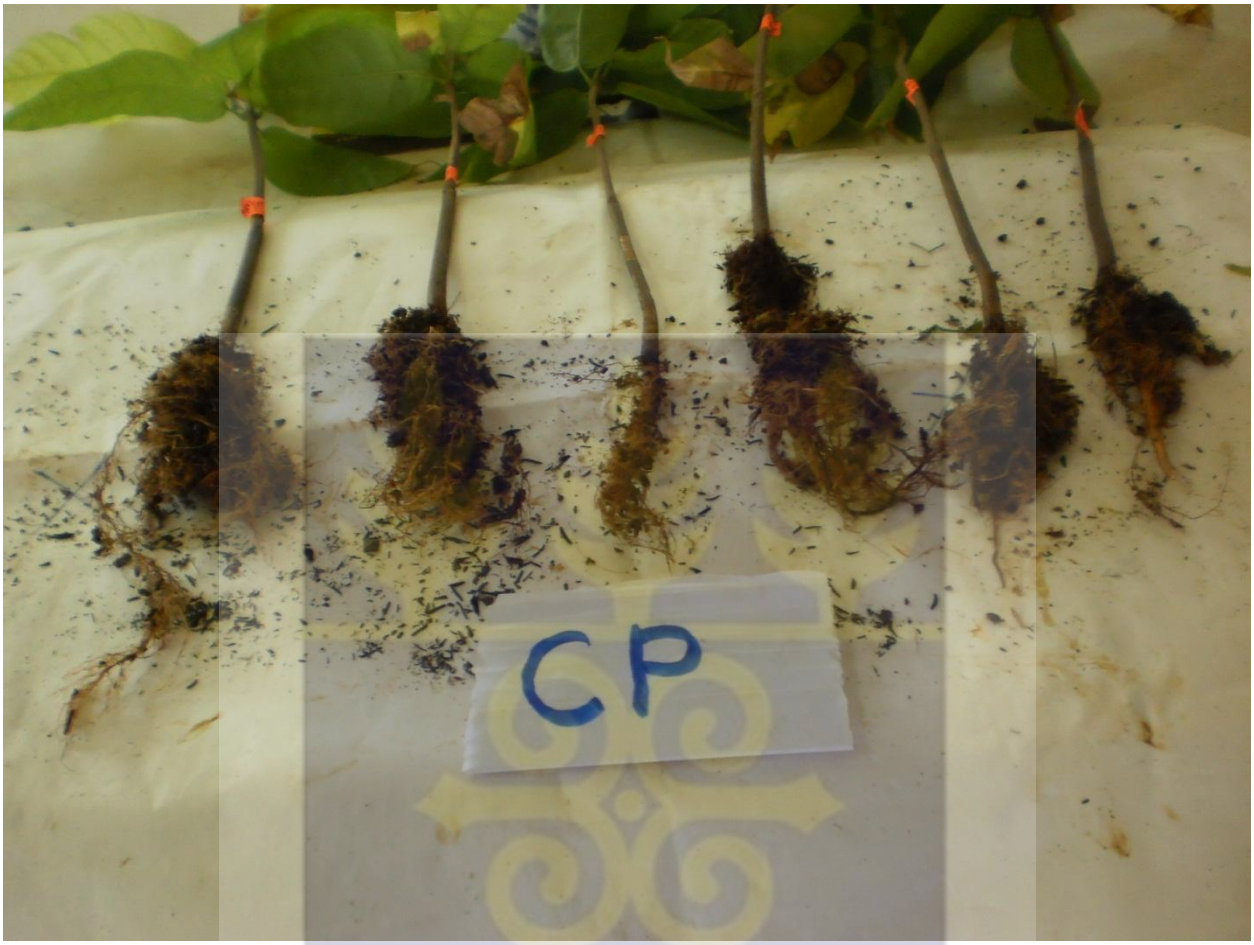

Plate 4. Root development from seedlings grown in coco peat at three months

Appendix 4. Root development from seedlings grown in soil at three months

Plate 5. Root development from seedlings grown in soil at three months

Appendix 5. Seedlings grown in soil + cocoa pod husk medium compared with soil only at three months

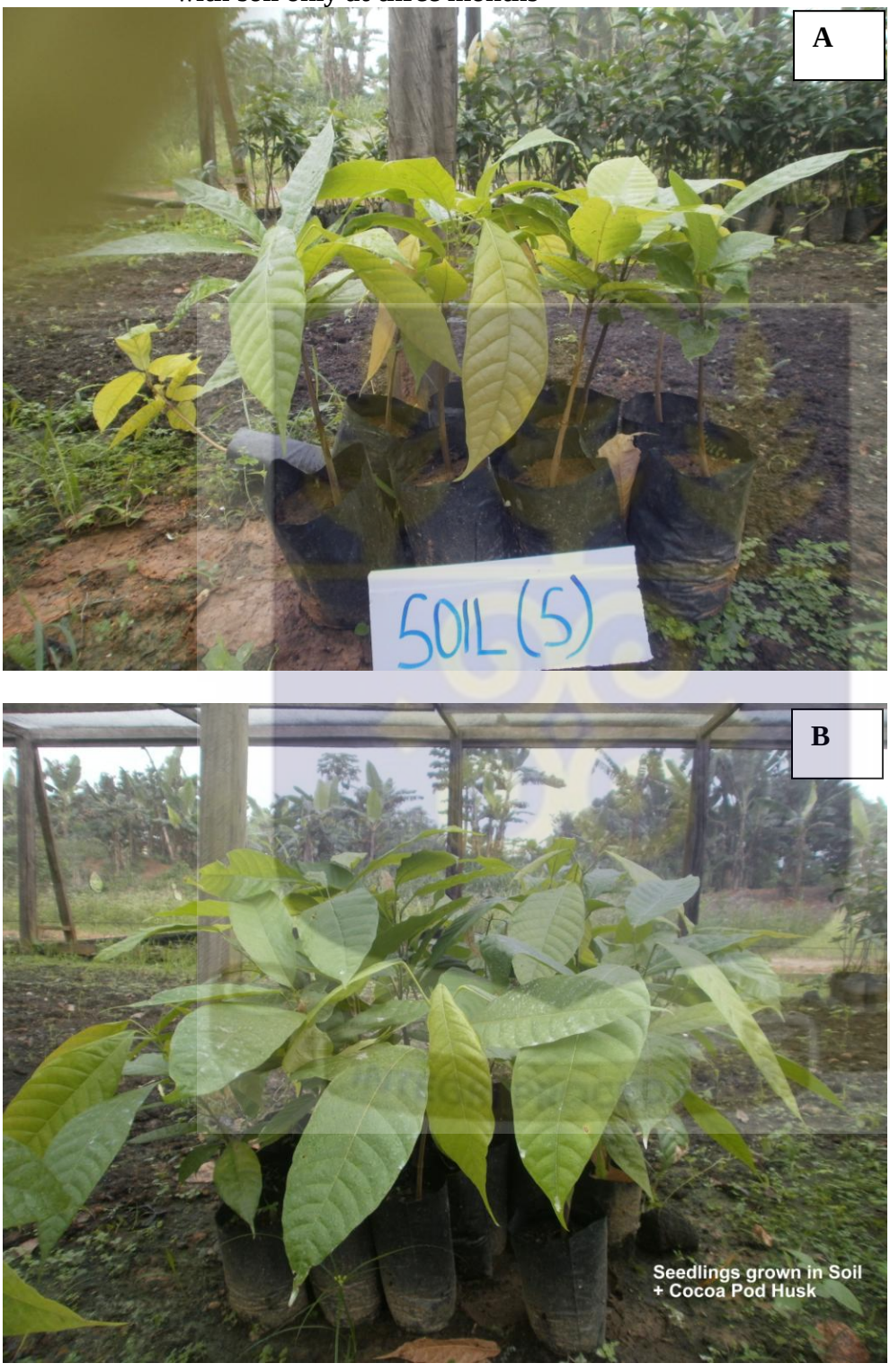

Plate 6. Seedlings grown in soil only (a) and soil + cocoa pod husk (b)

Appendix 6. Seedlings grown in carbonated rice husk + cocoa pod husk medium compared with cocoa pod husk + cocopeat at three months

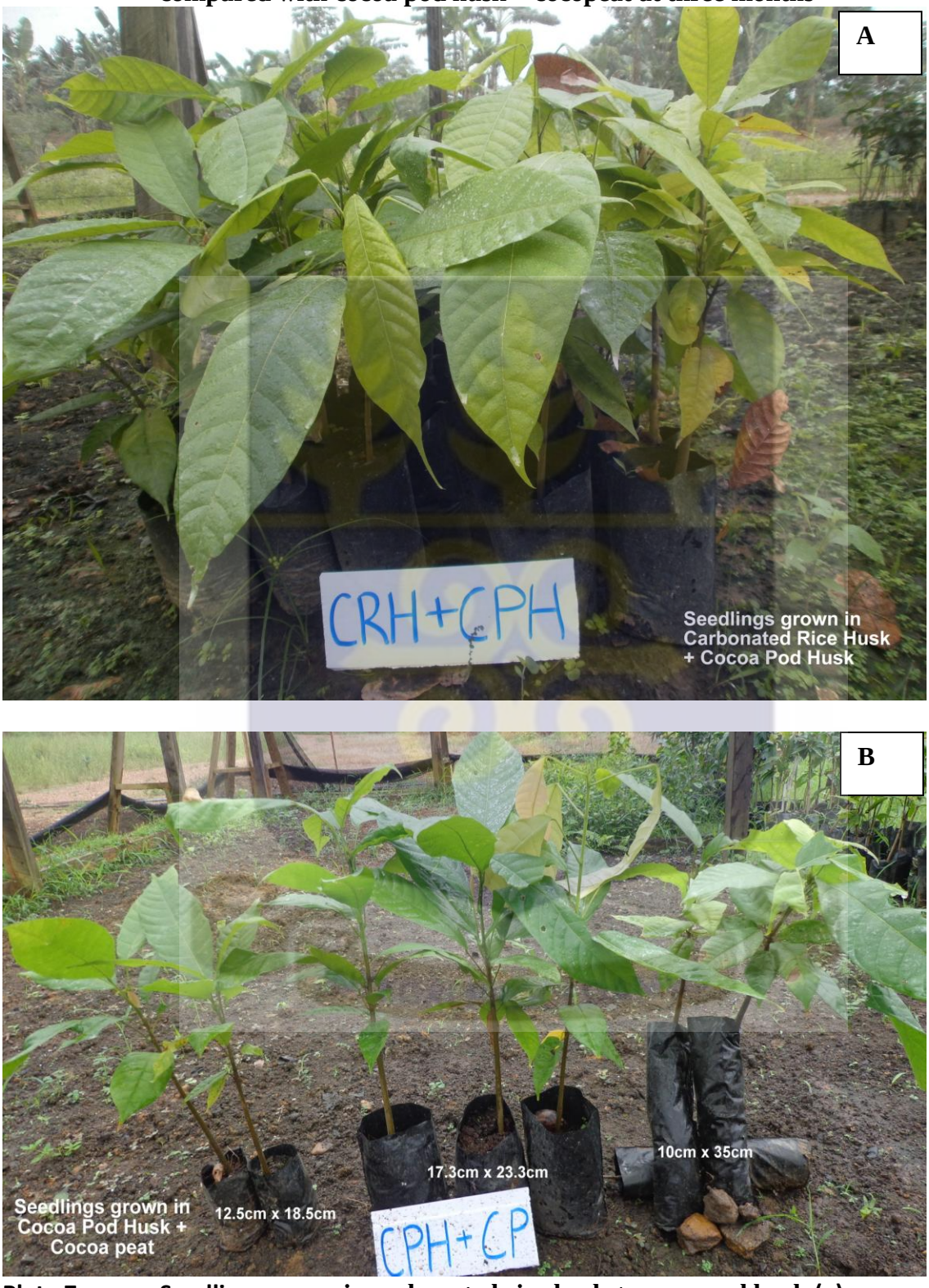

Plate 7. Seedlings grown in carbonated rice husk + cocoa pod husk (a) and cocoa pod husk + cocopeat (b)

Appendix 7. Seedlings grown in sawdust only at three months

Plate 8. Seedlings grown in saw dust only

Appendix 8. Analysis of variance for total dry matter yield of seedlings at three months

Variate: Total dry matter yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.0373	0.0186	0.14	
REP.MEDIA stratum					
MEDIA	14	303.9817	21.7130	160.59	<.001
Residual	28	3.7857	0.1352	0.36	
REP.MEDIA.POLYBAG stratum					
POLYBAG	2	31.2966	15.6483	41.70	<.001
MEDIA.POLYBAG	28	65.1930	2.3283	6.21	<.001
Residual	60	22.5138	0.3752		
Total		134 426.8081			

Appendix 9. Analysis of variance for leaf dry weight of seedlings at three months

Variate: Leaf dry weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.0350	0.0175	0.25	
REP.MEDIA stratum					
MEDIA	14	151.7497	10.8393	152.61	<.001
Residual	28	1.9887	0.0710	0.69	
REP.MEDIA.POLYBAG stratum					
POLYBAG	2	6.0534	3.0267	29.41	<.001
MEDIA.POLYBAG	28	33.1027	1.1822	11.49	<.001
Residual	60	6.1745	0.1029		
Total		134 199.1041			

Appendix 10. Analysis of variance for shoot root ratio of seedlings at three months

Variate: Shoot root ratio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.0110	0.0055	0.01	
REP.*Units* stratum					
MEDIA	14	305.2883	21.8063	41.43	<.001
POLYBAG	2	24.7037	12.3518	23.46	<.001
MEDIA.POLYBAG	28	114.8007	4.1000	7.79	<.001
Residual	88	46.3231	0.5264		
Total	134	491.1267			