Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Annals of Biological Research, 2012, 3 (2):755-772
(http://scholarsresearchlibrary.com/archive.html)

Scholars Research Library
ISSN 0976-1233
CODEN (USA): ABRNBW

Growth analysis of cashew seedlings as affected by nut-size in the nursery

L. A. Hammed

Department of Horticulture, College of Plant Science and Crop Production (COLPLANT). Federal University of Agriculture Abeokuta (FUNAAB), P. M. B. 2240, Ogun State. Nigeria.

ABSTRACT

The use of growth analysis technique in elucidating the physiological factors affecting growth of cashew is limited, which has hitherto created a serious gap in the cultivation of the crop. Three nut-sizes (jumbo ($\geq$ 16 g), medium (4 – 8 g) and madras ($\leq$ 2 g)) were subjected to detailed growth analysis technique in a non-shaded nursery in Nigeria. The experiment was in completely randomized design with 4 replicates. Two seedlings were randomly sampled per nut-size per replicate for destructive analysis at 1 monthly interval for the 12-month study period. Total leaf area and dry matter per plant were taken, from which leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR) and relative growth rate (RGR) were computed. Results show that leaf area and dry matter of cashew seedlings were linearly related with r^2 = 0.9. At 1 Month After Sowing (MAS), seedlings raised from jumbo nut-size had 62.4% and 375% dry matter advantages over seedlings raised from medium and madras nut-sizes respectively. These variations reduced to 1.7% and 26.9% at 12 MAS. Total leaf area followed a similar pattern as the dry matter yield. The LAI of seedlings raised from jumbo nut-size was 91.7% and 66.7% higher than the LAI values of seedlings raised from medium and madras nut-sizes respectively. While mean NAR of cashew seedlings reduces from2.8 g/m^2/day at 1 MAS to 1.02 g/m^2/day at 12 MAS, the mean CGR increases, reaching peak values at 3, 7, 10 and 12 MAS. Cashew seedlings raised from madras nut-size had highest NAR of 3.88 g/m^2/day followed by that of medium and jumbo nut-sizes with 2.9 g/m^2/day and 1.66 g/m^2/day respectively. The higher size of jumbo nut of cashew is translated into improved dry matter yield with time compared to cashew nuts of lighter sizes.

Keywords: Cashew seedlings, Total leaf area, Dry matter, Growth rate measurement.

INTRODUCTION

Cashew (*Anacardium occidentale*, L.) belongs to the family *Anacardiaceae*, which is known for having resinous bark and often, caustic oils in leaves, barks and fruits. It consists of 73 genera and 600 species in tropical and subtropical regions (Nakasone and Paull, 1998). Out of about 8 species of *Anacardium* native to tropical America, cashew (*occidentale*) is the most economic (Ohler, 1979).

In Nigeria, commercial plantations of cashew, which started in 1950 (Togun, 1977), have been established through seedlings raised in the nursery and transplanted into the field. Unfortunately, transplanting operations had always been accompanied with high mortality of the transplants, which necessitates continuous gapping-ups the following planting season(s). This had led to a conclusion that cashew does not transplant well into the field (Adenikinju *et al*., 1989; Opeke, 2005). Recent studies have shown that transplanting of cashew seedlings into the field had hitherto, been based on the measurements of morphological growth parameters of the seedlings (Ohler, 1979; Opeke, 2005) rather than the physiological growth rates whose measurements are based on leaf area and dry matter production over time (Adeyemi, 1999).

Besides, some scientists always relied on morphological growth measurements such as plant height, girth, number of leaves and leaf area to evaluate treatment effects and transplanting stage of tree crops like oil palm, coconut and cocoa (Ikuenobe *et al*., 1991; Adeyemi, 1993). In cashew, the size of nuts sown had been reported to have significant influence on the morphological growth performance of the seedlings in the nursery (Adebola, *et al*., 1999) and they therefore recommended the use of bigger nut sizes rather than smaller nut sizes for raising cashew seedlings for plantation establishment. Their findings were based on morphological growth measurements of the cashew seedlings rather than the physiological growth rates. These measurements are not as efficient as growth analysis in estimating the crop growth since they do not measure the dry matter changes over time and neither do they measure net growth rate of crops. Besides, Hammed (2008), found that the size of cashew nuts sown, do not only influence the morphological growth performance of seedlings, it also affects dry matter yield in favour of bigger nut size. Thus, understanding of the relationship between dry matter yield and leaf area of cashew seedlings with respect to nut size, will aid understanding of processes and forms within the seedling for the overall development of the crop.

Plant growth analysis had been identified as an explanatory, holistic and integrative approach to interpreting plant form and function. It involves the use of simple primary data such as weights, areas, volumes and content s of plant components to investigate processes within and involving the whole plant (Evans, 1972; Causton and Venus, 1981; Hunt, 1990). The empirical information on the physiological growth rate of seedlings had been used as a major factor determining the time of transplanting tree crops' seedlings into the field (Lucas, 1977). Lucas (1977) thus, reported that tree crops' seedlings are best transplanted into the field when the growth rate is maximum and environmental condition (especially, rainfall) is conducive. Goodall (1950) and Atanda (1971) reported that the growth rate of cacao seedlings was maximum between 5 and 6 months after sowing in the nursery. Thus, cacao seedlings are recommended for transplanting into the field within this period. Likewise, in oil palm, Lucas (1977) found out that the growth rate of oil palm seedlings reached peak at 11 months after sowing in the nursery. Thus, oil palm seedlings were recommended for transplanting into the field at the environmentally conducive time after the attainment of maximum growth rates.

Therefore, non-availability of information on growth rate analysis of cashew seedlings might have been responsible for reliance on morphological growth parameters as determinant factors for the time of transplanting the seedlings into the field. This had since been fraught with problems of seedling mortality after transplanting. The experiment was therefore set up to evaluate the effects of nut-size on growth rates of cashew seedlings in the nursery, using Leaf

Area Index (LAI), Leaf Area Ratio (LAR), Relative Growth Rate (RGR), Crop Growth Rate (CGR) and Net Assimilation Rate (NAR). Besides, the study aims at identifying the period of peak growth rates as a possible transplanting period of cashew seedlings into the field.

MATERIALS AND METHODS

The seedlings used for this study were raised from three different nut sizes of cashew at the nursery section of the Cocoa Research Institute of Nigeria (CRIN) headquarters, Ibadan, Southwestern Nigeria. These nuts included jumbo size ($\geq$ 16 g), medium (4 g – 8 g) and madras ($\leq$ 2 g) nut-sizes. The jumbo and madras nuts are exotic imported from Brazil and India respectively while medium nut-size is a proven local selection; all are established at the experimental stations of CRIN. The nuts were sown on their sides as recommended by CRIN (1971); Hammed and Adeyemi (2005) inside black polythene pots of 5 litres, filled with well-sieved, 5 kg forest top-soil, leaving a space of 5 cm to the brim, in order to allow for watering. The nuts were sown at seeding rate of one per pot. The polythene pots were evenly arranged on polythene sheet. This is to prevent the root system of the seedlings from growing out of the rhizosphere.

The experiment was laid out in Completely Randomized Design with four replications. The three nut-sizes constituted the treatments and 96 seedlings per treatment, giving a total of 288 potted seedlings of cashew used for the study, which was set up in an open environment as recommended by Adenikinju, *et al*., (1989).

Samples of the plants (seedlings) were taken at 28 days interval (Lucas, 1977) for the determination of leaf area and dry matter yield. Two seedlings were randomly sampled per treatment at each sampling period. The shoot was severed from the root at the shoot / root junction. The root was carefully immersed and rinsed inside water baths. The intact roots were air-dried on a laboratory bench.

The seedlings' organs, namely leaves, stems and roots were separately dried in an oven at 80^0 C until constant weights were obtained and the dry weights were taken. The growth rates of cashew seedlings were estimated from the data obtained from leaf area and dry weights of these seedlings using the "classical approach" of growth analysis (Blackman, 1919; Evans, 1972).

These include –

Leaf Area Index (LAI), defined by Watson (1952) as the leaf area of a plant divided by land area covered.

$$LAI = \frac{\text{Leaf area per plant } (m^2)}{\text{Land area per plant } (m^2)}$$

Relative Growth Rate (RGR) is the ratio of the increase in seedling's dry weight per time interval. Increase in seedling's dry weight per unit weight already present (Fisher, 1920). It is estimated from Hunt *et al*., (2002) software on classical approach of growth analysis and expressed in g/g/day.

Leaf Area Ratio (LAR), which was also defined as the ratio of leaf area to unit dry weight by Watson (1952) and estimated from Hunt *et al*., (2002).

Net Assimilation Rate (NAR) is an estimation of the seedling's dry weight accumulation per unit leaf area. It is an estimate of photosynthetic production and it expresses growth on the basis of leaf area (Gregory, 1926; Williams, 1946). It is computed from NAR = RGR/LAR ($g/m^2/day$). RGR and LAR computed from Hunt *et al*., (2002).

Crop Growth Rate (CGR) was defined as increase in plant dry weight per unit time. It is a measure of dry matter production and estimated from CGR = NAR x LAI ($g/m^2/day$) (Watson, 1958).

The data were subjected to analysis of variance procedures and means separated using standard error bars.

RESULTS

The relationship between changes in dry weight and total leaf area of cashew seedlings, in the nursery, is as presented in (Figure 1). The plotting of the leaf area against dry weight of cashew seedling is linear with regression equation:

$$Y = 0.0056x + 0.0476 \qquad R^2 = 0.93$$

Y = total leaf area, and x = plant dry weight

Dry weight production.

The changes in dry weight production during the successive sampling periods are as presented in Table 1 and Figure 2b. The seedlings raised from jumbo nut-size of cashew had highest amount of dry weight, which was, mostly, significantly different ($P < 0.05$) from that of seedlings raised from medium nut-size. However, dry weight of cashew seedlings raised from madras nut-size was significantly ($P < 0.05$) lower compared to dry weights of seedlings raised from jumbo and medium nut-sizes (Table 1). Between 1 and 12 Months After Sowing (MAS), the dry weights of cashew seedlings raised from jumbo nut-size are 62.4% and 21.5% higher than dry weights of cashew seedlings raised from medium nut-size, respectively. The differences are significant ($P < 0.05$), except at 3 and 4 MAS when the seedlings raised from medium nut-size had 6.7% and 17.9% lower dry weight production compared to seedlings raised from jumbo nut-size and the differences are not significant at 3 and 4 MAS at $P < 0.05$ (Table 1). However, cashew seedlings raised from madras nut-size had significantly ($P < 0.05$) lower dry weight production, to the tune of between 375.7% and 26.9% compared to cashew seedlings raised from jumbo nut-size and the differences are significant ($P < 0.05$) between 1 and 12 MAS, respectively. Comparing dry weight production between cashew seedlings raised from medium and madras nut-sizes, those from medium nut-size are higher and the percentage difference is between 192.9% and 33.3% at 1 and 11 MAS and the differences are significant at P 0.05. At 12 MAS, the margin of the difference reduced to 4.4% which is not significant at $P < 0.05$ (Table 1).

The mean dry weight yield (Figure 2) of cashew seedlings in the nursery progressively increased from 2.03 g/plant at 1 MAS to 50.28 g/plant at 12 MAS. However, there are sharp increases in dry weight yield at 3, 7, 11 and 12 MAS in the nursery. It is only at these respective stages that the increase in dry weight yield of cashew seedlings is significantly different ($P < 0.05$) from the immediate previous dry weight yield (Figure 2).

Total leaf area

Cashew seedlings raised from jumbo nut-size had highest value of total leaf area. This was closely followed by seedlings raised from medium nut-size, while the seedlings raised from madras nut-size had lowest value of total leaf area (Figure 3a). The differences were significant at $P < 0.05$. At the inception of sampling, the seedlings raised from jumbo nut-size, was 80.0% and 350.0% higher in total leaf area than the seedlings raised from medium and madras nut-sizes respectively. At final sampling period, the percentage differences had fallen to 1.97% and 42.1% in that order (Figure 3a).

The changes in mean total leaf area during the successive periods of sampling are as presented in (Figure 3b). The mean total leaf area increased with time reaching a peak of 401.98 cm^2 at 6 MAS and slightly reduced to 369.85 cm^2 at 7 MAS, in the nursery and the reduction did not make a significant difference ($P < 0.05$). The mean total leaf area value increased again, attaining a maximum value of 806.22 cm^2 at 11 MAS and another slight reduction 739.98 cm^2 at 12 MAS (Figure 3b). Cashew seedlings, in the nursery had highest values of mean total leaf area between 10 and 12 MAS. At these periods, the values of mean total leaf area were significantly different ($P < 0.05$) from the previous leaf area values (Figure 3b).

Leaf Area Index (LAI)

The LAI of cashew seedlings, in the nursery, was significantly affected by size of nuts sown (Figure 4a). The seedlings raised from jumbo nut- size consistently had higher values of LAI throughout the period of study. This was, in most cases, significantly different ($P < 0.05$) from the values of LAI of the seedlings raised from both medium and madras nut-sizes. Therefore, at the inception of sampling, LAI of cashew seedlings raised from jumbo nut-size was 91.7% and 666.7% higher than the LAI values of the seedlings raised from medium and madras nut-sizes respectively. The percentage difference, at final sampling reduced to 2.0% and 42.1% in that order (Figure 4a).

Meanwhile, the mean LAI of cashew seedlings in the nursery progressively increased with the age of the seedlings in the nursery. The values of LAI increased from 0.51 at 1 MAS to attain the maximum value of 7.9 at 11 MAS with slight declinations at 7 and 12 MAS. The reduction in LAI values of cashew seedlings at 7 and 12 MAS did not make significant difference ($P < 0.05$) compared to the values of LAI of the seedlings at 6 and 11 MAS respectively (Figure 4b).

Crop Growth Rate (CGR)

The influence of cashew nut-size on dry matter production of cashew seedlings per unit ground covered (CGR) varied widely (figure 5a). Cashew seedlings raised from jumbo nut-size mostly had significantly ($P < 0.05$) higher values of CGR compared to the seedlings raised from medium and madras nut sizes. The values of CGR of seedlings raised from jumbo and medium nut sizes increased between 2 and 3 MAS thereafter decreased at 4 MAS, the CGR value of seedlings raised from madras nut-size was decreasing from 2.74 to 0.35 g/m2/day. The CGR of the three types of cashew seedling increased again to attain a second peak at 7 MAS, where seedlings from jumbo nut-size had a higher value of 9.75 g/m2/day. This was followed by a drastic fall in CGR of the three types of the seedlings at 8 MAS where they had lowest values. This was again followed by another and final rise in CGR of these seedlings with seedlings raised from madras nut-size having significantly ($P < 0.05$) higher values especially at 10 and 11 MAS (Figure 5a).

Meanwhile, the mean CGR revealed that, cashew seedlings in the nursery, had four periods of peak CGR (Figure 5b). These are 3, 7, 10 and 12 MAS. The mean CGR increased to reach the first peak of 6.01 g/m^2/day at 3 MAS. A reduction in mean CGR, 1.51 g/m^2/day, at 4 MAS was followed by progressive increase to reach a second peak value of 6.88 g/m^2/day at 7 MAS. The mean CGR of cashew seedlings fell to a minimum value of 0.40 g/m^2/day at 8 MAS and this was followed by the third peak of 5.28 g/m2/day at 10 MAS. The highest mean value of CGR of 7.63 g/m^2/day was attained at 12 MAS (Figure 5b). The differences are all significant at P , 0.05 (Figure 5b).

Net Assimilation Rate (NAR)

The influence of cashew nut-size on rate of dry matter yield per unit leaf area (NAR) of the seedlings raised in the nursery widely varied. Generally, NAR decreased with age if cashew seedlings in the nursery. At the onset of sampling, NAR of the seedlings raised from the three nut-sizes was highest, while 4 and 8 MAS are periods of lowest NAR for the three types of cashew seedlings (Figure 6a). at 1 MAS, cashew seedlings raised from madras nut had highest value of NAR of 3.75 g/m^2/day followed by seedlings raised from medium and jumbo nut-sizes with 2.82 g/m^2/day and 1.44 g/m^2/day in that order. The differences were significant at $P < 0.05$. The NAR slowly declined to 0.27, 0.33 and 0.53 g/m^2/day, for the seedlings raised from madras, medium and jumbo nut-sizes, respectively (Figure 6a). Net assimilation rate of the seedlings gradually increased to 1.88, 1.5 and 2.17 g/m^2/day for seedlings raised from madras, medium and jumbo nut sizes, respectively. This was followed by another decrease in NAR of the three types of cashew seedlings at 8 MAS and another gradual increase till 12 MAS when the seedlings raised from madras, medium and jumbo nut sizes, respectively had 1.29, 1.03 and 0.90 g/m^2/day (Figure 6a).

With regard to mean NAR of cashew seedlings in the nursery, there was a decreasing trend between 2 and 12 MAS (Figure 6b). Four peaks of NAR were however, discernible in cashew seedlings in the nursery. Mean NAR was highest at the initial stage of sampling with 2.67 g/m^2/day. Net assimilation rate declined to 0.34 g/m^2/day at 4 MAS. A gradual increase in NAR was terminated by another declination at 8 MAS after a second peak of 1.85 g/m^2/day at 7 MAS. Cashew seedlings had NAR values of 0.77 and 1.07 g/m^2/day at 10 and 12 MAS, in the nursery. The differences are significant at $P < 0.05$ (Figure 6b).

Leaf Area Ratio (LAR)

The LAR of cashew seedlings raised from the three nut-sizes, assumed a decreasing trend between1 and 12 MAS (Figure 7a). The seedlings raised from jumbo nut-size had highest values of LAR of 1.81 and 1.42 cm^2/g at 2 and 4 MAS respectively. At the same period, the values of LAR of the seedlings raised from medium nut-size of cashew were 1.28 and 1.23 cm^2/g while those of the cashew seedlings raised from madras nut-size were 1.17 and 0.90 cm^2/g respectively. The differences were significant at P < 0.05 (Figure 7a). At other periods of sampling, the size of cashew nuts sown mostly had no significant effect (P < 0.05) on the LAR of the seedlings raised.

The mean LAR was higher at initial stages of sampling reaching the peak of 1.42 cm^2/g at 2 MAS. LAR declined slowly until a lower value of 0.56 cm^2/g was reached at 7 MAS after which there was a gradual and slowly rise which was again terminated by another declination at 12 MAS, which happened to be the period of lowest value of mean LAR (0.55 cm^2/g) of cashew seedlings in the nursery (Figure 7b).

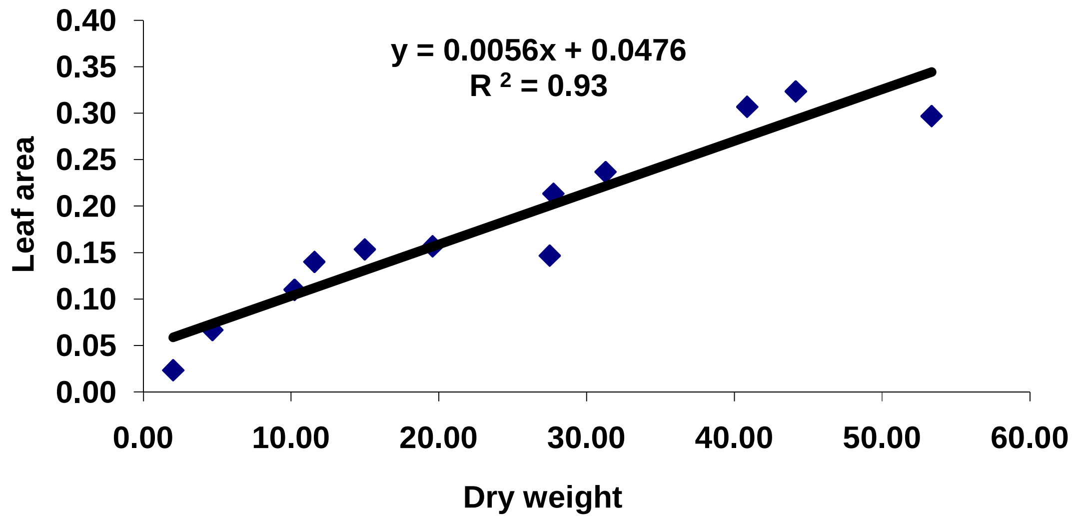

Figure 1: Relationship between mean leaf area (m^2) and mean dry weight (g/plant) of cashew seedlings in the nursery.

Table 1: Dry weight (g/plant) of cashew seedlings as affected by nut-size in the nursery

	Months After Sowing (MAS)											
Types of cashew seedlings	1	2	3	4	5	6	7	8	9	10	11	12
Jumbo	3.33	6.44	13.73	16.50	22.43	25.77	36.56	36.75	39.60	45.58	49.54	57.77
Medium	2.05	5.01	12.87	14.00	16.05	20.86	28.85	29.08	32.60	35.39	47.17	47.54
Madras	0.70	2.57	4.08	4.20	6.49	12.14	17.12	17.44	21.66	29.86	35.39	45.52
se (±)	0.76	1.13	3.08	3.75	4.63	3.98	5.65	5.61	5.22	4.60	4.38	3.79

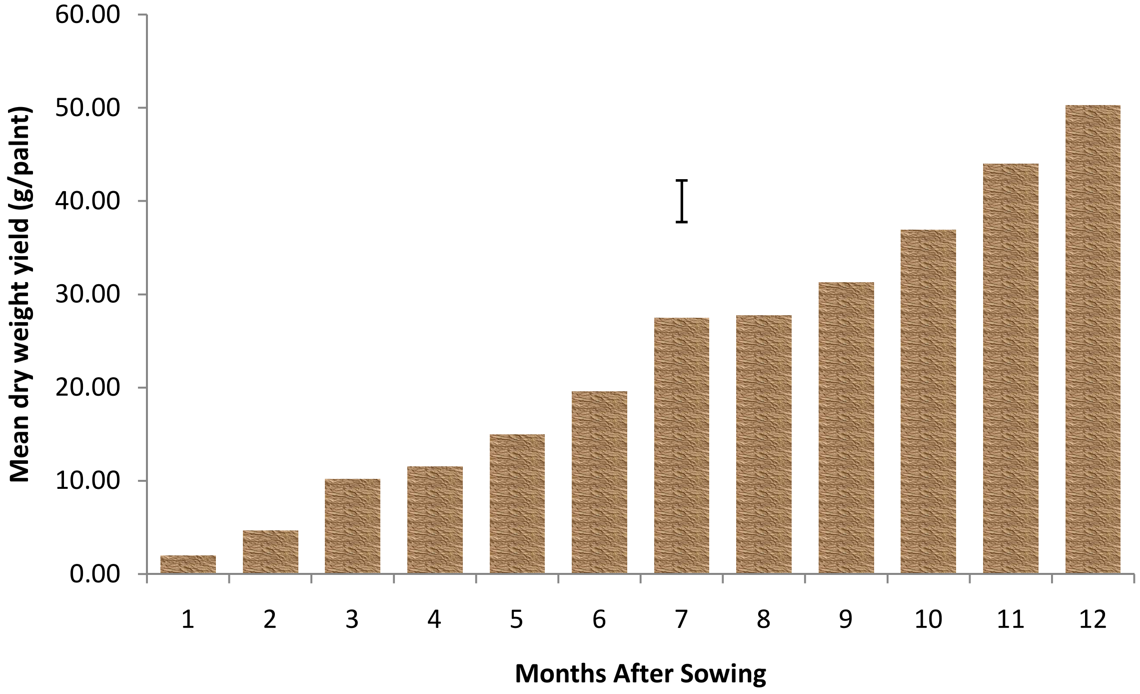

Figure 2: Mean dry weight yield (g/plant) of cashew seedlings in the nursery.

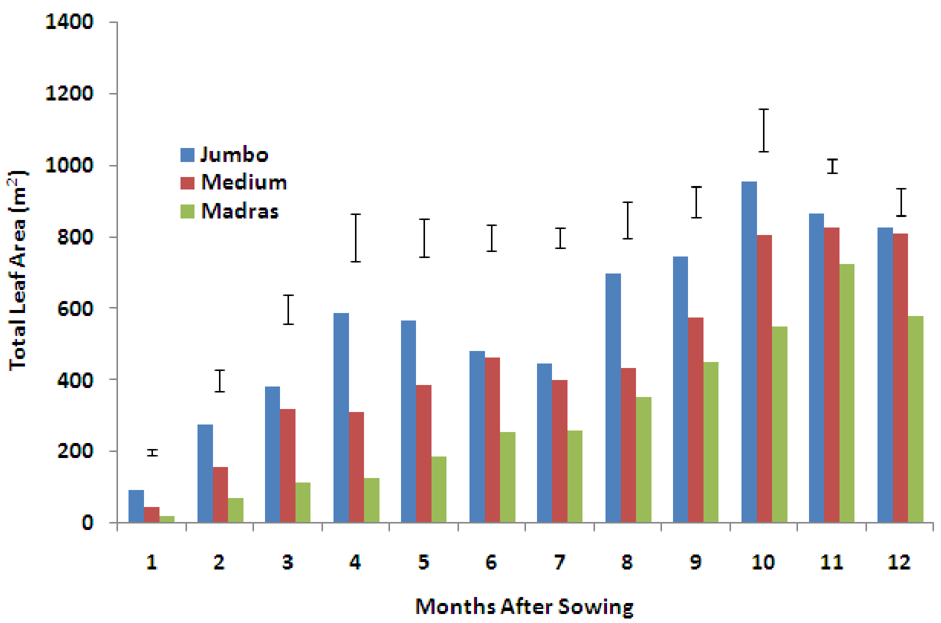

Figure 3a: Total Leaf Area (cm^2) of cashew seedlings as affected by nut-size in the nursery.

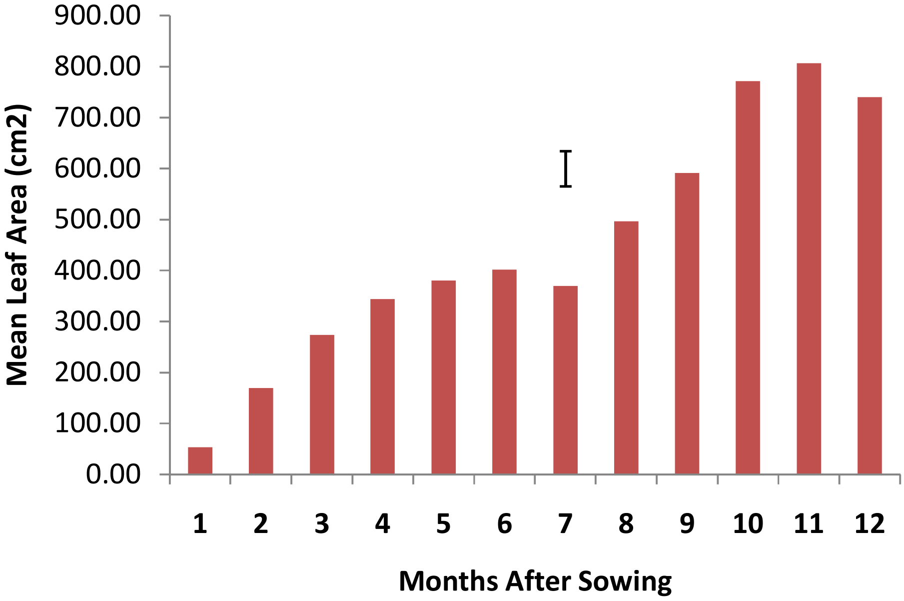

Figure 3b: Mean leaf area (cm^2) of cashew seedlings in the nursery.

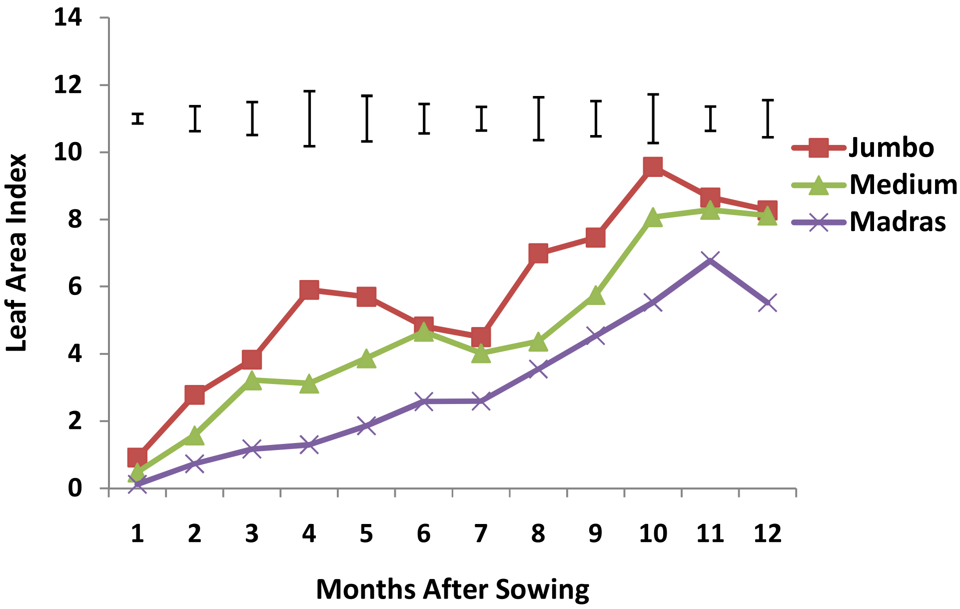

Figure 4a: Leaf Area Index of cashew seedlings as affected by nut-size in the nursery.

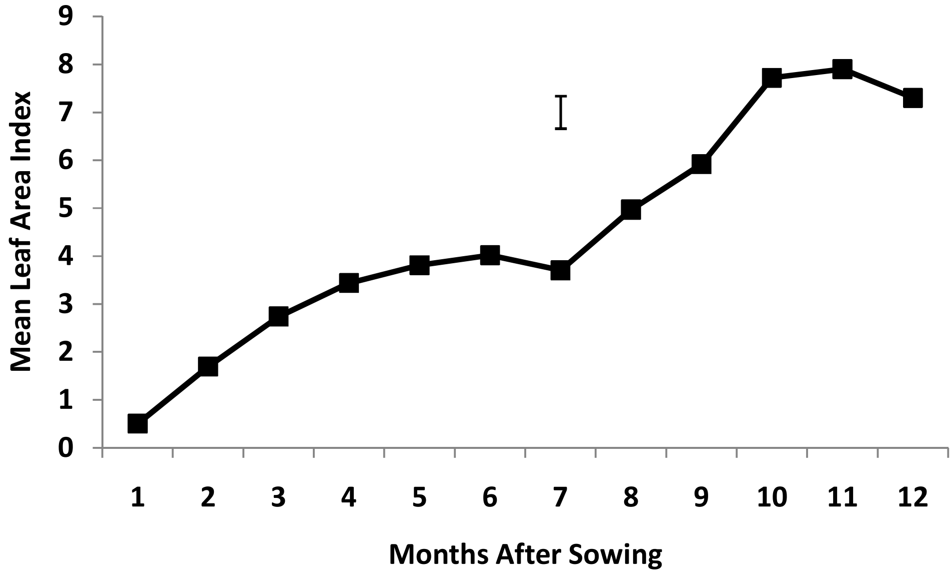

Figure 4b: Mean Leaf Area Index of cashew seedlings in the nursery.

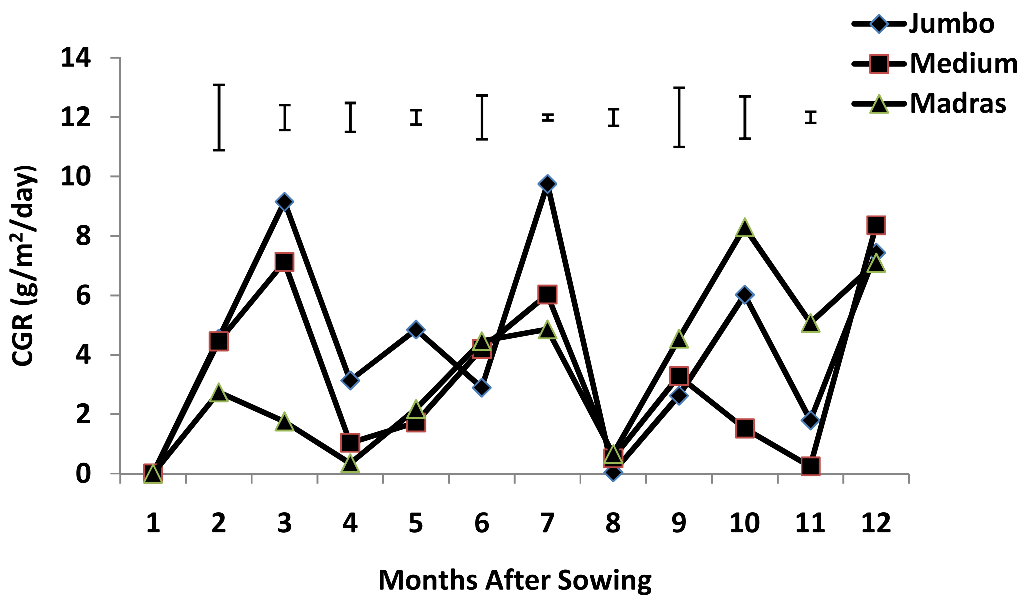

Figure 5a: Crop Growth Rate of cashew seedlings as affected by nut-size in the nursery.

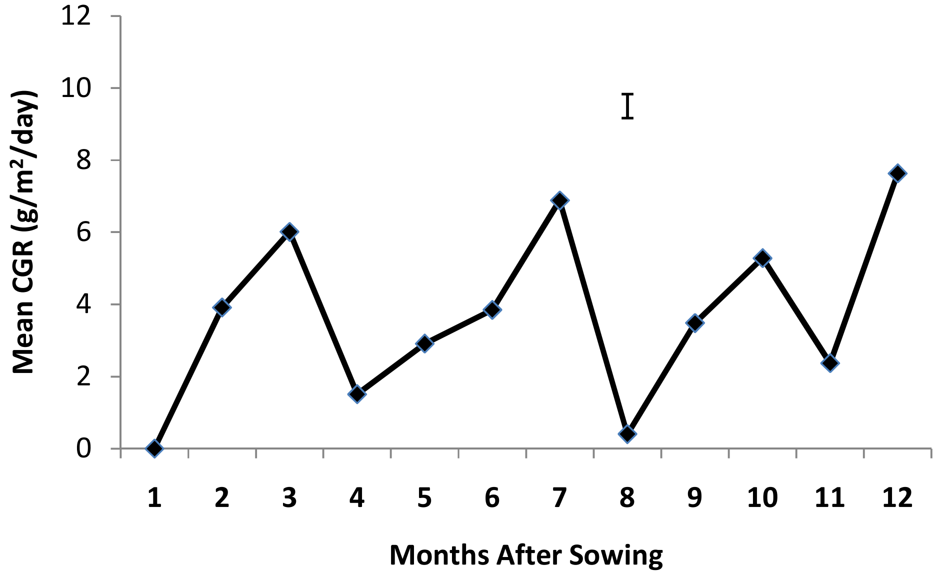

Figure 5b: Mean Crop Growth Rate of cashew seedlings as affected by nut-size in the nursery.

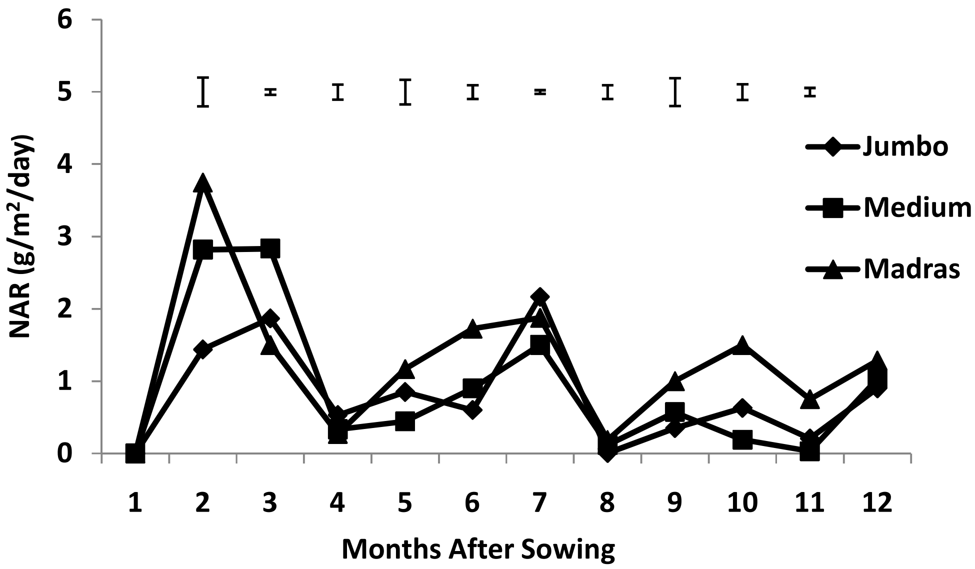

Figure 6a: Net Assimilation Rate (NAR) of cashew seedlings as affected by nut-size in the nursery.

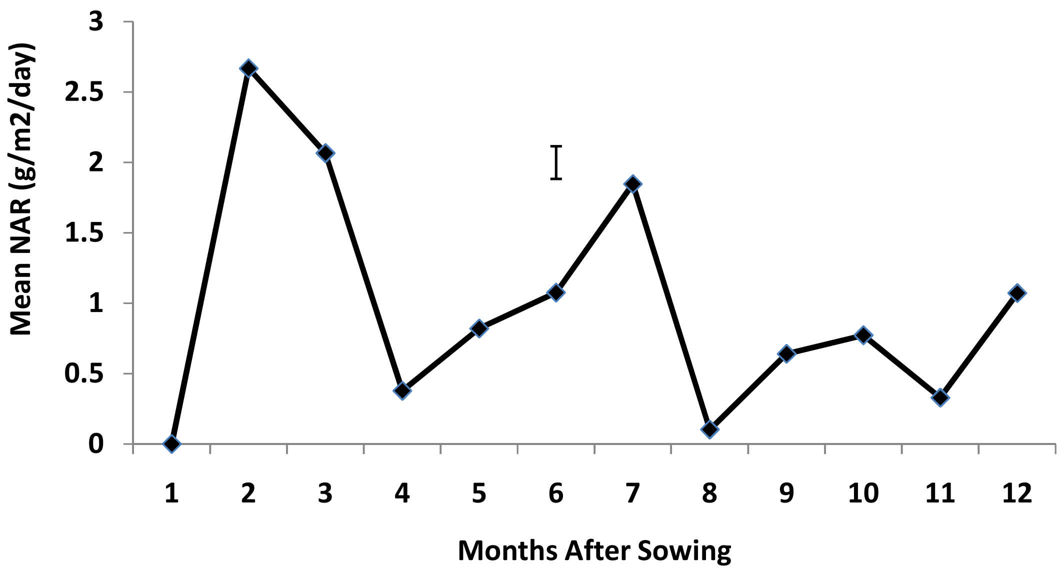

Figure 6b: Mean Net assimilation Rate (NAR) of cashew seedlings in the nursery.

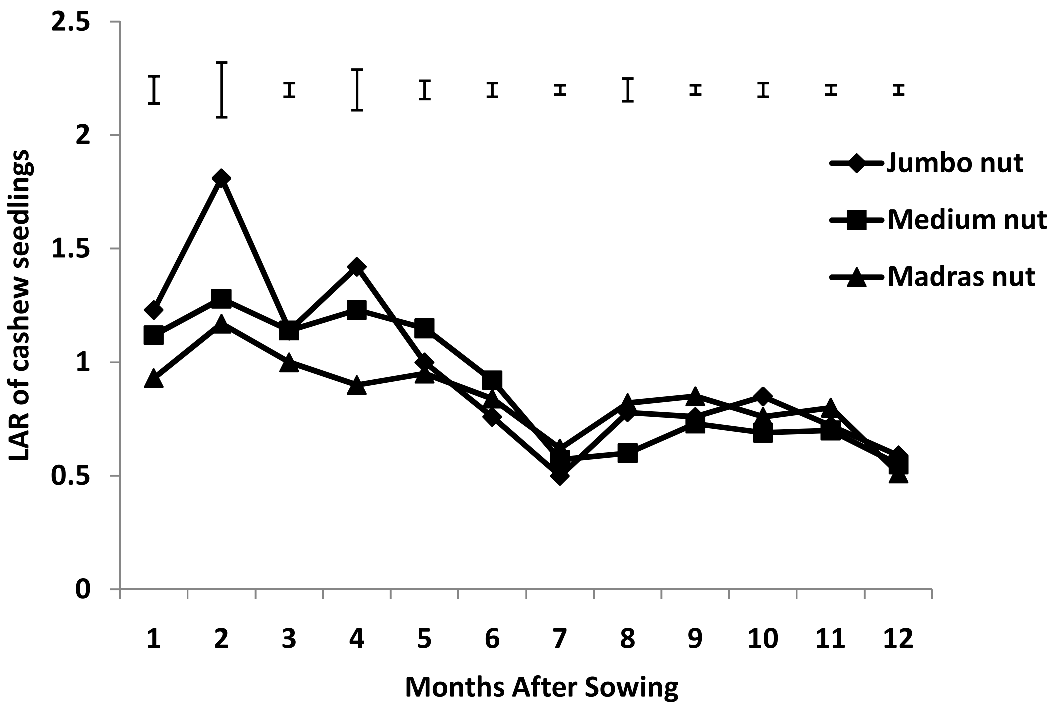

Figure 7a: LAR (cm^2/g) of cashew seedlings as affected by nut-size in the nursery.

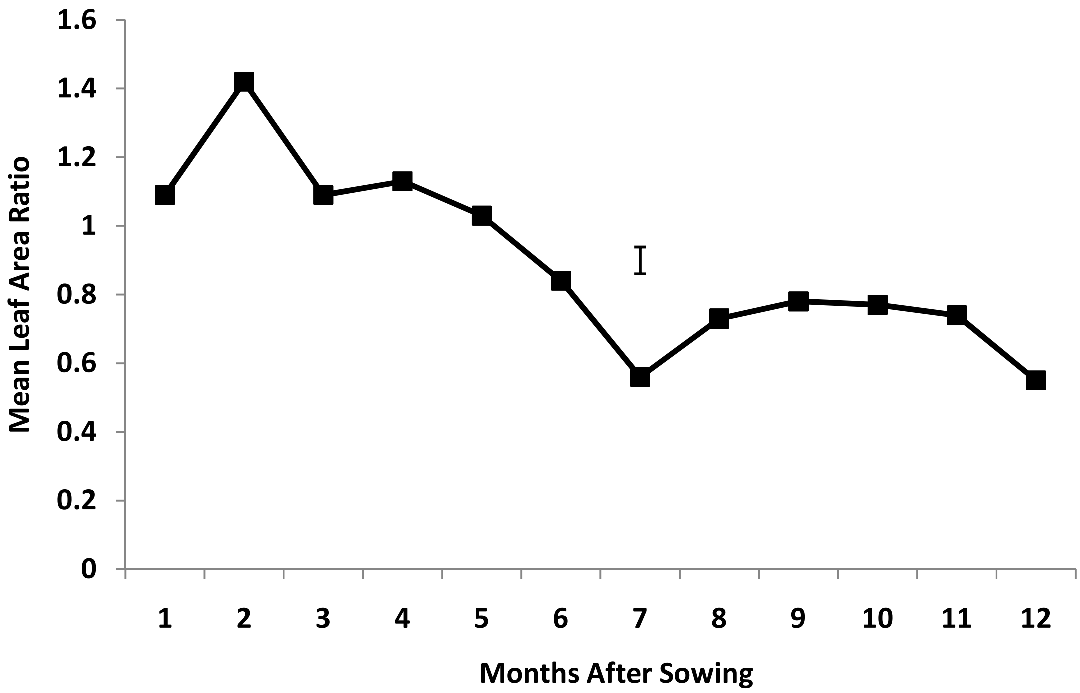

Figure 7b: Mean LAR of cashew seedlings in the nursery

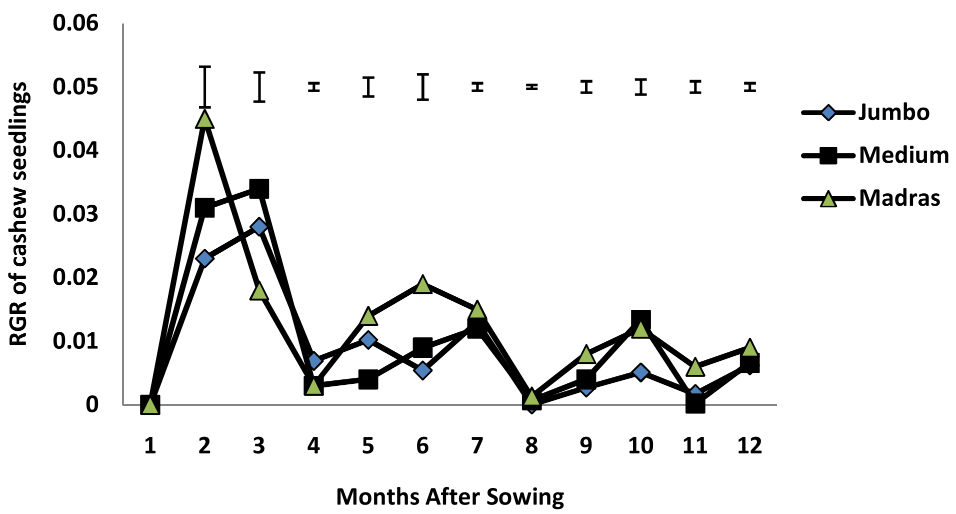

Figure 8a: Relative growth rate (RGR) of cashew seedlings as affected by nut-size in the nursery.

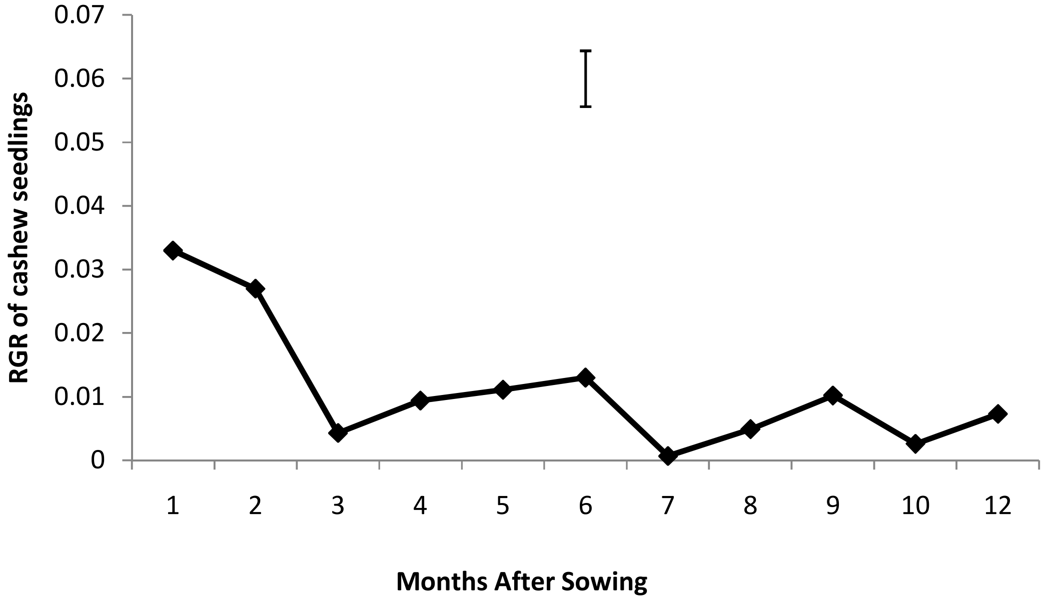

Figure 8b: Mean Relative Growth Rate (RGR) of cashew seedlings in the nursery.

DISCUSSION

Growth analysis, which includes LAI, CGR, RGR, LAR and NAR have been identified as best and appropriate tools for evaluating the performances of plant species in any cropping situations (Blackman, 1919, 1968; Williams, 1946; Watson 1952; Haynes *et al.*, 1967). Haynes *et al.*, (1967), Evans (1972) and Hunt, (1982) specifically explained classical approach of growth analysis as the dry matter changes of component plant parts in relation to leaf area.

In cashew, the size of nuts sown, not only influences the performance of the seedlings (Adebola, *et al.*, 1999), but equally found to positively influence the dry matter yield and total leaf area of the seedlings of cashew in the nursery (Hammed, 2008). This is an indication that, the differences in the weights of cashew nuts is a reflection of the differences in the nutrient reserves contained in these nuts. Therefore, cashew seedlings raised from jumbo nut-size ($\geq$ 16 g) recorded higher amounts of dry matter and total leaf area probably because of higher amount of nutrient reserves in this category of nuts, compared to seedlings raised from medium nut-size (6 – 8 g) as well as seedlings raised from madras nut-size ($\leq$ 2 g). Though, the magnitude of the differences reduces with time. The development of photosynthetic apparatus by seedlings raised from medium and madras nut sizes, with time, might have not been unconnected with the reduction.

The leaf area and dry matter production of cashew seedlings increased with increase in size of cashew nuts sown. This observation might be indicative of the differences in nutrient reserves of these cashew nuts, in which case, the reserves in larger nuts are expectedly larger than the reserves in smaller nuts of cashew. Ibikunle and Komolafe (1973), Oladokun (1985, 1988) made similar observations in kola seedlings raised from kola nuts of different sizes. Adebola *et al*., (1999) equally observed that cashew seedlings raised from larger nut-sizes had higher leaf area values compared to seedlings raised from smaller nut-sizes of cashew. This indicates the significance of considering the size of nuts while raising cashew seedlings. Also, the dry matter production and leaf area expectedly continue to increase with time in the nursery, as observed in this study. Earlier studies have shown similar observations in cacao (Goodall, 1949, 1950; Atanda, 1971; Chinwuko and Lucas, 1986).

The net assimilation rate is calculated with assumption that, 'changes in leaf area and dry matter are linear (Williams, 1946). In cashew seedlings therefore, the linear relationship observed in changes between leaf area and dry matter with R^2 (coefficient of determination) of 0.9 is an indication that the dry matter production of the seedlings could be explained on the basis of leaf area (Williams, 1946). Therefore, the maximum value of net assimilation rate (2.07 g/m^2/day) observed at 2 MAS showed that estimation of dry matter production of cashew seedlings on the basis of leaf area was maximum at this period. With increasing, nursery period, the net of assimilation rate of cashew seedlings was irregular. This irregular patterns observed in net assimilation rate of cashew seedlings might be due to the fact that, with prolonged nursery periods and restricted rhizosphere, production and development of leaves in cashew seedlings might become irregular. This observation might particularly be connected with the withering of the older leaves while the restricted rhizosphere might have restricted production of more new leaves because of the prolonged stay in the nursery. Besides, some seedlings might form a fresh flush and thus increase their leaf area just at the sampling period, the net assimilation rate might be over-estimated. In some other seedlings, similar leaf expansion may occur towards the end of the sampling period, this might result in underestimates of net assimilation rate. These observations were equally made in cacao seedlings by Goodall (1950) and Atanda (1971). The fall in net assimilation rate with increasing nursery period was also reported in coffee (Famaye, 2002).

The dry matter production per unit land area (Crop Growth Rate) of cashew seedlings, in the nursery, attained maximum value at 3 ,7 ,10 and 12 MAS, with the value at 3 MAS being highest. These periods were the periods when cashew seedlings have highest dry matter production based on the available rhizosphere. These might be the periods when the cashew seedlings maximally exploited environmental resources, especially soil nutrients and light interception. In the findings of Brown (1984), he reported that the periods of highest dry matter accumulation in plants coincide with the periods of highest conversion rate of solar energy. At these periods, the seedlings would be able to compete well with weeds on the field according to the recommendations of Lucas (1977). The intermittent leaf flushes and leaf senescence with increasing nursery periods might largely be responsible for the inconsistent values of CGR after 3 MAS. Therefore, the periods of low CGR is suggestively connected with the periods of intermittent leaf senescence. Thus, incomplete leaf cover and low percentage sunlight interception might have contributed to low CGR at these periods.

In tree crop culture, the seedlings are recommended for transplanting into the field, when the crop's growth rate is maximum, especially, in oil palm (Lucas, 1977), cocoa (Goodall, 1949, 1950; Atanda, 1971) and coffee (Famaye, 2002). In cashew therefore, the seedlings at 3 MAS are vigorous enough to exploit environmental resources to the greatest degree, with highest conversion rate of solar energy and of maximum leaf expansion (Brown 1984). Beyond this period, the cashew seedlings displayed intermittent falls in dry matter production due to intermittent leaf senescence. This might probably be an indication that, transplanting of cashew seedlings into the field should not exceed 3 MAS.

Moreover, the increasing parts of cashew seedlings that are structurally active rather than being metabolically active, especially, with prolonged nursery period might be responsible for sharp reduction in RGR after 3 MAS. This is in line with explanation of Brown (1984) that, the structurally active organ/parts of a plant do not contribute to growth, unlike metabolically active parts. This implies that, the increasing numbers of older leaves and branches on cashew seedlings that stayed beyond 3 MAS in the nursery, might be detrimental to the growth of the seedlings and thus, might even be one of the causal factors of the seedlings mortality after transplanting into the field. This observation again, agreed with the reports of Goodall (1950), Atanda (1971), Chinwuko and Lucas (1986) on cacao seedlings. Atanda (1971) while quoting Gregory (1926) attributed the decreasing RGR with increasing age of seedlings in the nursery to the slowing down of the seedlings internal metabolism on which RGR is largely dependent.

In summary, the superior physiological growth performance of cashew seedling raised from jumbo-size nuts over the seedlings raised from either medium or madras nut-sizes might not only be due to photosynthetic efficiency of its leaves, but rather to more rapid increase and bigger size of its photosynthetic system, the leaf area. This has a corresponding increasing effect on dry matter content. This has implications in the stability of the seedlings against environmental stresses and shock after transplanting into the field.

CONCLUSION

Cashew seedlings raised from jumbo nut-size had higher dry matter production per unit leaf area (NAR), unit land area (CGR), marginal dry matter content (RGR) and leaf area per unit ground cover (LAI) including LAR than the seedlings raised from medium and madras nut sizes of cashew in the nursery. Besides, the first period of peak rate of dry matter production per unit land area (CGR) might be a period when cashew transplants are more stable and withstand transplanting and environmental shock after transplanting into the field.

Acknowledgment
I sincerely acknowledge the supports of the Executive Director of Cocoa Research of Nigeria (CRIN) and dedication to duty of my technical staffs – Messrs Adebambo and late Wale Kunuola.

REFERENCES

[1] Adebola, P.O., Esan, E.B. and Famaye, A.O. **1999**. Effect of nut weight on germination and seedling vigour in cashew. *Nigerian Journal of Tree Crop Research*, 2 (1): 6-11.
[2] Adenikinju, S.A., Esan, E.B. and Adeyemi, A.A. **1989**. Nursery techniques, propagation and management of cocoa, kola, coffee, cashew and tea. In: *Progress in Tree Crop Research* (Second Edition), CRIN, P.1-27.
[3] Adeyemi, A.A. **1993**. Effects of some selected herbicides on weed control and growth performance of cocoa (*Theobroma cacao*) seedlings in the early years of establishment. *Nigeria Journal of Weed Science*, 6: 31-41.
[4] Adeyemi, A.A. **1999**. Weed infestation in cocoa (*Theobroma cacao*): Physiological basis of the effects of weeds on the establishment and growth of cocoa seedlings after transplanting to the field. *Nigeria Journal of Tree Crop Research*, Vol. 3, No.1. P.20-34.
[5] Atanda, O.A. **1971**. Growth analysis of F_3 Amazon and West African amelonado seedlings under nursery conditions. *Nigerian Journal of Science*. Vol. 5, No. 1 p.45-59.
[6] Blackman, V. H. **1919**. The compound interest law and plant growth. *Annals of Botany*. 33, 353 – 360.
[7] Blackman, C. E. **1968**. The application of concept of growth analysis to the assessment of productivity. In: Eckadt, P. E. (ed.): Functioning of terrestrial ecosystem at the primary production level, Paris, UNESCO, P. 243 – 259.
[8] Brown, R.H. **1984**. Growth of the green plant. In: *Physiological Basis of Crop Growth and Development*. American Society of Agronomy-Crop Science Society of America, 1984. P.153-174.
[9] Chinwuko, U.M. and Lucas, E.O. **1986**. Effect of different particle sizes of sawdust and forest top soil on germination, growth and development of two cocoa varieties in the nursery. *Turrialba*, Vol. 36, No. 3, p.307-314.
[10] CRIN, **1971**. Germination of cashew nuts. The Annual Report of Cocoa Research Institute of Nigeria, 1970/71, Ibadan, Nigeria. P.90-93.
[11] Famaye, A.O. **2002**. Effect of shade regimes on growth of coffee species in Nigeria. *Moor Journal of Agricultural Research*. Vol. 3, No.2: 184-194.
[12] Goodall, D. W. **1949**. A quantitative study of early development of the seedling of cacao (*Theobroma cacao*). *Annals of Botany*, N.S. Vol. XIII, No. 49. P. 1 – 21.
[13] Goodall, D. W. **1950**. Growth analysis of cacao seedlings. *Annals of Botany*, N.S. 14, p. 219 – 306.
[14] Gregory, F.G. **1917**. Physiological conditions in cucumber houses. Experimental and Research Station, *Third Annual Report, Chestunt, 19*.
[15] Gregory, F. G. **1926**. The effects of climatic changes on the growth of barley. *Annals of Botany, NS* 40:1-26.
[16] Hammed, L. A. and Adeyemi, E.A. **2005**. Germination and seedling performance of cashew (*Anacardium occidentale*, L.) as affected by nut-sowing orientations and cotyledon removal. *Nigerian Journal of Horticultural Science (NJHS)*, Vol. 10, 59-64.
[17] Haynes, P.H., Spencer, J.A. and Walter, C.J. **1967**. The use of physiological studies in the agronomy of root crops. In: *Proceedings of the first International Symposium on Tropical Root and Tuber Crops*. St. Augustine, Trinidad, University of West Indies, 3: 1-17.
[18] Ibikunle, B.O. and Komolafe, D.A. **1973**. Some experiments on the germination of cashew nuts (*Anacardium occidentale*, L.). *Nigerian Journal of Science*, 7, 19-29.

[19] Ikuenobe, C.E. Okokhere, S.O. and Utulu, S.N. **1991**. The influence of weed interference on coconut (*Cocos nucifera*) seedling growth in polybag nursery. *Nigeria Journal of Weed Science*, 4:17-25.
[20] Lucas, E.O. **1977**. Growth analysis of polybag nursery oil palm seedlings. *Technical Consultation on Oil Crops for West and Central Africa. A Technical paper OC/77/15, FAO-UN*, 13p.
[21] Nakasone, H.Y. and Paull, R.E. **1998**. Tropical fruits CAB International, U.K. 432p.
[22] Ohler, J.G. **1979**. *Cashew*. Department of Agricultural Research, Royal Tropical Institute, Amsterdam, The Netherlands.
[23] Oladokun, M.A.O. **1985**. Germination studies on *Cola acuminata* (P.Beauv.) Schot and Endlicher, *Turialba* (San Jose), Volume 35, p.109-115.
[24] Oladokun, M.A.O. **1988**. Physiological aspects of kola improvement. *Café, Cacao, The*, Volume XXXII, No. 4, P.311-318.
[25] Opeke, L.K. **2005**. Tropical tree crops. *Spectrum Books Limited*, Ibadan, Nigeria. P. 242-250.
[26] Togun, A. **1977**. A review of the prospect of cashew industry. 39pp.
[27] Watson, D. J. **1952**. The physiological basis of variation in yield. *Advances in Agronomy*, IV, 101 – 145.
[28] Watson, D. J. **1958**. The dependence of net assimilation rate on leaf area index. *Annals of Botany*, N.S. 22, p. 37 – 54.
[29] Williams, R. F. **1946**. The physiology of plant growth with special reference to the concept of net assimilation rate. *Annals of Botany*, 10, p. 41 – 72.