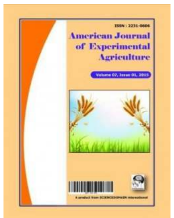

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Effect of Transplanting Time and Rainfall on the Establishment, Growth, Development and Yield of Oil Palm in the Semi-deciduous Forest Zone of Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author SAO designed the study, wrote the protocol and wrote the first draft of the manuscript. Author EL reviewed the experimental design and all drafts of the manuscript. Authors FD and ID managed the analyses of the study. Authors SAO and PA performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Oil palm (*Elaeis guineensis Jacq*) establishment, growth and yield depend to a large extent on physical and climatic characteristics of the environment in which the palm is established. A ten (10) year researcher managed on-station experiment was conducted from 1995 to 2005 to assess the effect of transplanting period on the establishment, growth and yield of oil palm in the semi-deciduous forest zone of Ghana. Farmers need to know the appropriate time to transplant their seedlings in southern Ghana in order to minimise the seedlings lost at the time of planting. This work seeks to address which month(s) of the year is (are) appropriate to transplant oil palm seedlings in order to achieve high percentage establishment and high yields. In this study, twelve

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months old Tenera (Dura and Pisifera crosses) from OPRI, -(D x P ex OPRI)- oil palm seedlings were transplanted onto the field in May, July, September and November signifying different moisture/ rainfall regimes of the year. Treatments were arranged in Randomised Complete Block Design (RCBD) with 4 replicates. It was observed that seedlings transplanted in July had better field establishment, growth, development and yield than those in May, September and November. The findings of this study have important ramification for oil palm farmers, extension services and future studies in order to maximise the yield of Fresh Fruit Bunches (FFB). It is recommended that under current climate variability transplanting of oil palm seedlings should be done in July in the semi-deciduous forest zone of Ghana.

Keywords: Oil palm; water availability; transplanting time; establishment; semi-deciduous.

1. INTRODUCTION

Water is the most critical factors determining crop establishment in the field. Water interacts greatly with soil nitrogen, affects nutrient uptake and subsequently crop productivity. The effect of water stress on production vary according to the crop, soil characteristics, the root system and severity and timing of the shortages of water during the growth cycle [1]. Oil palm growth and yield is dependent on climate in which the palm is established. Oil palm yield potential is reduced when exposed to stressful conditions such as drought [2]. In water-limited environment soil water content at sowing is important in determining plant establishment.

The importance of oil palm to Ghana's economy cannot be underestimated in recent times. Over 636,000 households, mainly in the rural communities, are engaged in oil palm cultivation generating about 8.75 million Ghana Cedis to the agricultural sector [3]. Understanding of the growth and development of the crop under field conditions is key to maximise yield. Farmers depend solely on rains to cultivate oil palm. Therefore, monitoring rainfall is useful in predicting oil palm establishment, growth and yield.

Studies by [4] recommended that in Nigeria oil palm seedlings aged between 10 to 12 months, should be transplanted onto the field in April and May for good crop performance. That is palms transplanted in these months have good establishment rate and growth. [5] also indicated that in Ghana, oil palm seedlings should be transplanted to the field in the months of May and June for the same reason. However, rainfall variability under the current face of climate variability in the semi-deciduous forest zone of Ghana has directed attention to the search for appropriate time for transplanting oil palm seedlings to the field so as to increase seedling establishment with subsequent positive effect on yield. The transplanting time is also believed to affect the yield cycle of the palm. Therefore manipulating the time of transplanting so as to shift the fruiting period to coincide with period of Fresh Fruit Bunches (FFB) scarcity may have positive economic implication as high price of FFB for producers. [6] indicated that the timing of the peak and lean yield of oil palm may vary with year, location and planting material. Some farmers also perceive that this cycle varies with the time/month that the seedlings are transplanted and that the seedlings transplanted late in the year, September and November produce their peak yield late in the year (personal communication with farmers). This study seeks to establish:

- The impact of rainfall or water variability on oil palm establishment, growth and development
- Define appropriate planting time / month for oil palm seedlings establishment and
- Determine when peak yields are obtained in the year at different transplanting times.

2. MATERIALS AND METHODS

A ten (10) year researcher managed on-station field experiment was conducted at the Council for Scientific and Industrial Research - Oil Palm Research Institute (CSIR-OPRI), Kusi in the Kwabibirem District of Eastern Region, Ghana from 1995 to 2005. D X P (ex OPRI) oil palm seedlings aged 12 months were transplanted onto the field at a planting distance of 8.8 m triangular, equivalent of 148 palms per hectare. The experiment was laid in Randomised Complete Block Design (RCBD) with four (4) replications. Each experimental plot measured 15 m^2 and had 24 palm seedlings. The months of transplant constituted the experimental treatments. The treatments were May transplants, July transplants, September transplants and November transplants.

Cultural practices carried out include growing of a cover crop, *Pueraria phaseoloides* to suppress weeds among others. The cover crop was seeded at 3.75 kg per ha in the experimental field. Ring weeding was done in a radius of 1-1.5 m around the base of the palms using cutlass, 2-4 times per year depending on palm age. The inter-rows were slashed every two months to control excessive weeds. One kilogram (1 kg) each of muriate of potash, single super phosphate and ammonium sulphate fertilizers were applied per annum to supply nutrients requirement of the oil palm. Phytosanitory inspection was also carried out monthly to check the onset of pests and diseases.

2.1 Rainfall

Rainfall data for the period of the trial were obtained from the meteorological station of Oil Palm Research Institute (OPRI). The monthly rainfall over the experimental period is shown in Fig. 1. Bimodal rainfall pattern was displayed for all the years. The major rainfall season occurred in April, May and June with values around 250 mm/month in 1995. The minor season started in September and ended in November. February recorded the lowest rainfall of 10 mm but that did not affect the transplanting periods. The rainfall in December was higher than that of January that same year but there was a sharp decline in rainfall to below 10mm in January 1996. In the following year (1996), the rain started early. Less than 10 mm rainfall was recorded in January, 36 mm in February and as high as 360 mm was recorded in the month of March. Unlike the year of transplant, where there was rainfall value of more than 130 mm from March to December, there was a sudden drop of rainfall in April 1996 to less than 90 mm as shown in Fig. 1. The rainfall data for the rest of the experimental period is shown in Appendix 1.

2.2 Seedlings Establishment

Seedling establishment on the field was recorded for the first 2 years. The data obtained was used to calculate the seedling establishment percentage on the field. Percentage establishment was determined by counting the number of established palms per plot in the 2nd year after transplanting of seedlings to the field.

2.3 Vegetative Measurement

The plant height was measured with graduated measuring pole from the base (ground level) of the palm to the point of insertion of leaf/frond number 33.

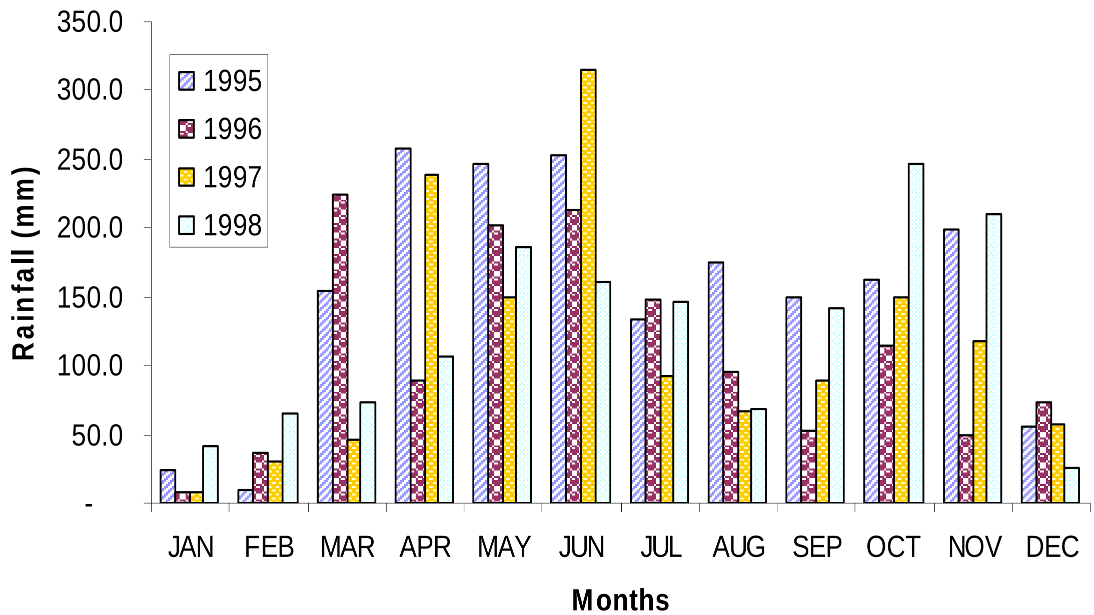

Fig. 1. Monthly rainfall data from 1995-1998

Leaf area (LA), Leaf area index (LAI) and Frond Dry weight (FDW) were taken twice a year (March and November), and averaged to represent the year. These parameters were determined from the relationship below;

LA was computed using the equation by [7].

$$LA = b(n \times LW) \quad (1)$$

Where:

n= number of leaflets, LW=mean of length x mid-width for a sample of the largest leaflets, and b= correction factor=0.55.

$$\text{LAI} = \frac{\text{leaf area}}{\text{ground area}} \quad (2)$$

FDW was obtained using formula developed by [8]. The width and depth of the petiole of the frond number 17 was measured with callipers and values of FDW were estimated using equation 3 as shown below.

$$\text{FDW} = 0.1026 \times W \times D + 0.2362 \text{ (kg)} \quad (3)$$

Where: W= width of the petiole of frond 17
D= depth of the petiole of frond 17

2.4 Yield Measurement

The number and weight of FFB per palm were taken at each harvesting round (weekly) from 2000 to 2005, and these were further compiled to tons/ha/yr.

The data collected were analysed with GENSTAT 2007 statistical package and subjected to analysis of variance (ANOVA) and treatment differences were separated by $P < 0.05$.

3. RESULTS

3.1 Seedlings Establishment

Seedlings establishment was determined in terms of percentage survivability of the total seedlings per month of transplant in the 2^{nd} year of after transplanting. High establishment was recorded in the order July > May> September > November (Table 1). The July transplants were significant from the September and November but not significant as compared to May transplants. There were no significant differences between the May, September and November transplants.

Table 1. Seedlings establishment (2 years after planting)

Treatment / month	Seedling establishment	
	Mean establishment	**Percentage establishment**
May	19.3	80.2
July	22.8	94.8
Sept	18.8	78.1
Nov.	17.8	74.0
Lsd	3.5	14.53
CV%	16.1	16.1

3.2 Effect of Time / Months of Transplant of Oil Palm on LA and LAI

The leaf area and leaf area index showed a linear increase with increase in age of the palms (Figs. 2 and 3). There were no significant differences (P<0.05) between the LA of the treatments. Oil palm transplanted in July had a relatively higher leaf area in all the years under consideration with a mean value of 1.65 m^2 with the lowest of 1.40 m^2 being recorded in November transplants. There was a sharp increase in LA for seedlings transplanted in September eight years after transplanting. LA of palms transplanted in May and November were similar at nine and ten years after transplanting. The LAI increased with increasing palm age (Fig. 3). July transplants recorded the highest LAI in the years under investigation. However it was not significantly different from the other transplants / treatments. This was followed by May transplants at 5 and 7 years after transplanting. From 9^{th} to 10^{th} year after transplanting, September transplants recorded LAI which was higher than that of May but lower than that of July. November transplants recorded the lowest LAI in 9^{th} and 10^{th} year after transplanting.

3.3 Effect of Transplanting Time on Palm Height

Fig. 4 shows the effect of transplanting time / month on plant height. Differences in height were observed among the trannsplants. TheJuly transplant recorded the highest plant height of 0.85 m in the 7^{th} year after transplanting. It recorded the highest plant height to the 10^{th} year,this was followed by those transplanted in November. Height of September transplant and May transplant did not vary significantly for all the periods of the trial.

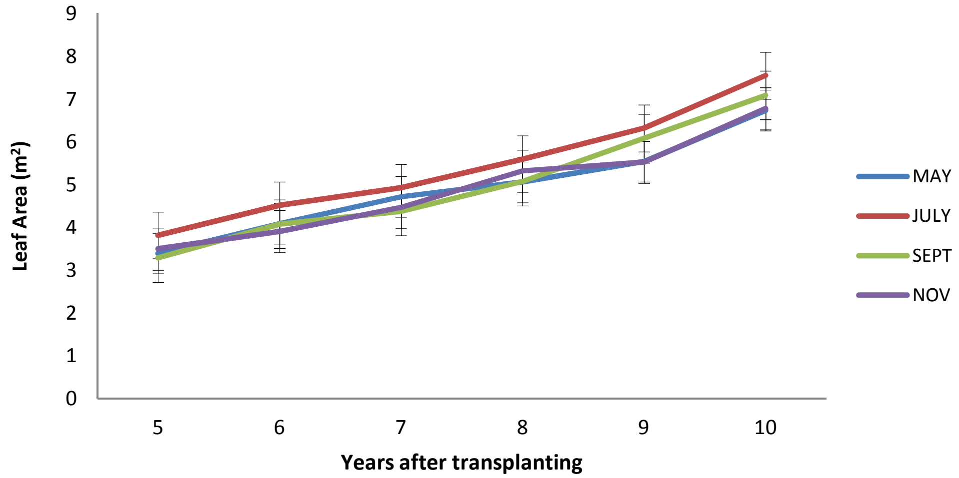

Fig. 2. Effect of time / month of transplants on LA

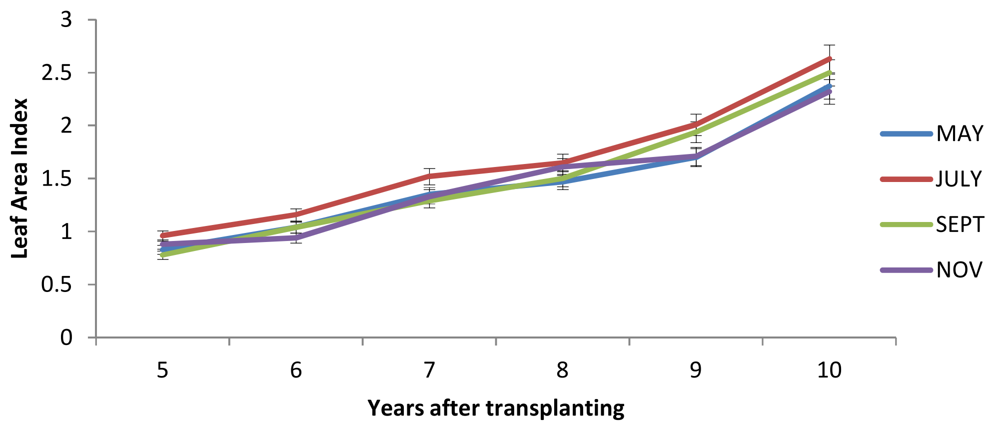

Fig. 3. Effect of time / month of transplants on LAI

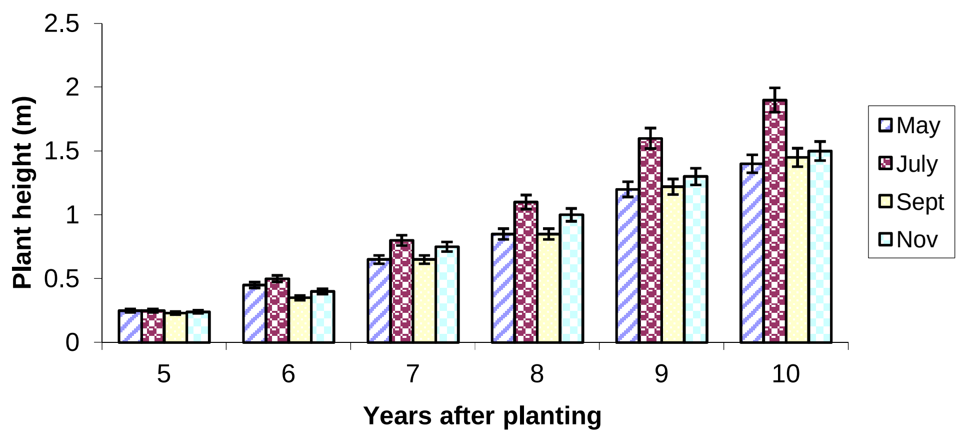

Fig. 4. Effect of different planting time on plant height

3.4 Effect of Different Planting Time on Frond Dry Weight

Fig. 5 shows the accumulation of frond dry weight from the year 2000 to 2005. The frond dry weight for the periods 2000-2001 were in the order: July transplant > May transplant > November transplant > September transplant. There was no significant difference (P≤0.05) between the treatments. However, July transplant recorded the highest frond dry weight throughout the experimental period with a mean value of 1.74 kg and this was about 16% higher than the September transplants which recorded the lowest mean value of 1.5 kg. September transplants on the other hand recorded the least frond dry weight in all the experimental years. May transplants came second after the July transplants. It was only in 2003, that is eight (8) years after transplanting that the November transplant produced more FDW than that of May transplant.

3.5 Yield and Yield Components

There were no significant differences between the yields of the same year (Fig. 6 and Table 2). There was an increase in bunch weight with palm age. In the 5th year after transplanting, July transplants recorded relatively high single bunch weight than the other transplants. In the 6th year September and November transplants produced heavier single bunches than the other transplants. This trend for September transplants continued to the 9th year and then declined during the 10th year. May transplants trailed in all the years except the 5th year and the 10th year. After the 6th year, September and July transplants produced relatively heavier bunches than that of November and May transplants (Fig. 6). Cumulatively, during the period of the experiment, the highest mean single bunch weight of 30.0 kg was recorded by July transplants with the lowest of 25.82 kg being recorded by May transplants ten (10) years after transplanting.

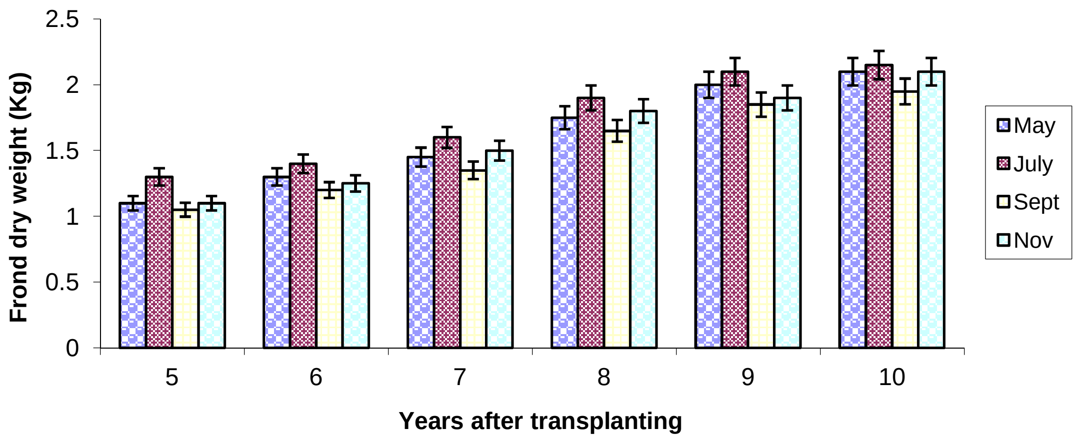

Fig. 5. Effect of different planting time on frond dry weight production

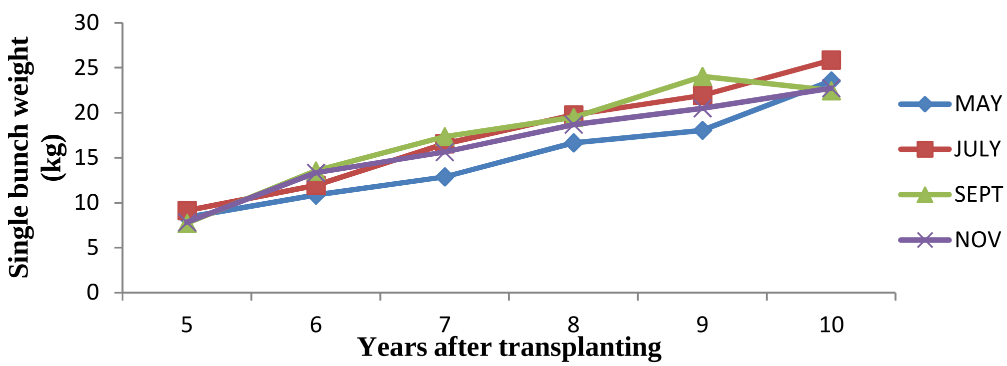

Fig. 6. Single bunch weight at different transplanting times

Table 2. Number of bunches per palm per year

Treatment	Years after planting					
	5	**6**	**7**	**8**	**9**	**10**
May	8.54	7.59	8.54	11.30	12.45	10.63
July	9.61	7.84	8.22	10.77	11.23	11.27
Sept	9.41	8.08	7.90	10.72	10.84	10.21
Nov	10.4	8.50	9.13	11.33	11.19	11.72
CV%	20.40	23.90	5.20	13.20	7.60	9.50
lsd	2.97	1.26	0.76	1.60	2.10	1.66

The effect of transplanting time on the number of bunches per palm per year is shown in Table 2. The number of bunches per palm per year increased with age. The yield became somewhat stable at 8 and 10 years stage with mean values around 10.50–12.50 bunches/palm/year. Even though there were no significant differences between the single bunch weight of palms of the same age, the November transplants had relatively high number of bunches per plant per year from the 5th to 8th year after transplanting. However, the bunch weight of the November transplants are somewhat small as compared to the others except May transplants. May transplants had the highest overall mean number of bunches per year of 9.84 kg and this was about 15% higher than the November transplants which recorded the lowest mean number of bunches per year.

There was linear increase in yield with age of palm, (Fig. 7). Though there were no significant differences between the various treatments, at the 5th year, oil palm transplanted in July produced 6.82 tons/ha/yr. This was higher than the other treatments, November, September and May which had 6.54, 6.40 and 6.22 ton/ha/yr respectively. From the 6th to 8th year, November transplants recorded higher yield in ton/ha/yr than the other treatments. At the 9th year, the September transplants had the highest yield, followed by July transplants, May and then November transplants. With the exception of 10th year, yield differences among the transplant were small. However, July transplants recorded highest yield of 18.82 tons/ha/yr.

Results of the trial also indicated that, in a year, one lean yield period and 2 peak yields were recorded over the experimental period. One of the peaks occurred between March to May and the other between August to November. In the first peak season, palms transplanted in May gave the highest yield followed by July transplants. September and November transplants recorded the least yields. In the second peak season which occurred around August, September and October, the yield was in order of November > July > September > May (Fig. 8). The dip in the yield of the May transplant may be attributed to the time of planting.

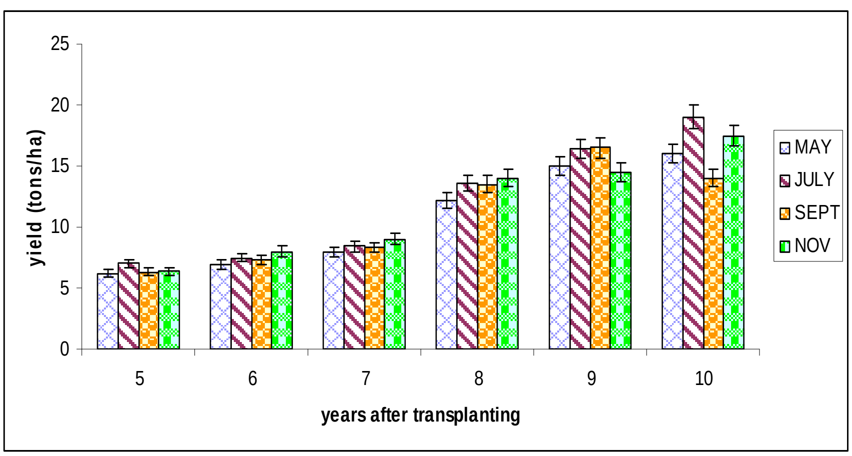

Fig. 7. Palm yield (tons/ha) in response to time of transplanting.

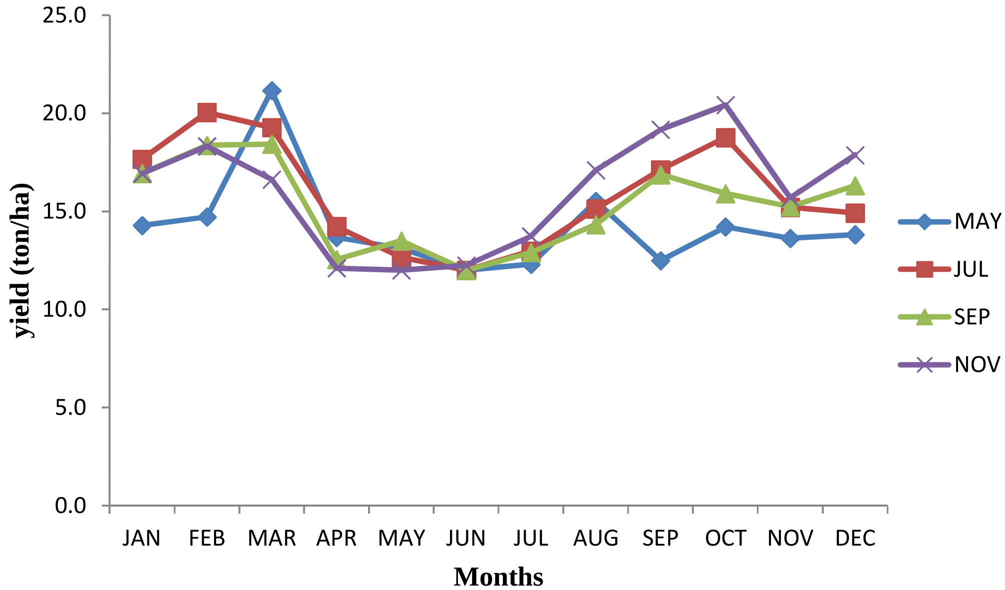

Fig. 8. Production spread over the experimental period (8 to 10 years after planting)

4. DISCUSSION

4.1 Effect of Transplanting Time on Oil Palm Establishment

Water availability affected seedling establishment on the field. The number of plants that were able to establish and grow successfully were in the order of July > September > May > November (Table 1). Transplants of September were better established than May transplant probably due to the carry over effects of rains from the previous months. Also there was enough rainfall throughout the year of transplant (Fig. 1) this might have also contributed to relatively good establishment and better performance of the September and November transplants.

4.2 Effect of Transplanting Time on Leaf Expansion / Leaf Area Index

Water affects both the activity and size of the leave. For young palms the early expansion of the canopy facilitates radiation capture is of crucial importance for yield [9]. The leaf area and leaf area index of the seedlings increased with age. This supports [10] finding that leaf area varies with age. The effect of water availability on the leaf area was prominent in July transplants (Fig. 2). High leaf area and leaf area index of seedlings planted in July maybe attributed to enough moisture/rainfall availability that aided good establishment. The availability of water for seedling establishment also affected the subsequent growth and development of the oil palm. Even though there was not much rainfall in July, the preceding months had adequate rainfall. Therefore the soil might have had enough moisture reserve in July when the transplanting was done.

4.3 Effect of Transplanting Time on Palm Height

Time of transplanting affected the height of the palm. Even though there was no significant difference among the treatments, the July transplants were ahead of all the treatments (Fig. 4). This can be considered as an advantage since its canopy will close faster than the other treatments. Closed canopy smoother weeds, reduce sun impact on the soil and therefore reduce evaporation from the soil surface and reduce weed control frequency.

4.4 Dry Matter Weight Accumulation of Oil Palm after Transplanting

Oil palm productivity is influenced by total dry matter production of each palm. Dry matter production is highly dependent on the photosynthetic rate of the palm [11]. Dry matter production is used for both vegetative and reproductive growth. In oil palm, vegetative growth assumes priority over the reproductive growth [12]. Thus the requirement of vegetative growth must necessarily be satisfied before dry matter is diverted into fruit production.

Inadequate rainfall at the time of transplanting affected the rate of growth, development and dry matter production. Seedlings transplanted in May and November where there was inadequate rainfall expressed reduced crop growth and development. Because there had been enough moisture in the previous months before July, the seedlings transplanted had good growth rate. It therefore had slightly high dry matter than the other treatments.

4.5 Effect of Transplanting Time on Yield and Yield Components

The yields were also affected depending on the extent of dry matter produced. The impact of soil water affected the vital phenological and growth processes. This observation was similar to findings by [13]. The number of bunches per palm per year was higher in May and November transplants on the 8th and 9th year. July and September transplants recorded smaller number of bunches per palm. Single bunch weight was higher in those transplanted in July and September. This shows that when oil palms are transplanted when rainfall is inadequate, the number of bunches per palm increase at the expense of single bunch weight. Due to adequate rainfall of 270 mm, 160 mm and 200 mm for June, July and August respectively, July transplants received enough moisture which led to good establishment rate and high dry matter accumulation at the vegetative stage and diverted into fruit production at the initial yields. Therefore the initial yields for July transplant were higher as compared to the other treatments. The findings of this work show that transplanting time have effect on the yield of the crop. This finding is in line with findings by [14], who stated that the time of sowing affected yield in most crops. This work found out that, seedlings transplanted in minor dry seasons and the end of major rainy season which occurs in November and July respectively, give high peak yield in the dry season, around November and December when palm fruits are expensive.

The bimodal peaks can also be attributed to the bimodal rainfall season in the area which increases soil moisture that matched or mirrored the yield peaks.

5. CONCLUSION

Depending on when regular rain starts, it is suggested that, two to three months rainfall should be allowed before transplanting seedlings. In these months, a minimum of 150 mm monthly rainfall should be recorded. This will increase moisture in the soil, for high percentage seedling establishment and good vegetative growth. From the rainfall values in 1995, it can be deduced that high precipitation in months preceding transplanting time is highly important in plant establishment and subsequent development. The second peak season which occurs in November is very important since palm fruits attract high prices. It is therefore important to do split planting, i.e. plant some seedlings at July and some at November so that yield could be obtained throughout the year.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX – 1

Monthly rainfall (mm) data from 1999-2007 (Rest of the experimental period)

	1999	2000	2001	2002	2003	2004	2005	2006	2007
Jan	30.8	25.9	-	7.0	25.0	32.4	0.2	60.20	-
Feb	3.7	5.6	11.9	02.4	19.6	43.6	40.6	73.60	10.00
Mar	93.8	65.5	119.3	68.0	93.0	122.4	34.7	149.80	61.60
Apr	64.0	39.1	132.3	05.3	166.4	85.6	10.0	11.60	65.30
May	90.7	09.7	77.3	98.9	82.6	69.8	181.4	69.60	249.40
Jun	234.9	65.1	406.8	76.6	149.8	67.8	19.2	74.60	02.20
Jul	11.9	27.6	116.6	30.6	30.2	63.8	21.2	69.20	83.80
Aug	18.6	74.8	31.6	73.2	20.2	87.2	31.0	50.00	82.00
Sep	72.0	79.9	106.6	31.4	90.3	56.2	59.2	87.90	11.20
Oct	95.9	38.7	184.0	30.5	86.8	76.4	82.8	29.60	81.10
Nov	25.7	28.4	76.0	69.6	21.0	54.6	25.8	68.80	54.70
Dec	26.0	6.1	15.8	27.0	64.2	73.8	46.4	59.00	20.20

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