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Effects of Repetitive Transplanting and Leaf Pruning on Growth and Dry Matter Partitioning of Enset (*Ensete ventricosum* (Welw.) Cheesman)

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Abstract: The practices of repetitive transplanting and leaf pruning methods of enset (*Ensete ventricosum*) plants are not consistent over enset growing areas. Current yield levels in enset production are relatively low and vary between growing areas depending on the different repetitive transplanting and leaf pruning practices. Patterns of enset plant growth over the entire growing season and relative distribution and accumulation of dry matter to the harvestable parts of the crop as influenced by the different practices are important parameters to understand and modify the management practices in an effort to increase the yield of the plant. Influence of repetitive transplanting and leaf pruning methods on growth, dry matter partitioning and dry matter production were studied at the Areka Research Centre, North Omo, Southern Ethiopia. Transplanting treatments significantly affected height, circumference of pseudostem and dry matter yield of corm and pseudostem at all harvest dates. Increase in dry matter was earlier in once (T_1) compared to twice (T_2) and thrice (T_3) treatments. Maximum total plant dry matter yield per unit space of T_1 and T_2 transplanted enset suckers was obtained at flowering at 104 and 234 weeks after first transplanting, respectively. Repetitive transplanting reduced the fitted maximum rate of increase (g m^{-2} week^{-1}) compared to direct transplanting. The dry matter partitioning to the harvestable parts however, were increased as a result of repetitive transplanting. Partitioning of dry matter to the harvestable organs of the plant seems more important than total dry matter production for determining kocho yield of enset plants. For early yield, livestock feed and other purposes however direct transplanting might be practical. Leaf pruning alone or the interaction between leaf pruning and transplanting did not significantly affect dry matter production and partitioning. Circumference of the pseudostem seems a good indicator for high yield of kocho.

Key words: Enset, transplanting, dry matter partitioning, corm, pseudostem, kocho

INTRODUCTION

Enset (*Ensete ventricosum* (Welw.) Cheesman) is a monocarpic, perennial herb, that grows to a height of about 4-8 m tall (sometimes even up to 11 m). The plant consists of an adventitious root system, an underground stem structure known as a corm, a pseudostem which is distinctly dilated at the base by leaf sheaths that extend from the base of the plant, leaves and inflorescence (Tseagye and Struik, 2001).

Enset crop is cultivated mainly for a starchy human food and livestock feed. It is a main source of food for 7-10 million people in the highlands of south and southwestern Ethiopia. The pseudostem, corm and stalk of inflorescence constitute the most important source of food for humans, whereas the whole plant except the roots is fed to livestock. Enset also yields fibre whose structure and strength is equivalent to the fibre of abaca, a world-class fibre crop (Huffnagel, 1961; Bezuneh *et al*., 1967; Brandt *et al*., 1997). Local people believe that enset also has various medicinal properties (Tsegaye and Struik, 2000).

The traditional enset cultivation methods including propagation, transplanting, leaf pruning, harvesting and fermentation encompass many procedures and these vary from place to place in Southern Ethiopia. Commonly, enset is propagated vegetatively by means of immature enset mother plants of about 2-3 years of age. The suckers that emerge after 2-3 months remain for at least a year on the corm before they are separated and transplanted out in a row in a well- prepared plot or nursery bed. After another 1-2 years, depending on the growth rate, the transplants may either be ready for planting out into a permanent field or they may go through one or more transplanting cycles in nurseries, depending on the region. The advantage of repetitive transplanting are controversial among researchers and farmers, yet, many researchers stress the disadvantages of repetitive transplanting, claiming that it takes longer time to flower. Farmers on the other hand believe that repetitive transplanting increase yield and quality.

Enset leaf pruning methods also vary between growing areas. The leaves are primarily used as livestock feed, house construction and wrapping bread dough during baking. Near urban areas enset leaves are good sources of cash for a female household as they are sold for wrapping butter and chat (*Cata edulis*) leaves. The number of leaves removed from an enset plant depends on other available sources of leaves for the above-mentioned uses. In densely populated dry areas where forage supply is most limited, leaf pruning to the point of complete defoliation of the plant is practiced. As in all green plants, enset leaf is the main photosynthetic organ for biomass production and severe leaf pruning, could affect biomass production in enset plantation.

The practices of repetitive transplanting and leaf pruning are not consistent over enset growing areas. Farmers in Sidama start with a relatively dense plantation and then transplant the thin suckers only once to give adequate space to develop into a normal plant. In Sidama it is common to feed livestock the thinned enset suckers. In Hadiya and Wolaita a clear planting pattern was observed whereby every one or two years suckers change their location at wider spacing. Leaf pruning to the point of complete defoliation of the plant is practiced in Wolaita and Hadiya during dry seasons. Current yield levels in enset production are relatively low and vary between growing areas depending on the aforementioned cultural practices. Patterns of enset plant growth over the entire growing season and relative distribution of dry matter to the harvestable parts of the crop as influenced by the different transplanting and leaf pruning practices are important parameters to understand and modify the management practices in an effort to increase the yield of the plant. Tsegaye and Struik (2000) have observed that transplanting enset suckers once shortens the period until maturity, provides a reasonable yield soon after removing suckers from the corm and reduce the chance of attack by disease and pest. However the effects of these cultural practices on growth, dry matter production and partitioning have not yet been reported. In this study, therefore, the effect of repetitive transplanting and leaf pruning methods on growth, dry matter partitioning to the corm, pseudostem, leaves and inflorescence of the enset plant were investigated.

MATERIALS AND METHODS

Experimental site: This study was carried out at Areka Research Centre (ARC), North Omo Zone, southern Ethiopia. ARC is located 7° 09' N and 37° 47' E at an elevation of 1750-1820 m asl; it is a mandate centre for enset and root and tuber crops research. The average annual rainfall (1993-2001) was 1546 mm with a mean minimum/maximum air temperature of 14.5/25.8°C. The soil was well-drained, stone free, with texture class of silt loam at 0-15 and 30-45 cm depth and loam at 15-30 cm depth. The pH was 4.9, 4.5 and 4.6 at 0-15, 15-30 and 30-45 cm depth, respectively. The total N% (Kjeldahl) and CEC at 0-15 cm were 0.196 and 22.1 meq per 100 g, respectively. Fertilisers (100 kg urea ha^{-1} $year^{-1}$ and 100 kg DAP ha^{-1} $year^{-1}$) were applied for the first two years both in nursery beds and permanent fields.

Treatments and experimental design: The treatments consisted of three transplanting methods combined with two leaf pruning methods. The transplanting methods were (I) transplanting 1-year- old suckers produced in the nursery from the corm directly into the permanent field (T_1), (ii) transplanting two year old transplants into permanent field after they had been raised from the corm nursery by transplanting into nursery beds (T_2) and (iii) transplanting 3-years-old transplants into the permanent field after they had been raised by transplanting twice into nursery beds (T_3). (Fig. 1; Tsegaye and Struik, 2000). Nursery spacings were 1.0×1.0 m for sucker production (to give adequate space to the 50-150 new shoots per corm), 1.0×0.5 m for raising 1 year old transplants into 2 year old transplants and 1.0×1.0 m for raising 2 year old transplants into 3 year old transplants. The spacings during transplant raising are in accordance with common practice and aim to optimize land use. The nursery sites were located adjacent to the permanent field. The leaf pruning methods were (I) no leaf pruning (P0) and (ii) with leaf pruning (P1).

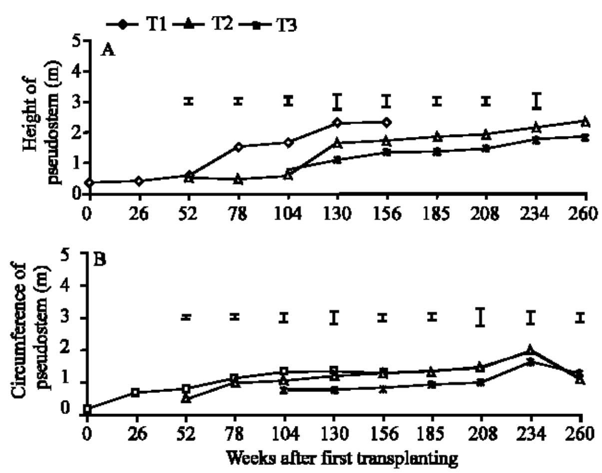

Fig. 1: Average height (A) and circumference (B) of pseudostem during the growing period for the different transplanting treatments: Note: At the time of transplanting into permanent field and afterwards at 26-week intervals, measurements were recorded. T_2 (transplanted twice), T_3 (transplanted thrice) plants were transplanted into permanent field 52 and 104 weeks later than T_1 (transplanted once) plants, respectively. Vertical bars indicate LSD (p = 0.05) where differences were significant

The six treatment combinations were tested in the permanent field in a randomized complete block design with four replicates. The plants were grown in a 1.5×3.0 m plant arrangement giving 24 plants per plot.

Crop management: Two-year old plants of the cultivar Halla were cut 10-15 cm above the junction of the peudostem and corm. The corms were split longitudinally into two parts and the apical buds were removed to induce several buds from the mother corm piece to grow into shoots (suckers). The split corms were then planted 1 m apart under 10 to 20 cm layer of soil mixed with cow manure on 2 March 1993. In March 1994, suckers were separated from the mother corm and either transplanted directly into the permanent field (T_1) or transplanted into a second nursery bed. In March 1995, some 2-years-old transplants were transferred into the permanent field (T_2), while the remaining shoots were transplanted into a third nursery bed at a spacing of 1.0×1.0 m. These 3-year old transplants were later transplanted into the permanent field in March 1996 (T_3). (Fig. 1; Tsegaye and Struik, 2000). The last harvest was accomplished in April 2000.

Leaf prunings (P1) were carried out as follows: the dead leaf sheaths and the old green leaf blades on the lower part of the plant were removed twice a year in March and September leaving at least eight functional leaves on the plant. Plants without leaf pruning (P0) were allowed to grow freely.

Data collection and analysis: During transplanting suckers into the permanent field and then at 26-week intervals, data of plant components were recorded. No data were recorded during the nursery phases. At each sampling, two plants per plot were measured, uprooted and separated into corm, pseudostem, leaf blades and sheaths and inflorescence. Pseudostem height was measured from ground level to the base of the upper petiole of the oldest leaf, while the pseudostem circumference was measured at a point 60 cm above the junction between the corm and pseudostem. Fresh weight of all above ground fractions was determined. These fractions were then chopped and sub sampled. Five hundred grams of fresh material per fraction was then dried at 105°C for 24 h in a forced-air ventilated oven to assess the dry matter concentration. It proved impossible to recover roots quantitatively. Dry weight partitioning between corm, pseudostem, leaves and flower of the plants were expressed as percentage of the dry weight of the whole plant.

The development over time of the dry weights was expressed per unit space (i.e., as g m^{-2}). As the spacing of transplants in the nurseries and of the plants in the permanent field was different in the various phases, total plant dry matter yield per unit space was only assessed for the period after final transplanting. Logistic curves were fitted to the yield per area in the three transplanting regimes. The effects of transplanting methods on the parameters describing this logistic growth were subsequently tested using a t-test.

The data were processed by analysis of variance procedures (Genstat 5.4.1) and significant treatment means separated by LSD (0.05).

RESULTS

Height of the pseudostem: The increase in pseudostem height was very slow in both T_1 and T_2 treatments, during the fist year (Fig. 1A). The pseudostem height of T_1 plants increased rapidly after 52 weeks of transplanting until senescence. In case of T_2 plants, the height increased rapidly for six months and then from 130 weeks onwards the growth was constant. Unlike in T_1 and T_2 plants, the pseudostem height of T_3 plants increased at a constant rate from the time of first transplanting until flowering.

Transplanting treatments significantly affected the pseudostem height at all harvest dates except at 260 weeks after transplanting (Fig. 1A). Compared to T_2 and T_3 treatments, until 130 weeks after first transplanting, T_1 plants had the highest pseudostem, after which they rapidly died. At 156, 182, 208 and 234 weeks after first transplanting the T_2 treatment significantly increased pseudostem height by 28, 38, 31 and 21%, respectively compared to T_3 treatment. The pseudostem continued to grow after flowering in all three transplanting treatments because of the appearance of new leaves, until shortly before flowering. Leaf pruning treatments did not affect height of pseudostem. There were no statistically significant interactions between transplanting and leaf pruning treatments

Circumference of the pseudostem: The circumference of T_1 plants increased constantly from transplanting till flowering and then declined. In case of the T_2 and T_3 plants, the circumference initially showed a constant increase and thereafter (between 208 and 234 weeks) a sharp increase (Fig. 1B).

Transplanting treatments significantly affected circumference of the pseudostem at all harvest dates (Fig. 1B). Up to 130 weeks from transplanting, T_1 plants had the longest pseudostems. At 156, 182, 208 and 234 weeks after first transplanting T_2 treatment significantly increased circumference of the pseudostem by 55, 40, 44 and 20%, respectively compared to T_3

treatment. At 260 weeks after first transplanting, however, the pseudostem circumference of T_2 plants declined by 13% as a result of plant senescence. The average maximum circumferences of pseudostems were 2.0 and 1.7 m for T_2 and T_3 treatments, respectively and were reached at flowering or shortly before flowering. Leaf pruning treatments did not affect circumference of pseudostem. Interactions between transplanting and leaf pruning treatments were not statistically significant.

Dry matter yield of corm per plant: Dry matter yield of corms of T_2 plants were greater than those of T_2 and T_3 plants 104 and 130 weeks in both pruned and unpruned plants (Table 1). Since enset plants transplanted once were dead, it was not possible to compare the dry matter yield of corm of the three transplanting treatments after 156 weeks of transplanting. Compared to transplanting thrice, transplanting twice increased the dry matter yield of corm by 75, 56, 29 and 36% at weeks 156, 182, 208 and 234 weeks, respectively.

The largest corm dry matter yields of T_1 and T_2 plants were at flowering, while for T_3 plants it was obtained shortly before flowering. The maximum corm dry matter yields of T_2 and T_3 plants were higher by 139 and 43%, respectively compared to that of T_1 plants.

Leaf pruning treatments did not significantly affect corm dry matter yield. Also, there were no significant interactions between transplanting and leaf pruning treatments.

Dry matter yield of the pseudostem: Transplanting effects on dry matter yield of pseudostem were significant at all harvest dates except at 260 weeks after the first transplanting (Table 2). Maximum dry weights of

Table 1: Dry matter yields of corm (kg/plant) of the enset plant at different weeks after first transplanting into permanent field for different transplanting and leaf pruning treatments. Plants of T_1 senesced rapidly after 130 weeks of first transplanting

Transplanting (A)	Leaf pruning (B)	Weeks after removal from the mother corm: 104	130	156	182	208	234	260
Once (T_1)	Without	4.22	5.15					
	With	4.65	3.58					
	Mean	4.44a	4.37a					
Twice (T_2)	Without	1.03	2.84	5.88	6.60	7.41	9.99	9.01
	With	1.06	3.07	5.93	6.87	8.21	11.25	7.24
	Mean	1.05b	2.96b	5.91a	6.74a	7.81a	10.62a	8.13
Thrice (T_3)	Without	0.46	1.32	3.45	4.23	6.31	8.03	8.03
	With	0.33	1.30	3.30	4.42	5.83	7.60	7.09
	Mean	0.40c	1.31c	3.38b	4.33b	6.07b	7.82b	7.57
Average (B)	Without	1.90	3.10	4.67	5.42	6.86	9.01	8.52
	With	2.01	2.65	4.62	5.65	7.02	9.43	7.17
	Grand mean	1.96	2.88	4.64	5.53	6.94	9.22	7.84
	CV (%)	33.7	21.6	20.5	18.6	15.4	18.6	27.9
	p or LSD (0.05) A	0.7***	0.66***	1.1**	1.2**	1.2*	1.94*	ns
	p or LSD (0.05) B	ns	p<0.09	ns	ns	ns	ns	ns
	p or LSD (0.05) A X B	ns	0.9*	ns	ns	ns	ns	ns

Note: ns, *, ** and *** stands for non-significant, significant at p<0.05, 0.01 and 0.001, respectively (F-test). Different letter(s) in a column indicate significant difference at p<0.05

Table 2: Dry matter yields of pseudostem (kg/plant) of the enset plant at different weeks after first transplanting into permanent field for the different transplanting and leaf pruning treatments. Plants of T_1 senesced rapidly after 130 weeks of first transplanting

Transplanting (A)	Leaf pruning (B)	Weeks after removal from the mother corm: 104	130	156	182	208	234	260
Once (T_1)	Without	13.50	17.67					
	With	12.98	15.50					
	Mean	13.24a	16.59a					
Twice (T_2)	Without	2.60	8.50	12.67	17.11	21.80	26.20	11.97
	With	3.34	9.86	13.04	13.63	17.80	26.90	15.19
	Mean	2.97b	9.18b	12.86a	15.37a	19.80a	26.55a	13.58
Thrice (T_3)	Without	1.73	3.65	5.58	10.67	14.30	18.90	15.33
	With	1.38	2.81	5.32	8.05	11.80	14.40	13.01
	Mean	1.56c	3.23c	5.45b	9.36b	13.10b	16.65b	14.17
Average (B)	Without	5.94	9.94	9.13	13.89	18.05	22.55	13.65
	With	5.90	9.39	9.18	10.84	14.80	20.65	14.10
	Grand mean	5.92	9.67	9.15	12.37	16.40	21.60	13.88
	CV (%)	27.2	21.0	25.6	28.8	27.1	26.2	16.8
	p or LSD (0.05) A	1.7***	2.16***	2.6***	4.0**	5.03*	6.4*	ns
	p or LSD (0.05) B	ns	ns	ns	p<0.12	ns	ns	ns
	p or LSD (0.05) A X B	ns	ns	ns	ns	ns	ns	ns

Note: ns, *, ** and *** stands for non-significant, significant at p<0.05, 0.01 and 0.001, respectively (F-test). Different letter(s) in a column indicate significant difference at p<0.05

Table 3: Parameter values (with SE in brackets) for fitted model by the logistic function Y = A + C/(1+ EXP(-B(X-M))) describing the growth of enset from first transplanting into permanent field to soon after (T_1 and T_2 plants) or at flowering (T_3)

Treatments		Fitted initial relative growth rate (Week^{-1}) (B)	Fitted time of maximum growth (Weeks) (M)	Fitted increment (g m^{-2}) (C)	Fitted minimum weight (g m^{-2}) (A)	Fitted maximum rate of increase (g m^{-2} week^{-1}) (MI)*	R^2
T_1	(n = 7)	0.152(0.26)a	74(9.36)a	5144(989)a	250(720)a	195	0.86
T_2	(n = 9)	0.038(0.02)a	150(14.90)b	8213(1949)b	88(1252)a	79	0.89
T_3	(n = 7)	0.040(0.01)a	178(7.18)c	6485(1013)c	512(618)a	65	0.98

Figures accompanied by different letter(s) are significantly different (t-test, $p<0.05$). (MI)* is calculated as B x C/4

pseudostem were 16.59 and 26.55 kg per plant for T_1 and T_2, respectively and were obtained at flowering in T_2 and shortly after flowering in T_1. Enset plants transplanted once or twice showed an increase in dry weight of pseudostem until 130 and 234 weeks after the first transplanting, respectively and thereafter in both cases the yield decreased. At 104 and 130 weeks after first transplanting, T_1 treatment gave the highest dry weight of pseudostem per plant compared to T_2 and T_3 treatments. At 156, 182, 208 and 234 weeks after first transplanting the T_2 treatment increased dry weight of pseudostem by 136, 64, 51 and 59%, respectively compared to the T_3 treatment. At 260 weeks after first transplanting, T_2 and T_3 treatments gave similar yields of the pseudostem per plant.

Leaf pruning treatments as well as interactions between transplanting and leaf pruning treatments were not significant.

Total dry matter production per unit space and time: Transplanting treatments significantly affected the fitted time of maximum growth and the fitted increment (Table 3). Increase in dry matter was earlier in T_1 plants, as shown by the mid point (M) of the fitted curve which was achieved 76 and 104 weeks earlier compared to T_2 and T_3 treatments, respectively. The fitted increment (g m^{-2}) of T_2 plants was 60 and 27% higher than T_1 and T_3 plants, respectively. Similarly, the fitted maximum rate of increase of T_1 plants 147 and 200% higher than T_2 and T_3 plants, respectively. However, the fitted initial relative growth rate and minimum weight were similar for all transplanting treatments.

Dry matter partitioning: At the time of transplanting suckers or transplants into permanent field and afterwards until or soon after flowering the dry matter of T_1, T_2 and T_3 treatments were apportioned largely to the pseudostem (Fig. 2). The proportion of dry matter of the pseudostem of T_1 treatment reached 61% soon after flowering and, thereafter declined rapidly to 46%. The maximum pseudostem dry matter proportions of T_2 and T_3 treatments were 57 and 54%, respectively and were occurred shortly before flowering. The dry matter

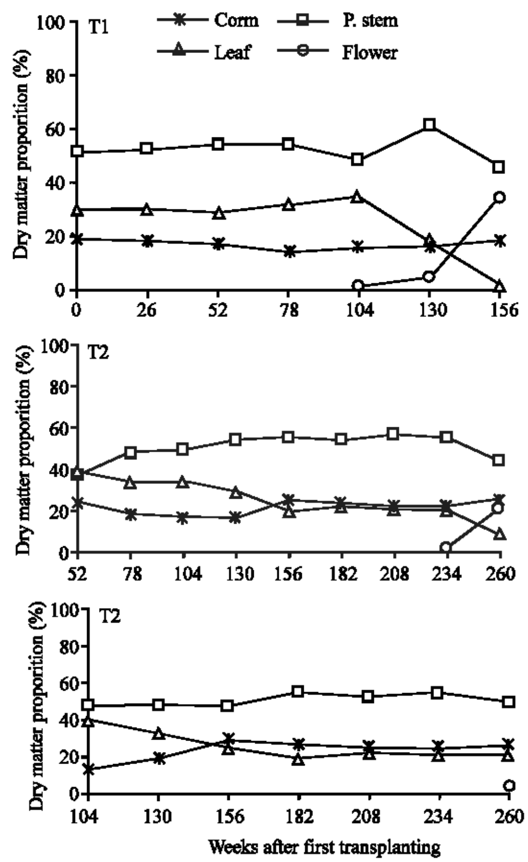

Fig. 2: Proportion (%) of corm, pseudostem, leaves and flower in the total plant dry matter after first transplanting. Note: T_2 (transpalnted twice) and T_3 (transplanted thrice) plants were transpalnted into permanent field 52 and 104 weeks later than T_1 (transpalnted once) plants, respectively

proportion of the pseudostem of T_1 plants was constant from first transplanting until flowering, whereas in T_2 and T_3 the proportion of the pseudostem increased after 104 and 156 weeks of first transplanting, respectively.

The corm dry matter proportion of the T_1 treatment varied between 16-19% from transplanting until flowering. That for T_2 increased steadily at least between 130 and 156 weeks, while foe T_3 between 104-156. The increases of T_2 and T_3 plants were from 19 to 26% for T_2 and 17 to 26% for T_3.

The proportion of dry matter in the leaves was between 30 and 35 percent for T_1 treatment. At flowering it declined to 18 percent by the 130 weeks and to near zero in week 156. In the T_2 treatment a high proportion of leaf dry matter (about 35%) was recorded until 104 weeks after first transplanting declined thereafter to 9% in the 260th week after first transplanting (6 months after flowering). The proportion of dry matter to the leaves for the T_3 treatment decreased from 40% at 104 weeks to less than 20% at the time of flowering. As T_3 plants were completely destroyed by corm rot disease, data were not taken after flowering.

DISCUSSION

Height and circumference of pseudostem: The data in Fig. 1 show that the maximum pseudostem height of T_1 and T_2 treatments were 2.32 and 2.38 m, respectively, which were within the range of 2.30-3.50 m mean pseudostem height reported by Kefale and Sandford (1991). The maximum pseudostem height of T_3 treatment (1.86 m) was close to the mean pseudostem height (1.69 m) reported by Endale (1997), but lower than the reported measurements of Kefale and Sandford (1991). The decline in pseudostem height of T_3 treatment could be caused by corm rot, a fungal disease that is common when plants are in the field for too long. It is possible that the pseudostem height of T_3 plants with a longer vegetative period would have been higher if the disease had not attacked the plants. The maximum pseudostem height of T_1 and T_2 treatments were measured six months after flowering indicating the continuous increase of pseudostem height by prolonged photosynthetic activity of enset leaves produced soon before flowering. Although the growth period (234 weeks) of T_2 treatment was much longer compared to that of T_1 (130 weeks), the difference in pseudostem height was only 0.50 m. This result indicates that repetitive transplanting delays height growth.

Maximum pseudostem circumferences of T_2, T_3 and T_1 treatments were 2.00, 1.67 and 1.34 m, respectively (Fig. 1). Bezuayehu *et al.* (1993) reported 1.9, 1.9 and 1.7 m for direct, twice and three times transplanted enset suckers, respectively, which shows that in our experiment effects were larger. The maximum circumferences of T_2 and T_3 treatments were higher by 49 and 25%, respectively over to T_1 treatments indicating substantial increase in circumference of pseudostem as a result of repetitive transplanting. This effect is in contrast with that for height. The improved pseudostem circumference as a result of repetitive transplanting may have important implications for stored starch yield at the later stage of growth. In enset growing regions, farmers use circumference of pseudostem to evaluate kocho yield of enset land races and to predict the time of maturity. The enset plant is considered mature and productive in terms of kocho yield when it attains the highest circumference of pseudostem. A sharp increase in pseudostem circumference of T_2 and T_3 treatments after 208 weeks of transplanting might suggest the starting period of the growth of the apical bud of repetitively transplanted enset suckers. The enset plant has an apical bud in the centre of the corm. It is usually the largest bud on the corm that starts to grow up slowly through the centre of the pseudostem forming the true stem which later carries the inflorescence. Indeed the trends over time for the circumference of pseudostem and for T_3 were very similar (Fig. 1).

There was a long interval of on increase in circumference in T_3 as the growth of plants was disturbed when plants were transplanted at large size. This was less strong in T_2 treatments. The absence of sudden increase in circumference of pseudostem of T_1 plants might indicate a steady growth of the apical bud of pseudostem into inflorescence.

Dry matter production and distribution: The rate of enset development from transplanting to flowering was highly influenced by methods transplanting. Flowering was delayed by 130 weeks (T_2) and by 156 weeks (T_3) (Fig. 2). This implies that perhaps the growth of the apical bud in the centre of the corm was slowed as a result of repetitive transplanting. The fitted maximum rate of increase (g m^{-2} $week^{-1}$) of T_1 plants was higher compared to T_2 and T_3 plants (Table 3). The lower fitted maximum rates of increase in T_2 and T_3 plants are associated with a longer growth period. If dry matter yield of kocho per unit space and time was considered, however, the maximum yields of T_2 and T_3 plants were higher than T_1 by 68 and 29%, respectively (Tsegaye and Struik, 2001). This result indicates higher improvement kocho as a result of two transplantings.

Although the fitted maximum rate of increase of T_1 plants was higher compared to T_2 and T_3 plants, the partitioning of dry matter to the harvestable parts and the harvest indices at the different stage of processing was improved as a result of repetitive transplanting (Fig. 2, Table 1 and 2). The larger fitted maximum rate of increase of T_1 plants on the other hand might be interesting for farmers who produce enset for other purposes such as livestock feed fibre and wrapping.

The proportion of dry matter allocated to the corm, pseudostem and leaves of T_1 plants was similar in magnitude with the course of time until flowering (Fig. 2), indicating that the dry matter partitioning is very conservative over time. This finding is in good agreement with the findings of Rodrigo *et al.* (1997) who reported constant dry matter partitioning to the different parts of banana plants. In T_2 and T_3 treatments, however, a variation in proportion of dry matter distribution between corm, pseudostem and leaves was observed with the advancement in crop age as a result of repetitive transplanting (Fig. 2, Table 1 and 2). In these treatments, in the first one-year substantial leaf growth and after 2½ years, corm and pseudostem growth was observed. In directly transplanted enset suckers the corm and pseudostem (sink) did not develop fully and thus sink-limited growth may be possible. Thus, the corm, pseudostem and leaves might grow simultaneously in about constant proportions until flowering, after which the leaves ceased active growth. In T_2 and T_3 plants, however, a large proportion of corm and pseudostem dry matter were present at the time of transplanting and thus substantial leaf growth was observed for the first one year which then was followed by the growth of corm and pseudostem (Fig. 2).

In this study, in general the proportion of dry matter to the corm increased steadily with the advancement in crop age up to maturity and did not declined at the end (Fig. 2). The proportion of pseudostem dry matter also increased steadily with the advancement in crop age but declined soon after flowering. This finding is in agreement with the general pattern observed in root crops. A decrease in proportion of dry matter into leaves, petiole and fibrous roots as season progresses and an increase in proportion of dry matter into the tuberous roots was reported in cassava (Chowdhury, 1988), foot yam (Das *et al*., 1997) and yam (Lahai *et al*., 1999).

An increase in dry matter proportion of corm and pseudostem in T_2 and T_3 treatments as the season progresses may presumably be due to the higher rate of translocation of photosynthates from the source (leaves) to the sink (corm and pseudostem). Repetitive transplanting retarded the growth rate of the pseudostem and corm at early stage of growth but at the later growth stage it increased the sink size and capacity (the competitive ability of corm and pseudostem to receive or attract assimilates). As the leaf emergence rate of enset is high at early stage of growth and leaf pruning treatments did not affect the yield of enset, source limitation is unlikely. Thus, a well-developed sink both in size and capacity as a result of repetitive transplanting might have the potential capacity to receive or attract more assimilates. The primarily regulation of partitioning of assimilates among sinks by the sinks themselves was suggested by Bouwkamp and Hassam (1988) in sweet potato and Marcelis (1994) in cucumber.

Leaf pruning: Leaf pruning did not affect height and circumference of pseudostem, dry weight of pseudostem and corm and total plant dry matter yield. Interaction between transplanting and leaf pruning were also not significant. Lack of a significant yield reduction as result of removal of leaves, twice a year, leaving 8 functional leaves suggest that enset can be productive with small number of leaves than it maintains. The suggestion of Tsegaye and Struik (2000) that at later stages of growth prolonged leaf pruning might have an effect on the yield of plant components and kocho was not substantiated. Robinson *et al.* (1992) indicated that also in bananas, a plant in the same family disadvantages of moderate leaf pruning (eight leaves retained) are minimal as a result of photosynthetic compensation when leaves are pruned and the greater photosynthetic efficiency of healthy leaves.

Practical implications: Repetitive transplanting decreased the fitted maximum rate of increase (g m^{-2} $week^{-1}$) of the enset plant and thus prolonged the immaturity period of enset. The dry matter partitioning to the harvestable parts, however, were increased as a result of repetitive transplanting. Partitioning of dry matter to the harvestable organs of the plant seems more important than total dry matter production rate for determining kocho yield of enset plants. Thus it might be practical to transplant several times in order to increase the partitioning of dry matter to the corm and pseudostem which is the harvestable parts of the enset plants. For early yield, livestock feed and other purposes, direct transplanting might more beneficial. Circumference of the pseudostem seems a good indicator for high harvest index after fermentation.

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