Standing Biomass, Dry-Matter Production, and Nutrient Demand of Tenera Oil Palm

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Supplementary Materials

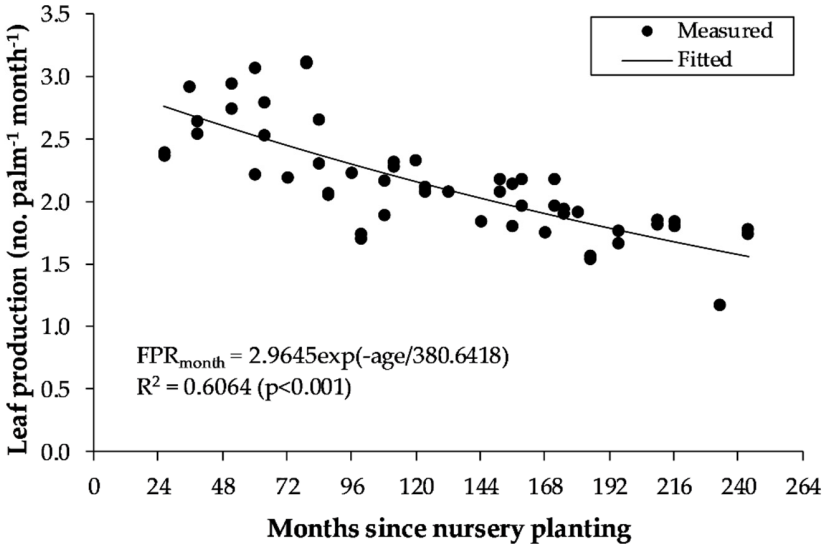

Figure S1. Leaf production rate of tenera oil palm grown under Malaysian inland environment. Data were obtained from three oil palm planting density trials carried out under Malaysian inland environment [30]. Data were recorded from experimental palms planted at 136–148 palms per hectare. The regression line was derived by fitting data to nonlinear regression functions using TableCurve 2D version 5.01 (SYSTAT Software Inc., 2002).

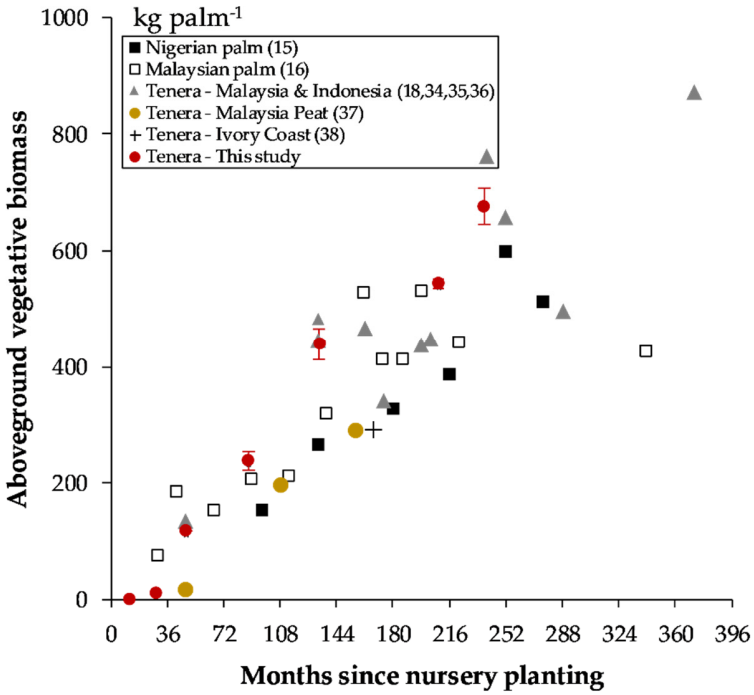

Figure S2. Aboveground vegetative biomass of oil palm as quantified in this study and in previous studies [15,16,18,34,35,36,37,38]. Malaysian palms sampled by Corley et al. [16] were mostly dura while Rees and Tinker [15] did not specify the type of palm they sampled in Nigeria but likely of the dura type. The aboveground vegetative biomass of oil palm presented here excludes leaf bases. Error bars are standard errors.

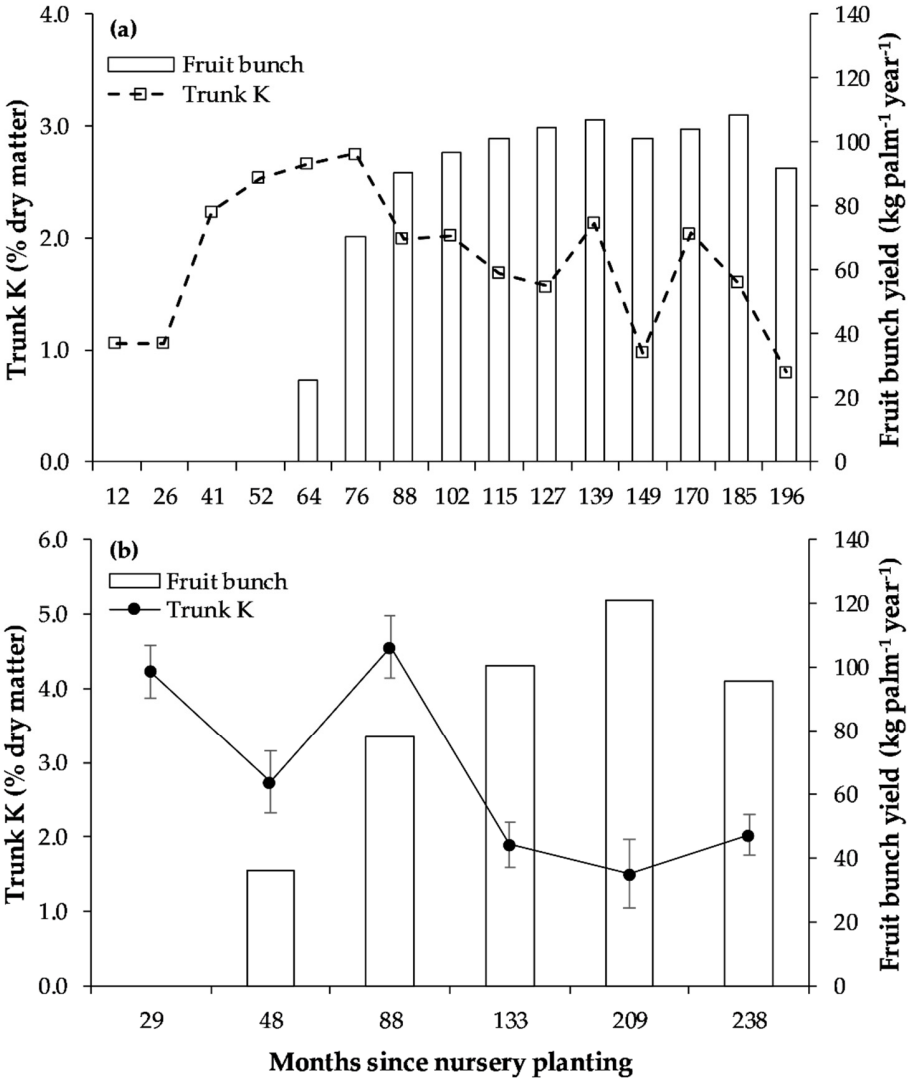

Figure S3. Trunk K concentration in relation to palm age and fruit bunch yield in Ng et al. [2] (a) and this study (b). Fresh fruit bunch yields were converted to dry weight by multiplying 0.5275 [32].

Table S1. Concentrations (mean ± SE) of N, P, K, Mg, Ca and B in spear leaves, rachis, petiole, leaflets and leaf bases of tenera oil palms of different ages. Palm age is given in month since nursery planting. SE denotes standard error.

Palm	% dry matter					mg kg^{-1}
age	N	P	K	Mg	Ca	B
			Spear leaves			
12	1.86 ± 0.20	0.312 ± 0.021	2.38 ± 0.10	0.28 ± 0.02	0.39 ± 0.04	11.6 ± 0.3
29	1.90 ± 0.03	0.314 ± 0.017	2.13 ± 0.04	0.29 ± 0.01	0.44 ± 0.01	11.9 ± 0.6
48	1.52 ± 0.12	0.268 ± 0.021	2.02 ± 0.15	0.22 ± 0.02	0.35 ± 0.03	10.5 ± 2.6
88	1.26 ± 0.20	0.156 ± 0.010	2.01 ± 0.07	0.16 ± 0.01	0.28 ± 0.02	10.3 ± 1.0
133	1.13 ± 0.14	0.148 ± 0.014	2.03 ± 0.14	0.15 ± 0.01	0.29 ± 0.02	10.0 ± 0.9
209	1.18 ± 0.12	0.152 ± 0.018	1.79 ± 0.09	0.14 ± 0.01	0.26 ± 0.02	12.4 ± 2.3
238	0.99 ± 0.07	0.143 ± 0.009	2.24 ± 0.18	0.17 ± 0.01	0.28 ± 0.03	9.2 ± 0.3
			Rachis			
12	0.53 ± 0.05	0.106 ± 0.015	1.90 ± 0.06	0.09 ± 0.01	0.24 ± 0.04	6.4 ± 0.4
29	0.46 ± 0.06	0.124 ± 0.036	1.11 ± 0.06	0.15 ± 0.04	0.34 ± 0.05	4.4 ± 0.7
48	0.25 ± 0.02	0.056 ± 0.006	1.42 ± 0.04	0.08 ± 0.01	0.25 ± 0.02	6.2 ± 0.3
88	0.25 ± 0.02	0.075 ± 0.020	1.91 ± 0.16	0.07 ± 0.01	0.32 ± 0.03	5.7 ± 0.8
133	0.18 ± 0.02	0.047 ± 0.007	1.56 ± 0.21	0.07 ± 0.01	0.37 ± 0.02	6.2 ± 0.2
209	0.27 ± 0.03	0.087 ± 0.013	1.44 ± 0.22	0.06 ± 0.01	0.30 ± 0.04	7.0 ± 1.2
238	0.29 ± 0.05	0.051 ± 0.005	1.52 ± 0.07	0.06 ± 0.01	0.21 ± 0.02	6.6 ± 0.8
			Petiole			
12	0.55 ± 0.10	0.119 ± 0.012	1.50 ± 0.11	0.14 ± 0.01	0.20 ± 0.02	8.3 ± 0.3
29	0.58 ± 0.06	0.142 ± 0.024	1.35 ± 0.05	0.19 ± 0.02	0.28 ± 0.04	7.9 ± 0.7
48	0.39 ± 0.03	0.101 ± 0.014	2.17 ± 0.14	0.15 ± 0.01	0.40 ± 0.01	11.3 ± 1.2
88	0.45 ± 0.03	0.113 ± 0.021	2.58 ± 0.16	0.16 ± 0.02	0.47 ± 0.07	12.1 ± 1.1
133	0.35 ± 0.04	0.068 ± 0.004	2.25 ± 0.23	0.14 ± 0.02	0.45 ± 0.03	10.2 ± 1.5
209	0.43 ± 0.06	0.120 ± 0.020	2.20 ± 0.23	0.13 ± 0.02	0.43 ± 0.05	11.8 ± 1.6
238	0.44 ± 0.06	0.087 ± 0.015	2.23 ± 0.15	0.13 ± 0.01	0.31 ± 0.03	10.1 ± 0.9
			Leaflets			
12	2.60 ± 0.10	0.186 ± 0.003	1.95 ± 0.07	0.27 ± 0.04	0.49 ± 0.03	13.0 ± 0.4
29	2.55 ± 0.06	0.173 ± 0.005	1.08 ± 0.04	0.37 ± 0.04	0.73 ± 0.06	9.6 ± 1.3
48	1.63 ± 0.10	0.157 ± 0.019	0.98 ± 0.05	0.20 ± 0.01	0.50 ± 0.06	11.8 ± 1.1
88	1.84 ± 0.16	0.135 ± 0.006	1.04 ± 0.04	0.19 ± 0.03	0.57 ± 0.05	11.1 ± 1.2
133	1.72 ± 0.09	0.118 ± 0.007	1.07 ± 0.09	0.18 ± 0.01	0.55 ± 0.05	13.6 ± 2.3
209	1.82 ± 0.06	0.124 ± 0.010	0.92 ± 0.07	0.20 ± 0.03	0.56 ± 0.07	13.3 ± 0.1
238	1.85 ± 0.16	0.117 ± 0.003	0.96 ± 0.05	0.23 ± 0.02	0.47 ± 0.02	11.9 ± 0.7
			*Leaf bases			
12	-	-	-	-	-	-
29	-	-	-	-	-	-
48	0.51 ± 0.10	0.112 ± 0.020	1.75 ± 0.11	0.26 ± 0.03	0.25 ± 0.02	14.6 ± 1.3
88	0.64 ± 0.11	0.074 ± 0.014	2.52 ± 0.37	0.13 ± 0.02	0.21 ± 0.02	6.2 ± 1.5
133	0.53 ± 0.10	0.057 ± 0.007	1.95 ± 0.35	0.27 ± 0.02	0.23 ± 0.02	9.8 ± 1.0
209	0.61 ± 0.04	0.122 ± 0.030	1.51 ± 0.13	0.28 ± 0.02	0.32 ± 0.06	11.3 ± 0.3
238	0.41 ± 0.03	0.059 ± 0.010	2.13 ± 0.15	0.13 ± 0.03	0.46 ± 0.14	8.3 ± 0.9

*No leaf bases were recovered from 12 and 29 months old tenera palms.

Table S2. Concentrations (mean ± SE) of N, P, K, Mg, Ca and B in cabbage, trunk, bole and roots attached to bole of tenera oil palms of different ages. Palm age is given in month since nursery planting. SE denotes standard error.

Palm	% dry matter					mg kg^{-1}
age	N	P	K	Mg	Ca	B
			†Cabbage			
12	-	-	-	-	-	-
29	-	-	-	-	-	-
48	2.45 ± 0.47	0.363 ± 0.066	5.06 ± 0.08	0.90 ± 0.06	0.90 ± 0.03	17.9 ± 1.2
88	2.41 ± 0.11	0.412 ± 0.033	5.04 ± 0.37	0.72 ± 0.07	0.85 ± 0.12	22.2 ± 2.0
133	2.19 ± 0.24	0.409 ± 0.056	4.79 ± 0.19	0.70 ± 0.10	0.83 ± 0.11	20.8 ± 1.1
209	2.75 ± 0.29	0.519 ± 0.070	5.00 ± 0.29	0.74 ± 0.11	0.82 ± 0.08	22.7 ± 2.1
238	2.23 ± 0.17	0.327 ± 0.043	5.30 ± 0.85	0.56 ± 0.03	0.76 ± 0.08	20.3 ± 1.9
			‡Trunk			
12	-	-	-	-	-	-
29	2.62 ± 0.13	0.532 ± 0.027	4.23 ± 0.35	0.68 ± 0.04	0.86 ± 0.08	14.5 ± 0.9
48	0.67 ± 0.07	0.109 ± 0.010	2.18 ± 0.39	0.10 ± 0.01	0.27 ± 0.02	13.5 ± 1.4
88	0.78 ± 0.11	0.110 ± 0.018	4.50 ± 0.46	0.09 ± 0.01	0.33 ± 0.01	11.7 ± 2.4
133	0.49 ± 0.09	0.073 ± 0.006	1.82 ± 0.30	0.08 ± 0.01	0.27 ± 0.03	7.6 ± 0.4
209	0.63 ± 0.16	0.083 ± 0.016	1.44 ± 0.46	0.09 ± 0.01	0.22 ± 0.03	6.8 ± 1.1
238	0.55 ± 0.04	0.078 ± 0.015	1.97 ± 0.27	0.08 ± 0.01	0.18 ± 0.02	6.4 ± 0.5
			Bole			
12	1.28 ± 0.29	0.224 ± 0.023	1.39 ± 0.08	0.16 ± 0.01	0.18 ± 0.05	8.8 ± 0.3
29	1.21 ± 0.19	0.205 ± 0.017	1.08 ± 0.10	0.12 ± 0.01	0.32 ± 0.03	9.0 ± 0.7
48	0.43 ± 0.10	0.042 ± 0.006	2.10 ± 0.40	0.05 ± 0.02	0.27 ± 0.01	9.3 ± 1.0
88	0.75 ± 0.23	0.067 ± 0.026	2.23 ± 0.18	0.08 ± 0.01	0.32 ± 0.02	9.0 ± 1.4
133	0.31 ± 0.05	0.034 ± 0.003	2.36 ± 0.44	0.08 ± 0.01	0.33 ± 0.02	9.3 ± 1.1
209	0.42 ± 0.08	0.042 ± 0.008	1.76 ± 0.34	0.09 ± 0.02	0.28 ± 0.02	8.8 ± 2.5
238	0.49 ± 0.06	0.037 ± 0.007	1.57 ± 0.06	0.09 ± 0.02	0.22 ± 0.01	6.8 ± 0.3
			Roots attached to bole			
12	0.82 ± 0.14	0.107 ± 0.007	1.61 ± 0.06	0.13 ± 0.01	0.16 ± 0.05	13.8 ± 2.0
29	0.59 ± 0.06	0.080 ± 0.011	1.09 ± 0.08	0.08 ± 0.01	0.11 ± 0.01	4.5 ± 1.3
48	0.25 ± 0.03	0.054 ± 0.017	0.63 ± 0.12	0.08 ± 0.01	0.07 ± 0.01	5.3 ± 0.2
88	0.37 ± 0.05	0.026 ± 0.005	0.98 ± 0.08	0.07 ± 0.01	0.08 ± 0.01	5.0 ± 0.4
133	0.30 ± 0.03	0.033 ± 0.005	0.59 ± 0.14	0.07 ± 0.01	0.06 ± 0.01	5.0 ± 0.8
209	0.34 ± 0.01	0.014 ± 0.005	0.55 ± 0.05	0.06 ± 0.01	0.05 ± 0.01	5.8 ± 1.3
238	0.30 ± 0.04	0.016 ± 0.001	0.53 ± 0.06	0.06 ± 0.01	0.06 ± 0.01	3.5 ± 0.3

†Cabbage tissue of 12-month-old palm was not separated but treated as bole tissue while cabbage tissue of 29-month-old palm was treated as trunk tissue. There was no trunk tissue for 12-month-old palm.

Table S3. Dry matter production (mean ± SE) of mature oil palms in Malaysia, Nigeria and Ivory Coast, estimated from destructive measurements. Except data from this study, all other data were after Corley and Tinker [11]. Other studies did not report SE values.

Reference	Palm age (years)	Annual dry matter production (kg palm^{-1} year^{-1})								
		Leaves	Trunk	Leaves + trunk	Bole	‡Roots	Total vegetative	Bunches	Whole palm	Site
This study	7-20	125.0 ± 6.8	24.2 ± 2.4	149.2 ± 8.0	3.5 ± 0.6	15.0 ± 0.8	168.2 ± 8.5	98.9	267.0 ± 8.5	1
Rees and Tinker [15]	7-22	67.6	21.6	89.2	-	7.4	96.6	32.4	129.1	2
Ng et al. [2]	8-15	70.5	57.3	127.8	-	2.5	130.3	94.6	224.9	1
Corley et al. [16]	6-18	113.1	18.0	131.1	-	3.3	134.4	103.3	237.7	1
Dufrene [38]	10	76.2	14.7	90.9	-	80.4	171.3	61.5	232.9	3

‡Except for this study and Dufrene [38] where annual root dry matter production was estimated, other figures for roots represent net annual increase in total dry weight only. This study used Equation 4 to estimate annual root dry matter production.
Site: 1: Malaysia; 2: Nigeria; 3: Ivory Coast

Table S4. Nutrient balance sheet prepared for the studied mature (88–238 months old) tenera oil palms grown on Harimau Series soil (Typic Paleudult) in Malaysia.

Net nutrient demand based on palm demand and lost (kg ha^{-1} $year^{-1}$)				
	N	**P**	**K**	**Mg**
Palm demand				
1. Nutrients required to grow 27 t FFB ha^{-1} $year^{-1}$	128	21	171	35
2. Nutrients required to grow spear leaves, trunk, bole, roots	35	4	115	5
Total	163	25	286	40
Environmental demand				
1. Nutrients lost through leaching (%) [49]	3.0	1.5	2.9	15.5
2. Nutrients lost through erosion and surface runoff (%) [50]	8.0	1.6	15.3	7.6
Expected total losses (%)	11.0	3.1	18.2	23.1
Expected total losses of nutrients	14	1	52	9
Accounted for palm and environmental demand	177	26	338	49
Average amount of nutrients applied to the sampled palms	131	33	284	38
Surplus or (deficit)	(46)	7	(54)	(11)

Fresh fruit bunch yield of 27 t ha^{-1} was averaged from actual yields of sampled palms aged 88, 133, 209 and 238 months. The average amount of nutrients applied to the sampled tenera palms was calulated from Table 1. Nutrients in the leaves, male flowers and dead roots were considered to be recycled in the oil palm ecosystem as the standard plantation practice [6]. Thus, only nutrients required to support net increase in dry weight of vegetative tissues and fruit bunches are considered [2,11].