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A cost-effective novel biochemical fertilizer for the better management of nutrient levels and vegetative growth in the immature oil palm (*Elaeis guineensis* Jacq.)

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Table S1: The rates of fertilizers applied at nursery period.

Fertilizer	Rates (codes)	g/seedling		
Ammonium sulphate	21%N	0.0 (N0)	112 (N1)	224 (N2)
CIRP	34% P_2O_5	0.0 (P0)	71 (P1)	142 (P2)
MOP	60% K_2O	0.0 (K0)	34 (K1)	68 (K2)

Note: CIRP= Christmas Island Rock Phosphate; MOP= Muriate of Potash

Table S2: Fertilizer application periods and rounds for standard practice application (Treatment 1; T1) and Universiti Putra Malaysia (UPM) Biochemical Fertilizer (Treatment; T2), at Telang trial project from 2015-2018.

Year	Treatment	J	F	M	A	M	J	J	A	S	O	N	D	No.
2015	T1	■			■			■			■			4
	T2	■				■				■				3
2016	T1		■		■	■			■		■			5
	T2	■				■				■				3
2017	T1		■		■	■		■			■			5
	T2		■		■			■			■			4
2018	T1		■		■	■		■			■			5
	T2	■			■			■			■			4

Note: No= number of fertilizer applications per year. Boxes in green are T1 applications. Boxes in black are T2 applications.

Table S3: Regime/composition of fertilizer applications in standard practice application (Treatment 1; T1) and Universiti Putra Malaysia (UPM) Biochemical Fertilizer (Treatment; T2), from 2015-2018.

Year	Treatment	Contents	Formulation ratio	Total (kg/palm)	Fertilizer cost/mt	Total fertilizer cost (RM/palm)*	Total fertilizer cost (RM/ha)*	Cost saved (RM)
2015	T1	NPK Granular	9/9/12/4	3.5	973	3.4055	463.15	-159.9
	T2	UPM-BCF	11/11/15/4	4.25	1078	4.5815	623.08	
2016	T1	NPK Granular	9/9/12/4	6.5	973	6.3245	860.13	273.7
	T2	UPM-BCF	11/11/15/4	4	1078	4.312	586.43	
2017	T1	NK 27	11.6/27	7	1121	7.847	1067.19	92.9
		Kieserite	27 MgO	1	700	0.7	95.20	
		ERP	28% P_2O_5	2	400	0.8	108.80	
	T2	UPM-BCF	8.5/6.2/20/3	8	1083	8.664	1178.30	
2018	T1	NK 27	11.6/27	7.25	1121	8.12725	1105.31	120.1
		Kieserite	27 MgO	1	700	0.7	95.20	
		ERP	28% P_2O_5	1.8	400	0.72	97.92	
	T2	UPM-BCF	8.5/6.2/20/3	8	1083	8.664	1178.30	
							Total cost saved	326.8

Note: It is estimated that one hectare has a total of 136 oil palm trees. ERP= Egyptian Rock Phosphate; UPM-BF is in the form of pellets. *Costs of both fertilizers were based on 2022 by the Department of Statistic Malaysia, 2022. DOSM/BPHPP/4.2022/Series 36 - How Fertiliser Price Was Affected By The Global Situation. https://www.dosm.gov.my/v1/uploads/files/6_Newsletter/Newsletter%202022/DOSM_BPHPP_4_2022_Series%2036_compressed.pdf (assessed on August 3, 2022).

Table S4. Normality test of Shapiro-Wilk results based on all the data investigated in the presented study.

Variables	Statistics T1	Sig.	Statistics T2	Sig.
MAP	0.927	0.005*	0.927	0.005*
TotN	0.977	0.453	0.970	0.261
P	0.659	0.000*	0.738	<0.001*
K	0.987	0.857	0.952	0.047*
Ca	0.951	0.043*	0.928	0.006*
Mg	0.984	0.768	0.977	0.446
B	0.973	0.342	0.868	<0.001*
TLC	0.981	0.606	0.983	0.725
KTLC	0.965	0.161	0.909	0.001*
MgTLC	0.948	0.034*	0.974	0.375
CaTLC	0.948	0.035*	0.913	0.002*
CriticalP	0.842	0.000*	0.865	<0.001*
RachisP	0.877	0.000*	0.759	<0.001*
RachisK	0.961	0.107	0.972	0.311
FL	0.955	0.062	0.960	0.096
FNL	0.917	0.002*	0.929	0.006*
FW	0.919	0.003*	0.952	0.047*
FT	0.867	0.000*	0.892	<0.001*
CI	0.756	0.000*	0.845	<0.001*
Canopy	0.942	0.019*	0.954	0.058

Note: If the significance value of the Shapiro–Wilk Test is greater than 0.05, the data is normal. If it is below 0.05 (indicated by *), the data significantly deviate from a normal distribution.

Table S5: Comparisons of chemical concentrations pre-treatment soils of oil palms between Treatment 1 (T1) and Treatment 2 (T2) from two different depths (0-15 cm and 15-30cm) collected from Weeded Circle (WC).

WC 0-15 (N= 6)	Mean (T1)	SE	Min	Max	Mean (T2)	SE	Min	Max	WC 0-15	P	F-ratio
pH	4.25	0.05	4.14	4.47	4.29	0.02	4.20	4.34	T1 pH vs. T2 pH	0.47	4.50
Tot N	0.12	0.01	0.10	0.14	0.10	0.00	0.08	0.11	T1 Tot N vs. T2	0.05	1.97
Org C	2.27	0.22	1.65	3.26	1.98	0.08	1.78	2.32	T1 Org C vs. T2	0.25	7.32
Tot P	240	41.6	106	410	212	36.1	103	368	T1 Tot P vs. T2	0.63	1.32
Av P	11.3	4.52	2.00	33.0	8.00	1.29	5.00	12.0	T1 Av P vs. T2	0.49	12.2
CEC	4.64	0.32	3.62	5.52	4.34	0.34	2.84	5.12	T1 CEC vs. T2	0.54	1.14
Ex K	0.12	0.01	0.09	0.15	0.10	0.01	0.06	0.14	T1 Ex K vs. T2	0.25	2.64
Ex Ca	0.98	0.19	0.41	1.63	1.15	0.09	0.94	1.57	T1 Ex Ca vs. T2	0.42	4.11
Ex Mg	0.33	0.09	0.09	0.65	0.39	0.04	0.22	0.52	T1 Ex Mg vs. T2	0.51	4.59
Ex Al	0.49	0.08	0.28	0.74	0.41	0.02	0.32	0.49	T1 Ex Al vs. T2	0.32	10.9
B	1.94	0.18	1.34	2.44	1.91	0.08	1.63	2.11	T1 B vs. T2 B	0.85	4.32
WC 15-30 (N= 6)	T1 Mean	SE	Min	Max	T2 Mean	SE	Min	Max	WC 15-30	p	F-ratio
pH	4.18	0.05	3.99	4.39	4.31	0.02	4.24	4.37	T1 pH vs. T2 pH	0.05	8.83
Tot N	0.12	0.01	0.10	0.13	0.10	0.01	0.08	0.11	T1 Tot N vs. T2	0.05	1.50
Org C	2.36	0.20	1.68	2.98	1.85	0.14	1.46	2.44	T1 Org C vs. T2	0.07	2.01
Tot P	240	35.2	139	359	209	29.3	146	348	T1 Tot P vs. T2	0.51	1.44
Av P	10.5	2.68	4.00	23.0	8.17	0.70	6.00	10.0	T1 Av P vs. T2	0.42	14.5
CEC	5.27	0.36	4.07	6.16	4.19	0.47	2.38	5.95	T1 CEC vs. T2	0.10	1.75
Ex K	0.12	0.01	0.09	0.15	0.10	0.01	0.07	0.14	T1 Ex K vs. T2	0.28	2.28
Ex Ca	0.95	0.20	0.41	1.60	1.10	0.08	0.91	1.47	T1 Ex Ca vs. T2	0.51	6.31
Ex Mg	0.38	0.09	0.11	0.68	0.35	0.06	0.10	0.58	T1 Ex Mg vs. T2	0.76	2.26
Ex Al	0.53	0.08	0.31	0.75	0.42	0.03	0.35	0.51	T1 Ex Al vs. T2	0.24	10.2
B	1.83	0.17	1.22	2.33	1.85	0.08	1.59	2.13	T1 B vs. T2 B	0.92	4.42

Note: pH is unitless; Total N in %; Organic (Org) C in %; Total P in mg/kg; Available P in mg/kg; CEC in cmol(+)/kg; exchangeable K, Ca, Mg and Al in cmol(+)/kg; B in mg/kg.

Table S6: Overall mean concentrations (%) of P and K in the rachis of oil palm from the present study, from 6 to 48 months after planting (MAP).

K		T1		T2			
N= 6	MAP	Mean	SE	Mean	SE	t-value	P
	6	1.786	0.034	1.790	0.022	-0.090	0.930
	12	1.694	0.024	1.659	0.035	0.808	0.438
	18	1.508	0.042	1.487	0.032	0.397	0.700
	24	1.471	0.023	1.416	0.031	1.431	0.183
	30	1.641	0.109	1.602	0.133	0.229	0.823
	36	1.023	0.057	1.094	0.069	-0.794	0.446
	42	1.549	0.159	1.678	0.132	-0.623	0.547
	48	1.812	0.062	1.849	0.086	-0.348	0.735
P		T1		T2			
N= 6	MAP	Mean	SE	Mean	SE	t-value	P
	6	0.109	0.001	0.111	0.001	-2.414	0.036
	12	0.100	0.001	0.098	0.001	1.685	0.123
	18	0.096	0.001	0.096	0.001	0.155	0.880
	24	0.095	0.000	0.095	0.001	-0.255	0.804
	30	0.114	0.012	0.169	0.014	-2.939	0.015
	36	0.124	0.008	0.129	0.006	-0.504	0.625
	42	0.113	0.005	0.116	0.003	-0.536	0.604
	48	0.107	0.008	0.115	0.003	-0.920	0.379

Note: Fonts in red are significantly different ($P < 0.05$).

Table S7: Overall results of T-Test analysis of nutrients concentrations of the leaflets of oil palms from 6 to 48 months after planting between Treatment 1 (T1) and Treatment 2 (T2) (N= 48 for T1 and T2).

T1 vs T2	Mean	SD	Mean	SD	T-value	P	F-ratio
	T1	T1	T2	T2			
N (%)	2.92	0.13	2.95	0.15	-1.20	0.23	1.20
P (%)	0.17	0.00	0.17	0.01	0.67	0.51	1.61
K (%)	1.34	0.14	1.31	0.14	1.05	0.30	1.04
Ca (%)	0.66	0.15	0.68	0.16	-0.62	0.54	1.13
Mg (mg/kg)	0.27	0.04	0.28	0.04	-1.18	0.24	1.18
Bo (mg/kg)	17.65	2.81	17.92	2.56	-0.49	0.62	1.21

Note: SD= standard deviation

Table S8: Overall mean values of T-Test analysis of vegetative parameters of the oil palms from 6 to 48 months after planting between Treatment 1 (T1) and Treatment 2 (T2) (N= 48 for T1 and T2).

Treatment	T1		T2				
Parameters	Mean	SD	Mean	SD	t-value	P	F-ratio
Frond length	256	103	260	100	-0.18	0.85	1.05
Frond no leaflet	98.1	31.1	102	29.8	-0.59	0.55	1.09
Frond width	3.75	1.13	3.85	1.09	-0.43	0.67	1.07
Frond thickness	2.24	0.69	2.27	0.69	-0.20	0.84	1.00
Chlorophyll index	67.7	7.25	68.8	5.44	-0.84	0.41	1.78
Canopy	2529	110	258	110	-0.27	0.79	1.00

Note: SD= standard deviation.