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Soil Properties and Nutrient Concentrations of Oil Palm Leaf Collected from Small Orchards on the Southern Central Plain of Thailand

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Abstract:** Minimum fertilizer application accompanies with optimum yield is the goal for properly nutrient management for plant production including oil palm (Elaeisis quineensis). To overcome this goal, soil fertility and leaf nutrient concentration should be well understood. Thus, the study aimed at evaluating soil properties and leaf nutrient concentrations of the small oil palm orchards in the eastern fringe of Bangkok. Two orchards, the raised-bed plot and the ordinary-planting on the original flat terrain plot were selected. The soil is acid sulfate soil. Each plot had two rows, 6 oil pam trees were randomized collected from each row. Soil and leaf sampling were done and laboratory analyzed following the standard method. Soil fertility was evaluated following the criteria of Land Development Department (1992). Leaf nutrients concentrations were compared with the standard values "the adequate range" according to Reuter and Robinson (1997). The results had showed that either the raised-bed plot or the ordinary plot had more or less the same properties with some small variability among rows of each plot or between plot. They had silty clay texture and contained more than 35 cmol(+) kg-1 of the cation exchange capacity (CEC pH 7.0). They had extremely acid to moderately acid resulting their parent materials (3.88-5.80). Both plots had high fertility, considering from organic matter, available phosphorus and extractable bases. The cationic micronutrients were very high. The concentrations of leaf N, P and K were far lower from the adequate range. Among them, the K concentrations were severely low. The leaf Ca and Mg were higher than the adequate range. For trace elements (Fe, Mn, Cu, Mn), all were higher than the adequate range, especially the Fe and Mn. The raised-bed plot had somewhat higher nutrient uptakes of P, Ca, Mg, Fe and Mn while the remainders were less than those found on the ordinary plot.

Keywords: **oil palm (Elaeisis quineensis), soil, nutrition, Central Plain.**

I. BACKGROUND/ OBJECTIVES AND GOALS

Oil palm (Elaeisis quineensis), one of the most important economic plant of Thailand, mainly produced in the Peninsular Thailand and some locations in the Southeast Coast where climatic condition was the tropical monsoon, Am. It was a water-requirement plant, approximately 150 to 200 liters per plant a day (Surat Thanee Oil Palm Research Center, 2010). Consequently, the growing areas were widespread to the other regions, especially the Southern Central Plain. This area had irrigation system from the Chao Phraya River; hence, water was not the limiting factor for oil palm production. Major soils in the Southern Central Plain were acid sulfate

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soils which derived from marine and brackish water deposits with contained pyrite, FeS_2. On the processes of soil formation, the oxidation of pyrite resulted in sulfuric acid and jarosite-the actual acid soil which the unique phenomenon is very low pH and available phosphorus, high aluminum, iron and manganese in soil solution together with sulfur (Kawakuchi and Kyuma, 1969). A study of Kanyawongha (1989) revealed the very low pH (3.5 to 4.5, soil: water = 1:1) and available phosphorus (less than 5 mg kg^{-1}) and high aluminum is soil solution (more than 3000 mg kg^{-1}). This soil was originally paddy field, then, gradually changed to citrus planation. The gardeners dug the ditches, put the subsoil on surface to become raised-bed and then started growing citrus. Approximately some decades ago, due partially to pathogen and improperly management, the citrus orchards were replaced by oil palm plantation.

The oil palm plantation in the Southern Central Plain were mainly on the raised-bed which the area about 5-10 ha, in average. Ordinary plantings on the original-flat terrain were barely observed, especially the small orchards. The climatic conditions also far differed from those grown in the southern Thailand. In most, the raised-bed oil palm orchards had systematic management, either fertilizers or pesticides. However, the nutrient imbalances were still recognized. Because oil palm is the new variety for this region, thus, the properly management might not well understand. A study of Kanyawongha and Anongnat (2013) on the raised-bed oil palm-growing soils in this area showed the very strongly to strongly acid (pH 3.34-5.39, soil:water = 1:1). The organic matter contents were high in topsoil and decreased according to depth, ranging from very low to very high (5.40-50.5 g kg^{-1}). The exchangeable bases (Ca, Mg, K, Na) were low and decreased with depth. The cationic micronutrients were high and very high and decreased with depth. Phanjindawan and Nucharee (2013) studied the nutrients in soil and oil palm leaf in this region and found that the soils had very strongly to strongly acid and high in organic matter. The available phosphorus, extractable bases and cationic micronutrients of the healthy orchards were higher than those observed in the hidden hunger ones. Leaf nutrient concentrations were lower than the adequate range, in most cases, excepted for calcium.

The studied of Kanyawongha and Anongnat (2013) and Phanjindawan and Nutcharee (2013) were conducted on the systematic management together with large area orchards, still nutrition imbalance was noticeable. How about the small orchards? Fertilizers consume more than half of the budget of oil palm production (Nillanon et al., 1991). To Minimize the fertilizer application, accompany with optimum yield is the goal for plant production in small orchards of Thailand. The oil palm is one of this goal. To overcome this goal, knowing basic soil properties together with leaf nutrient concentrations should be well understood. Thus the small oil palm orchards in the Southern Central Plain were selected.

II. METHODS

The studied plots consisted of two orchards located on Bang Mam Prieo District, Chachoengsao Province-the eastern fringe of Bangkok. They were the raised-bed orchard and the ordinary-planting orchard (which subsequently called "the ordinary orchard"). Each orchard had two rows, the raised-bed orchard had 110 plants whilst the ordinary one had 140 plants. They had approximately 6 years' age at that time of sampling. Fertilizer application were the mixtures of 21-0-0, 0-0-60 and 16-20-0 into the ratio of 1-1-2. They yielded since the

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fourth year of planting which average yield was 2 tons per month. Soil of the studied site is acid sulfate soil-Chachoengsao series (Typic Tropaquepts, according to the USDA Soil Taxonomy) (Soil Survey Division, 1981).

A. Leaf Sampling and Analyses.

Each row, six oil palm trees were randomized selected. Leaf samplings were done following the standard method (Reuter and Robinson, 1997: from frond 17, 8 leaflets from the middle of the frond, the 6 inches of each sub-sampled). Before grinding, the samples were cleaned, oven-dried with 70 ^{o}C for 48 hours and weighted. The laboratory analyses consisted of total analysis by double acid digestion (HNO_3:$HClO_4$ = 4:1). The P concentration of the aliquot was colorimetric method by spectrophotometer whilst the others (K, Ca, Mg, Fe, Mn, Cu, Zn) by atomic absorption spectrophotometry. Leaf nitrogen concentration was performed by the wet digestion with sulfuric acid (H_2SO_4) and followed by the kjeldahl method (Phoovarodom, 2012). Then, the leaf nutrient concentrations were compared with the standard values "the adequate range" as proposed by Reuter and Robinson (1997). The nutrient uptakes were also calculated.

B. Soil Sampling and Analyses

Soil samplings (0-20 centimeter) were taken from the selected oil palm trees which the leaf samples were collected. Composite samples were grouped from four sites in the directions of north, south, east and west around the tree. After getting air-dried, the soils were ground and sieved pass through the 2 mm in diameter sieved-size. Analyses of the fine earth comprised of the soil reaction (pH, soil: water = 1:1) (Blackemore, et al., 1987), the electrical conductivity (EC, soil:water = 1:1) (Rhoades, 1996), organic matter (International Institute of Tropical Agriculture, 1979), available phosphorus (Bray II method), extractable bases (Ca, Mg, K, Na) and cationic micronutrients (Fe, Mn, Cu, Zn) following the standard methods (Phoovarodom, 2012). For particle size analysis together with textural classes and cation exchange capacity (CEC pH 7.0), the soil samples of each orchard were again composited, and analyzed (Gee and Bauder, 1986; International Institute of Tropical Agriculture, 1979). Subsequently, the soil properties were evaluated using the criteria proposed by Land Development Department (1992).

III. RESULTS AND DISCUSSION

A. Soil Properties

Soils of both plots had silty clay texture. Their clay, silt and sand particles were 480 g kg^{-1}, 460 g kg^{-1}, 60 g kg^{-1} for the raised-bed plot and 510 g kg-1, 450 g kg^{-1}, 40 g kg^{-1} for the ordinary plot. They had very high cation exchange capacity (CEC pH 7.0) (36.24 cmol $_{(+)}$ kg^{-1} for the former and 35.59 cmol $_{(+)}$ kg^{-1} for the latter). Because of similar in parent materials, brackish water deposited on marine deposit, either the raised-bed plot or the ordinary plot had more or less the same properties with some small variability among rows of each plot or between plot (Table 1). Both plot had extremely acid to moderately acid resulting their parent materials, similar to the study of Kanyowongha and Anongnat (2013). In average, the ordinary plot showed lower pH than the raised-bed plot. However, the pH values of the latter revealed high variability than those on the former (3.91-5.80 and 3.88-5.16, respectively). The ordinary plot had higher and less variability in electrical conductivity (EC) than those on the raised-bed plot (in average, 1.22 and 1.04 mS cm^{-1}, respectively) resulting

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in higher the extractable Na. Considering the quite high EC which extracted with 1:1 ratio of soil to water, the ordinary plot had tendency to be “the acid saline soil” (Brady and Weil, 2008). The organic matter contents were mainly higher than 25 g kg^{-1} in the ordinary plot, whilst for the raised-bed plot, more variability were observed, the row 1 the higher. The available phosphorus more or less followed the organic matter, the ordinary plot-the higher in average. The raised-bed plot revealed good interaction between organic matter and available phosphorus, the higher organic matter-the higher available phosphorus. However, such interaction was detectable only in the row 3 of the ordinary plot.

For extractable bases, calcium and magnesium contents were very high in both plots. Calcium was higher than 2000 mg kg^{-1} in average, and the raised-bed plot had slightly higher than those on the ordinary plot. Magnesium was higher than 600 mg kg^{-1} in average. Both plots had more or less the same contents of magnesium, however, high variability among plants were clearly observed in the raised-bed plot. The ordinary plot contained lower extractable potassium and higher extractable sodium than those noticed on the raised-bed plot. High extractable sodium in this plot reflected the high electrical conductivity, as afore mentioned.

Both plots had high cationic micronutrients, especially extractable iron and manganese due partially to the acid sulfate soil- the very low pH soil. The ordinary plot contained higher extractable iron, lower extractable manganese and zinc than those on the raised-bed plot, and somewhat similar contents for extractable copper.

To evaluate soil fertility, the criteria proposed by Land Development Department (1992) was used (Table appendix A). In summarize, both plots had high fertility, considering from organic matter, available phosphorus and extractable bases. The cationic micronutrients were very high so that the toxicity could be expected.

B. Leaf Nutrient Concentrations

The nutrient concentrations of oil palm leaf were presented in the table 2 together with the standard values for “adequate range” according to Reuter and Robinson (1997).

Macronutrients, concentrations of the primary elements (N, P, K) were far lower from the adequate range, similar to the studied of Phanjindawan and Nucharee (2013). Among them, the K concentrations were severely low, followed by the N and the P. However, the ordinary plot had slightly higher the N and the K, and lower the P than those on the raised-bed plot. Both plot had higher the secondary elements (Ca, Mg) than the adequate range. Similar to the P, the raised-bed plot had higher the Ca and Mg than those noticed on the ordinary plot. For trace elements (Fe, Mn, Cu, Mn), contrarily from Phanjindawan and Nucharee (2013) ’s finding, all were higher than the adequate range, especially the Fe and Mn. Thus, they had high probability to be toxic. Comparing between plots, the concentrations of N, K, Cu and Zn of the raised-bed plot were lower than those on the ordinary plot, the Ca and Mg were somewhat higher and the P, Fe and Mn were more or less the same contents. Considering from the soil properties, all nutrients were high, especially the cationic micronutrients resulting in higher concentrations of such nutrients than the adequate range. In case of very high phosphorus in soil solution but low in leaf, this might due partially to the antagonistic interaction between P and Zn. Another antagonism was between the low leaf K and high leaf Ca and Mg (Tisdale et al., 1990), similar to the studied of Phanjindawan and Nucharee (2013)

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C. Nutrient Uptake

The raised-bed plot had somewhat higher nutrient uptakes of P, Ca, Mg, Fe and Mn while the remainders were less than those found on the ordinary plot (Table 3). Within the raised-bed plot, the row 1 had slightly higher in Mn, Cu and slightly lower in N and Zn uptakes than the ones on the row 2, and more or less similar contents in P, K, Ca and Mg uptakes. For the ordinary plot, the row 3 had less N, Ca, Mg, Fe, Mn uptakes than those on the row 4.

IV. CONCLUSION

Soils of the studied plots, either the raised-bed or the ordinary orchards were high in fertility, even their weak point is very low pH. They had high possibility to be the toxicity of Fe, Mn and/or Al. Extractable bases and available phosphorus in soil solution were high together with the cationic micronutrients. However, the nutrient imbalances in leaf were very well noticeable. The nutrients concentrations in leaf were lower than the adequate range for N, P and K, whilst the others higher. For preliminary amelioration, the organic residues should be added to the soil together with lime. More amount of N, P, K fertilizers than usual is recommended, especially the K. Further researches about properly nutrient management should be recommended.

REFERENCES

[1] Blackemore, L.C., P.L. Searle and B.K. Daly.(1987). Methods for Chemical Analysis of Soils. Lower Hutt, New Zealand: NZ Soil Bureau Scientific Report 80. New Zealand Soil Bureau, Department of Scientific and Industrial Research.

[2] Brady, N.C. and R.R. Weil.(2008). The Natures and Properties of Soils. Revised 14th edition. New Jersey, USA: Prentice Hall.

[3] Gee, G.W. and J.W. Bauder.(1986). Particle-size Analysis, pp 383-441. In A. Klute (ed.) Method of Soil Analysis, Part 1, Physical and Mineralogical Methods. 2nd edition. No. 9 in Agronomy. Madison, Wisconsin, USA: Soil Sci. Soc. Amer., Inc.

[4] International Institute of Tropical Agriculture.(1979). Selected Methods for Soil and Plant Analysis. 2nd revised edition. Manual Series No. 1. Ibadan, Nigeria: IITA.

[5] Kanyawongha, P.(1989). Genesis and Fertility Capability of Acid Sulfate Soils in Central Plain of Thailand. (Master Thesis, Kasetsart University, Bangkok, Thailand).

[6] Kanyawongha, P and A. Sriprachote.(2013). Properties of Raised-bed Oil Palm-Growing Soils on Acid sulfate Soils of Thailand: A Case Study on 3 to 6 years Oil Palm Orchards. Academic Journal of Science, 2(2): 301-310.

[7] Kawakuchi, K. and K. Kyuma.(1969). Lowland Rice Soils in Thailand. Report on Research in Southeast Asia. Natural Science Series No 4. Kyoto, Japan: The Center for Southeast Asian Studies, Kyoto University.

[8] Land Development Department.(1992). Manual of Soil Quality Evaluation for Economic Plant of Thailand. Bangkok, Thailand: Land Use Planning Division, Land Development Department, Ministry of Agriculture and Cooperatives.

[9] Nillanon, C., T. Chantrniyom, P. Tongkam and T. Akesomtramate.(1991). Fertilizer application for Oil Palm. Songkhla, Thailand: Faculty of Natural Resources, Prince of Songkhla University.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 9, Issue 1, January 2020

[10] Phanjindawan, N. and N. Boonplang.(2013). Soil Properties and Seasonal Variation in Nutrient Concentration of Oil Palm Leaf in Saraburi Province. Bangkok, Thailand: Faculty of Agricultural Technology, King Mongkut 's Institute of Technology, Lad Krabang.

[11] Phoovarodom, S.(2012). Soil and Plant Analysis Manual. Bangkok, Thailand: Department of Soil Science, Faculty of Agricultural Technology, King Mongkut 's Institute of Technology, Lad Krabang .

[12] Reuter, D.J. and J.B. Robinson (eds.). (1997). Plant Analysis: An Introduction Manual. 2nd edition. Victoria, Australia: CSIRO Publishing.

[13] Rhoades, L.D.(1996). Salinity: Electrical Conductivity and Total Dissolved Salts, pp 417-435. In D.L. Sparks et al. (eds.). Methods of Soil Analysis. Part 3. Chemical Methods. No. 5 in The Soil Sci Soc. Amer. Book Series. Madison, Wisconsin, USA: Soil Sci. Soc. Amer., Inc.

[14] Soil Survey Division.(1981). Detailed Reconnaissance Soil Map of Chachoengsao Province, scale 1:100000. Bangkok, Thailand: Soil Survey Division, Department of Land Development, Ministry of Agriculture and Cooperatives.

[15] Surat Thanee Oil Palm Research Center.(2010). Surat Thanee, Thailand: http://it.doa.go.th/palm/ link Technical/oilpalm.html. (Online date : April, 10, 2011).

[16] Tisdale, S.L., W.L. Nelson and J.D. Beaton. 1990. Soil Fertility and Fertilizers. 4th edition. New York, USA: Macmillan Publishing Company.

APPENDIX

Criteria for soil quality evaluation for economic plants of Thailand.

Criteria	Ranges						
	Very low	Low	Slightly low	Medium	Moderately high	High	Very high
OM (g kg^{-1})	< 5	5-10	10-15	15-25	25-35	35-45	>45
Avail.P (mg kg^{-1})	< 3	3 - 6	6 - 10	10 - 15	15 - 25	25 - 45	> 45
K (mg kg^{-1})	< 30	30 - 60	–	60 - 90	–	90 - 120	> 120
Ca (mg kg^{-1})	< 400	400 - 1000	–	1000 - 2000	–	2000 - 4000	> 4000
Mg (mg kg^{-1})	< 36	36 - 120	–	120 - 360	–	360 - 960	> 960
Fe (mg kg^{-1})	0.25	–	–	2.6 - 4.5	–	> 4.5	–
Cu (mg kg^{-1})	0 - 0.4	–	–	0.4 - 0.6	–	> 0.6	–
Mn (mg kg^{-1})	< 1.0	–	–	–	–	> 1.0	–
Zn (mg kg^{-1})	0.005	–	–	0.6 - 1.0	–	> 1.0	–

Source: Land Development Department (1992)

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Table 1. Basic soil properties of the studied oil palm orchards.

Row	Plant	pH (1:1)	EC (1:1) (mS cm^{-1})	OM (g kg^{-1})	Avail. P (mg kg^{-1})	Ca	Mg	K	Na	Fe	Mn	Cu	Zn
						mg kg^{-1}							
						The Raised-bed plot							
1	**1**	4.92	1.20	30.7	59.1	3335	821	2278	169	200	54.6	1.45	5.01
	2	4.76	1.18	31.3	99.0	2767	883	2941	79.0	166	77.6	2.01	5.51
	3	4.63	1.05	23.9	104	2785	1001	2734	79.0	231	119	2.83	7.51
	4	4.86	0.65	33.8	111	3083	853	2000	149	203	73.7	1.57	5.42
	5	5.23	0.97	43.9	205	3883	825	3047	77.0	278	101	1.80	9.11
	6	5.34	1.19	47.2	179	3495	1004	2557	155	290	93.8	1.79	5.97
	7	4.91	0.98	30.8	82.9	2680	937	2139	202	281	83.6	2.36	5.60
	8	4.65	1.44	32.8	64.9	3107	957	2298	257	325	91.0	2.13	5.10
	9	4.80	0.66	27.9	96.2	2409	1206	1804	333	266	133	2.36	5.62
	10	4.64	1.14	24.0	96.4	2796	962	2726	142	256	102	1.84	5.55
	11	4.63	1.22	38.6	102.9	3054	949	2723	111	261	121	1.49	5.91
	12	5.8	0.77	22.3	82.4	2854	1548	2066	190	220	75.3	1.71	4.90
2	**13**	4.59	1.67	27.3	88.6	2900	993	2038	282	220	73.3	1.61	4.94
	14	4.20	0.86	18.1	55.1	2400	1015	1716	127	163	53.8	1.85	4.30
	15	4.46	0.76	26.1	87.0	2594	917	1785	196	251	67.4	1.84	7.14
	16	4.62	0.63	26.9	63.0	2615	967	1726	245	294	73.8	2.14	4.68
	17	4.33	0.81	22.6	100	2465	971	2286	65.0	160	73.4	1.45	4.16
	18	4.73	0.82	35.2	112	2868	870	2416	284	272	75.5	1.43	5.82
	19	4.31	0.65	23.2	46.0	2709	896	1826	275	343	76.5	1.98	6.10
	20	4.13	0.99	19.4	42.0	2836	952	981	512	274	68.9	2.46	5.61
	21	3.98	0.92	24.4	62.0	2451	815	2153	175	361	76.2	1.99	4.73
	22	4.30	1.49	31.9	80.0	2709	839	3293	200	307	106	1.36	5.88
	23	3.91	1.58	28.9	78.0	2782	771	2512	228	430	95.9	2.22	5.74
	24	4.27	1.28	23.4	47.0	2924	917	2123	245	250	99.9	2.06	5.40
	Mean Row 1	4.93	1.04	32.27	106.9	3020.67	995.5	2442.75	161.92	248.08	93.8	1.95	5.93
	SD Row 1	0.34	0.23	7.44	41.2	383.86	193.72	382.57	73.55	43.17	21.77	0.39	1.15
	Mean Row 2	4.31	1.04	25.62	71.7	2687.75	910.25	2071.25	236.17	277.08	78.38	1.87	5.38
	SD Row 2	0.24	0.35	4.68	21.7	175.21	71.84	535.3	104.12	74.93	14.25	0.33	0.82
	Mean Plot	4.63	1.04	28.94	89.31	2854.21	952.88	2257.00	199.04	262.58	86.09	1.91	5.65
	SD Plot	0.43	0.31	7.20	38.14	348.97	155.46	511.73	99.58	64.20	20.38	0.37	1.06
						The Ordinary plot							
3	**25**	4.35	1.31	28.4	37.4	2910	949	1322	529	341	69.3	2.32	5.42
	26	4.89	1.11	37.0	75.9	4653	766	1080	334	476	59.9	2.43	5.64
	27	5.16	1.02	42.2	66.7	2785	730	1189	361	490	72.4	1.84	4.52
	28	4.04	1.26	29.4	48.7	2307	846	1569	498	349	84.0	1.94	4.73
	29	4.14	1.05	25.1	24.7	2445	883	895	508	294	76.3	2.07	4.30
	30	4.04	1.20	37.7	54.4	2308	687	965	500	540	71.3	2.04	5.67
	31	4.25	0.89	27.4	50.1	2342	931	912	611	386	63.0	1.96	5.13
	32	4.27	0.94	38.6	40.0	2372	845	1323	571	534	69.3	2.18	4.83
	33	3.99	1.22	25.1	64.8	2156	846	979	617	386	59.9	2.08	4.56
	34	4.55	1.15	32.8	83.9	2615	1026	1020	662	396	54.6	1.98	4.54
	35	4.57	1.40	25.2	55.7	2901	983	1093	710	310	46.0	1.65	4.17
	36	4.41	2.25	29.9	53.1	2671	1035	1212	1053	315	47.1	1.77	3.85
4	**37**	4.21	3.66	35.1	83.7	2660	1795	1488	1755	442	85.5	1.72	4.82
	38	4.96	1.41	28.9	74.3	3738	1572	928	1773	281	62.7	1.91	5.10
	39	4.85	1.25	38.6	220	3074	1651	999	1204	391	56.6	1.82	4.68
	40	4.21	0.74	39.7	215	2456	930	1505	643	478	80.2	2.35	4.94
	41	4.39	0.77	29.6	190	2431	1000	1008	852	430	69.3	2.48	3.97
	42	4.07	0.44	22.8	196	2385	972	1283	656	256	60.5	1.70	4.86
	43	3.91	1.07	21.9	209	2407	822	1346	712	352	81.8	1.31	5.31
	44	3.88	1.19	33.1	202	2369	784	1413	704	368	78.8	1.59	4.66
	45	4.03	1.14	35.9	208	2504	811	1822	597	351	79.1	2.35	4.58
	46	4.34	1.33	29.0	194	2619	934	1819	633	319	60.3	1.91	6.95
	47	4.06	0.84	37.2	224	2854	792	2020	606	346	88.9	2.19	5.95
	48	4.45	0.77	26.4	221	3089	957	1457	553	321	62.3	1.94	4.79
	Mean Row 3	4.38	1.23	31.57	54.62	2705.42	877.25	1129.92	579.5	401.41	64.43	2.02	4.78
	SD Row 3	0.34	0.34	5.7	15.88	633.67	107.82	192.74	177.75	83.89	11.04	0.21	0.56
	Mean Row 4	4.28	1.22	31.57	186.42	2715.5	1085	1424	890.67	361.25	72.17	1.94	5.05
	SD Row 4	0.33	0.79	5.74	49.21	393.97	349.47	330.05	423.88	62.69	10.88	0.33	0.73
	Mean Plot	4.33	1.22	31.54	120.52	2710.46	981.13	1276.96	735.08	381.33	68.30	1.98	4.92
	SD Plot	0.35	0.62	5.84	76.98	538.99	284.68	314.29	368.09	78.38	11.87	0.29	0.68

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Table 2. Nutrient concentration of oil palm leaf of the studied orchards.

Row	Plant	Dried Weight (g)	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
			%					$mg\ kg^{-1}$			
					The Raised-bed plot						
	A1	6.03	2.26	0.12	0.62	0.83	0.45	185	611	13.00	4.37
	A2	6.90	2.25	0.12	0.68	0.79	0.49	193	585	12.20	2.49
	A3	7.49	1.94	0.12	0.66	0.71	0.56	189	535	13.50	0.88
	A4	6.48	2.07	0.12	0.56	0.86	0.51	196	683	11.20	1.46
	A5	8.08	2.04	0.12	0.62	0.84	0.52	185	580	10.00	15.20
	A6	5.43	2.22	0.13	0.61	0.74	0.52	237	528	12.90	21.10
1	**A7**	8.35	2.17	0.12	0.56	0.85	0.52	154	522	10.10	17.70
	A8	7.23	1.98	0.10	0.65	0.71	0.54	185	504	9.09	18.60
	A9	6.77	2.38	0.12	0.57	0.83	0.59	219	644	9.63	15.40
	A10	6.19	2.23	0.11	0.77	0.68	0.48	194	371	9.01	15.10
	A11	6.26	2.44	0.11	0.45	0.89	0.52	175	702	8.55	16.20
	A12	5.64	2.39	0.12	0.53	0.84	0.49	193	530	8.52	23.20
	A13	4.48	2.41	0.11	0.63	0.68	0.52	212	530	8.54	18.70
	A14	6.66	2.35	0.13	0.45	0.89	0.54	209	634	6.74	17.10
	A15	8.29	1.67	0.13	0.49	0.86	0.51	203	668	7.47	17.60
	A16	5.42	2.66	0.11	0.41	0.91	0.56	204	731	7.86	14.30
	A17	8.45	2.32	0.12	0.6	0.8	0.51	183	806	7.82	14.10
2	**A18**	6.22	1.96	0.11	0.51	0.88	0.53	177	636	6.26	14.90
	A19	4.77	2.45	0.11	0.99	0.61	0.37	201	336	7.52	18.10
	A20	7.74	2.35	0.11	0.52	0.83	0.48	265	590	7.77	18.80
	A21	5.36	2.57	0.12	0.44	0.78	0.52	200	518	9.36	19.50
	A22	6.65	2.74	0.11	0.79	0.63	0.44	174	437	6.75	16.90
	A23	7.62	2.53	0.10	0.45	0.75	0.50	208	605	8.63	37.10
	A24	6.69	2.57	0.11	0.53	0.76	0.60	182	731	6.33	13.50
	Mean Row 1	6.63	2.20	0.12	0.61	0.80	0.52	192.08	566.25	10.64	12.64
	SD Row 1	0.88	0.16	0.007	0.08	0.07	0.04	19.72	85.81	1.76	7.70
	Mean Row 2	6.52	2.38	0.11	0.57	0.78	0.51	201.50	601.83	7.59	18.38
	SD Row2	1.27	0.29	0.008	0.17	0.10	0.06	22.97	126.83	0.91	5.97
	Mean Plot	6.63	2.29	0.12	0.59	0.79	0.51	196.79	584.04	9.11	15.51
	SD Plot	1.12	0.25	0.01	0.13	0.08	0.05	22.39	111.85	2.12	7.62
					The Ordinary plot						
	A25	7.06	2.37	0.11	0.54	0.83	0.50	147	454	8.20	18.20
	A26	5.03	2.63	0.12	0.71	0.62	0.61	194	505	24.50	21.60
	A27	5.25	2.50	0.12	0.65	0.68	0.55	155	546	17.60	23.90
	A28	6.99	2.56	0.13	0.53	0.81	0.57	205	806	17.90	72.50
	A29	6.22	2.55	0.13	0.61	0.77	0.56	164	775	20.90	51.30
3	**A30**	6.84	2.75	0.12	0.75	0.62	0.36	309	450	15.40	20.10
	A31	6.01	2.51	0.11	0.64	0.71	0.48	138	573	14.90	17.00
	A32	7.30	1.88	0.11	0.58	0.68	0.32	194	473	13.30	16.80
	A33	8.02	2.49	0.11	0.78	0.60	0.44	206	643	14.10	16.40
	A34	6.22	2.21	0.12	0.70	0.68	0.38	245	462	13.30	17.70
	A35	6.62	2.30	0.10	0.61	0.70	0.43	214	404	14.00	20.80
	A36	5.73	2.40	0.10	1.03	0.55	0.36	170	283	11.90	27.30
	A37	5.57	2.52	0.11	0.80	0.84	0.53	192	652	12.30	16.80
	A38	7.58	2.83	0.12	0.49	0.81	0.43	196	544	11.90	22.90
	A39	4.65	2.49	0.11	0.56	0.90	0.58	156	482	13.00	16.80
	A40	4.98	2.54	0.11	0.56	0.79	0.47	162	925	9.75	22.80
	A41	7.62	2.64	0.09	0.72	0.81	0.41	392	798	13.40	21.10
	A42	6.27	2.20	0.07	0.67	0.64	0.45	218	519	11.40	18.20
4	**A43**	6.65	2.28	0.10	0.81	0.69	0.44	153	558	8.97	58.60
	A44	5.05	2.50	0.08	0.92	0.71	0.44	307	433	11.50	19.60
	A45	6.47	2.54	0.08	0.67	0.77	0.47	145	663	12.20	18.00
	A46	6.21	2.43	0.09	0.66	0.91	0.45	186	849	12.60	21.90
	A47	7.05	2.55	0.10	0.64	0.80	0.48	176	649	13.50	18.70
	A48	6.12	2.42	0.09	0.69	0.84	0.50	206	635	13.10	24.10
	Mean Row 3	8.44	2.43	0.12	0.68	0.69	0.46	195.08	531.17	15.50	26.97
	SD Row 3	0.83	0.22	0.009	0.13	0.08	0.09	45.48	143.94	4.09	16.50
	Mean Row 4	6.19	2.50	0.10	0.68	0.79	0.47	207.42	642.25	11.97	23.29
	SD Row 4	0.94	0.15	0.014	0.11	0.08	0.05	69.21	144.04	1.35	10.91
	Mean Plot	6.31	2.46	0.11	0.68	0.74	0.47	201.25	586.71	13.73	25.13
	SD Plot	0.91	0.19	0.02	0.13	0.10	0.07	60.15	157.65	3.60	14.41
	Adequate Range*		2.7-2.8	0.18-0,19	1.3	≤0.6	0.3-0.35	>50**	150-200	5-8	15-20

Note * : Reuter and Robinson (1997); ** : Nillanon et al. (1991)