SOIL PROPERTIES UNDER SIX COCONUT CROPPING SYSTEMS

DOAH DEKOK TARIGANS

Pusat Penelitian dan Pengembangan Tanaman Perkebunan

ABSTRACT

There were a number of factors causing differences in coconut growth and soil properties under field condition. To cope with the existing variation farming system in relation to soil properties, six coconut farming systems with four species of perenial crops as intercrop(s) namely banana, papaya, coffee and pineapple were conducted understudy. The objectives of the study were to study soil chemical and physical properties and nutrient element content in the coconut leave under various coconut cropping systems. Six coconut farming system as used for the study namely (1) coconut (control), (2) coconut + pineapple, (3) coconut + coffee, (4) coconut + papaya + pineapple, (5) coconut + banana + coffee, and (6) coconut + banana + papaya + coffee + pineapple. Total area for each system is 0.5 ha. Data on leaf analysis parameters, soil chemical properties and soil physical parameters, were statistically analyzed in randomized complete block design (RCBD) with three replications. The organic matter, pH and cation exchange capacity of the soils did not differ significantly with cropping pattern, although intensively cropped farm tended to have higher organic matter and cation exchange capacity values. Nitrogen, phosphorus and potassium were also significantly higher in intercropped farms but calcium and magnesium did not vary significantly. While moisture content, water holding capacity, bulk density of the soil did not show significantly difference with cropping patterns. Leaf nitrogen and calcium increase while potassium decreased with intensity of cropping. Phosphorus and magnesium showed no difinite trend. Leaf nitrogen, phosphorus and calcium were all positively correlated with soil nitrogen but soil phosphorus was weakly correlated with all nutrient element in the leaf. The exchangeable potassium in the topsoil was positively and insignificantly with nitrogen, potassium and calcium but negatively insignificantly with phosphorus and magnesium concentration in coconut leaf. While the exchangeable calcium in the subsoil was significantly and positively correlated with nitrogen in the leaf but negatively correlated with potassium.

Key words : *Cocos nucifera*, soil properties, cropping system, leaf analysis, correlation analysis

RINGKASAN

Sifat-sifat tanah pada enam areal pola tanam kelapa

Pada kondisi lapang, beberapa faktor dapat mempengaruhi sifat-sifat tanah dan pertumbuhan tanaman kelapa dalam areal pertanaman kelapa campuran. Untuk mengetahui bagaimana pengaruh tersebut dilakukan penelitian secara terencana dengan memilih pertanaman kelapa campuran dengan tanaman sela tahunan yaitu pisang, pepaya, kopi dan nenas. Pola tanam kelapa yang diteliti, dipilih pada areal perkebunan kelapa rakyat produktif (berumur 40 tahun) serta tanaman sela yang homogen, dan tingkat pemeliharaan yang sama. Enam pola tanam kelapa ditetapkan dalam studi ini berturut-turut (1) kelapa monokultur (kontrol), (2) kelapa + nenas, (3) kelapa + kopi, (4) kelapa + pepaya + nenas, (5) kelapa + pisang + kopi, dan (6) kelapa + pisang + pepaya + kopi + nenas, *masing-masing* pola seluas 0.5 ha. Penelitian disusun menggunakan rancangan acak lengkap dengan tiga kali ulangan. Paramater yang diamati meliputi sifat-sifat kimia dan fisika tanah dan unsur hara daun. Hasil penelitian menunjukkan bahwa kandungan bahan organik, pH, dan kapasitas tukar kation tanah tidak dipengaruhi oleh pola tanam kelapa namun memiliki tendensi bahwa semakin intensif pola tanaman kelapa akan meningkatkan kandungan bahan organik dan kapasitas tukar kation tanah. Kandungan nitrogen, fosfat (P_2O_5), dan kalium dalam tanah meningkat dengan adanya pola tanam campuran namun tidak mempengaruhi kandungan kalsium dan magnesium tanah. Dalam pada itu, kelembaban tanah (moisture content), kapasitas memegang air (water holding capacity), dan bobot isi tanah tidak dipengaruhi secara nyata. Kandungan nitrogen dan kalsium dalam daun kelapa bertambah sedang unsur kalium menurun dengan meningkatnya intensitas pola tanam kelapa. Fosfor dan magnesium tidak menunjukkan pola yang jelas. Kandungan nitrogen, fosfor dan kalsium dalam daun berkorelasi positif dengan nitrogen dalam tanah, namun fosfat dalam tanah memiliki korelasi yang lemah dengan semua unsur hara daun. Kandungan kalium (K_2O) pada lapisan olah tanah (topsoil) mempunyai korelasi positif dan tidak nyata dengan nitrogen, kalium, dan kalsium, namun berkorelasi negatif dengan fosfor dan magnesium dalam daun kelapa. Sedang kalsium pada subsoil mempunyai korelasi yang positif dan nyata dengan nitrogen dalam daun namun berkorelasi negatif dengan kalium.

Kata kunci : *Cocos nucifera*, sifat-sifat tanah, pola tanam, analisis daun, analisis korelasi

INTRODUCTION

The coconut is as industrial crop widely grown in Indonesia, Philippines, India, Sri Lanka, Malaysia and some other Asian countries. Indonesian coconut industry receives a considerable share of national attention because of its contribution to national economy. The importance of coconut is manifested in terms of land area devoted to coconut, labor force utilized and farm generated. Over 3.24 million hectares of land under coconut plantation produce more than 2.7 million ton equivalent copra.

Meanwhile, the socio-economic characteristic of coconut farming in Indonesia is such that the market price of copra, the principal product, is highly fluctuating and the farmers income from coconut is not stable. This is further complicated by relatively small coconut farm size and high population density which resulted to very small per capita income (CARLOS, 1983).

CREENCIA (1978) suggested to maximize utilization of coconut land to provide promising cushion from any drop in the price of copra. He mentioned multiple cropping as a solution to increase productivity of coconut land. The fact that intercropped palms were more productive then when solely planted can be attributed to the constant cultivation and fertilization made on the intercrops (MARGATE, 1978). Intercropping improves the yield of coconut (MAGAT, 1976) and increase copra yield with one or more cropping combination ranged from 10-46 percent (MARGATE, 1978).

Meanwhile, soil properties such as total nitrogen in the soil, available phosphorus, exchangeable magnesium, organic matter and texture of the soil affects the growth and production of the coconut and intercropped plant under various coconut cropping systems. The organic matter content in the soil were positively through correlated with number of functional leaves, weight of copra, nut production to number of bunch at full nut stage but negatively correlated with percentage of nut shelding. These implied that increase organic matter content in the soil will increase growth and production parameter.

A significant positive correlation was observed between nitrogen in the topsoil with weight of copra and nut production under various coconut cropping patterns. This finding jibed with that FREMOND *et al.* (1966) who reported on nitrogen nutrient effect on the number of nut and weight of copra per nut.

ESCRITOR (1954) reported that the average total nitrogen content of the high yielding soil was 1.35 percent, while the poor-yielding soil, 0.105 percent, noticeable, the difference was highly significant. While, a good suppy of phosphorus was said to hasten plant maturity. Plants deficiency in phosphorus had poor root systems, smaller leaves and stunted growth, (REMANY, 1983). NETHESINGHE (1963) reported that the growth as indicated by leaf production and age of flowering was largely influenced by application of phosphorus. However, WAHID *et al.* (1977) reported that phosphorus application had no significant positive effect neither on yield of nuts nor in copra content of coconut. This was contested by significant increase in yield of copra due to phosphorus application obtained from four out of seven location in Sri Lanka (ANON., 1972). In India, MULIYAR and NELLIAT (1971) found a very significant increase in yield after the ninth years of phosphorus annual application.

Meanwhile, the coconut palm as a heavy consumen of potassium. Studies conducted in all the coconut growing countries of the world have shown that potassium judicious application (REMANY, 1983). ESCRITOR (1954) found the amount of exchangeable potassium, and essential element in the development of chlorophyl, in starch formation, and in the translocation of sugar, very much higher in the soils giving good yields of nuts than in the poor-yielding soil.

As far as coconut is concerned several studies have shown that coconut grow on different kind of soil with pH ranging from 5.5 to 6.9 (CHILD, 1974) and from 5.0 to 8.0 (FREMOND *et al.*, 1966). The cation exchange capacity is the capacity of soil to absorb cations on the surface of the fraction or component. In fact, soil series with lower values showed relatively higher nut count than in the soil series with higher cation exchange capacity. Thus, under these condition, it could be deduced that CEC does not greatly influence the yield performance of coconut.

Physical properties of the soil such as texture and water holding capacity of the soil affect the growth of coconut. Texture affects tree growth possible by influencing the available water and nitrogen supply in the soil and the development of the roots system (MARAR, 1962).

While, water holding capacity is defined as the amount of water taken up by a unit weight of dry soil when immersed in water under standardized conditions. ESCRITOR (1954) showed that the average water holding capacity of the good-yielding surface soil was 34.96 percent while the subsoil was 42.40 percent.

The objective of the study, to investigate soil properties under six cropping system of coconut with perennial crops conducted in relation to the nutrient content of coconut leaves.

MATERIAL AND METHODS

Study on soil properties under six cropping systems was conducted in an area of coconut smallholders. Cropping systems under study was based on preliminary survey conducted in area of coconut smallholders. The results obtained were the basic for this study as presented in Table 1.

The experiment was designed as randomized complete block design with six cropping systems as used for the study. Total area for each systems is 0.5 ha with three replications.

Data Gathered

Soil properties

Chemical properties of the analysis were total nitrogen, available phosphorus, exchangeable potassium, exchangeable magnesium, soil pH, organic matter and cation exchange capacity. Physical properties of the soil determined were moisture content of the soil, water holding capacity, bulk density and particle density of the soil. Procedure of analysis followed the standard method of analysis for soil, plant, tissue and fertilizers (ANON., 1980).

Table 1. Six cropping systems used in the study
Tabel 1. Enam pola tanam yang diteliti

Cropping pattern *Pola tanam*	Crops planted *Tanaman*	Code *Kode*
I	Coconut (control)	cc
II	Coconut + pineapple	cc/pi
III	Coconut + coffee	cc/cf
IV	Coconut + papaya + pineapple	cc/pa/pi
V	Coconut + banana + coffee	cc/ba/cf
VI	Coconut + banana + papaya + Coffee + pineapple	cc/ba/pa/cf/pi

Nutrient content of the leaves

Nutrient concentration of the leaves was measured by tissues analysis. Nutrient concentration of the leaves analyzed were nitrogen, phosphorus, potassium, calcium and magnesium. The leaf samples collected were immediately prepared for leaf analysis following the recommended laboratory procedure for soil analysis was the same procedural employed in leaf analysis, for the said nutrient element.

Correlation analysis

Correlation analysis were performed on the following :

1. Leaf chemical components with soil chemical properties
2. Leaf chemical components with soil physical properties
3. Relationship among nutrient element in the coconut leaves under six cropping systems

RESULTS AND DISCUSSIONS

Chemical Properties

Organic matter

The average content in the topsoil, was not statistically affected by cropping pattern. The highest content of organic matter accured in the cropping pattern coconut/banana/coffee (cc/ba/cf) and lowest accured in monoculture (Table 2).

In the subsoil, cropping system cc/ba/cf had the highest organic matter content followed by cropping system cc/ba/pa/cf/pi, with averages of 1.97 and 1.83 percent, respectively. These were significantly higher than that of cropping system cc/cf but significantly different from those of cropping system cc/pa/pi and cc/pi. The organic matter content of soil in coconut monoculture was significantly higher than that of cc/cf but did not differ appreciably from that of the soil in other patterns of cropping.

In general, the data indicated that the mean organic matter content in the topsoil was higher than thet in the subsoil. This may be due to accumulation of humus derived from the breakdown of plant materials on the soil surface. The application of plant part or crop residues on the soil increases soil organic matter (FOTH and TURK, 1974; MILLER and AMSTAD, 1971).

Soil pH

The reactions of the topsoils in different coconut cropping patterns were acidic, varying slightly from pH 4.83 to pH 5.27. The subsoil were also acidic, generally higher than the topsoil and varied only slightly with the cropping patterns.

Soil pH in the topsoil tended to decrease in the presence of intercrops but did not differ significantly. This may be due to regular application of urea fretilizer being practiced in the farm. Carbon dioxide released from the docomposition of crop residues reacted with water to produce carbonic acid that may also had contribute to soil acidification (DHAR, 1968). The generally higher pH in the subsoil may be due to less acidifiation in that layer since there was much less organic matter in it.

Table 2. Chemical properties of top and subsoil under six cropping system
Tabel 2. Sifat-sifat kimia topsoil dan subsoil pada enam pola tanam

Cropping system *Pola tanam*	Organic matter(%) *Bahan organik (%)*		Soil pH *pH tanah*		Cation exchange capacity *Kapasitas tukar kation*	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
1. Coconut monoculture	2.15 a	1.65 ab	5.27 a	5.27 a	33.86 a	38.37 ab
2. Coconut + pineapple	2.49 a	1.38 bc	4.90 a	5.10 a	32.89 a	38.44 ab
3. Coconut + coffee	2.23 a	1.15 c	4.83 a	5.03 a	36.34 a	40.59 ab
4. Coconut + papaya + pineapple	2.19 a	1.37 bc	4.83 a	5.27 a	34.67 a	41.57 a
5. Coconut + banana + coffee	2.70 a	1.97 a	5.07 a	5.33 a	34.14 a	37.63 b
6. Coconut + banana + papaya + coffee + pineapple	2.58 a	1.83 a	5.03 a	5.17 a	38.38 a	41.53 a
CV (%)	10.116	10.985	5.093	4.967	7.493	3.057

Note : Means followed by a common letter (s) are not significantly different at the 5 % level
Keterangan : *Angka yang diikuti huruf yang sama pada setiap kolom tidak berbeda nyata pada taraf 5%*

Cation exchange capacity

The cation exchange capacity in the topsoil was not significantly different among cropping patterns in coconut, although it was generally higher in more intensive patterns of cropping. The cation exchange capacities of the subsoil, however, were significantly higher with cc/ba/pa/cf/pi and cc/pa/pi than cc/ba/cf cropping pattern.

The presence of more organic matter and lower pH in more intensively cropped patterns may account for the higher cation exchange capacity of the soils compared to monocropped coconut plantations. It had been shown that an increase in soil organic carbon of 0.54 percent resulted in an increased cation exchange capacity by 2.2 me/100 g soil (JONES, 1971). At low pH value, the permanent charges of the clay and a small portion of organic calloids held ions that can be replaced by cation exchange; under these conditions, the cation exchange capacity was generally low (CHARREOUS, 1974).

Total nitrogen

Cropping patterns in coconut significantly affected total nitrogen in topsoil with cc/ba/pa/cf/pi system having the highest (Table 3) and statistically the same as those of cc/ba/cf, cc/pi, cc/pa/pi and cc/cf. Coconut monoculture system had the lowest total nitrogen in the topsoil.

Improvement of total nitrogen in the topsoil by cropping pattern may be due to the regular application or urea fertilizer being practiced in the farms and increased organic matter (Table 2). The application of crop residues increased soil organic matter (FOTH and TURK, 1974; MILLER and AMSTAND, 1971) and nitrogen derived from the breakdown of plant formed humus (CHILD, 1964). On the other hand, deficiency of organic matter coexists with the deficiency of nitrogen in the soil (AMMA, 1977).

In the subsoil, however, cropping system cc/pa/pi and cc/ba/cf had significantly higher total nitrogen than cropping system cc/cf. The rest are intermediate and did not differ significantly from the above.

Available phosphorus (P_2O_5)

The more intensive the cropping system, the higher was available phosphorus in the topsoil (Table 3). This was not the same in the subsoil where available phosphorus was lowest in the most intensive system and highest in cc/pa/pi and cc/ba/cf. The significant difference was found at 5 and 1 percent levels (Table 3).

In general, the P_2O_5 content in the soil for six cropping systems studied was low. CORDOVA (1965) suggested that the critical level for P_2O_5 in the soil was about 10 ppm. Although low, the slightly higher P_2O_5 in the topsoil of intensively cropped areal may be due to the decomposed material available in that layer. The low P_2O_5 in the subsoil may be caused by the heavy uptake of the various crops in the most intensively cropped systems.

Table 3. **Nutrient element content of top and subsoil under six cropping systems**

Tabel 3. ***Kandungan unsur hara topsoil dan subsoil pada enam pola tanam***

Cropping system Pola tanam	N (%)		P_2O_5 (ppm)		K_2O (me/100 g)		CaO (me/100 g)		MgO (me/100 g)	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
1. Coconut monoculture	0.103 b	0.080ab	3.16b	4.21a	0.77b	0.433b	10.02a	11.42b	6.77a	7.49a
2. Coconut + pineapple	0.120 ab	0.083ab	3.28b	2.23ab	1.11ab	0.990a	8.90a	12.51ab	6.54a	7.55a
3. Coconut + coffee	0.107ab	0.060b	3.76b	2.58b	1.19ab	1.243a	9.03a	12.17ab	6.00a	7.14a
4. Coconut + papaya + pineapple	0.107ab	0.087a	4.33ab	5.03a	1.56a	1.230a	9.89a	13.31a	6.01a	7.99a
5. Coconut + banana + coffee	0.130ab	0.097a	6.14a	4.95a	1.42a	1.090a	10.59a	12.88ab	6.94a	7.17a
6. Coconut + banana + papaya + coffee + pineapple	0.133a	0.083ab	6.14a	1.92b	1.34ab	1.017a	10.92a	12.64ab	5.94a	8.29a
CV (%)	8.853	11.178	18.382	11.296	17.259	14.446	8.799	4.924	16.697	5.83

Note : Means followed by a common letter in each column are not significantly different at 5% level

Keterangan : Angka yang diikuti huruf yang sama pada setiap kolom tidak berbeda nyata pada taraf 5%

Exchangeable potassium (K_2O)

Coconut farms with more intensive cropping systems tended to have higher K_2O than intensively cropped ones. Cropping pattern cc/ba/pa/cf/pi, cc/ba/cf and cc/pa/pi had significantly higher K_2O in the topsoil than monocropped (cc) coconut farms. This was true for both the topsoil and subsoil. This may be traced to higher organic matter produced in more intensively cropped systems than in less intensively cropped ones (Table 2). The available potassium, calcium and magnesium were increased by crop residue mulch and crop residue incorporation (AGBOOLA AND COREY,1978; LAL, 1975). FAGI (1980) reported that mulching with non-leguminous crop residues did not only increase significantly the concentration of K^+, Ca^{2+}, and Mg^{2+}, but also increased Fe^{2+}, Mn^{2+} and Zn^{2+} when fertilized with urea.

The amount of K_2O in the soil was sufficient when compared to the threshold value (0.15-0.20 me/100 g) and suggested by OLLAGNIER (1979). These results implied that potassium fertilizer application is not needed for coconut palm under five coconut cropping systems under study.

Exchangeable calcium (CaO)

The average exchangeable calcium in the topsoil ranged from 8.90 to 10.92 me/100 g (Table 3). The highest was observed in cropping systems cc/ba/pa/cf/pi followed by cc/ba/cf, coconut monoculture, cc/pa/pi, cc/cf and cc/pi with average exchangeable calcium of 10.59, 10.02, 9.89, 9.03 and 8.90 me/100 g, respectively. Analysis of variance, nonetheless, showed insignificant differences among means, indicating that this parameter in the topsoil was not affected by cropping systems in coconut.

In the subsoil, however, a significant difference was observed between cropping system cc/pa/pi and coconut monoculture (Table 3), but neither was significantly different from cropping systems cc/ba/cf, cc/ba/pa/cf/pi, cc/pi and cc/cf.

Further, the results showed that average exchangeable calcium in the soil increased with depth. This finding may explained higher pH in the subsoil compared to the topsoil.

Exchangeable magnesium (MgO)

The highest exchangeable magnesium in the topsoil was observed in cropping pattern cc/ba/cf while the lowest was in cc/ba/pa/cf/pi systems with averages of 6.94 and 5.94 me/100 g, respectively (Table 3). Statistically, however, cropping system effect means were just comparable, indicating that exchangeable magnesium in the topsoil was not influenced by cropping system in coconut.

Magnesium in the subsoil is neither significantly affected by cropping system but is generally higher than MgO in the topsoil. This finding revealed antagonistic characteristics between cations (Mg, Ca, and K) in the subsoil than the topsil. COSICO (1983) reported strong antagonism between Mg and Ca against K in Philippine coconut soil. However, ESCRITOR (1954) suggested that the trend in the concentration of magnesium was different from that of other elements. The low yielding soils had more magnesium that the high yielding ones.

Physical Properties

Moisture content

Analysis of variance showed no significant difference among cropping system with respect to water content (Table 4), cropping system in coconut did not significantly affect the percentage of moisture content in the topsoil.

Similarly in the subsoil, moisture content was slightly varied, ranging from 14.11 to 17.67 percent from cc/ba/cf and cc/pi system.

The data implied that the cropping systems under study did not significantly affect the moisture content in the soil. The results were possibly caused by relatively low organic matter and depth of solumn of the soil under the six cropping system. The less organic matter content in the soil, the lower was the moisture content. The depth of solumn exerted profound influence in the amount of water available for use. Under a dry environment, very likely the palms on shallow soils will be subjected to a longer period of moisture stress than those palm on the deep soil.

Extreme moisture regimes affected the coconut trees in a number of ways. To a larger extent, it promoted, abortion of spathe, while low moisture disturbed nitrification and badly affected the activity of the absorbing root system (OLLAGNIER, 1979). This condition could be a contributory factor in the yellowing of palm and low nut yield (TOLENTINO, 1980).

Water holding capacity

In general, the water holding capacity of the topsoil is slightly higher than the water holding capacity of the subsoil. This was because the former had higher organic matter than the latter.

The water holding capacity of the topsoils ranged from 72.71 percent in the coconut monoculture system to 78.16 in cc/cf while in the subsoil, water holding capacity ranged from 67.09 to 74.36 with cc/pi and cc/ba/cf, respectively. In both cases, cropping system did not significantly affect water holding capacity of the soils.

Bulk density

The bulk density of top and subsoil, varied slightly among cropping systems. Analysis of variances for both soil layers showed no significant difference between cropping systems. This finding suggested that cropping systems in coconut did not significantly affect the bulk density in the soil.

Particle density

The highest particle density in the topsoil was observed in cropping systems cc/pi or cc/cf while the lowest was in cc/ba/pa/cf/pi pattern with averages 2.81 and 2.73 g/cc, respectively (Table 4). Statistically, however, cropping systems effects on particle density were just comparable, indicating that particle density in the topsoil was not influenced by cropping systems in coconut.

Particle density in the subsoil was not significantly affected by cropping systems and generally higher than particle density in the topsoil. This finding confirmed the fact that topsoil have higher organic matter content than the subsoil (Table 2). BRADY (1984) suggested that surface soil which almost always have higher organic matter content than the subsoils, usually possessed lower particle densities than do subsoils.

Leaf Nutrient Content

Nitrogen (N)

The highest nitrogen concentration of coconut leaf under six cropping systems was observed in cc/pi while the lowest was in coconut monoculture (cc) system with averages of 1.91 and 1.52 percent, respectively (Table 5). Statistically, however, the means were just comparable, indicating that nitrogen concentration of coconut leaves was not influenced by cropping system.

Further, the data indicated that all coconut palms with intercrop (s) had higher percentages of nitrogen in their leaves compared to those under monoculture. This was due to regular application of urea fertilizer practiced in these farms.

Nitrogen concentration in the coconut leaves under coconut monoculture (cc) and cc/cf pattern were found to be below the critical level for N for normal nut production (FREMOND *et al.*, 1966), while N concentration of coconut leaves on the other cropping systems were within the normal range (N=1.8 to 2.0%).

Phosphorus (P)

The phosphorus concentration in the coconut leaves was not affect by the type of cropping system (Table 5). Coconut palms with pineapple (cc/pi) had the highest

Table 4. Physical properties of top and subsoil under six cropping systems
Tabel 4. Sifat-sifat fisika topsoil dan subsoil pada enam pola tanam

Cropping system *Pola tanam*	Moisture content (%) *Kelembaban tanah (%)*		Water holding capacity (%) *Daya pegang air (%)*		Bulk density *Bobot isi* (g/cc)		Particle density *Kerapatan jenis tanah* (g/cc)	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
1. Coconut monoculture	16.80a	15.96a	72.71a	71.29a	1.18a	1.23a	2.76a	2.82a
2. Coconut + pineapple	18.20a	17.67a	75.87a	67.09a	1.29a	1.38a	2.81a	2.84a
3. Coconut + coffee	17.36a	14.44a	78.16a	69.69a	1.22a	1.29a	2.81a	2.82a
4. Coconut+ papaya + pineapple	15.00a	17.48a	73.78a	73.64a	1.23a	1.30a	2.79a	2.82a
5. Coconut + banana + coffee	13.77a	14.11a	74.81a	74.36a	1.10a	1.16a	2.74a	2.78a
6. Coconut + banana + coffee + pineapple	13.83a	15.19a	74.87a	74.27a	1.43a	1.18a	2.73a	2.82a
CV (%)	13.551	12.957	5.067	5.835	11.736	9.741	1.745	2.380

Note : Means followed by a common letter in each column are not significantly different at 5% level
Keterangan : Angka yang diikuti huruf yang sama pada setiap kolom tidak berbeda nyata pada taraf 5%

concentration of P in the leaves (0.15%), while those from other cropping system had the same concentration (0.13%). However, the P concentration of the leaves of palms in all cropping systems were within the satisfactory levels (0.12%) for coconut as suggested by MAGAT (1976). This suggested that application of inorganic phosphorus fertilizer to the farms is not favorable.

Potassium (K)

The potassium concentration of the coconut leaves did not vary significantly with different cropping systems in the coconut plantation (Table 5), although the data ranged from 0.63 percent in cc/ba/cf to 1.08 percent in monocropped farm.

Cropping system with banana and pineapple have K concentration in coconut leaves lower than the critical level (0.80 percent) as indicated by KANAPATHY (1971). This suggested that these two crops, which contained so much fiber in their biomass, competed more strongly for K with the coconut palms. Banana had been reported to be a heavy feeder of nutrients particularly potassium and can deplete the soil quickly if not fertilizer (ANON., 1984). Pineapple should be supplied with large amounts of potassium fertilizer to obtain appreciable yield. The effects of potassium are seen on fruit size, weight and quality (ANON., 1977).

Coconut palms with coffee or in monoculture have sufficient K in their leaves for normal growth and production but those in the former pattern have barely enough K in their leaves. This suggested that the present of coffee reduces K in the nutrient uptake of the palms. But this reduction is greater where pineapple and banana are intercropped with the palm. This means that K must be supplied in greated quantity where coconut palms are interplanted with these crops.

Calcium (Ca)

Leaf Ca concentration was the highest (0.19 percent) in cropping system cc/ba/pa/cf/pi and the lowest (0.15 percent) in coconut monoculture and cc/pi system (Table 5). No significant variation was observed in leaf Ca among cropping patterns, suggesting that cropping systems did not influence the Ca concentration in the leaves.

The Ca concentration of the leaves in all cropping systems, however, were lower than the critical level (0.30 percent) as suggested by MAGAT (1976). ANUNCIADO (1974) and SANTIAGO (1983) reported that Ca concentration in the leaves decreased with decrease in rainfall. The data indicated that generally K and Ca concentration in the leaves were low, implying that the results did not follow the synergysm between K-Ca as proposed by ZILLER and PREVOT (1962) who reported that K-Ca synergysm exists when percentage of K is low.

Magnesium (Mg)

Like the other elements considered in the study, Mg level in the leaves was not affected by cropping systems in coconut (Table 5). Coconut monoculture (cc), however, had the highest (0.20 percent) Mg concentration while cc/pa/cf and cc/ba/pa/cf/pi had the lowest (0.17 percent). The rest had 0.19 percent.

Magnesium concentration in the coconut leaves for all cropping systems, however, were close to the critical level (0.2 percent) for nut production as suggested by MAGAT (1976). As in Ca, this result did not follow the synergysm effect between K-Mg as proposed by ZILLER and PREVOT (1962) who reported that K-Mg synergysm exists when percentage of K is low.

These observations indicated that Mg fertilizer can be utilized by the coconut palms to improved nutrient balance in the leaf.

Table 5. Nutrient content of coconut leaves under six cropping systems
Tabel 5. Kandungan hara daun kelapa pada enam pola tanam

Cropping system *Pola tanam*	N (%)	P (%)	K (%0	Ca (%)	Mg (%)
1. Coconut monoculture	1.52a	0.13a	1.08a	0.15a	0.20a
2. Coconut + Pineapple	1.91a	0.15a	0.70a	0.15a	0.19a
3. Coconut + Coffee	1.72a	0.13a	0.82a	0.16a	0.19a
4. Coconut + Papaya + Coffee	1.86a	0.13a	0.74a	0.17a	0.17a
5. Coconut + Banana + Coffee	1.80a	0.13a	0.63a	0.18a	0.19a
6. Coconut + Banana + Papaya + Coffee + Pineapple	1.82a	0.13a	0.65a	0.19a	0.17a
CV (%)	9.452	8.766	20.527	13.100	16.572

Note : Means followed by a common letter in each column are not significantly different at the 5% level
Keterangan : Angka yang diikuti huruf yang sama pada setiap kolom tidak berbeda nyata pada taraf 5%

Correlation Analysis

Leaf analysis vs soil chemical properties

Results of linear correlation between leaf analysis and soil chemical properties under six cropping systems in coconut is presented in Table 6.

Organic matter

The organic matter content in the top and subsoil were negatively correlated with potassium and magnesium concentration in the coconut leaf, but positively correlated with nitrogen, phosphorus and calcium. However, correlation coefficient (r) values were not significant. The results implied that the chemical components of the coconut leaf were not very sensitive to the organic matter content of the soil with six cropping systems.

Soil reaction (pH)

The nutrient elements in the coconut leaves were weakly correlated with soil pH. This relationship was positive for calcium and potassium but negative for nitrogen and phosphorus with both soil layers. For magnesium, it was positive with the topsoil and negative with the subsoil.

There was low uptake of NH^+ at low pH (AGBOOLA and COREY, 1978). Phosphorus tied up by Al and Fe under the same condition. Potassium and calcium absorption seemed unimpeded at the pH ranges of the soils.

Cation exchange capacity

The cation exchange capacity in the top and subsoil was positively correlated with nitrogen and calcium concentration of coconut leaf but negatively correlated with phosphorus, potassium and magnesium concentrations.

The r-values were, however, not significant at five percent level. These results implied that cation exchange capacity of the soil had no significant relationship with coconut leaf nutrients.

Nitrogen

The nutrient concentration in the coconut leaf were weakly correlated with nitrogen in the soil, except for leaf potassium which was significantly but negatively correlated with soil nitrogen. Leaf nitrogen, phosphorus and calcium were all positively correlated with soil nitrogen. These results implied that the higher nitrogen

Table 6. Linear correlation (r) between coconut leaf nutrients and soil chemical properties under six cropping systems

Tabel 6. Korelasi linier antara kandungan unsur hara daun kelapa dengan sifat kimia tanah pada enam pola tanam

Soil chemical properties *Sifat kimia tanah*		Nutrient in the leaf *Unsur hara dalam daun*				
		N	P	K	Ca	Mg
Organic matter *Bahan organik*	TS	0.14436	0.18477	-0.27679	0.23390	-0.03292
	SS	0.12010	0.16108	-0.07596	0.39661	-0.03973
Soil reaction (pH) *Reaksi tanah (pH)*	TS	-0.40889	-0.22198	0.39630	0.16286	0.04186
	SS	-0.29548	-0.22897	0.27787	0.13107	-0.19815
Cation exchange capacity *Kapasitas tukar kation*	TS	0.18111	-0.44131	-0.14971	0.30481	-0.32312
	SS	0.25521	-0.08129	-0.27673	0.04294	-0.31310
N	TS	0.17804	0.05618	-0.46819	0.37741	-0.07029
	SS	0.22654	0.05913	-0.19361	0.26481	0.02642
P	TS	0.12915	0.40645	-0.22151	0.41981	-0.46181
	SS	-0.18711	0.24578	0.14146	0.03892	0.06121
K	TS	0.42881	-0.14585	0.43083	0.25573	-0.28518
	SS	0.52018 *	-0.00399	0.44730	0.12125	-0.43215
Ca	TS	0.08647	-0.45216	-0.15142	0.53324 *	-0.19720
	SS	0.50974 *	-0.01636	-0.56907	0.27429	0.34697
Mg	TS	0.01125	0.03113	-0.30061	-0.11234	0.02002
	SS	0.01798	-0.06901	-0.06108	0.24004	0.00016

Note : TS - Topsoil SS - Subsoil

Keterangan : ** - Significant different at 1% level *Berbeda nyata pada taraf 1%*

* - Significant different at 5% level *Berbeda nyata pada taraf 5%*

present in the soil the lower potassium concentration be in the leaf. This finding is in consonance with that of CHILD (1974) who reported that response to nitrogen or potassium may be restricted when one or the other is in deficiency. Soil N is below the critical level (Table 3).

Phosphorus

Soil phosphorus is weakly correlated with all nutrient element in the leaf. These relationships were positive for both calcium and phosphorus. However, correlation coefficient value were not significant. These results suggested that the nutrient elements in the coconut leaf were not very sensitive to the phosphorus content of the soil.

Potassium

The exchangeable potassium in the topsoil was positively and insignificantly with nitrogen, potassium and calcium but negatively insignificantly with phosphorus and magnesium concentratrion in the coconut leaf. As exchangeable potassium in the topsoil increases, there is slight increase in nitrogen, potassium and calcium in the leaf of the palms. The exchangeable potassium in the subsoil was positively and significantly correlated with nitrogen element but insignificantly correlated with potassium and calcium nutrient of coconut leaf. However, it was negatively though insignificantly correlated with phosphorus and magnesium nutrients in the leaf. These results suggested that higher exchangeable potassium in the subsoil increases nitrogen significantly but slightly increase pottasium and calcium nutrient in the coconut leaf.

Magnesium

The exchangeable magnesium in the topsoil was weakly correlated with leaf nutrient content. This was positively and significantly correlated with nitrogen, phosphorus, and magnesium nutrient in the leaf; but negatively correlated with potassium and calcium. These results suggested that nutrients elements in the coconut leaf are weakly influenced by exchangeable magnesium in the topsoil.

The exchangeable magnesium in the subsoil, however, was positively correlated with nitrogen, calcium and magnesium nutrient of the leaf although negatively correlated with phosphorus and potassium element. These results nutrients in the leaf of the palm were practically insensitive to exchangeable calcium in subsoil.

Leaf Analysis vs Soil Physical Properties

Results of linear correlation analysis between coconut leaf nutrients and soil physical properties are presented in Table 7.

Table 7. Linear correlation (r) between coconut leaf nutrients and soil physical properties under six cropping systems
Tabel 7. Korelasi linier antara kandungan unsur hara daun kelapa dengan sifat fisika tanah pada enam pola tanam

Soil physical properties *Sifat fisika tanah*		Nutrient in the leaf *Unsur hara dalam daun* N	P	K	Ca	Mg
Percent sand	TS	-0.18528	0.50682*	0.34159	-0.39044	0.22046
Kandungan pasir	SS	-0.07038	0.10530	0.38695	-0.57020*	0.00319
Percent silt	TS	0.25271	-0.29122	-0.34733	0.03154	-0.50981*
Kandungan debu	SS	-0.06252	0.07660	0.03550	-0.50382	-0.15655
Percent clay	TS	-0.08894	-0.09591	0.063442	0.23737	0.28313
Kandungan liat	SS	-0.13236	-0.07511	0.28069	0.59899**	0.22704
Bulk density	TS	0.06756	0.28235	0.40693	0.11342	0.07950
Bobot isi	SS	0.01142	0.23037	0.41729	-0.25562	-0.05215
Water holding capacity	TS	0.32370	0.04906	-0.40686	0.16474	0.09008
Daya pegang air	SS	-0.09633	-0.15907	-0.24645	0.64032**	0.12189
Particle density	TS	0.13618	0.40360	0.03425	-0.17589	0.29727
Kerapatan jenis tanah	SS	0.08137	0.20260	-0.14833	0.20232	0.50152
Moisture content	TS	-0.06170	0.30385	0.09484	-0.29638	0.30765
Kelembaban tanah	SS	0.06786	0.38197	-0.10288	-0.01684	0.16182

Note : TS - Topsoil
Keterangan : SS - Subsoil
* - Significant at 5% level * - *Berbeda nyata pada taraf 5%*
** - Significant at 1% level ** - *Berbeda nyata pada taraf 1%*

Percent sand

Percent sand in the topsoil positively and significantly correlated with phosphorus but insignificantly correlated with potassium and magnesium nutrient in the leaf. This result suggested that higher percent sand in the topsoil results in higher phosphorus nutrient element in the leaf.

In the subsoil, a negative and significant correlation with calcium element but insignificantly correlated with nitrogen nutrient was found. Sand was also positively but insignificantly correlated with phosphorus, potassium and magnesium. These results implied that higher percent sand in the subsoil depresses calcium concentration in the coconut leave.

Percent silt

Percent silt in the topsoil was negatively and significantly correlated with magnesium nutrient but insignificantly correlated with phosphorus and potassium elements. These results suggested that higher percent silt in the topsoil will depress magnesium nutrient in the leaf of coconut. Silt was also positively but insignificantly correlated with nitrogen and calcium.

Percent silt in the subsoil was negatively and insignificantly correlated with nitrogen, calium and magnesium but was weakly correlated to phosphorus and potassium nutrient in the leaf. These results implied that nutrients in the leaf were practically insensitive to percent silt in the subsoil, even if the concentration was increased.

Percent clay

Percent clay in the topsoil was positively and insignificantly correlated with potassium, calcium and magnesium but negatively correlated with nitrogen and phosphorus. The data implied that nutrient element in the leaf were weakly related with percent clay in the topsoil under cropping patterns in coconut.

In the subsoil, however, percent clay was positively and highly significantly correlated with calcium but insignificantly correlated with magnesium nutrient. These results suggested that the higher percent clay is in the subsoil the higher calcium be in the leaf of coconut palm. However, percent clay was negatively though insignificantly correlated with nitrogen, phosphorus and potassium.

Bulk density

The bulk density in the topsoil was positively and insignificantly correlated with nitrogen, phosphorus, potassium and magnesium in the leaf. Negative and insignificantly correlated with calcium nutrient also existed. These results implied that the nutrients in the leaf were practically insensitive to the bulk density of the topsoil.

Subsoil bulk density was positively and insignificantly correlated with nitrogen, phosphorus and potassium. Also, it was negatively and insignificantly correlated with calcium and magnesium nutrient in the leaf of coconut.

Water holding capacity

The water holding capacity in the topsoil was positively correlated with nitrogen, phosphorus, calcium and magnesium but negatively correlated with potassium element. The r-values, however, were not significantly at five percent level. These results implied that at 72.71 to 78.16% water holding capacity in the topsoil, no significant relationship with nutrient concentration in the leaf existed.

In the subsoil, water holding capacity was positively and highly significantly correlated with calcium but insignificantly correlated with magnesium element. This suggested that with higher water holding capacity in the subsoil, higher calcium in the leaf was absorbed. Negative but insignificant correlation with nitrogen, phosphorus and potassium also existed. These results suggested that higher water holding capacity of subsoil depresses nitrogen, phosphorus and potassium concentration in leaf.

Particle density

The particle density in either top or subsoil was weakly correlated to nutrient element in the leaf. The relationship is positive for most parameters except for calcium element.

In the subsoil, positive correlation was observed in nitrogen, phosphorus, calcium, and magnesium but negative correlation was found with potassium nutrient in the leaf.

Moisture content

A positive correlation was observed between moisture content in the topsoil with phosphorus, potassium and magnesium nutrient. Negative correlations with nitrogen and calcium also existed. The relationships were low, suggesting that these nutrients in the leaf were practically insensitive to moisture content in the topsoil, even if the moisture content was increased.

The moisture content in the subsoil were positively correlated with nitrogen, phosphorus and magnesium. Negative but insignificant correlation with potassium and calsium also existed.

CONCLUSIONS

The organic matter of the top soil were practically the same under various cropping system but the subsoil have higher organic matter in more intensively cropped areas. The pH and topsoil cation exchange capacity did not also differ but cation exchange capacity in the subsoil varied widely. Intercropping areal have significantly more nitrogen, phosphorus and potassium in the topsoil than monocropped coconut areas. Calcium and magnesium did not differ significantly, except in the subsoil where calcium was also lowest in the monocropped areas.

The moisture content, water holding capacity, bulk density and particle density of the soil in the various cropping systems in coconut did not vary significantly. The nutrient concentration of the coconut leaves under six cropping systems differed only slightly, with nitrogen and calcium increasing with farming intensity and potassium decreasing. Phosphorus and magnesium showed no relation with cropping intensity.

Leaf nitrogen, phosphorus and calcium were all positively correlated with soil nitrogen but soil phosphorus is weakly correlated with all nutrient element in the leaf. The exchangeable potassium in the top soil was positively and insignificantly with nitrogen, potassium and calcium but negatively insignificantly with phosphorus and magnesium concentration in the coconut leaf. While the exchangeable calcium in the subsoil was significantly and positively correlated with calcium in the leaf but negatively correlated with potassium. Magnesium was postively and insignificantly correlated with nitrogen, phosphorus and magnesium nutrient in the leaf.

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